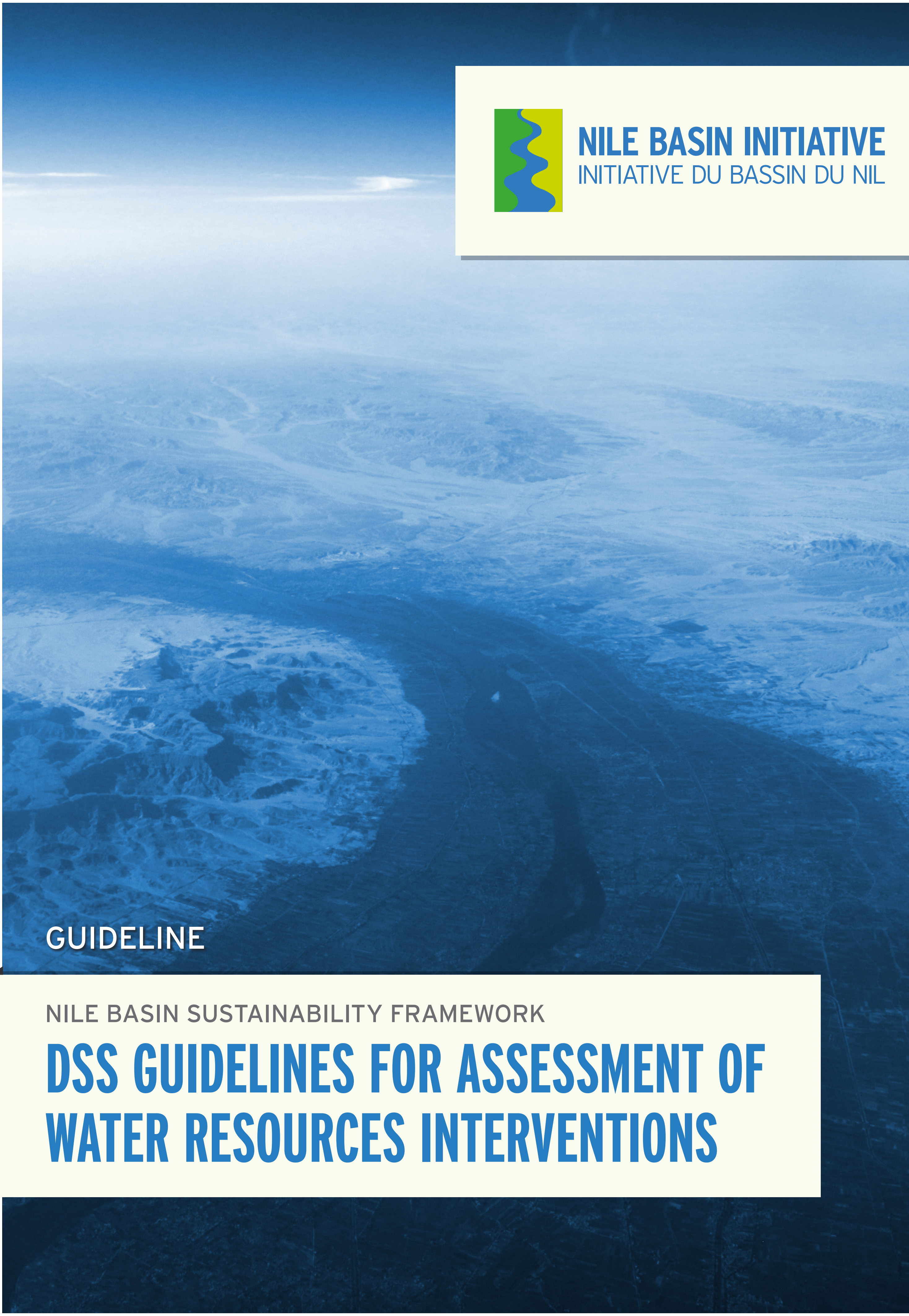

NILE BASIN INITIATIVE
INITIATIVE DU BASSIN DU NIL

GUIDELINE

NILE BASIN SUSTAINABILITY FRAMEWORK

DSS GUIDELINES FOR ASSESSMENT OF WATER RESOURCES INTERVENTIONS

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Document Control Sheet

Title	DSS Guidelines for Assessment of Water Resources Interventions
Document type	☐ Policy ☐ Strategy ☒ Guidelines ☐ Legal and Foundational Document
Prepared by	☐ Nile-SEC ☐ ENTRO ☐ NELSAP-CU ☒ Other: WRPM Project
Status	☒ New Policy/Strategy/Guideline/Legal and Foundational Document ☐ Revision of existing Policy/Strategy/Guideline/Legal and Foundational Document
Revision Date	
Effective Date	December 2012

Consideration by Nile-COM~~/EN-COM/NEL-COM~~ (cross out whichever body is not applicable)	
Date of submission for consideration	
Action by Council of Ministers	
Comments satisfactorily addressed	☐ Yes ☐ No ☐ Not Applicable

Consideration by Nile-TAC~~/ENSAPT/NEL-TAC~~ (cross out whichever body is not applicable)	
Date of submission for consideration	
Action by the Technical Advisory Committee:	
Comments satisfactorily addressed	☐ Yes ☐ No ☐ Not Applicable

Responsible Officer: Dr. Abdulkarim H. Seid

Data Compilation and Pilot Application of the Nile Basin Decision Support System (NB-DSS): Work Package 2: Stage 2

GUIDELINE FOR THE EVALUATION OF WATER MANAGEMENT INTERVENTIONS

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GUIDELINE FOR THE EVALUATION OF WATER MANAGEMENT INTERVENTIONS

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PROJECT NAME	**:**	Data Compilation and Pilot Application of the Nile Basin Decision Support System (NB-DSS): Work Package 2: Stage 2
REPORT TITLE	**:**	Evaluation of Water Management Interventions: Guideline
AUTHORS	**:**	Study Team
REPORT STATUS	**:**	Final
AURECON REPORT NO.	**:**	7330/107486
DATE	**:**	Dec 2012

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Evaluation of Water Management Interventions: Guideline

Project	Data Compilation and Pilot Application of the Nile Basin Decision Support System (NB-DSS): Work Package 2: Stage 2
Main Authors	Study Team
Status	Final
Date	Dec 2012

Reason for Circulation
Final

Circulation List
NBI DSS Core Team NBI Country representatives

Nature of comments required	
N.A.	
Date of Receipt of Comments	-

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LIST OF ACRONYMS

BCR	Benefit Cost Ratio
CBA	Cost Benefit Analysis
DEM	Digital Elevation Model
EWR	Environmental Water Requirement
FSL	Full Supply Level
GDP	Gross Domestic Product
GIS	Geographic Information System
IMS	Information Management System
IRR	Internal Rate of Return
IWRM	Integrated Water Resource Management
MCA	Multi Criteria Analysis
NB-DSS	Nile Basin Decision Support System
NPV	Net Present Value
QA	Quality Assurance
QC	Quality Control
SAM	Social Accounting Matrix
WP	Work Package
WRPM	Water Resource Planning and Management

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1. INTRODUCTION

1.1 BACKGROUND

Under the aegis of its Water Resources Planning and Management (WRPM) Project, the NBI is in the process of establishing a Nile Basin Decision Support System (NB-DSS) to support water resources planning and investment decisions in the Nile Basin, especially those with trans-boundary or basin level ramifications. Within the NBI's overall vision, which is "to *achieve sustainable socioeconomic development through the equitable utilization of, and benefit from, the common Nile Basin water resources*", the NB-DSS will play a pivotal role in terms of the evaluation of water management interventions. A key objective related to the development of the NB-DSS, is the development of scenario evaluation capability within the context of transboundary, integrated water resource planning and management, with the focus on potential economic, environmental and social impacts of development interventions and management options.

This report presents a Guideline for the Evaluation of Water Management Interventions in the Nile Basin. It provides a general, best practice scenario evaluation framework as well as a step-by-step guide on how to use the scenario analysis tools and functionalities embedded in the NB-DSS.

1.2 CONCEPTUAL APPROACH

Over the past decade, the World Bank has published numerous reports to assist decision making related to water resource developments. Figure 1-1 presents a typical six step conceptual approach towards the evaluation of water management interventions.

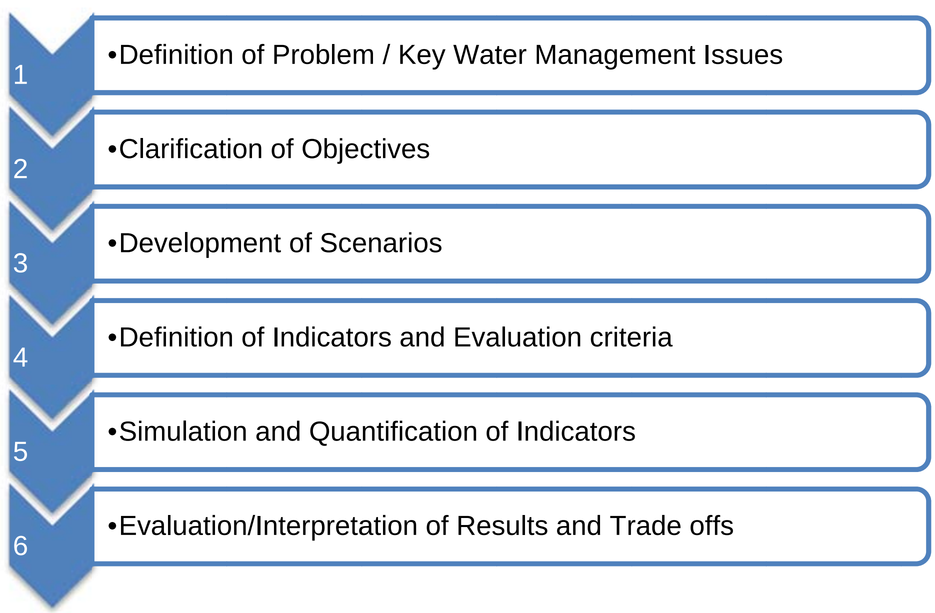


Figure 1-1 : Conceptual Approach for Scenario Evaluation (adapted from Kusek, 2004 and World Bank, 2008)

1.3 DATA TO SUPPORT SCENARIO EVALUATIONS

Data compilation constitutes a critical component in water resource development scenario analysis and relates to the collection, review, preparation and compilation of quality assured and relevant data sets. Data include hydro-meteorological and physical catchment data to support hydrological and hydrodynamic modelling, data on water resource infrastructure and associated operating rules to support system modelling and environmental-, social- and economic related data to support multi-criteria scenario evaluation. The quality and trustworthiness of data and information are critical to improve confidence in decision making and the six criteria in Table 1-1 below can provide a useful indication in this regard:

Table 1-1 : Data criteria

Criteria	Description
Impartiality	The data collection, analysis and reporting process should be free of political or other bias and deliberate distortions. The information should be presented with a description of its strengths and weaknesses. All relevant information should be presented.
Usefulness	The data collection, analysis and reporting process should be relevant, timely, and structured in an understandable form. It needs to address the questions asked, allow the accurate quantification of indicators and ensure that the criteria which will be used for scenario evaluation are presented in a form desired and best understood by decision makers.
Technical adequacy	The data needs to meet relevant technical standards—appropriate design, correct sampling procedures, accurate wording of questionnaires and interview guides, appropriate statistical or content analysis, and adequate support for conclusions and recommendations.
Stakeholder involvement	There should be adequate assurances that the relevant stakeholders have been consulted and involved in the data collection, analysis and reporting process. If the stakeholders are to trust the information, take ownership of the findings, and agree to incorporate what has been learned into ongoing and new policies, programs, and projects, they have to be included in the data collection process as active partners. Denying involvement to stakeholders during the data collection phase could generate hostility and resentment toward the process.
Feedback and dissemination	Sharing information in an appropriate, targeted, and timely fashion is a frequent distinguishing characteristic of data utilisation. There will be communication breakdowns, a loss of trust, and either indifference or suspicion about the findings themselves if: (a) data is not appropriately shared and provided to those for whom it is relevant; (b) the evaluator does not plan to systematically disseminate the information and instead presumes that the work is done when the report or information is provided; and (c) no effort is made to target the information appropriately to the audiences for whom it is intended.
Value for money	Gathering expensive data that will not be used is not appropriate, nor is using expensive strategies for data collection when less expensive means are available. The cost of evaluation needs to be proportional to the overall cost of the initiative.

1.4 PURPOSE AND SCOPE

This guideline has been prepared to provide a structured approach towards the evaluation of water management interventions within a water resource planning context. It provides guidance on an evaluation framework and addresses data, the identification and evaluation of scenarios, the definition and quantification of indicators and the evaluation of alternative scenarios by means of indicator processing and Multi Criteria Analysis (MCA).

1.5 TARGET AUDIENCE

These Guidelines are aimed at technical personnel who will be using the NB-DSS for the evaluation of alternative water resource development interventions and/or management options. However, it also provides water resource managers and other high level water resource decision makers with an improved understanding of general scenario analysis concepts and, more specifically, of NB-DSS outputs and its interpretation to ensure that informed investment and management decisions are made.

2. SCENARIO EVALUATION FRAMEWORK

2.1 INTRODUCTION

MCA methods utilise a decision matrix to provide a systematic analytical approach for integrating risk levels, uncertainty, and valuation, which enables evaluation and ranking of many alternatives. In line with the World Bank conceptual approach (Figure 1-1), MCA can be distilled into eight generic components that comprise a framework for thinking about and approaching multi criteria decision problems as shown in Figure 2-1.

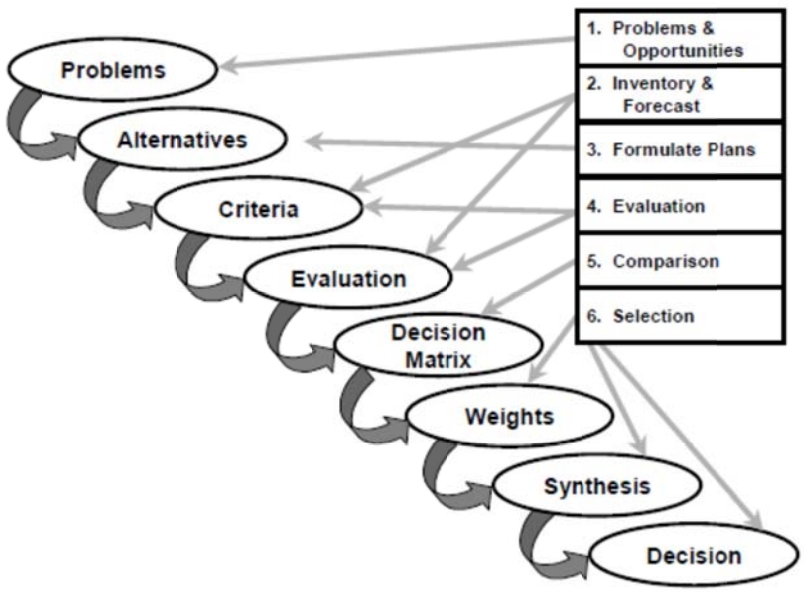


Figure 2-1 : Relation of Planning Process to Multi Criteria Decision Support Framework (Source: U.S. Army Corps of Engineers Institute for Water Resources, 2002)

The first step in this decision process is to identify the relevant problems, opportunities and key water management issues. This is done in step one of the planning process.

Next, the alternative solutions to the problem are identified. That is accomplished in step three of the planning process which involves identifying development interventions and management options aimed at addressing the issues identified in Step 1.

Criteria for evaluating the alternative solutions to the problem are required. These criteria are identified in the data collection and evaluation steps, steps two and four of the planning process.

All multi criteria decision making techniques are virtually identical in general concept, though often quite different in practice, through creation of the decision matrix. This work is equivalent to the work done in the comparison step (step five) of the planning process.

Multi criteria decision-making techniques are most distinctive in the manner in which they accomplish the last three steps of the decision support framework. Weights can be applied in a variety of ways. The nature and extent of the synthesis and the final decision are also markedly different. These tasks would be accomplished in the final step of the planning process.

Like the planning process, the decision support framework is iterative. Although it is presented in a linear fashion, it may begin at many steps, and the steps may be repeated an asymmetric number of times in any order. The framework provides structure, order, transparency and replicability to the decision-making process when it is followed purposefully and systematically.

In the following paragraphs each of the eight components of the decision support framework is discussed in more detail.

2.2 PROBLEMS (ISSUES)

Multicriteria decision-making techniques all begin with problems that need to be solved. Water resource planning begins with problems related to water management issues and opportunities. Problems are situations to be avoided. Opportunities are situations we hope to attain or realize. Problem and opportunity statements provide the specific reasons for planning. Identifying problems and opportunities is akin to making clear the specific question(s) the planning team is trying to answer. In this sense the problems and opportunities form the mission statement for the planning team. To have an effective decision-making process it is essential that everyone involved in the decision have a clear understanding of the decision context. This includes understanding the problems, opportunities and the planning objectives for the planning investigation. It also means understanding who the decision makers are.

A decision support framework is relevant to water resource planning investigations because planning investigations tend to have multiple problems. These problems tend to be multidimensional and complex and involve conflicting objectives as well as conflicting value systems. Aggregating or optimising any single objective cannot produce solutions to such problems. Solutions generally involve multiple criteria, trade-offs, compromise, conflict resolution and judgment, especially in shared river basins where there are many riparian countries.

2.3 ALTERNATIVES (SCENARIOS)

Development interventions and/or management options form the basis of alternatives, which are expressed in the form of different scenarios. Scenario analysis involves a structured process which highlights key issues around decision making processes. Scenarios are used to compare various “what if” cases and provide a structured method of thinking about possible future water resource development and management options, opportunities and risks, and how these might interact. The results are useful for consensus building and decision making. Scenario analysis assists decision makers with managing risk, developing concrete contingency plans and exit strategies and building consensus for change. Furthermore, scenario analysis augments the understanding about the future by highlighting issues and exposing underlying forces in a sector or geographic region that would otherwise not be considered.

Within the context of the NBI, a scenario is defined as *“a contemplated state of the Nile Basin induced either through targeted human intervention (e.g. combinations of development and management interventions) or through externalities (e.g. climate change, economic policies etc.)”.*

The definition of scenarios need to be informed by the prioritisation of key water management issues in the study area, in conjunction with the identification of potential development interventions and water management options to address these issues. Scenarios are most valuable when they are brought in at the point in the project cycle at which the overall direction of the intervention is being designed or significantly rethought. If it is meant to be the key strategic framework for an operation, the scenario process should be integrated with the budgeting, negotiation, and implementation of a project rather than treated as a stand-alone exercise.

The actual creation of scenarios should preferably take place with a group in a workshop. Because scenarios are developed with a team of knowledgeable stakeholders, they are an effective way to gain acceptance for strategies.

As part of the scenario definition process it is important to recognize two main categories of driving forces viz. external and organizational forces.

- External forces are the social, economic, environmental, and political forces in society that are relevant to the topic of the scenario discussion but are outside the participants' control.
- Organizational forces are the product of the actions of the stakeholders and refer to the implementation of development interventions, management strategies, policies etc.

Although these forces will remain the skeleton of each future narrative, it is important to develop a structured scenario plot to include a larger number of driving forces. The key elements of a good scenario plot include "Critical Planning Issues" and "Critical Scenario Drivers" from the Impact/Uncertainty Matrix. The impact-uncertainty matrix provides a useful tool to prioritise scenarios in terms of expected impacts and uncertainty issues and can be used to narrow the list of forces to the most relevant for differentiating scenarios.

Scenario plots are different futures that are designed specifically to highlight opportunities and risks associated with certain decisions. In the water resources domain, these decisions typically relate to investment in new infrastructure and management or operational interventions and decisions e.g. whether to construct new dams, how to operate the dams, identifying and quantifying anticipated impacts, assessing possible external drivers and their impacts etc. Scenario plots should be built around high-impact/low uncertainty issues (highly relevant issues with predictable future outcomes for which current planning must prepare) and high-impact/high uncertainty issues (issues that could shape different futures which planning should take into account) (see Table 2-1). By addressing rather than minimizing uncertainty, scenarios spur innovative and robust solutions.

Scenario plots should differ from one another without being widely positive or negative. It is important that they challenge assumptions while remaining balanced enough that they are not dismissed out of hand.

Some plot types that can help create stories about the future include:

• Winners and losers. These scenarios explore the future in terms of ascendant versus declining forces.

• Good news/bad news. These stories ask decision makers "what if?" questions about the logic of their long-term plans in the face of key forces that can move in unexpected directions.

• States of change. This model is one of additive change, a world in which a series of alterations feed off one another to move society into a different mode.

• Cycles. Another way of looking at change is through cycles, both economic and political.

• Wild cards. Wild-card stories explore how catalytic developments could completely reshape future developments.

Table 2-1 : Impact-Uncertainty Matrix

Degree of Uncertainty				
Low	**Medium**	**High**		
Critical planning issues Highly relevant and fairly predictable (can often be based on existing projections). Should be taken into account in all scenarios.	**Important scenario drivers** Extremely important and fairly certain. Should be used to differentiate scenarios. Should be based on projections but potential discontinuities also should be investigated.	**Critical scenario drivers** Factors and forces essential for success and highly unpredictable. Should be used to differentiate scenario plots and trigger exit strategies.	**High**	**Level of impact**
Important planning issues Relevant and very predictable. Should be figured into most scenarios.	**Important planning issues** Relevant and somewhat predictable. Should be present in most scenarios.	**Important scenario drivers** Relevant issues that are highly uncertain. Plausible, significant shifts in these forces should be used to differentiate scenario plots.	**Medium**	
Monitorable issues Related to the decision focus but not critical. Should be compared to projections as scenario is implemented.	**Monitorable issues** Related but not crucial to the decision focus. Should be monitored for unexpected changes.	**Issues to monitor and reassess impact** Highly unpredictable forces that do not have an immediate impact on the decision focus. Should be closely monitored.	**Low**	

Qualitative and quantitative research on relevant issues should be carried out before scenarios are defined. Scenario development is not easy. The process demands significant effort, thought, and creativity. Some of the critical factors to be considered towards development of sustainable scenarios include:

1. Failure to gain the support of key decision makers: To be credible, scenarios need to be integrated in the decision making apparatus of the organization in which they will be implemented.

2. Unrealistic goals and expectations: Scenarios do not produce action plans; they help decision makers envision what will happen. The methodology is not suited to addressing specific strategic issues. It is rather meant to provide a broad view of the uncertainties facing an intervention. Strategic decisions follow from this understanding, but they are not a direct product of the exercise.

3. Failure to develop a clear map of the future with monitorable indicators: It is essential that clear, monitorable milestones of progress are developed toward the various scenarios. These milestones should have a direct relationship to the goals and planned outcomes of the intervention.

4. Scenarios that are not credible: Scenario workshops are not brainstorming sessions. Scenarios must be based on solid quantitative as well as qualitative projections if they are to be credible to those implementing them. Because scenarios do not assign probabilities or project against current trends, it is important to make sure that they are based on strong research.

5. Scenarios that are not tied to the planning process: The indicators and thinking in scenarios must be directly built into the way that an intervention is planned. Scenario indicators should be closely monitored and associated with explicit changes in strategy, including exit strategies. Similarly, scenarios should be related to the policy cycles of respective stakeholders.

6. Not enough time to carry out the scenario process: The process requires discipline and attention. It can be divided in two phases: scenario building and relating scenarios to strategy.

7. Inappropriate time frame and scope: Scenarios that focus on current crises and existing problem areas rather than looking at the interaction of broader forces do not generate the kind of new thinking necessary to jump-start an agenda.

8. Failure to tell a dynamic, internally consistent story: Scenarios should be dynamic. Each scenario should be a smooth narrative that makes intuitive sense. The main aspects of the future should be internally consistent; the outcomes postulated for the two key uncertainties should be able to coexist; and the actions of stakeholders should be compatible with their interests.

9. Lack of diversity of inputs: If the scenario team members are of homogeneous educational backgrounds and institutional affiliations, they will be much less likely to come up with innovative solutions. To build successful scenarios, the participation of a diverse group of people is essential.

2.4 CRITERIA (INDICATORS)

Within the context of water management intervention scenario evaluations, indicators are required to quantify and simplify information in a manner that facilitates an understanding of impacts related to water resource interventions. Typically, their aim is to assess how interventions affect the direction of change in environmental, social and economic performance, and to measure the magnitude of that change. Evaluation criteria are then defined through a single or combined set of indicators, which have been identified and quantified during scenario planning and appraisal and which forms the basis of scenario evaluation.

The selection and specification of indicators is a core activity during the evaluation of water management interventions as it drives all subsequent data collection, analysis and reporting tasks. The table below provides a categorization of indicators based on the structure of the results-based approach to project design and management. A structured set of indicators needs to be identified during scenario planning and appraisal and will form the basis of scenario evaluation.

Table 2-2 : Structured indicators for evaluation of water management interventions

<table>
<tr><th>Category</th><th colspan="3">Type of Measurement</th></tr>
<tr><td>Impact indicators:
measures of medium or long term physical, financial, institutional, social, environmental or other developmental change that the project is expected to contribute to.</td><td rowspan="2">Leading indicators: advance measures of whether an expected change will occur for outcomes and impacts.</td><td rowspan="5">Cross-cutting indicators: measures of crosscutting concerns at all levels.</td><td rowspan="5">Exogenous or external indicators: measures of necessary external conditions that support achievement at each level</td></tr>
<tr><td>Outcome indicators:
measures of short-term change in performance, behavior or status of resources for target beneficiaries and other affected groups.</td></tr>
<tr><td>Output indicators:
measures of the goods and services produced and delivered by the project.</td><td rowspan="3"></td></tr>
<tr><td>Process indicators:
measures of the progress and completion of project activities within planned work schedules.</td></tr>
<tr><td>Input indicators:
measures of the resources used by the project.</td></tr>
</table>

Within the context of water management intervention scenario evaluations, Impact and Outcome indicators, which are indicators for 'results' monitoring and evaluation, are most relevant.

The selection of indicators should be based on the following considerations:

- ability to distinguishing between alternative development scenarios
- relevance to key issues and associated multi-criteria analysis
- compatibility with the resolution and limitations of the DSS
- availability of reliable data
- simplicity and ability to easily interpret and understand
- ability to be quantified across different model scenarios

Four main steps are recommended for the formulation of indicators:

1) Clarify project objectives

Clear and precise statements of the scenario evaluation objectives greatly aid the specification and definition of indicators.

2) Develop a list of possible indicators

Identification of relevant outcome and impact indicators can be difficult and requires some analysis. The analysis must consider the information that will be needed to quantify indicators. The selection of environmental social and economic indicators for scenario evaluation should be done in collaboration and consensus building with key stakeholders. Participation of all key stakeholders in defining indicators is important because they are then more likely to understand and use the information provided by the indicators for management decision making. In addition, the feasibility of quantifying the indicators based on links (responses) to water-related DSS outputs and by the availability of relevant external data to support these links are also critical considerations during the indicator selection stage. In practice, a trade-off may be necessary between an indicator that would give all information needed and the 'practicalities' of data collection and analysis.

The process of indicator definition is iterative and not a simple progression, and definition of indicators cannot be separated from consideration of data collection, analysis, and use. Ultimately the choice of indicators must be well adapted to the characteristics of the project, data availability and accessibility, and the evaluation framework that is to be used. Table 2-3 provides examples of different indicator types.

Table 2-3 : Examples of different indicator types

Indicator Types	Examples	Explanation
Simple quantitative indicators	change in low flows no of households displaced average energy generated	Direct measurement of the appropriate single quantity or ratio.
Complex quantitative indicators	loss in productive land direct employment opportunities	Requires specification of more than one data element. Such as: months, type of food shortage, type of household.
Compound indicators	environmental impact rating	Requires a standard to be defined, and an individual assessment made for each unit of concern. E.g. 'effective' functioning for each water unit area.
Indices	ecological stress index	Indices combine a number of different indicators to enable comparison. Requires consistency in the selection, measurement and weighting of variables used for the index.
Proxy indicators	availability of water (water stress) impact on recession agriculture	Needed when it is difficult or too costly to measure an outcome or impact indicator directly. Provides an indirect or approximate measure based on an assumed relationship.
Open ended qualitative indicators	stakeholder perceptions of project outcomes stakeholder perceptions of reasons for change	Open ended enquiry can establish stakeholder priorities and reveal unexpected changes and outcomes. Data collected can be difficult to process and analyze.
Focused qualitative indicators	farmer explanations of higher yields farmer identification of problems with gate operation	Can collect specific information. Possible responses can often be identified by pilot survey and pre-coded to aid data collection and analysis.

Source: Guijt and Woodhill, 2002.

3) Assess each possible indicator

Each indicator initially selected for inclusion in the scenario evaluation needs to be carefully scrutinized and tested before acceptance. Table 2-4 presents criteria against which indicators can be tested to ensure that they are suitable for inclusion.

Table 2-4 : Criteria for selection of indicators

Criteria	Description
Relevant	Indicators must be representative of the most important aspects of implementation and of the outcomes and impacts intended.
Clear	Indicators must be unambiguous and clearly defined in the project's context, and in a manner understood and agreed by all stakeholders.
Specific	Indicators should measure specific changes, and be specific to a timeframe, location and target or other stakeholder group.
Measurable	There must be practical ways to measure the indicator, either in quantitative or qualitative terms, that are within the capability of the monitoring organization. It must be possible to collect, process and analyze data in time and within budget.
Consistent	The values of the indicators should be reliable and comparable over time when collected using the same methods. This is more likely when indicators are measured in a standardized way and with sound sampling procedures.
Sensitive	Indicators should be sensitive to the expected changes. It is especially important that leading indicators are capable of revealing short-term movements. Indicators that require long time series of values are practically useless for implementation decisions.
Attributable	In moving from inputs and outputs to outcomes and impacts, attribution must typically rely less on direct observation of cause and effect and more on statistical evidence of change and its probable cause.

Source: Adapted from Guijt and Woodhill, 2002, and Kusek and Rist, 2004

4) Finalise selection of indicators

The initial list of indicators generated needs to be narrowed down to a usable and feasible set. It is important to keep data collection within a manageable scope, and hence to reduce the number of indicators to the minimum necessary to meet key management and reporting needs. Monitoring too many indicators can be self- defeating. However, it is important to ensure that as a minimum, the set of selected indicators should enable a reliable assessment of the five core evaluation criteria as listed below:

- Impact: The effect of the project on its wider environment, and its contribution to the wider policy, sector or Country Assistance Strategy development objectives.
- Relevance: The appropriateness of project objectives to the problems intended to be addressed, and to the physical and policy environment within which the project operates.
- Effectiveness: How well the outputs contributed to the achievement of project component outcomes/ results and the overall Project Development Objective(s), and how well assumed external conditions contributed to project achievements.
- Efficiency: Whether project outputs have been achieved at reasonable cost, i.e. how well inputs have been used in activities and converted into outputs.
- Sustainability: The likelihood that benefits produced by the project continue to flow after external funding has ended.

Frequent changes in indicators should be avoided so as to maintain the continuity and consistency of data collection, but the selection made does need to be kept under review and may need to be updated as a project evolves. If the information being provided by an indicator is not being used then it should be dropped or revised

An effective multi criteria analysis requires a clearly defined set of criteria. Thus, multi criteria analysis requires the analyst to distill the candidate planning objectives and plan attributes down to a coherent set of criteria for use in plan selection and decision making. Roy (1985) defines a set of criteria as coherent if the following three properties are satisfied: (1) exhaustiveness, (2) consistency and (3) nonredundancy.

Exhaustiveness is satisfied when no important criterion has been forgotten. When discriminating among scenarios, the decision maker should not have to resort to any test, principle, rule, or standard that is not explicitly included among the criteria.

A good set of criteria is consistent between all scenarios. If a set of criteria is exhaustive and consistent, then we call them non-redundant if removing any one single criterion, leads to the remaining criteria no longer being exhaustive or consistent.

Criteria are often correlated. Although there is no reason to expect criteria to be independent, they should not be redundant. For example, there can be many environmental objectives in a planning process, and there may be many environmental attributes. Including each one among your criteria may add nothing to your ability to discriminate among plans, identify trade-offs or resolve conflicts among values. Once the initial set of criteria is developed, closely related criteria should be combined. Then try to eliminate each criteria in turn. If nothing of value is lost to the decision maker, the eliminated criterion is redundant for decision-making purposes.

Criteria can be both qualitative and quantitative:

Qualitative data are divided into empirical and subjective categories. Empirical data are based on observation or experience. Not all qualitative impacts can be empirically determined. Some must be expressed in qualitative terms such as equitable or inequitable, acceptable or not acceptable, sustainable or unsustainable and so on.

Quantitative measurements are expressed numerically. The first natural division of the quantitative criteria is based on the quantitative content of the numbers used. Hence, quantitative criteria can be ordinal or cardinal. Ordinal data can be used to order or rank the alternatives for an individual criterion These ranks can be expressed in nominal terms, such as large, medium, small, or in numerical terms, such as first, second, third or one star, two stars, three stars. Cardinal data are ratio scale data. Ratio data are measured in fixed units of measure such as real numbers, degrees, dollars and the like. They can be used for ranking, and the ratio of such measures is meaningful.

2.5 EVALUATION (INDICATOR QUANTIFICATION)

The next component of the decision support model is evaluation. This is where indicators are quantified for each alternative (scenario). In essence, indicators to evaluate water management interventions are quantified based on response functions which describe the relationship or linkage between water resource driven processes (i.e. model outputs) and impacts on indicators by means of algorithms or matrices. Typically these response functions are based on empirical relationships derived from observed data, on physically based conceptual models which describe indicator responses in relation to physical parameters or on statistical indices or relevant values extracted from output time series. Within the context of the NB-DSS, the response functions are intended to describe the environmental, social and economic consequences of changed flow regimes and other developmental impacts due to development interventions and/or management options

2.6 DECISION MATRIX

This task usually has three distinct phases:

- Construction of the decision matrix.
- Pre-analysis of the decision matrix.

- Normalisation of the pre-analysed decision matrix.

The decision matrix summarises the performance of each alternative (scenario) for each criterion. By decision theory convention, the alternatives are listed in the rows and the criteria in the columns.

2.6.1 Construction of Matrix

The decision matrix lists criteria values for alternative scenarios from which the recommended scenario will ultimately be selected. The criteria values entered in the matrix express the performance of each scenario relative to other scenarios in terms of different combinations of indicator values. The information in the decision matrix forms the basis for either the recommendation to the decision maker or the decision maker's selection of the recommended plan. A simple example of a decision matrix is presented below.

Table 2-5 : Decision Matrix example - Nile Basin DSS

	Env sens area	Carbon emissions	Eco stress	Wet season duration	Bank stability	Wet season shift	Water availability	Malaria risk	Recession agric	Fish-dams	Loss in productive land	Physical displacement	BCR	Avg energy produced system	Food production	Navigation
Group	ENV	ENV	ENV	ENV	ENV	ENV	SOC	SOC	SOC	SOC	SOC	SOC	ECON	ECON	ECON	ECON
Unit	km2	million t	Index	% change	Index	no weeks	% change	%	% change	ton/a	km2	no households	Index	GWh/a	million t/a	change in days/year
BAS 1_1	0	0.4	-5	-16	-1	8.4	322	0	-3	7530	18	2401	2.89	8486	0.0	80
BAS 2_1	979	1.7	-5	-22	-1	15.7	294	7	-8	7750	20	2936	3.79	5714	5.5	76
BAS 3_1	979	2.0	-5	-34	-1	8.4	286	7	-3	8373	37	4742	3.27	8486	5.5	80

2.6.2 Pre-Analysis

Once the preliminary decision matrix is assembled, it should always be subjected to a simple, structured review before the analysis proceeds. This step is called the pre-analysis. The alternatives identified in the matrix have presumably survived the evaluation step of the planning process. This means they have been subjected to some sort of disjunctive or conjunctive process that has qualified them for consideration for selection.

The first step in the pre-analysis is to eliminate redundant criteria that do not vary from one scenario to the next. These criteria, as important as they may be to qualifying a plan, serve no useful purpose in the decision matrix. They do not discriminate among plans and therefore are not essential to the choice of a recommended plan.

The next step in the pre-analysis is to eliminate alternatives from the matrix that are dominated by one or more other alternatives. If any one alternative dominates all others, there is no need to proceed with the decision process. The decision has been made, or it is time to go back and formulate more plans. In some cases a plan may dominate one or more but not all other plans. In these cases the dominated plan(s) should be eliminated from the decision matrix or reformulated to avoid domination.

Table 2-6 : Pre-Analysis example from the NB-DSS

	Costs	Urban water supply deficit	Groundwater Pumping	Flows below Dam	Irrigation	Public Acceptance
Rank	rank	rank	rank	rank	rank	rank
Future scenario (2020) - No Action	1	5	1	3	1	5
Future scenario (2020) - Reduce Irrigation	2	3	1	3	4	3
Future scenario (2020) - Groundwater Augmentation	4	2	5	3	1	2
Future scenario (2020) - Mix of Actions	5	3	4	2	3	3

Green	dominating
Yellow	redundant
Red	not included
Orange	dominating and not included
Light green	dominating and redundant
Purple	redundant and not included
Blue	dominating, redundant and not included

2.6.3 Normalisation

Normalisation is an important interim process to ensure that the different criteria values are comparable. An example of normalized criteria is shown in the table below.

Table 2-7 : Transformed Decision Matrix in the NB-DSS

	Env sens area	Carbon emissions	Eco stress	Wet season duration	Bank stability	Wet season shift	Water availability	Malaria risk	Recession agric	Fish-dams	Loss in productive land	Physical displacement	BCR	Avg energy produced system	Food production	Navigation
Group	ENV	ENV	ENV	ENV	ENV	ENV	SOC	SOC	SOC	SOC	SOC	SOC	ECON	ECON	ECON	ECON
Unit	km2	million t	Index	% change	Index	no weeks	% change	%	% change	ton/a	km2	no households	Index	GWh/a	million t/a	change in days/year
BAS 1_1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.899	1.000	1.000	0.763	1.000	0.000	1.000
BAS 2_1	0.000	0.234	1.000	1.344	1.000	0.535	0.912	0.001	3.200	0.926	0.928	0.818	1.000	0.673	1.000	0.950
BAS 3_1	0.000	0.198	1.000	2.063	1.000	1.000	0.887	0.001	1.000	1.000	0.492	0.506	0.863	1.000	1.000	1.000

There are a variety of normalization routines. The goal is to take a series of measurements for a given criterion and convert these into a series of normalised values, usually between zero and one.

The four most common normalization techniques are defined below:

Percentage of Maximum

$$v_i = \frac{a_i}{\max a_i}$$

Percentage of Range

$$v_i = \frac{a_i - \min a_i}{\max a_i - \min a_i}$$

Percentage of Total

$$v_i = \frac{a_i}{\sum a_i}$$

Unit Vector

$$v_i = \frac{a_i}{\sqrt{(\sum_i a_i^2)}}$$

with:

a : the measurement of a criterion;

a_i : the criterion measurement for any given Scenario; and

v_i : normalized value of a_i.

There is no one single method that can prove itself to be the globally acceptable approach for normalization. Rather, characteristics of various indicators and parameters have to be evaluated and a normalisation process has to be selected that can support comparison of various parameters at a comparable scale.

As a general guidance the following recommendations are provided:

- If the normalized values are expected to range between 0 and 1, use 'percentage of range'.
- If the values are expected to sum to one, use 'percentage of total'.
- If the values of the indicators considered should remain constant in the interval [0; 1], the 'unit vector' technique should be used.
- If there is no basis for favoring one over the other, use 'percentage of maximum' - it is the most commonly used technique.

The remainder of this sub-section provides examples of the different normalisation techniques using the decision matrix in Table 2-8 as common basis.

Table 2-8 : Decision Matrix –Original criteria values

	Net NED Benefits	Aquatic Habitat	Upland Habitat
Scenario 1	$477,000	Slight decrease	+45HUs
Scenario 2	$196,000	Modest increase	+40HUs
Scenario 3	$260,000	No change	+30HUs
Scenario 4	$294,000	Slight increase	+60HUs

The first normalization technique is to calculate each criterion measurement as a percentage of the maximum value for that criterion. The resultant matrix is shown in Table 2-9.

Table 2-9 : Decision Matrix – Normalized by Percentage of Maximum

	Net NED Benefits	Aquatic Habitat	Upland Habitat
Scenario 1	1.0000	0.2500	0.7500
Scenario 2	0.4109	1.0000	0.6667
Scenario 3	0.5451	0.5000	0.5000
Scenario 4	0.6164	0.7500	1.0000

First, note that all values are expressed as numbers between zero and one. That will be true for all the techniques presented here. This is the most widely used technique, but not the only one. Scales from 1 to 10, 1 to 100 or others ranges can be used. This percentage of maximum technique respects cardinality and preserves proportionality. Note the values do not sum to one.

The values for each cell are obtained by identifying the maximum value in a column. Then each column value is divided by that maximum to obtain the normalized vector shown. For example, $477,000 is the maximum net benefit. The Scenario 3 value is $260,000/ $477,000 or 0.5451.

One weakness of this technique is that it does not cover the interval [0,1]. Another frequently used normalization technique is the percentage of range approach, which is designed to do just that. This result matrix is presented in Table 2-10.

Table 2-10 : Decision Matrix – Normalized by Percentage of Range

	Net NED Benefits	Aquatic Habitat	Upland Habitat
Scenario 1	1.0000	0.0000	0.5000
Scenario 2	0.0000	1.0000	0.3333
Scenario 3	0.2278	0.3333	0.0000
Scenario 4	0.3488	0.6667	1.0000

Notice that each criterion now has a zero value and a one value. This technique respects cardinality, but it does not preserve the proportionality of the original values. To derive these weights, calculate the range for a criterion and then divide each criterion value less the minimum by its range. For example, the range in benefits is $477,000 - $196,000 = $281,000. Then ($260,000 - $196,000)/$281,000 = 0.2278. Other values were calculated similarly. Note that these values do not sum to one either.

A third normalization procedure that is frequently used, for example in the analytical hierarchy method, is presented in the result matrix in Table 2-11. This is the percentage of total method. Adding all the criterion measurements then dividing each criterion value by this sum normalizes the values.

Table 2-11 : Decision Matrix – Normalized by Percentage of Total

	Net NED Benefits	Aquatic Habitat	Upland Habitat
Scenario 1	0.3888	0.1000	0.2571
Scenario 2	0.1597	0.4000	0.2286
Scenario 3	0.2119	0.2000	0.1714
Scenario 4	0.2396	0.3000	0.3429

Scenario 3 value for benefits is obtained by adding all the benefit measurements, \$477,000 + \$196,000 + \$260,000 + \$294,000 = \$1,227,000, then dividing each measurement by this sum. Hence, Scenario 3's benefit value is \$260,000/\$1,227,000 = 0.2119. This technique respects cardinality and preserves proportionality of the data. It is the only technique presented here where the normalized values are guaranteed to sum to one. For this reason, this technique is one of the most useful techniques for normalizing weights.

The final normalization technique presented here is the unit vector technique. Once again a denominator common to each measurement for that criterion divides the individual criterion measurement. In this case the denominator is the square root of the sum of the squares of all the individual criterion measurements. The values are presented in the result matrix of Table 2-12.

Table 2-12 : Decision Matrix – Normalised by Unit Vector

	Net NED Benefits	Aquatic Habitat	Upland Habitat
Scenario 1	0.7360	0.1826	0.4992
Scenario 2	0.3024	0.7303	0.4438
Scenario 3	0.4012	0.3651	0.3328
Scenario 4	0.4537	0.5477	0.6656

Once again the values are arrayed between zero and one. This technique respects cardinality and preserves proportionality. The modulus of the normalized vector always equals one with this technique, whereas in the others it is a variable value. To obtain the value for Scenario 3 benefits we take $\$260{,}000/(\$477{,}000^2+\$196{,}000^2+\$260{,}000^2+\$294{,}000^2)^{\wedge 0.5} = 0.4012$.

It is important to note that the choice of normalisation technique can make a difference in the answers obtained from a multi-criteria analysis.

2.7 WEIGHTING

Once the decision matrix has been completed and normalized, it is time to use it to help make a decision. The next crucial step in this process is to establish weights for the various criteria. Assigning weights to the criteria is often the most contentious task in multicriteria decision making because it is by definition the most subjective task. Weights are often normalized using the same techniques described for criteria measurement.

All criteria are not always going to be equally important. A decision maker may find one criterion more or less important than another. A weight is a measure of the relative importance of a criterion as judged by the decision maker. Assigning weights is in fact a technique for collecting data on human judgments about the relative value of a set of criteria. Weights, which may be ordinal or cardinal in nature, are used to define the relative importance of the decision matrix criteria.

Multi criteria analysis has an analytical component and a judgmental component. The judgmental component relies on subjective preferences held by the assumed decision maker. The analytical component comprises the extensive analyses undertaken in the planning studies that lead to the identification of alternatives and criteria as well as their detail, description and measurement. Weighting the criteria is the major judgmental component of the multi criteria analysis. The principal task of the framework's weighting component is to develop a set of cardinal or ordinal values that indicate the relative importance of each criterion. These values are subsequently used in a ranking algorithm to determine the relative score of each alternative, given the criteria and their relative importance.

The weighting techniques that are available in the NB-DSS are fixed point scoring, rating, and ordinal ranking. When choosing a weighting method, the analyst must make trade-offs between thoroughness and detail of information against complexity and the amount of time taken to develop the weights.

Fixed Point Scoring

This weighting method begins with a fixed number of points such as 100, 10 or any other number. The decision maker then distributes these points amongst the criteria. More points allocated to a criterion indicate greater importance. Percentages are sometimes used. Allocating weights that sum to one is another variation of this theme. The key is that the decision maker apportions the points directly. Simplicity and transparency are advantages of this technique. It also has the advantage of forcing the decision maker to make trade-offs. The only way to give greater importance to one criterion in a fixed-point approach is to give less importance to another criterion. This advantage then is also the greatest weakness of the method. Decision makers may find making these tradeoffs difficult. Nonetheless, this method may well be the most direct way to obtain information about the decision maker's preferences.

Table 2-13 shows how four criteria might be weighted using the fixed point scoring method. All are mathematically equivalent to the weights summing to one. Usually decimal weights or percentages are preferred. Nonetheless, the decision maker may be comfortable allocating points from 0 to 100 or some other scale. No matter how that is done, the weights can always be subsequently normalized to the [0,1] interval.

Table 2-13 : Fixed Point Scoring Examples

	Decimal	**Points**	**Weight (%)**
Net Benefits	0.15	15	15
First Cost	0.30	30	30
Aquatic Habitat	0.15	15	15
Upland Habitat	0.40	40	40
Total	**1.00**	**100**	**100**

Rating

The rating techniques allow the decision maker to place each criterion on a scale by assigning a number to each criterion. For example, movies are often rated on a scale of one to four stars. Rating systems use a common scale for each criterion and there is no limit on the number of points that can be assigned to a criterion other than the limit imposed by the choice of the scale. Scales of 1 to 100 and 1 to 10 are common. Likert scales are also used. Two examples of Likert scales are shown in Figure 2-2.

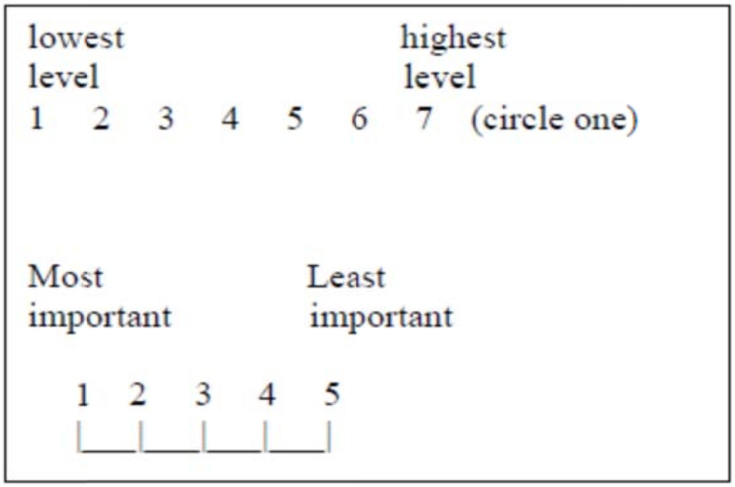


Figure 2-2 : Likert Scale Examples

The numbers in a Likert scale are used to indicate importance. The interval distance between values is implicitly identical with Likert scales. The choice of the number of integers used is somewhat arbitrary, as is the definition of the scale, e.g., lowest to highest, highest to lowest. Circumstances of the decision problem will usually dictate those choices, but some level of importance is likely to be most meaningful for addressing the weighting of criteria for multicriteria analysis. It is helpful to develop a consistent pattern in the use of any rating scale. This method does not constrain the decision maker's responses. It is possible to change the weight of one criterion without affecting the weight of another. A fixed point scoring method forces the decision maker to make explicit trade-offs; the rating technique does not. This is the most important difference between these two methods.

Ordinal Ranking

Ordinal ranking requires the decision maker to rank the criteria in order from least important to most important. This is an easy task to handle conceptually. An issue of some concern with this technique is that it is often still necessary to derive cardinal weights from the ordinal ranking because some aggregation techniques require cardinal rankings. Table 2-14 clearly illustrates the decision maker's ordinal preferences for these criteria. However, it is not yet clear how they might be combined with the criteria measurements in this form. One common approach is to transform the ordinal weights into cardinal weights. The naïve approach to this conversion is to scale the ordinal rankings to an [0,1] interval such that the new rankings sum to one. In the example, this would mean a rank with weights as shown in Table 2-15. Note that the ordinal ranking is first reversed in the importance points column to establish the desired relationship between rank order and weights. The points assigned to each rank are then summed and prorated in the last column. This is the simplest technique for developing cardinal weights from ordinal rankings.

Table 2-14 : Ordinal Ranking

	Points
Net Benefits	4
First Cost	2
Aquatic Habitat	3
Upland Habitat	1

Table 2-15 : Naïve Approach to normalising ordinal ranking

	Ordinal Ranking	Importance Points	Cardinal Weights
Net Benefits	4	1	1/10
First Cost	2	3	3/10
Aquatic Habitat	3	2	2/10
Upland Habitat	1	4	4/10
Sum	**10**	**10**	**1**

2.8 SYNTHESIS

This is the step in the decision framework when the alternatives, the criteria, the weights and the decision matrix are combined to aid the decision maker. This is achieved by calculating "scores" for each alternative (scenario) based on the normalized values and weights associated with the predefined criteria, which then allows the scenarios to be compared and ranked on a uniform basis. The differences in scenarios, i.e., the conflicts and trade-offs as well as their sensitivity to assumptions, are made explicit in this step. Opportunities to resolve conflicts cannot emerge unless and until the conflicts are recognized and understood. These opportunities may come in the form of additional iterations of the planning process. New scenarios may be formulated. Criteria may be added for better discrimination among plans; other criteria may be omitted. Values may be varied through the exploration of other weights.

The synthesis combines all the decision framework efforts and prepares them for use in the final step of the decision support framework: decision making. The precise manner in which that is done is extremely varied and depends on the decision-making model employed. The synthesis step combines all the separate analyses and judgments and prioritizes the alternatives of the decision problem. Discussion is an important component of the synthesis step. Decision makers must have a clear understanding of the elements of the decision matrix. They must have a clear understanding of the alternatives, the criteria and their measurements. They must understand the nature of the weights and the value systems that enter the decision process. In addition, they need a rudimentary understanding of the algorithms used to synthesize the analysis. Most importantly, they need a clear understanding of the results of the synthesis.

An example of a decision matrix in which the scenarios have been scored and ranked is shown below.

Table 2-16 : Scenario scores and ranking – NB-DSS

	Env Sens Area	Env Hotspot	Carbon Emissions	Eco Stress	Seasonal Shift	Water availability	Recession Agric	Fish Production	Physical displacement	CBR	Average Energy	Overall	
Score	score	score	score	score	score	score	score	score	score	score	score	**Score**	**Rank**
Kagera Scenario 1 WU	0.000	0.000	0.000	0.000	0.000	0.091	0.000	0.121	0.000	0.167	0.152	0.530	1
Kagera Scenario 2 WU	0.076	0.061	0.045	0.030	0.015	0.000	0.106	0.000	0.136	0.000	0.000	0.470	2

2.9 DECISION MAKING

The final component in the MCA process is where informed decisions are made based on the evaluation and interpretation of the MCA outcomes. This could entail a final decision on one single most favourable scenario based on the intervention with the highest overall score, the shortlisting of scenarios for further investigation or the ranking of scenarios for further detailed studies. Solutions generally involve multiple criteria, trade-offs, compromise, conflict resolution and judgment, especially in shared river basins where there are many riparian countries. In the case where a specific water management intervention (scenario) addresses the key problems and issues and sufficiently achieves the opportunities, this scenario is taken forward as the preferred scenario. If no feasible scenario presents itself, the scenarios can be modified to make them qualify or the existing scenarios will have to be discarded and new scenarios defined. When making decision related to water management interventions, it is important that cognizance is also taken of the potential impacts associated with external factors which could have a significant impact on the outcome and viability of the interventions under consideration. These include climate change impacts, economic trends, policy changes, changes in funding mechanisms etc. As part of the evaluation process, these externalities need to be evaluated by means of sensitivity analyses and other relevant techniques.

During the decision making phase, advanced analysis techniques such as sensitivity and trade-off analysis can also be used to further inform the decision on the most appropriate intervention.

2.9.1 Sensitivity analysis

During the synthesis stage sensitivity analysis sets up the basis of an important evaluation metric in all multi decision evaluation problems. The objective is to test the impact of individual parameters (either in the form of indicators or criteria) on the ultimate solution. Therefore, both sector specific and cross-sectoral decisions can be tested with respect to their individual or joint impacts on the solution. This process is quite important to allow decision makers objectively measure the impacts of various parameters and reach to conclusive actions rather than utilize subjective assumptions with respect to the impact of individual or joint parameters. Sensitivity analysis can be performed by varying weights assigned to respective criteria. As such original weights can be increased or decreased to evaluate associated impacts.

A good example can be the decision making process around economic, environmental and social parameters. A decision maker with a focus on economic benefits might have a subjective assumption that minimizing hydropower utilization potential along a river system, due to ecologically sensitive wetlands or socially vulnerable communities, would undermine economic gains. In fact, by establishing a set of indicator/criteria and performing sensitivity analysis might prove that even if economic related indicators/criteria are assigned higher weights, resulting economic gains might not justify significant hydropower investment to an area with significant environmental and social sensitivities.

As an example, Figure 2-3 below highlights the sensitivities of scenario scores in relation to different weights assigned to a specific criterion.

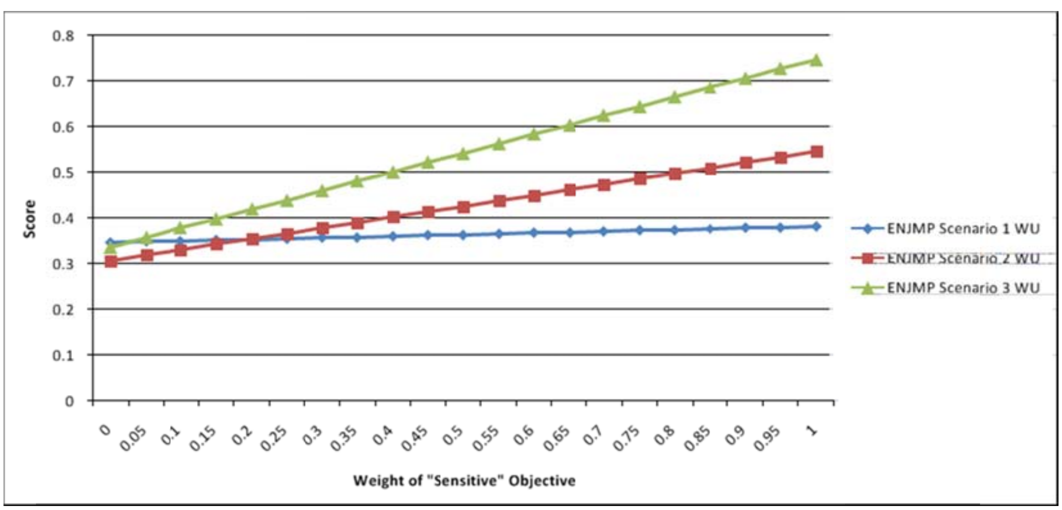


Figure 2-3 : Sensitivity analysis – Navigation

2.9.2 Trade-off Analysis

Trade-off analysis constitutes an integral tool when evaluating and interpreting the outcomes of MCA in order to arrive at a sustainable solution or decision in the light of competing objectives. Essentially, trade-off analysis answers the question: "How much must I give up to get a little more of what I want most?, i.e. determining the effect of decreasing one or more key factors and simultaneously increasing one or more other key factors in a decision.

Typically, trade-offs are required between different sectors related to water management e.g. environmental vs. economic vs social sectors. As a simple example, increased energy production by means of investment in hydropower dams has definite socio-economic benefits. However, the construction of large dams also have negative social and environmental consequences related to displacement, impacts on livelihoods, the downstream aquatic ecology, carbon emissions, etc. (see Figure 2-4).

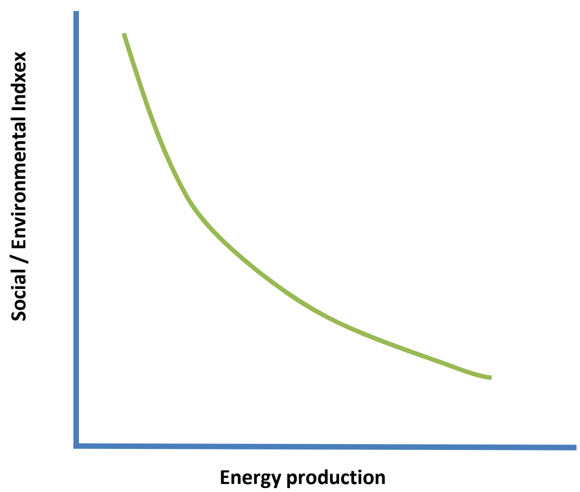


Figure 2-4 : Trade-off curve

Trade-offs could also be necessary between different components of any particular sector e.g. the economic benefits related to hydropower generation vs. water supply for irrigation vs. assurance of supply for domestic and industrial purposes etc.

In an integrated and shared water resource system, where upstream interventions can have significant cross-border implications, trade-offs also involve the consideration of upstream vs. downstream, socio-political and country benefits or impacts. In these environments, trade-off analysis allows the evaluation of benefits and consequences in a structured and systematic manner and serves as a useful tool in the decision making process.

It is important to note that not all outcomes need to be trade-offs. Win-win cases can also be accommodated.

3. PROCEDURAL GUIDANCE FOR EVALUATION OF WATER MANAGEMENT INTERVENTIONS IN THE NB-DSS

In light of the evaluation framework detailed in Section 2 above, this Section provides a stepwise guide to using the NB-DSS for the evaluation of water management interventions.

Figure 3-1 displays the main components associated with the evaluation of scenarios in the NB-DSS, which essentially involve (in sequential order):

Step 1 : Identification of key water management issues *(Problems)*

Step 2 : Development of baseline model

Step 3 : Scenario definition and implementation *(Alternatives)*

Step 4 : Definition of indicators *(Criteria)*

Step 5 : Quantification of indicators *(Evaluation)*

Step 6 : Cost based evaluation *(Evaluation)*

Step 7 : Scenario Evaluation using MCA *(Decision matrix, Weights, Synthesis)*

The final component in the NB-DSS evaluation process is where informed decisions are made based on the evaluation and interpretation of the MCA outcomes.

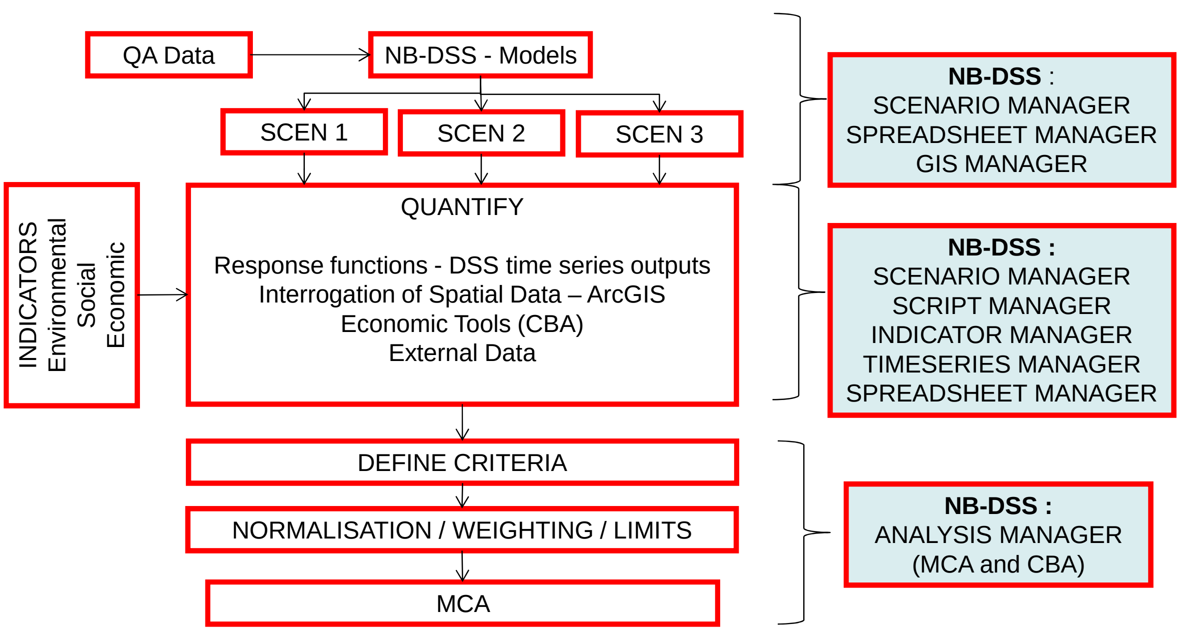


Figure 3-1 : NB-DSS Scenario evaluation flow chart

This procedural guidance is presented using scenario evaluation in the Baro-Akobo-Sobat basin as a case study.

3.1 IDENTIFICATION OF KEY WATER MANAGEMENT ISSUES (STEP 1)

Key water management issues, problems and opportunities within the study basin are identified during workshops with all stakeholders during the planning stages of water management interventions.

In the Baro-Akobo-Sobat basin for example, a key issue relates to the potential benefits and impacts of irrigation development vs. hydropower development.

3.2 BASELINE MODEL DEVELOPMENT (STEP 2)

Once key water management issues have been defined, the next step towards the evaluation of water management interventions in the NB-DSS involves the configuration, calibration and validation of relevant water resource models representing the baseline (current) condition of the study basin. The available models in the current configuration of NB-DSS are MIKE BASIN, MIKE 11 and MIKE SHE, which enable the user to perform water balance, hydrodynamic and integrated surface water / subsurface water analyses.

Figure 3-2 *shows the MIKE Basin baseline model for the Baro-Akobo-Sobat basin.*

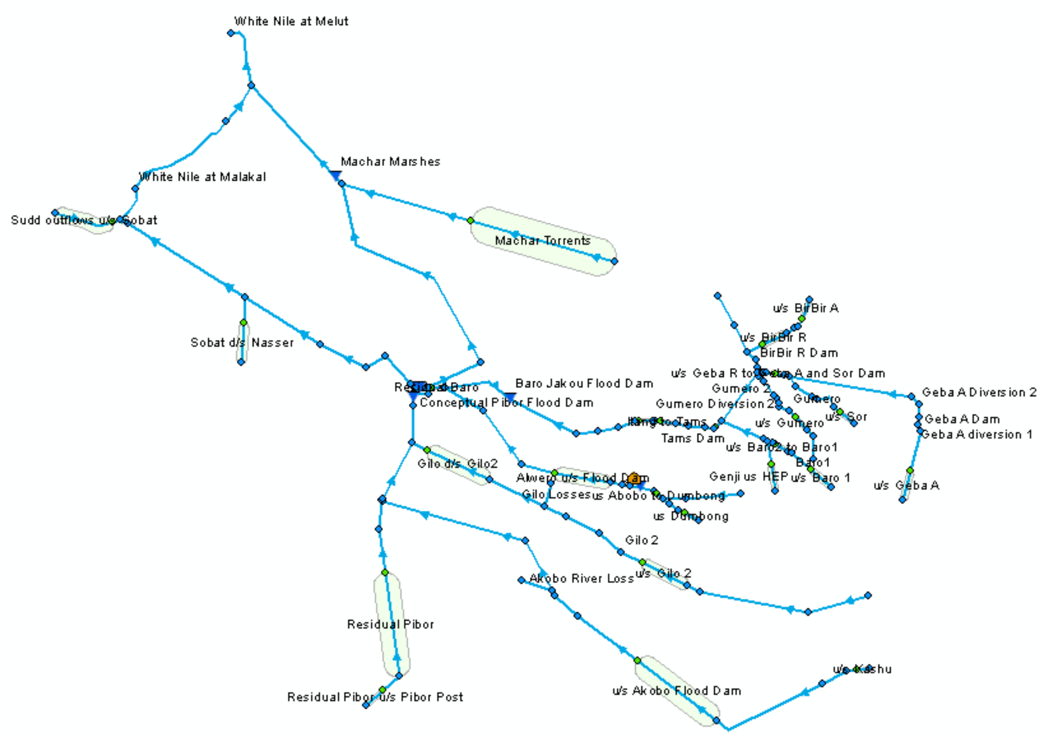


Figure 3-2 : BAS Mike Basin Baseline model configuration

Note: Although the baseline model represents the existing BAS system, the locations of potential future schemes were included and modelled as river nodes

3.3 SCENARIO DEFINITION AND IMPLMENTATION (STEP 3)

In consultation with stakeholders during workshops, development interventions and management options aimed at addressing the key water management issues identified in Step 1 are defined and constitute the basis of the alternatives which will eventually be evaluated in the form of different Scenarios.

This is followed by the development of Scenario Models representative of the development interventions and/or management options. These models will typically involve modifications to the Baseline Model(s) developed in Step 1 and allow the impacts of the various structural interventions and management options to be simulated.

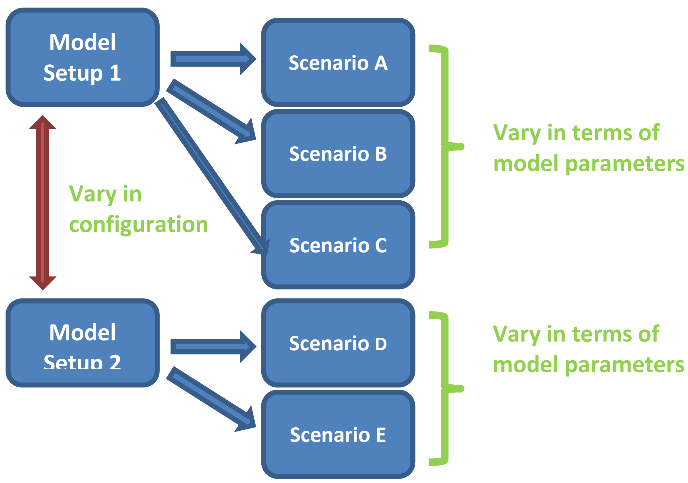


Figure 3-3 : Scenario model implementation

The baseline and scenario models are registered in the **NB-DSS Scenario Manager.** Under each model in the Scenario Manager, scenarios are defined which represent specific development interventions and/or management options to be simulated with that particular model. For each scenario, model objects (nodes) and associated output time series are specified as necessary. These represent the model nodes (locations) and time series where outputs will be generated for inclusion in the subsequent MCA and CBA analyses. In addition, to output time series, it is also possible to specify input time series for modification in the respective scenarios.

In the case of the Baro-Akobo-Sobat pilot case, various scenarios were defined and associated scenario models were developed. For the purpose of this Guideline, reference is made to Scenarios 1 and 2, details of which are presented in the table below.

Table 3-1 : BAS Scenarios 1 and 2

Scenario	Development Intervention	Management Option
SC0	Baseline	Current
SC1	TAMS Dam (Hydropower) Birbir A and Birbir R Dams (Hydropower)	Prioritise hydropower production
SC2	Tams Dam (Hydropower) Itang Irrigation Scheme Gilo-2 Dam and Irr Scheme	Prioritise Irrigation Supply

aurecon

Figure 3-4 shows the Baro-Akobo-Sobat Pilot Case scenario group structure for the baseline and scenario model development as configured in the Nile Basin DSS.

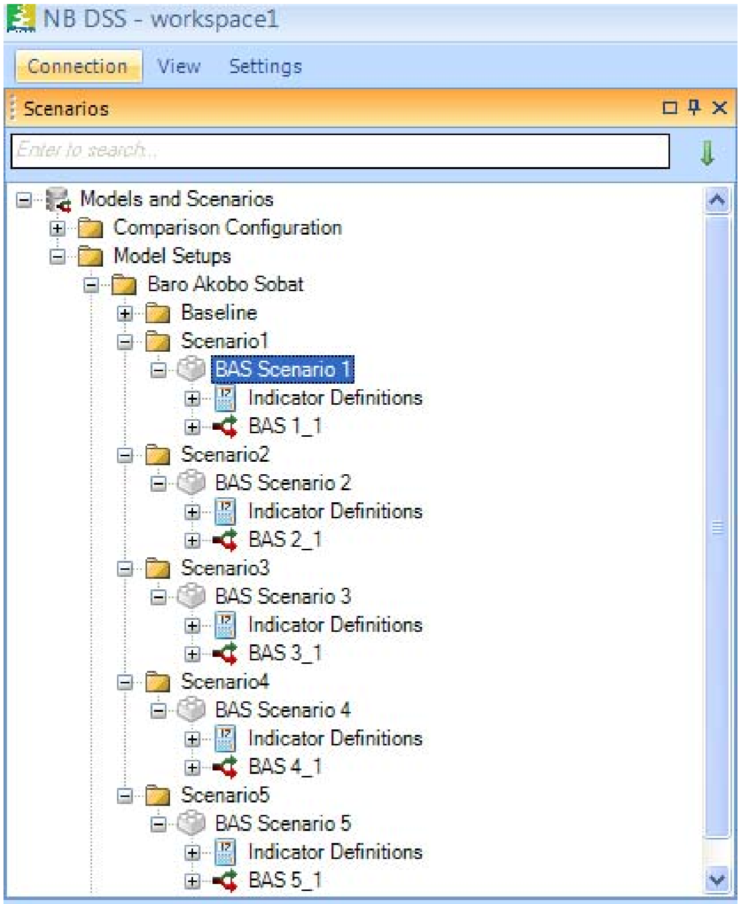


Figure 3-4 : BAS Scenario Manager Group Structure in NB-DSS

3.4 SELECTION OF INDICATORS (STEP 4)

Based on the unique characteristics of the scenarios to be evaluated, and bearing in mind the criteria which will eventually be used for scenario evaluation, relevant social, environmental and economic indicators are defined. This entails specifying the locations and types of indicators, which is critical to ensure an accurate and comprehensive representation of system behavior and impacts during scenario evaluation.

The selection of environmental social and economic indicators for scenario evaluation should be informed through consultations with stakeholders and the feasibility of quantifying the indicators based on links (responses) to water-related DSS outputs as well as the availability of relevant data to support these links. An indicator's defining characteristic is that it quantifies and simplifies information in a manner that facilitates understanding of environmental, social and economic implications related to water resource interventions by both decision makers and the public. The goal is to assess how interventions affect the direction of change in environmental, social and economic performance, and to measure the magnitude of that change.

3.4.1 Social Indicators

To obtain an understanding of the types of social impacts and their significance requires an understanding of the communities that are likely to be affected, their relationship with the rivers that stand to be impacted and the links between this relationship and their livelihood strategies. A good understanding of the baseline social conditions is therefore required. In this regard the World Commission on Dams notes that “the construction of a social baseline is central to the planning and implementation process. It provides key milestones against which project performance and positive and negative impacts on people can be assessed through periodic monitoring and evaluation”.

Social indicators can typically be defined under three broad categories viz.

- Water Availability
- Community Health and Safety
- Food security and Livelihoods

In the absence of detailed socio-economic baseline survey data it is difficult to accurately quantify social indicators. Due to a lack of baseline data for the assessment of downstream impacts, proxy indicators are often used. Proxy indicators refer to the use of another indicator as a surrogate for the behavior of the particular indicator. The identification and assessment of potential site specific social impacts is often based on an assessment of spatial data related to the social environment, including settlement densities and land uses, potentially impacted by affected areas. This assessment may be based on a review of satellite images and other readily available spatial data of the study areas affected by reservoir inundation and/or irrigation scheme developments. Table 3-2 below presents the list of social indicators that have been developed for the evaluation of scenarios in the NB-DSS. More details regarding the categorisation, definition and quantification of social indicators are provided in **Appendix A.**

Table 3-2 : List of Social Indicators used in NB-DSS

Indicator				Driver
Category	**ID**	**Name**	**Units**	**Description**
Water Availability	SO1	Change in availability of water for riparian users: domestic consumption, subsistence agriculture and livestock	% Change from Baseline	Dry season low flow: Median flow during lowest consecutive 3 months in dry season
Community Health and Safety	SO2	Susceptibility of irrigation scheme areas to malaria based on WHO malaria incidence map for Africa	Mean malaria endemicity of population within irrigation area footprint (%)	Malaria incidence map of Africa AND location of new irrigation schemes
	SO3	Prevalence of diseases resulting from pest species	Index	Proxy: EN7 - Abundance of Pest blackflies
	SO4	Water pollution d/s major urban areas	Time of decay (h) to acceptable coliform concentrations	Defined load factors; Constituent loads/concentrations in river; biological decay relationships
	SO5	No households within the 100 year flood line	% Change from Baseline	100 year flood envelope
	SO6	Drowning risk due to conveyance of water in open canal	km	Uninterrupted length of open canal

Indicator				Driver
Category	**ID**	**Name**	**Units**	**Description**
Food security and Livelihoods	SO7	Establishment of formal, commercial irrigation schemes	km2	New Irrigation Scheme Footprint Area
	SO8_1	Impact on Recession agriculture due to changes in flow regime - floodplain inundation	% Change from Baseline	Proxy: EN41 - Floodplain area inundated
	SO8_2	Impact on Recession agriculture due to changes in flow regime - bank stability	Index	Proxy: EN8 - Bank Stability
	SO9_1	Fish Production in dam / lake / wetland	ton/a	Proxy: EN3 - Fisheries production
	SO9_2	Change in Fish Productivity along river reach	% Change from Baseline	Proxy: EN6 - Biological production
	SO10	Productive land use for crops / grazing inundated by dam / lost due to establishment of irrigation scheme or canal	km2	Productive land (crops and grazing) in dam / irrigation scheme / canal footprint area
	SO11	Loss of access to natural resources due to inundation by dam / establishment of irrigation scheme / canal	km2	Proxy: EN1 - Environmentally Sensitive Area
Displacement	SO12	Physical displacement of population due to inundation by dam / establishment of irrigation scheme / construction of canal	No. households	No of households in dam, irrigation and canal footprint areas
	SO13	Economic displacement due to disruption of access to natural resources (cattle / people / wildlife) as a result of canal and dam construction	km	Uninterrupted length of open canal and fetch length of dam inundation area upstream of dam wall

3.4.2 Environmental Indicators

Environmental indicators may typically be grouped into three categories as follows:

- **Footprint Areas**. These are indicators associated with direct impact zones, and include areas of inundation, and/or areas identified for irrigation development, and the associated conveyance routes, access roads etc. Example indicators under this category include:
  - Environmentally Sensitive Areas
  - Carbon emissions
  - Fisheries Production
- **Downstream Areas**. These are indicators associated with secondary impact zones along the river and riparian areas downstream of any proposed dam or river diversion. Example indicators under this category include:
  - Floodplain / Wetland Area Inundated
  - Ecological Stress
  - Biological Production
  - Abundance of Pest Blackflies
  - Bank Stability
  - Recovery Distance
  - Seasonal Shift
- **Water Quality**. These are indicators associated with water quality changes. Examples include:
  - Phytoplankton Growth Potential
  - Aquatic Macrophytes Growth Potential

Table 3-3 presents the final list of environmental indicators as defined for the evaluation of scenarios.

More details regarding the categorisation, definition and quantification of environmental indicators are provided in **Appendix B.**

Table 3-3 : List of Environmental Indicators used in NB-DSS

Indicator				Driver	
Category	**ID**	**Name**	**Units**	**Description**	**Units**
Footprint Areas	EN1	Environmentally Sensitive Area	km2	Extent of Environmentally Sensitive Area within dam / irrigation scheme / canal footprint	km2
	EN1_1	Environmentally Sensitive rating	Index	Size of environmentally sensitive area / IUCN category in footprint	number
	EN1_2	Environmental hotspot	Index	Wetlands of international importance (Ramsar Sites) and Important Bird Areas (IBAs) that fall outside of protected areas, but within primary impact zones, are classified equivalent to IUCN Categories I & II (i.e. rating 5).	number
	EN2	Carbon emissions	million tons	Area of woody biomass and biomass carbon within dam footprint	km2 ; Carbon; t/ha
	EN3	Fisheries production	tons/a	Dam/ Lake / Wetland: Median surface area	km2
Downstream Areas	EN4_1	Floodplain Area Inundated	% change compared to baseline	Median flow during wettest month	m3/s
	EN4_2	Wetland Area Inundated	change compared to baseline (% or Area in km2)	Median surface area	km2
	EN5	Ecological Stress	Index	Dry season low flow: Median flow during lowest consecutive 3 months in dry season. Wet season low flow: Median flow during lowest consecutive 3 months in wet season. Within year flow variability: Median value of annual flow amplitude	% change compared to baseline
	EN6	Biological Production	% change compared to baseline	Wet season duration based on median monthly flows	days

Indicator				Driver	
Category	**ID**	**Name**	**Units**	**Description**	**Units**
Downstream Areas	EN7	Abundance of Pest Blackflies Risk	Index	Dry season low flow: Median flow during lowest consecutive 3 months in dry season. Wet season low flow: Median flow during lowest consecutive 3 months in wet season. Within year flow variability: Median value of annual flow amplitude Peak HPP Release With / Without re-regulation	% change compared to baseline
	EN8	Bank Stability	Index	Monthly flow – drawdown index / critical bank shear stress / riparian vegetation type	m3/s silt/clay content veg type
	EN9	Recovery Distance	km	Median discharge from impoundment	m3/s
	EN10	Seasonal Shift	no weeks delay in onset of wet season	Monthly flow	m3/s
Water Quality	EN11	Phytoplankton growth potential	No days	Retention time	days
	EN12	Aquatic macrophytes growth potential	Index	Total nitrate concentration in irrigation scheme return flow	mg/l

3.4.3 Economic Indicators

In order to inform Cost Benefit Analysis (CBA) as well as macro-economic analyses, economic indicators derived from location specific DSS outputs are necessary. Typical examples are listed in Table 3-4 below.

Table 3-4 : List of Economic Indicators used in NB-DSS

Indicator				Driver
Category	**ID**	**Name**	**Units**	**Description**
Navigation	EC1	Navigability - Vessels	Change from Baseline in days/year	Flow exceedence percentile value
Energy	EC2_1	Average Energy generated at specific HP node	GWh/a	Generated power at individual HP nodes
	EC2_2	Total Average Energy generated - system wide	GWh/a	Generated power at all HP nodes
Water conservation	EC3_1	Evaporation loss from specific dams/lakes/wetlands	million m3/a	Evaporation from specific dams/lakes/wetlands
	EC3_2	Total Evaporation loss - system wide	million m3/a	Evaporation from all dams/lakes/wetlands
Floods	EC4	Flood Damage	USD	Depth of inundation
Food production	EC5_1	Food production per irrigation scheme (new schemes)	ton/a	Crop yield of new irrigation schemes
	EC5_2	Impact of upstream developments on food production at existing irrigation schemes	ton/a	Potential reduction in crop yield of existing irrigation scheme
	EC5_3	Food production per irrigation scheme (new schemes)	USD/a	Income benefit of food production
	EC5_4	Impact of upstream developments on food production at existing irrigation schemes	USD/a	

The NB-DSS provides a CBA tool for the calculation of financial metrics for a single scenario over a user-defined evaluation period in a user-defined currency. Outputs from the CBA include Benefit Cost Ratio, Funding Ratio, Net benefit, Modified Internal Rate of Return, Equivalent Annual Cost, Break even years, and metrics related to funding shortfalls.

Furthermore, macro-economic indicators can also be identified. These indicators can be grouped into three categories viz. indications of Financial/Economic Efficiencies, magnitudes of Economic and Socio-Economic Impacts (Effectiveness criteria) and magnitudes of Regional, Sectoral and Environmental impacts, and are calculated by means of a macro-economic model, which incorporates CBA.

Financial and Economic Efficiency Parameters

This category includes standard CBA criteria e.g. Internal Rate of Return (IRR), Net Present Value (NPV) and Benefit Cost Ratio (BCR). However, it also calculates water development cost criteria/benchmarks e.g. cost per kiloliter of water for agricultural purpose (capital plus operating and maintenance cost) and cost for hydro-electricity purposes (per Mm^3) (capital plus operating and maintenance cost), which can in their own right serve as economic criteria. If unit costs are beyond a certain level it will be rather obvious that it will be beyond the means of certain potential users.

Economic and Socio-Economic Impact Parameters

Based on the relevant regional Social Accounting Matrices (SAMs), macro-economic and socio-economic impacts of the various investment scenarios can be assessed. The following macro-economic parameters illustrate/measure the size of the impacts on the economies involved:

- Economic Growth
  Net impact on Gross Domestic Product (GDP).
- Employment Creation
  Net direct employment opportunities; and
  Net total (direct, indirect and induced) employment opportunities.
- Poverty Alleviation (Household income generation)
  Net impact on low-income households; and
  Net impact on total household income.

GDP is a good indicator of economic growth and welfare as it contains, among other economic magnitudes, remuneration of employees and gross operating surplus (profits) which in part represents components of value added at all the levels of the economy.

The following two indicators focus on the creation of employment opportunities. A differentiation is made between the direct and the total impact on employment. The direct impact is in the first place less difficult to calculate and secondly it is very area-specific (Nile Basin). On the other hand the total employment impact also takes into account the ripple effects of the project intervention.

One of the crucial aspects of any macro-economic assessment is the personal income creation and distribution characteristics thereof, especially with regard to how the poorer sections of the population will be impacted. For this purpose the extent to which low-income households will be affected by the spin-offs created by the total project, is addressed.

Regional, Sectoral and Environmental Parameters

These parameters focus firstly on the regional distributional impacts of water, namely the impact that the project has on the primary country versus other areas/countries in the Nile Basin. Secondly, it has to do with specific objectives and externalities associated with water development and use, namely hydro-electricity sales and the environmental impact (net carbon emissions impact, only of hydro-electricity). These indicators can be summarized as follows:

- Inter-active impact (GDP and employment) on other Nile Basin countries.
- Specific objectives and externalities associated with water development and use:
  Hydro-electricity sales
  Net carbon emission impact (only impact of hydro-electricity).

More details regarding the categorisation, definition and quantification of economic indicators as well as relevant background information are provided in **Appendix C.**

3.5 QUANTIFICATION OF INDICATORS (STEP 5)

Once the environmental, social and economic indicators which will be used to evaluate scenarios have been defined, the indicators need to be quantified.

3.5.1 Scripts

In the NB-DSS**,** the quantification of indicators is achieved through the development of scripts in the **Script Manager**.

The NB-DSS incorporates an Ironpython - Microsoft .NET Framework scripting environment that makes it possible for users to write their own scripts and thereby create customized functionality using DSS Application Interfaces to other Managers and Tools. Scripting makes it possible to create customized workflow processes, tailored to specific needs.

As part of the WP2/1 Stage 2 project, a scripting library was developed for the calculation of scenario indicators. The scripts are organised into the following eight storages (see Figure 3-5):

- **BaseUtils**: Generic scripts for common mathematical calculations, interpolation, lookups etc. Not dependent on other storages.
- **SpreadsheetUtils** Scripts for accessing DSS spreadsheets and retrieving arrays and/or lookup values from the spreadsheets.
- **IndicatorUtils** Supporting scripts for calculating environmental, social and economic indicators. Calculation of ecologically relevant time series statistics.
- **NBIScripts** Scripts for calculation of food production indicators (Developed by M Byene of NBI)
- **RasterUtils** Scripts for raster processing, mainly for flood damage calculations.
- **Environmental Indicators** Calculation of environmental indicators. Calculable from Scenario Manager.
- **Social Indicators** Scripts for calculation of social indicators. Calculable from Scenario Manager.
- **Economic Indicators** Scripts for calculation of economic indicators. Calculable from Scenario Manager.

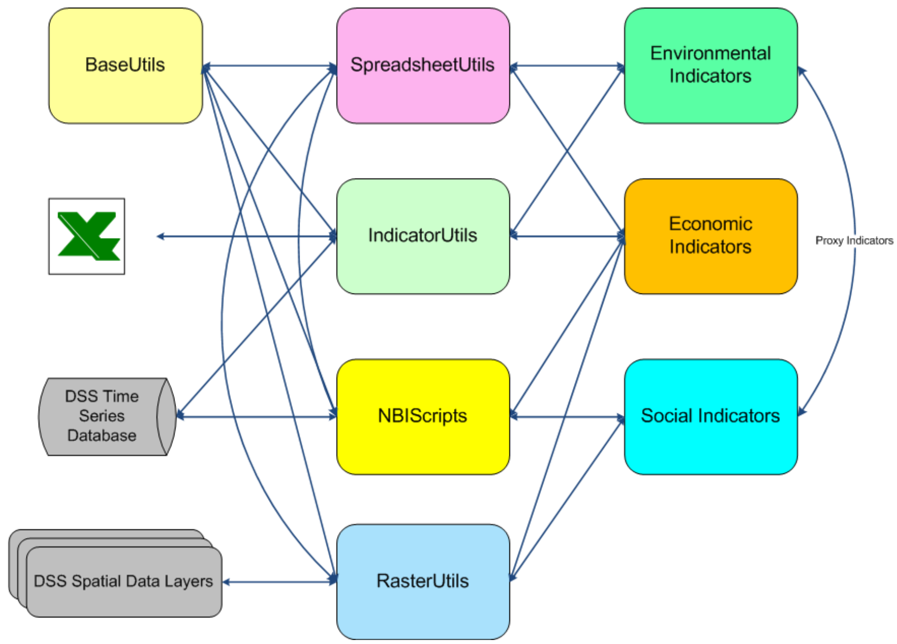


Figure 3-5 : Script Storages and Dependencies

In essence, scripts represent response functions which describe the relationship or linkage between water resource driven processes (i.e. model outputs) and impacts on indicators by means of algorithms or matrices. Typically these response functions are based on empirical relationships derived from observed data, on physically based conceptual models which describe indicator responses in relation to physical parameters or on statistical indices or relevant values extracted from output time series. Within the context of the NB-DSS, the response functions are intended to describe the environmental, social and economic consequences of changed flow regimes and other developmental impacts due to development interventions and/or management options.

An important consideration during the quantification of indicators, relates to the availability of good quality data to support the calculation of indicators. This data include time series outputs at predefined physical locations (model nodes) as generated by relevant water resource models (e.g. MIKE Basin, MIKE SHE, MIKE 11) which have been registered in the NB-DSS. Examples include time series of generated hydropower, monthly flows, reservoir surface area etc. Time series for use in the scripts can be accessed via either the **Time Series Explorer** or directly from the model results time series. Furthermore, external data and/or lookup tables which are necessary for the quantification of indicators, but which cannot be generated by means of model simulations may also be required. This commonly refers to default economic parameters e.g. crop yield, energy cost, certain parameters used in response functions e.g. nitrogen export coefficients / load factors in irrigation return flows and index ranges. External data can be stored in and accessed by the script, from the **Spreadsheet Manager**. The assessment of site specific social and environmental impacts involves to a large extent an assessment and interpretation of spatial data e.g. settlement densities, land use types, environmentally sensitive areas etc. Although the interrogation of spatial data can be done externally to the NB-DSS using standard geo-processing software, some interrogation of spatial data can also be done in the **GIS Manager** while the NB-DSS also allows the calling of GIS functions from the scripting environment. All results of the spatial analyses can be stored in and accessed by scripts from the **Spreadsheet Manager.**

Figure 3-6 schematically depicts the use of scripts for the quantification of indicators. (Note: The Figure depicts the case where geo-processing of spatial data takes place externally to the NB-DSS.)

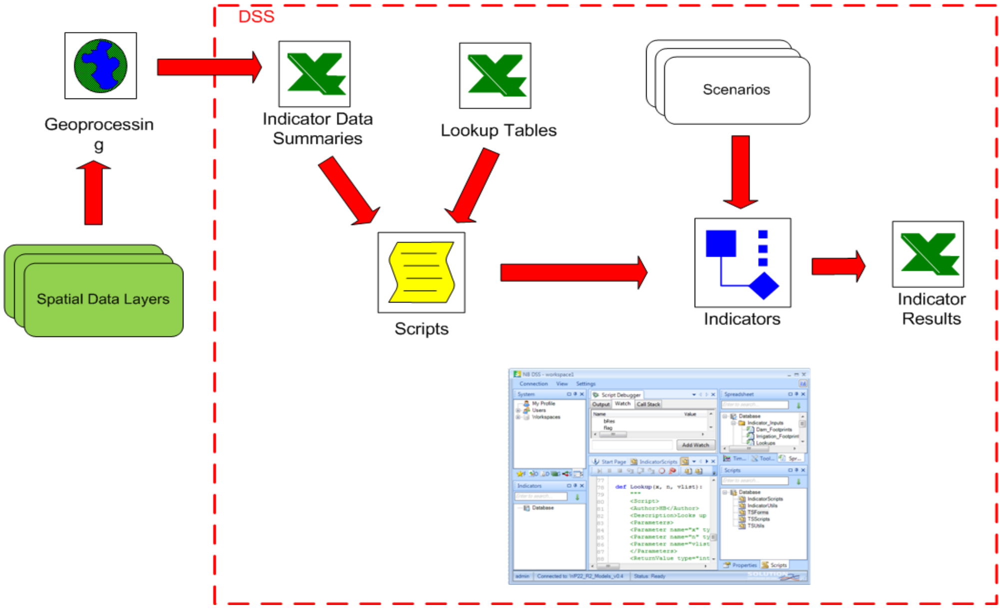


Figure 3-6 : Using scripts for indicator quantification

Appendix D provides a diagrammatic layout of individual scripts, organisation of these into storages, and dependencies between scripts.

3.5.2 Indicator definition

In the **NB-DSS Scenario Manager**, indicators are enabled for each model associated with scenarios, after which indicators are defined systemically as depicted in Figure 3-7. The definition of indicators entails four components:

- Name: Preferably, the name has to be representative of the type (ENV, SOC, ECON) and physical location of the specific indicator as this will facilitate subsequent analyses
- Description: A detailed description of the indicator.
- Script: Dragged and dropped from Script Manager.
- Parameters: These constitute the arguments in the scripts and typically include (a) time series outputs as “model reference” or “entity descriptor” types (b) integer values (for example IDs of structural features to allow cross referencing with pre-calculated data stored in the Spreadsheet Manager) (c) “string” type e.g. scenario path and (d) “boolean” type parameters e.g. True/ False.

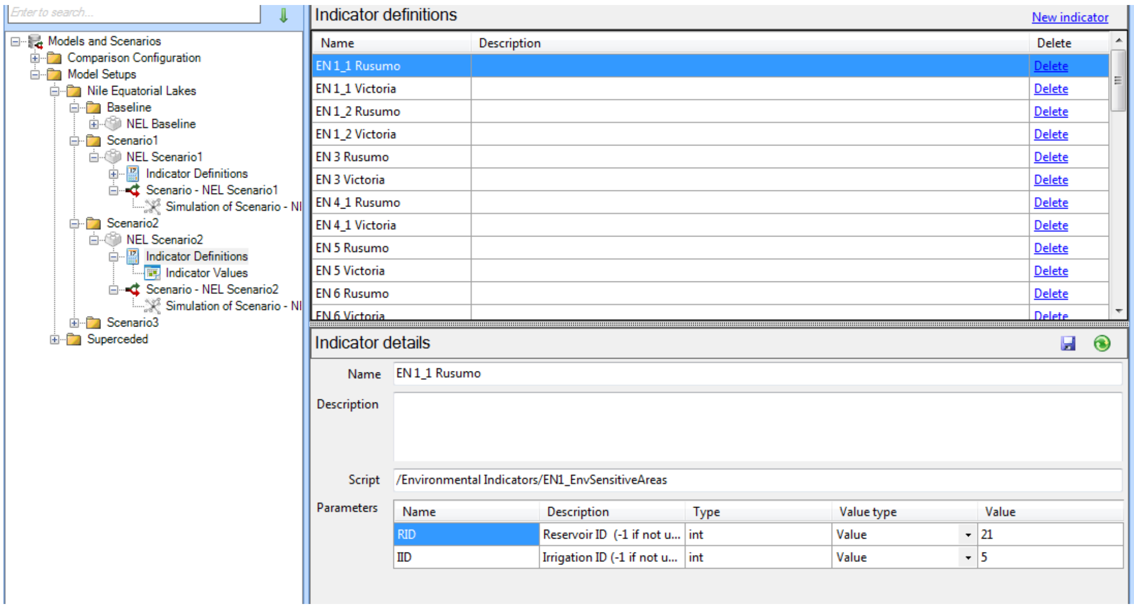


Figure 3-7 : Indicator Definition in NB-DSS Scenario Manager

3.5.3 Indicator calculation

Following a "simulation run" of any particular scenario, indicator values are generated and available for viewing via the Scenario Manager.

The table below shows the values of some indicators as calculated for the BAS Scenarios 1 and 2.

Table 3-5 : Indicator values as calculated for BAS Scenarios 1 and 2

	EN4 2 Machar Area	EN4 2 Machar PBC	EN5 Spills to Machar	EN7 Blackflies Abobo River	EN7 Blackflies Spills to Machar	EN5 1 Spills to Machar	EN5 2 Spills to Machar	EN5 5 Spills to Machar	SC1 Baro River ds Itang	SC1 Baro us White Nile	SC1 Machar Spills	EN8 DS Tams Dam	EN9 Tams Dam	SC11 Tams Dam
Id	I14	I15	I16	I17	I18	I19	I20	I21	I22	I23	I24	I25	I26	I27
Unit														
BAS 1 1	-1704.4	-50.8	-5	-1	-5	0	-75.5	-54.5	458.9	185.4	0	-1	55	0
BAS 2 1	-1695.7	-50.5	-5	-1	-5	0	-80.6	-66.1	427	160.8	0	-1	55	509

3.6 COST BASED EVALUATION (STEP 6)

Before Scenario Evaluation can be undertaken, it is important to undertake a Cost-Benefit Analysis (CBA) of the alternative schemes in order to ensure that relevant economic and/or financial parameters are included as evaluation criteria in the MCA. CBA is a systematic process for calculating and comparing the benefits and the costs associated with each scenario. Firstly, it allows decision makers to determine whether any particular scenario is financially viable. Secondly, it provides a basis for comparing scenarios.

The NB-DSS provides a CBA tool for the calculation of financial metrics for a single scenario over a user-defined evaluation period in a user-defined currency. Metrics are organized by ‘CBA Item’. Results are provided in tabular and graphical format for individual years or the entire period. It also allows comparison of multiple CBA results. The following paragraphs provide general guidance on how to undertake a CBA within the NB-DSS environment. For step-by-step instructions, please refer to the NB-DSS Help Menu.

1. Create a CBA Setup

In the Analysis Manager, create a new CBA Setup and define the general properties:

- Evaluation Period
- Monetary Units
  - All costs / benefits etc. will be converted to these units
- Scenario
  - The results from the latest simulation under this scenario will be used to compute any indicators used in this CBA *(Note: This property is not important if no indicators are used for the CBA).*

2. Define CBA Items and their properties:

Decide on the types of ‘items’ to be included in the CBA. This relates to new and existing water resource infrastructure e.g. dams, hydropower installations, canals, tunnels etc., new and existing irrigation schemes, activities which support economic trade, specific water resource management strategies with tangible outputs etc.

For each CBA Item, define the general properties as well as properties related to costs and benefits associated with that particular item.

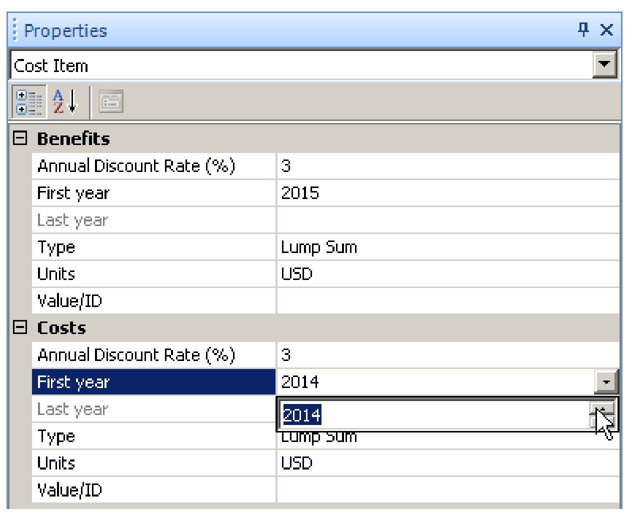


Figure 3-8 : CBA Item properties

Five CBA Item Types exist as detailed in Figure 3-9 below:

- Lump Sum
- Running value
- Yearly values
- Running value from indicator
    - Select indicators for the specified scenario or any other indicator
- Yearly values from time series
    - Select time series for the specified scenario or any other time series
    - Time series cannot include missing data
    - Annual totals will be computed

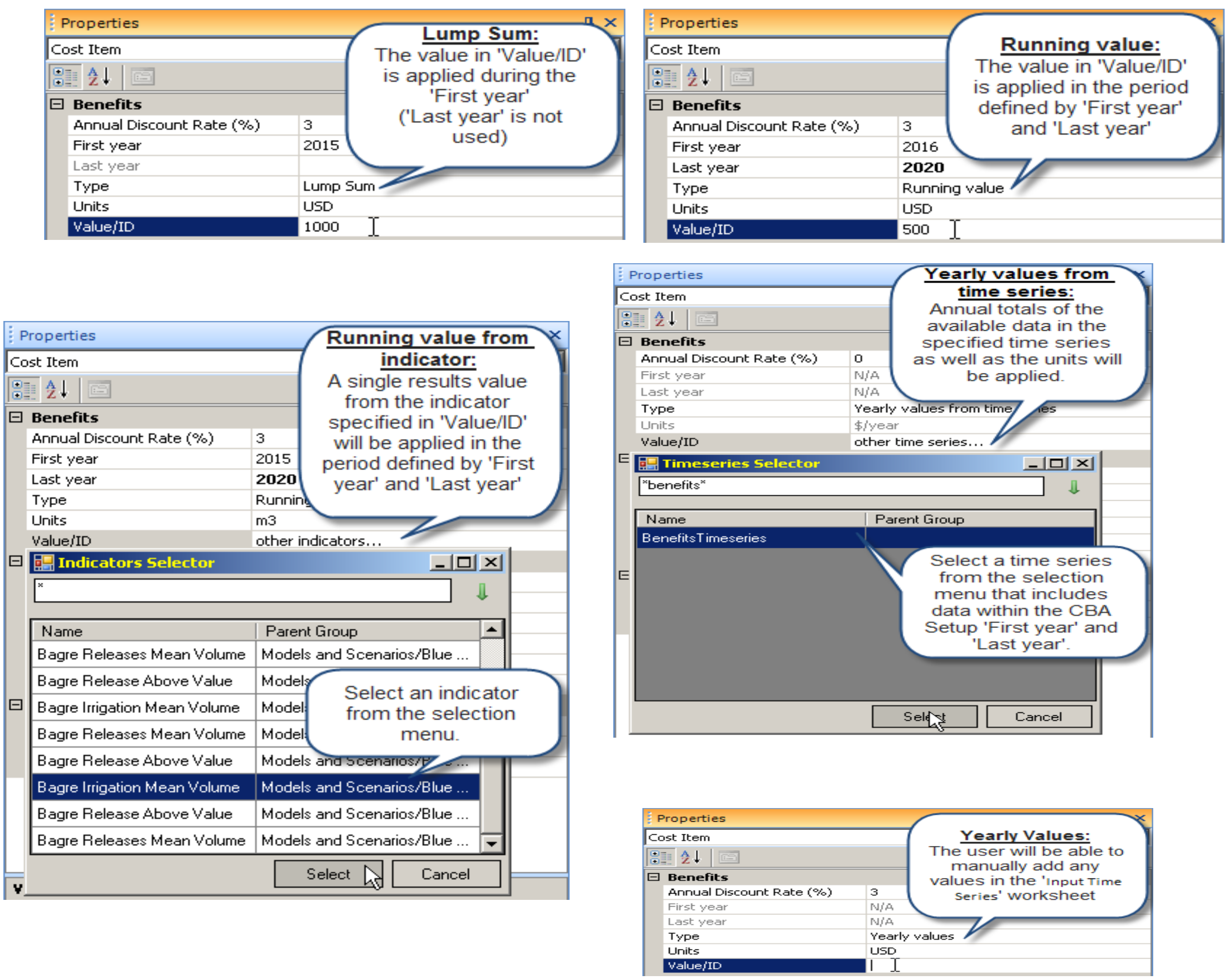


Figure 3-9 : CBA Item Types

3. Define cost and benefit input time series

For each CBA Item, define the costs and benefits. These typically include:

- Capital cost associated with new infrastructure e.g. dams and irrigation schemes. This can be phased (spread) over a number of years based on the construction / implementation schedule.
- Annual maintenance and operational costs associated with new infrastructure. These are typically expressed as a percentage of capital cost.
- Income streams linked to the generation of hydropower, improved navigation, food production etc.

This step entails defining annual values for each CBA Item in terms of annual costs and benefits as well as available funding and minimum benefits. Note that these values should be entered in the unit as defined in each CBA item's properties.

Table 3-6 *and* Table 3-7 *below show the CBA Items and their associated properties the BAS Scenarios 1 and 2.* Table 3-8 *displays input time series for BAS Scenario 1.*

Table 3-6 : CBA Items as defined for BAS Scenario 1

Cost Item	Item Name	Group	CBA Item Properties							
			Costs/Investments				Benefits			
			Type	ID/Value	Period [Year]	Units	Type	ID/Value	Period [Year]	Units
1	Tams	Dams and HP	Yearly values	CapOM	N/A	Million USD	Yearly values	HP Income	N/A	GWh
2	Birbir A and R	Dams and HP	Yearly values	CapOM	N/A	Million USD	Yearly values	HP Income	N/A	GWh
3	Navigation	Navigation	Running value	0	1951-1990	Million USD	Running value	80	1951-1990	days

Table 3-7 : CBA Items as defined for BAS Scenario 2

Cost Item	Item Name	Group	CBA Item Properties							
			Costs/Investments				Benefits			
			Type	ID/Value	Period [Year]	Units	Type	ID/Value	Period [Year]	Units
1	Tams	Dams and HP	Yearly values	CapOM	N/A	Million USD	Yearly values	HP Income	N/A	GWh
2	Gilo2	Irrigation	Yearly values	CapOM	N/A	Million USD	Yearly values	Food produced	N/A	million tons
3	Navigation	Navigation	Running value	0	1951-1990	Million USD	Running value	76	1951-1990	days
4	Itang IRR	Irrigation	Yearly values	CapOM	N/A	Million USD	Yearly values	Food produced	N/A	million tons

Table 3-8 : CBA Input time series for BAS Scenario 1

	Costs (actual values)			Benefits (actual values)		
Year	Tams Yearly values [Million USD]	Birbir A and R Yearly values [Million USD]	Navigation Running value [Million USD]	Tams Yearly values [GWh]	Birbir A and R Yearly values [GWh]	Navigation Running value [days]
1951	227	158.2	0	0	0	80
1952	227	158.2	0	0	0	80
1953	227	158.2	0	0	0	80
1954	227	158.2	0	0	0	80
1955	227	158.2	0	0	0	80
1956	3.9725	2.7685	0	0	0	80
1957	3.9725	2.7685	0	0	0	80
1958	3.9725	2.7685	0	5997	2808	80
1959	3.9725	2.7685	0	6179	2670	80
1960	3.9725	2.7685	0	6430	2634	80
1961	3.9725	2.7685	0	6387	2847	80
1962	3.9725	2.7685	0	6213	2820	80
1963	3.9725	2.7685	0	6343	2842	80

4. Define conversion factors

Enter yearly conversion factors for all CBA Item components that have units different than the CBA monetary units. Table 3-9 *shows conversion factors for BAS Scenario 1.*

Table 3-9 : CBA Conversion factors for BAS Scenario 1

	Cost Conversions			Benefit Conversions		
Year	Tams Yearly values	Birbir A and R Yearly values	Navigation Running value	Tams Yearly values [Million USD/GWh]	Birbir A and R Yearly values [Million USD/GWh]	Navigation Running value [Million USD/days]
1951				0.09	0.09	0.50
1952				0.09	0.09	0.50
1953				0.09	0.09	0.50
1954				0.09	0.09	0.50
1955				0.09	0.09	0.50
1956				0.09	0.09	0.50
1957				0.09	0.09	0.50
1958				0.09	0.09	0.50
1959				0.09	0.09	0.50
1960				0.09	0.09	0.50
1961				0.09	0.09	0.50
1962				0.09	0.09	0.50
1963				0.09	0.09	0.50

5. Create a new CBA Session

The CBA Session contains various spreadsheets which show the original input time series, the time series converted to monetary units and time series which have been converted to present values. It also summarises the CBA results.

Table 3-10 *and Table 3-11 display some of the key metrics as calculated for BAS Scenarios 1 and 2.*

*Note that C*BA items are aggregated by group. Cells for which CBA metrics cannot be computed (orange) are highlighted. The NB-DSS provides various tools for producing a variety of CBA related graphs.

Table 3-10 : CBA Summary - BAS Scenario 1

Cost Item	Item Name	Present Values				Benefit Cost Ratio
		Costs/Investments [Million USD]	Benefits [Million USD]	Available Funding [Million USD]	Net Benefit [Million USD]	
Group Dams and HP		1,651	4,341	0	2,691	2.63
1	Tams	973	2,994	0	2,021	3.08
2	Birbir A and	678	1,348	0	670	1.99
Group Navigation		0	430	0	430	-
3	Navigation	0	430	0	430	-
Grand Summary		1,651	4,772	0	3,121	2.89

Table 3-11 : CBA Summary - BAS Scenario 2

Cost Item	Item Name	Present Values				Benefit Cost Ratio
		Costs/Investments [Million USD]	Benefits [Million USD]	Available Funding [Million USD]	Net Benefit [Million USD]	
Group Dams and HP		973	2,919	0	1,946	3.00
1	Tams	973	2,919	0	1,946	3.00
Group Irrigation		497	2,248	0	1,750	4.52
2	Gilo2	275	1,973	0	1,699	7.18
3	Itang IRR	223	274	0	51	1.23
Group Navigation		0	409	0	409	-
5	Navigation	0	409	0	409	-
Grand Summary		1,470	5,575	0	4,105	3.79

6. Comparison of CBA Sessions

Finally, the NB-DSS comparison tool allows several CBA Sessions to be collected in order to compare the CBA metrics from these CBA Sessions in tabular format.

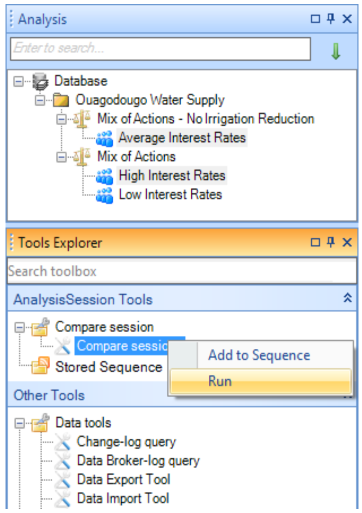


Figure 3-10 : Comparison tool

3.7 SCENARIO EVALUATION USING MULTI CRITERIA ANALYSIS (STEP 7)

The NB DSS Multi Criteria Analysis (MCA) tool compares criteria for various solutions (scenarios), weighted by preferences in matrix form. It also allows comparison of multiple decision matrices ("sessions") that were created by different stakeholders

1. Create a new MCA Setup in the Analysis Manager

- Define general properties
    - Description
    - Weighting method
        - Will assist stakeholders in defining their weights (preferences)
        - All stakeholders must use the same weighting method
    - General properties
    - Normalization method
        - Used to normalize all criteria values to dimensionless values between 0 and 1

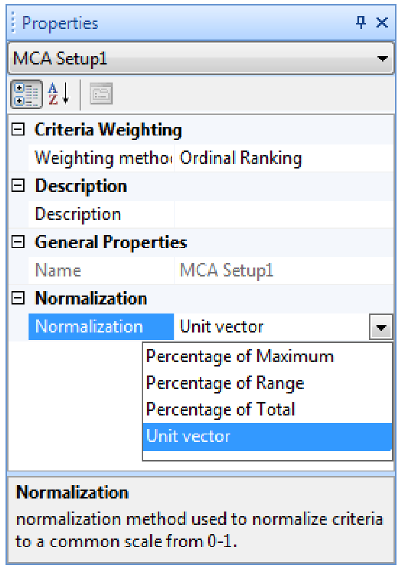


Figure 3-11 : MCA Setup properties

2. Add Scenarios and Define Evaluation Criteria

- Add scenarios and the associated indicators and edit relevant properties related to each indicator e.g. Indicator ID and Unit.
- Define Criteria and specify criteria properties. The properties dictate how each criteria is quantified (based on arithmetic functions linked to indicators), assigns each criteria to a Group, specifies the preferred 'direction' of each indicator and very importantly, assigns a Unit to each indicator.

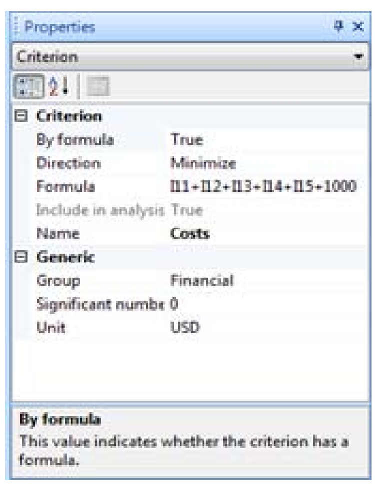


Figure 3-12 : Criteria property definition

Table 3-12 *shows the criteria as defined in the NB-DSS for BAS Scenarios 1 and 2.*

Table 3-12 : Evaluation Criteria as defined for BAS Scenario 1 vs Scenario 2

	Env Sens Area	Carbon emmissions	Machar Marshes change in Area	Eco Stress	Wet season duration	Bank Stability	Wet season shift	Water availability
Group	ENV	ENV	ENV	ENV	ENV	ENV	ENV	SOC
Unit	km2	million t	km2	Index	% change	Index	no weeks	% change
BAS 1_1	0	0	-1704	-5	-16	-1	8.4	322
BAS 2_1	979	2	-1696	-5	-22	-1	15.7	294

	Malaria incidence	Pest diseases	Formal irrigation	Recession agriculture	Fisheries-dams	Fisheries-river	Loss in productive land	Loss in natural resources	Physical displacement
Group	SOC	SOC	SOC	SOC	SOC	SOC	SOC	SOC	SOC
Unit	%	Index	km2	% change	ton/a	% change	km2	km2	no households
BAS 1_1	0	-4	0	-3	7530	-16	18	0	2401
BAS 2_1	7	-4	979	-8	7750	-22	20	979	2936

	Navigation	Avg system energy produced	Evap loss - system	Food production	BCR
Group	ECON	ECON	ECON	ECON	ECON
Unit	change in days per year	GWh/a	million m3/a	million ton/a	Index
BAS 1_1	80	8486	4219	0.0	2.89
BAS 2_1	76	5714	4319	5.5	3.79

3. **Review normalised criteria values and conduct pre-analysis**

- Once the criteria have been defined, it is important to review the normlaised values in order to ensure that these values comply and reflect the defined criteria properties.

Table 3-13 below shows the normalised values for some of the evaluation criteria as defined for BAS Scenarios 1 and 2.

Table 3-13 : Normalised criteria for BAS Scenarios a and 2

	Env Sens Area	Carbon emmissions	Eco Stress	Wet season duration	Bank Stability	Wet season shift	Water availability	Malaria incidence	Formal irrigation	Recession agriculture	Fisheries-dams	Fisheries-river	Loss in productive land	Physical displacement	BCR
Group	ENV	ENV	ENV	ENV	ENV	ENV	SOC	SOC	SOC	SOC	SOC	SOC	SOC	SOC	ECON
Unit	km2	million t	Index	% change	Index	no weeks	% change	%	km2	% change	ton/a	% change	km2	no households	Index
BAS 1_1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000	1.000	0.972	1.000	1.000	1.000	0.763
BAS 2_1	0.000	0.234	1.000	1.344	1.000	0.535	0.912	0.001	1.000	3.200	1.000	1.344	0.928	0.818	1.000

- Perform Pre-Analysis to identify redundant criteria (having the same ranks across scenarios) and dominating scenarios (ranking highest for all criteria)

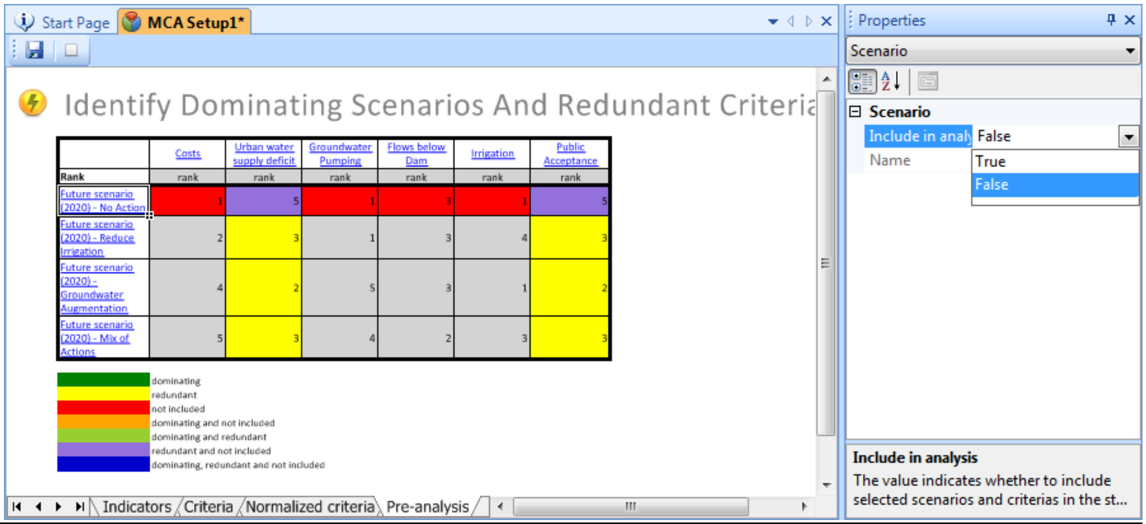


Figure 3-13 : Example of pre-analysis matrix

4. Create one or more MCA Sessions

Under each MCA Setup, various MCA Sessions can be created reflecting the preferences and key interests of different stakeholder groups or sectors e.g. Environmental vs. Social vs Economic. For each of these groups, weights (preferences) for each criteria need to be defined. Several weighting methods (as defined in the MCA Setup) are provided to assist. Normalized weights are used to scale the normalized criteria values

Table 3-14 below lists the weights as assigned to the three Groups (MCA Sessions) during the evaluation of BAS Scenarios 1 and 2.

Table 3-14 : BAS criteria weighting for Scenario 1 vs Scenario 2

Criteria	ECON	ENV	SOC
Env Sens Area	12	7	17
Carbon emmissions	13	6	16
Machar Marshes change in Area	14	1	12
Eco Stress	15	2	13
Wet season duration	16	5	14
Bank Stability	17	3	15
Wet season shift	18	4	11
Water availability	11	8	1
Malaria incidence	10	10	2
Pest diseases	9	9	5
Formal irrigation	2	12	3
Recession agriculture	6	11	7
Fisheries-dams	3	13	6
Fisheries-river	5	14	10
Loss in productive land	4	15	8
Loss in natural resources	7	16	9
Physical displacement	8	17	4
BCR	1	18	18

Within each MCA Session, it is possible to specify limits (lower and upper bounds) for each criterion (see Figure 3-14). Criteria values which violate these limits are highlighted in red in the MCA decision matrix and their scenarios are not ranked.

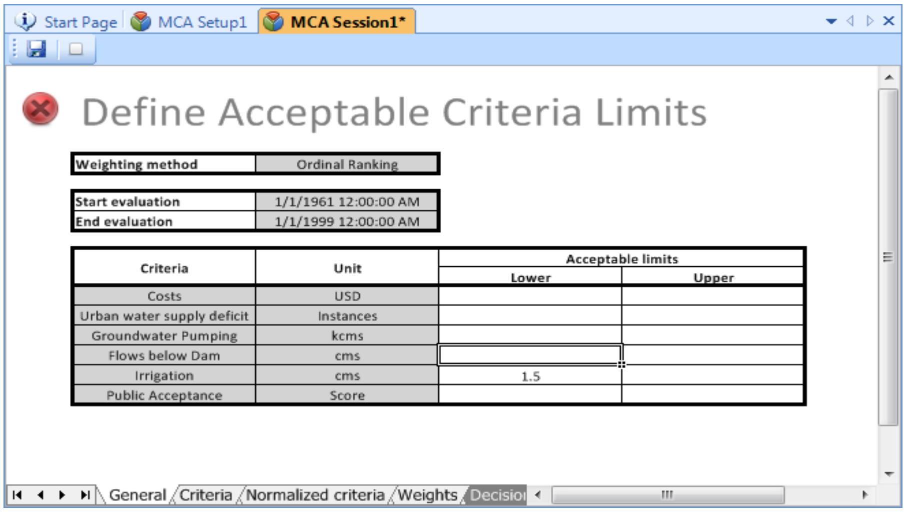


Figure 3-14 : Defining criteria limits

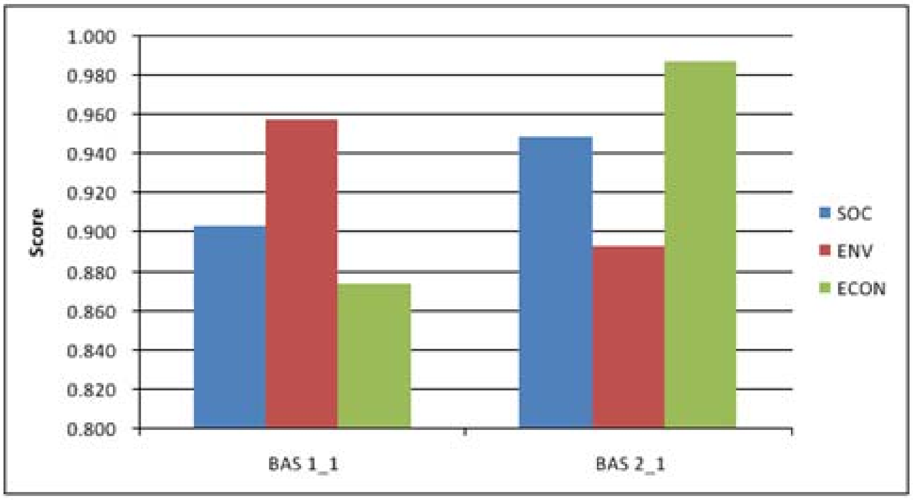
5. Review Scenario Scores and Ranking as part of Decision Matrix

Select several MCA Sessions from the same MCA Setup to create a comparison and run the comparison tool. Review the comparison matrix and the stakeholder scores.

Figure 3-15 for example shows the results of the scenario analysis for BAS Scenarios 1 and 2. The summary result tables show that SC2 (irrigation priority) scores higher from an economic and social perspective, while SC1 (hydropower priority) has the highest environmental score.

Review weighted score matrix

	SOC	ENV	ECON
BAS 1_1	0.903	0.957	0.873
BAS 2_1	0.948	0.892	0.986



Review scenario ranking matrix

	SOC	ENV	ECON
BAS 1_1	2	1	2
BAS 2_1	1	2	1

Figure 3-15 : Scenario scores and ranks for BAS Scenarios 1 and 2

6. Perform Sensitivity Analysis

During the synthesis stage sensitivity analysis sets up the basis of an important evaluation metric in all multi decision evaluation problems. The objective is to test how changes in individual criteria weights impact the ultimate solution. Therefore, both sector specific and cross-sectoral decisions can be tested with respect to their individual or joint impacts on the solution.

A good example can be the decision making process around economic, environmental and social parameters. A decision maker with a focus on economic benefits might have a subjective assumption that minimizing hydropower utilization potential along a river system, due to ecologically sensitive wetlands or socially vulnerable communities, would undermine economic gains. In fact, by establishing a set of indicator/criteria and performing sensitivity analysis might prove that even if economic related indicators/criteria are assigned higher weights, resulting economic gains might not justify significant hydropower investment to an area with significant environmental and social sensitivities.

As an example, the figure below highlights the sensitivities of scenario scores in relation to different weights assigned to a specific criterion.

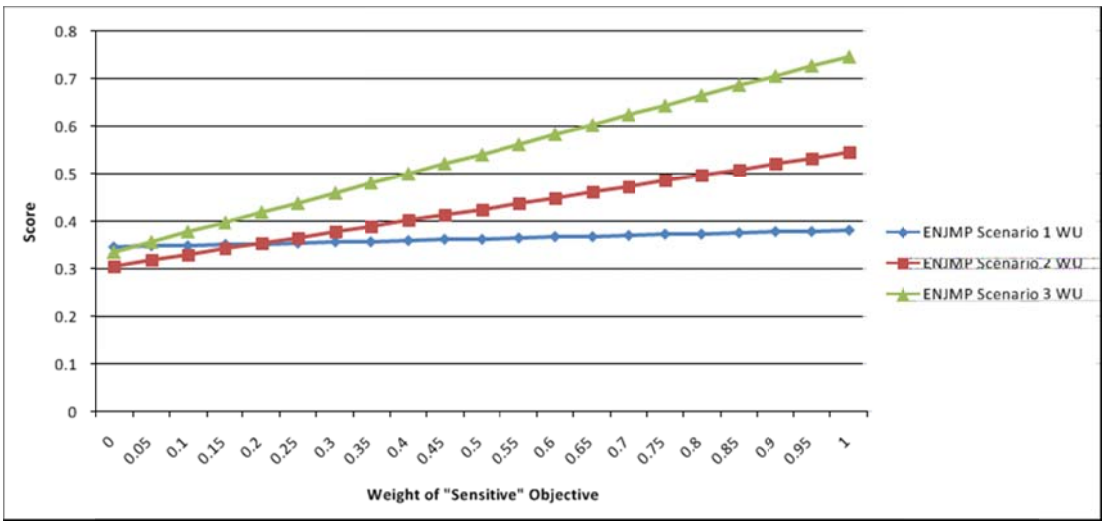


Figure 3-16 : Sensitivity analysis – Navigation

4. CONCLUSIONS

This Guideline provides a structured approach towards the evaluation of water management interventions within a water resource planning context, based on the conceptual approach as defined by the World Bank. The Guideline provides a best-practice evaluation framework for Multi Criteria Analysis comprising eight generic components, which address the identification of key water management issues, the definition of scenarios, the definition and quantification of indicators and the evaluation of alternative scenarios by means of user-defined criteria. In addition, the Guideline provides a stepwise guide on how to use the scenario analysis tools and functionalities embedded in the NB-DSS.

It is important to note that the indicators which have been defined in this Guideline represent a single set of indicators. Similarly, the Baro-Akobo-Sobat pilot case which was used as an example reflects the subjective definition of evaluation criteria and a relatively arbitrary weighting approach. However, the outcomes of the pilot applications of the NB-DSS confirmed that the NB-DSS is indeed a powerful tool which is sufficiently capable of advanced water management scenario evaluation. In future, more detailed planning appraisals and scenario evaluations in the Nile Basin will inevitably require changes to the existing indicators, the addition of more indicators and more inclusive approaches towards criteria weighting and normalisation, which will be done in stakeholder sessions.

Note: For step-by-step instructions on how to use the NB-DSS Analysis Manager, please refer to the NB-DSS Help Menu.

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APPENDIX A

SOCIAL INDICATORS: BACKGROUND INFORMATION

QUANTIFICATION OF SOCIAL INDICATORS

The final list of social indicator categories is:

- Water Availability
- Community Health and Safety
- Food Security and Livelihoods
- Displacement

Furthermore, it was deemed necessary to differentiate between:

- Site specific social impacts (dam, irrigation scheme and canal related)
- Downstream social impacts (these are largely linked to dams)
- Regional, National and Basin level social impacts

Note: This approach is consistent with the approach adopted for Environmental Indicators, which also considers site specific (Footprint Areas) and downstream (Downstream Areas) impacts. In addition, the Environmental Indicators also consider overall water quality.

The indicators required to assess the potential social impacts at each of these three spatial locations differ. This is highlighted by the World Commission on Dams (WCD, 2000) which notes that large dams result in “terrestrial, aquatic and riparian impacts that not only affect ecosystems and diversity but also have serious consequences for people who live both near and far from the dam site”. At the dam site itself, the scale of the social impact will largely depend on the size of the area of inundation and the number of households and type of land uses affected. Downstream of the site the social impacts can extend for many hundreds of kilometres and well beyond the confines of the river channel. However, social impacts are complex in that they vary in both time and space. In addition, affected communities are not homogenous and are likely to have differing livelihood strategies. In this regard WCD (2000) notes that “the impacts of dams on people and livelihoods-both above and below dams-have been particularly devastating in Asia, Africa and Latin America, where existing river systems supported local economies and the cultural way of life of a large population containing diverse communities”

The link between social, environmental and economic indicators:

SOCIAL INDICATORS

- Site specific impacts (dam, irrigation scheme and canal related);
- Downstream impacts
- Regional, National and Basin level impacts

SOCIAL INDICATORS: REGIONAL/NATIONAL/BASIN LEVEL

The social impacts at a regional, national and basin level will be linked to the economic impacts. If the economic indicators for financial and economic performance, together with the macro-economic and regional and sectoral indicators are positive, then one can assume that the broader social benefits will outweigh the potential local social impacts. Also, assumes that site specific and downstream impacts can be effectively mitigated with proper design and operation of dams. irrigation schemes

SOCIAL INDICATORS: SITE SPECIFIC LEVEL (DAM SITE, IRRIGATION SCHEME AND CANAL)

KEY SOCIAL ISSUES: DISPLACEMENT, LIVELIHOODS & COMMUNITY HEALTH

Relevant indicators

- Physical Displacement (Linked to physical area affected by dam inundation, irrigation scheme and or canal);
- Economic Displacement (Linked to disruption of access to key resources, such as agricultural land and natural resources, due to dam inundation, irrigation scheme and or canal);
- Livelihoods: Food security (Linked to area of inundation and loss of crop/grazing land and access to these resources. Also consider increase in crop potential due to irrigation. (Proxy Environmental Indicators linked to Footprint Area);
- Livelihoods: Loss of or access to natural resources (Proxy Environmental Indicators linked to Footprint Area);
- Community Health: Prevalence of waterborne diseases and pest species (Proxy Ecological Indicators include abundance of

SOCIAL INDICATORS: DOWNSTREAM

BASIC ASSUMPTION: Well-being and livelihoods of downstream communities are integrally linked to water quantity and quality. Therefore, if these two aspects can be addressed then social impacts can be effectively avoided and or mitigated. Dams also offer potential to improve water security during the dry season and drought events.

KEY SOCIAL ISSUES: FOOD SECURITY, LIVELIHOODS, COMMUNITY SAFETY AND HEALTH

For Dams: Some of the indicators are linked to proxy environmental indicators linked to water quantity and quality.

- Food security: Recession Agriculture (Proxy Ecological Indicators: Floodplain Areas Inundated and Bank Stability);
- Change in fish productivity along the river reaches (Proxy Environmental Indicator: Biological Production)
- Increase in food production associated with establishment of new or expanded irrigation scheme
- Community Health: Prevalence of waterborne diseases and pest species (Proxy Ecological Indicator: Abundance of pest black flies).

For Irrigation Scheme Projects and Canals: Some of the indicators are linked to proxy economic and environmental indicators.

- Food Security: Increase in crop yields (Macro-Economic and Socio-economic parameters);
- Livelihoods: Creation of employment and Household Income (Macro-Economic and Socio-economic parameters);
- Community Health: Prevalence of waterborne diseases and pest species (Proxy Ecological Indicators: Abundance of

SITE SPECIFIC LEVEL IMPACTS (DAM SITE, IRRIGATION SCHEMES AND CANALS)

The key site specific social issues associated with the establishment of a new dam, irrigation scheme or canal, including raising of existing dams or expansion of existing irrigation schemes, relate to:

- Displacement: Displacement impacts are divided into physical and economic displacement. Physical displacement is associated with the displacement of local communities due to dam inundation, and or area taken up by irrigation schemes and canals. Economic displacement is due to disruption of access for communities to resources upon which their livelihoods are dependent, such as productive agricultural land and natural resources. The disruption is linked to dam inundation, irrigation schemes and or canals;
- Livelihoods and Food security: Impacts linked to the physical loss of and or access to productive agricultural land and natural resources due to dam inundation, irrigation schemes and or canals. In addition, the proposed dam, irrigation scheme and or canal may also result in increase in crop potential due to irrigation opportunities. The establishment of dams may also create an opportunity to for an increase in fishing opportunities for local communities living in the vicinity of the dam.
- Community Health: Impacts linked to increase in prevalence of waterborne diseases and pest species. In the case of irrigation schemes the key impact is linked to the potential increase in malaria. Dam inundation areas and canals also pose a potential safety risk in terms of drowning.

The site specific level indicators are summarised below.

Site Specific Social Impacts: Relevant indicators

Category	Indicator Name and Description
Water Availability	➢ Change in availability of water for riparian users: domestic consumption, subsistence agriculture and livestock **Indicators** ➢ SO1: Dry Season Low Flow: Median flow during lowest consecutive 3 months in dry season
Community Health and Safety	**Health** ➢ Susceptibility of irrigation schemes to result in an increase in incidence of malaria ➢ Impact on humans resulting from pest species **Community Safety** ➢ Drowning risk due to open water bodies **Indicators** ➢ SO2: WHO malaria incidence map of Africa ➢ **SO3: Proxy Environmental Indicator: Abundance of pest black flies- EN7** ➢ SO6: Uninterrupted length of open canal and dam inundation area
Food Security and Livelihoods	➢ Loss of or access to productive agricultural land (crops and grazing) ➢ Loss of and or access to natural resources ➢ Increase in food production due to establishment of irrigation schemes ➢ Change in fish productivity levels ➢ Prevalence of disease affecting livestock resulting from pest species **Indicators** ➢ SO10: Productive land (crops and grazing) in dam / irrigation scheme / canal foot print area ➢ **SO11: Proxy Environmental Indicator : Environmentally Sensitive Areas- EN1** ➢ SO7: New Irrigation scheme footprint area ➢ **SO9-1: Proxy Environmental Indicator: Increase in fish production-EN3:** ➢ **SO3: Proxy Environmental Indicator: Abundance of pest black flies- EN7**
Displacement	➢ Physical displacement due inundation by dam / establishment of irrigation scheme / construction of canal; ➢ Economic displacement due to disruption of access to agricultural and natural resources as a result of dam and or canal **Indicators** ➢ SO12: Number of households in dam, irrigation scheme and canal footprint areas ➢ SO13: Uninterrupted length of open canal or extent of dam inundation area upstream of dam wall

DOWNSTREAM IMPACTS

Where required, the identification of appropriate environmental proxy indicators for downstream social impacts is based on the assumption that the well-being and livelihoods of downstream communities is integrally linked to both water quantity and quality. Therefore, if these two aspects can be addressed then the potential downstream social impacts associated with dams can be effectively avoided and or mitigated. Dams also offer the potential to improve water security during the dry season and drought events. It has been assumed that the flood line downstream of dams will be lower than the current natural state flood line. It is also assumed that an effective flood warning system will be implemented as part of the dam operating procedure and that dam failure will not occur. It is therefore assumed that the establishment of dams will result in an improvement of the safety of downstream communities.

The key social issues affecting downstream communities are associated with the proxy environmental indicators that are linked to water quantity and quality.

- Water Availability: Impacts linked to changes in the availability and quantity of water for riparian users, domestic consumption, subsistence agriculture and livestock
- Food Security and Livelihoods: Impacts linked to impact on recession agriculture and natural resources, including fish production
- Food Security and Livelihoods: Impacts linked to creation of employment and increase in household income and increase in crop yields
- Community Health and Safety: Impacts linked to prevalence of waterborne diseases and pest species. In addition, the improved safety associated with managing the flood regime.

The downstream indicators are summarised below.

Downstream Social Impacts: Relevant Indicators

Category	Indicator
Water Availability	➢ Change in availability of water for riparian users: domestic consumption, subsistence agriculture and livestock **Indicators** ➢ SO1: Dry Season Low Flow: Median flow during lowest consecutive 3 months in dry season
Community Health and Safety	**Health** ➢ Susceptibility of irrigation schemes to result in an increase in incidence of malaria ➢ Impact on humans resulting from pest species ➢ Water pollution downstream of urban areas **Community Safety** ➢ Households located within the 100 year flood line **Indicators** ➢ SO2: WHO malaria incidence map of Africa ➢ **SO3: Proxy Environmental Indicator: Abundance of pest black flies- EN7** ➢ SO4: Defined load factors; Constituent loads/concentration in river; biological decay relationships ➢ SO5: 100 year flood envelope
Food Security and Livelihoods	**Food Security** ➢ Impact on recession agriculture due to change in flood regime – floodplain inundation ➢ Impact on recession agriculture due to change in flood regime – bank stability ➢ Change in fish productivity along river reach ➢ Increase in food production associated with establishment of new or expanded irrigation scheme **Indicators** ➢ **SO8-1: Proxy Environmental Indicator : Floodplain Area Inundated – EN4-1** ➢ **SO8-2: Proxy Environmental Indicator : Bank Stability – EN8** ➢ **SO9-2: Proxy Environmental Indicator : Biological Production- EN6** ➢ SO7: New Irrigation Scheme Footprint Area

REGIONAL, NATIONAL AND BASIN LEVEL IMPACTS

The social impacts at a regional, national and basin level will be linked to the economic impacts. If the economic indicators for financial and economic performance, together with the macro-economic and regional and sectoral indicators are positive, then one could argue that the potential social benefits are likely to outweigh the potential site specific and downstream social impacts. This would however depend on the ability to effectively mitigate the potential site specific and downstream impacts associated with the proposed dam and or irrigation scheme, including the implementation of a successful resettlement programme and the continued maintenance of the downstream water quality and ecological condition of the affected river in question.

SOCIAL INDICATORS

Displacement

Displacement impacts are divided into physical and economic displacement. Physical displacement is associated with the displacement of local communities due to dam inundation, and or area taken up by irrigation schemes and canals. Economic displacement is due to disruption of access for communities to resources upon which their livelihoods are dependent, such as productive agricultural land and natural resources. The disruption is linked to dam inundation, irrigation schemes and or canals.

In the absence of detailed socio-economic baseline data on the communities affected by inundation, it is not possible to accurately quantify how many people will need to be resettled. All that is possible is to indicate which scenarios are likely to result in displacement and whether or not the displacement is likely to be low, moderate or high. This assessment was based on a review of existing baseline socio-economic data for the study areas and a review of Google Earth™ images of the study area affected by inundation. In the case of cultural landmarks affected, this indicator requires detailed information on the cultural sites in the study area affected by the dam and or irrigation scheme. This data was not available at the level of detail required to render the indicator effective and this indicator was consequently not quantified.

Displacement Indicator

INDICATOR	POPULATION DISPLACED OR AFFECTED BY ECONOMIC DISPLACEMENT
Type	Impact
Issue (s)	• The establishment of irrigation schemes or dams/reservoirs or canals may result in physical displacement of households • The establishment of irrigation schemes,, dams/reservoirs or canals may result in economic displacement due to the loss of or access to agricultural land (crops and grazing) and natural resources • The establishment of irrigation schemes or dams/reservoirs may impact on social and economic networks, such as access to family, friends and towns • The establishment of dams may pose a safety threat to households and communities immediately downstream of the dam and they may need to be resettled
Objective (s)	To avoid displacement where possible and if this is not possible to minimise the number of households affected
Target (s)	No resettlement where possible. Minimal resettlement where this is not possible
Definition	• Physical displacement due inundation by dam / establishment of irrigation scheme / construction of canal; • Economic displacement due to disruption of access to agricultural and natural resources as a result of dam and or canal
Units of Measurement	• SO12: Number of households in dam, irrigation scheme and canal footprint areas • SO13: Uninterrupted length of open canal or extent of dam inundation area upstream of dam wall
Monitoring Sites	All settlements and populated areas located within the inundated area, proposed irrigation scheme and the expanded flood lines
Legislation and Policy	International Finance Corporation (IFC) Performance Standard (PS) 5: Land Acquisition and Resettlement World Bank Operational Policy (OP) 4.12: Involuntary Resettlement
Policy Relevance	IFC PS 5 and World Bank OP 4.12 both state that resettlement should be avoided or minimised. Both also state that the livelihoods of resettlement communities should be restored to a condition that is better than the state they were in before resettlement.
Spatial Scale	Local and Regional and Nile Basin

Temporal Scale	Construction and Operational Phase of irrigation schemes and dams/reservoirs		
Method of calculation	Estimate the settlement density/number of households in the area affected by the proposed irrigation scheme or dam/reservoir by using Google Earth images of the site with the area affected superimposed on the image. Estimate of uninterrupted length of open canal or extent of dam inundation area upstream of dam wall Review existing baseline socio-economic data for the study area and the site if it is available.		
Frequency of calculation	Once-off for scenario assessment		
Measurability	Moderately Easy		
Data source (s)	• Google Earth • Information for GIS specialists indicating footprint of irrigation scheme, dam/reservoir or canal footprint area and expanded flood lines • Secondary baseline demographic data for the study area where it exists		
Timing (specific time of year)	Once-off calculation for scenario assessment		
Limitations	Estimate of the number of physically displaced households does not take into account the number of households that may be economically displaced-i.e. households that would lose access to arable land or other livelihood resources as a result of the proposed project. The approach also does not provide information on the cultural diversity and traditions within the affected area, the livelihood strategies of the affected community, the social and economic linkages between settlements and the availability of suitable land for resettlement.		
Rating	0	Zero	n/a
	-1	Negligible	<10 households
	-2	Low	10-50 households
	-3	Moderate	50-250 households
	-4	High	250-1000 households
	-5	Very High	>1000 households
Geo-Reference (regions of applicability as per legend below)	Ratings for respective regions (if relevant)		
Responsible Entity	GIS specialist, hydrologist and social specialist		
References	International Finance Corporation (IFC) Performance Standard (PS) 5: Land Acquisition and Resettlement World Bank Operational Policy (OP) 4.12: Involuntary Resettlement		

Water availability

The proposed indicator for the quantification of water availability as defined in the Final Inception Report was the percentage of households residing within a 1km buffer of a river or stream in the Nile basin that has access to sufficient volumes of water for drinking, domestic purposes, livestock and subsistence agriculture from the river or its tributaries. This indicator assumes that households within a 1km buffer of a river or stream in the Nile basin are dependent on the river or stream for their water. The unsuitability of this approach is linked to two factors. Firstly, the potential difficulty associated with measuring the percentage of households residing within 1km of a river or stream in the Nile basin. Secondly, determining how many of these households have access to sufficient volumes of water for drinking, domestic purposes, livestock and subsistence agriculture from the river or its tributaries. The indicator also requires the determination of what quantity of water is defined as “sufficient”. This data requires a detailed survey. However, the importance of water in terms of livelihoods remains a key indicator. In this regard it was assumed that water and access to water is most critical during the low flow periods of the affected rivers in question. Maintaining ecological baseline low flow values is therefore seen as a key management objective.

The proxy environmental indicator used to provide information on water availability, specifically during low flow conditions, is the Dry Season Low Flow: Median flow during lowest consecutive 3 months in the dry season.

Water Availability Indicator

INDICATOR	CHANGE IN AVAILABILITY OF WATER FOR DOMESTIC CONSUMPTION, SUBSISTENCE AGRICULTURE AND LIVESTOCK		
Type	Impact		
Issue (s)	• The establishment of irrigation schemes, dams/reservoirs or canals may impact on the availability of water to downstream communities for domestic consumption, subsistence agriculture and livestock • Changes in the flow regime and availability of water may also impact on natural resources used by downstream communities, including fish resources • Severe impacts on water availability could in turn have potential health, livelihood and food security implications for the affected households and communities. These impacts could result in economic displacement for affected households and communities		
Objective (s)	To maintain existing low flow conditions (water quantity and quality) and improve water security in and around and downstream of dams and irrigation schemes. The determination of low flow conditions should be based on the precautionary principle and err on the side of caution.		
Target (s)	No reduction of existing low flow conditions (water quantity and quality) of rivers affected by dams and irrigation schemes		
Definition	Change in availability of water for riparian users: domestic consumption, subsistence agriculture and livestock		
Units of Measurement	SO1: Dry Season Low Flow: Median flow volume (million m3) during lowest consecutive 3 months in dry season.		
Monitoring Sites	Selected populated and agricultural (crop and grazing) areas located downstream of irrigation schemes and dams that are potentially affected by changes in flow regimes		
Legislation and Policy	Refer to Nile Basin Initiative and relevant country Policies		
Policy Relevance	Refer to Nile Basin Initiative and relevant country Policies		
Spatial Scale	Local, Regional and Nile Basin		
Temporal Scale	Construction and Operational Phase of irrigation schemes and dams/reservoirs		
Method of calculation	% Change of baseline flow		
Frequency of calculation	Once-off for scenario assessment		
Measurability	Moderately Easy		
Data source (s)	• Hydrological data for affected rivers; • Dam operating specifications		
Timing (specific time of year)	Once-off calculation for scenario assessment		
Limitations	Requires accurate, up-to date hydrological data for affected rivers. Assumes that dams will be designed to enable releases to be made to maintain low flow conditions.		
Rating (Refer to Ecological Stress Ratings	5	Very High	
	4	High	
	3	Moderate	
	2	Low	
	1	Negligible	
	0	Zero	
	-1	Negligible	
	-2	Low	
	-3	Moderate	
	-4	High	
	-5	Very High	
Geo-Reference (regions of applicability as per legend below)	Ratings for respective regions (if relevant)		
Responsible Entity	GIS specialist, hydrologist and social specialist		
References	Nile Basin Initiative and relevant country policies		

Food security and livelihoods

The impact on food security and livelihoods will be felt both at the proposed dam site and also downstream of the dam. Data related challenges are associated with the indicators associated with Food Security, namely, Crop Yield, Fish Population per capita and Employment Rate as proposed during the Inception Phase.

It is proposed to replace Crop Yield with indicators reflecting the impact on food security due the potential impact on recession agricultural as a result of changes in the flow regimes and flood frequency in the areas downstream of dams and irrigation schemes and the potential increase in food production associated with establishment of new irrigation schemes. The Environmental Indicators are linked to floodplain inundation, bank erosion and biological productivity.

Food Security: Recession Agriculture Indicator

INDICATOR	FOOD SECURITY: RECESSION AGRICULTURE
Type	Impact
Issue (s)	• The impact on food security due the potential impact on recession agricultural due to change in flow regimes and flood lines in the areas downstream of dams and irrigation schemes • Increase in food production associated with establishment of new irrigation schemes
Objective (s)	To ensure that food security of communities located downstream of irrigation schemes and or dams is improved and not negatively impacted
Target (s)	Improve food security downstream of dams and irrigation schemes and in the Nile Basin as a whole
Definition	• Impact on recession agriculture due to change in flood regime – floodplain inundation • Impact on recession agriculture due to change in flood regime –bank stability • Change in fish productivity along river reach • Increase in food production associated with establishment of new or expanded irrigation scheme
Units of Measurement	• SO8-1: Proxy Environmental Indicator : Floodplain Area Inundated – EN4-1 • SO8-2: Proxy Environmental Indicator : Bank Stability – EN8 • SO9-2: Proxy Environmental Indicator : Biological Production- EN6 • SO7: New Irrigation Scheme Footprint Area
Monitoring Sites	• Selection of settlements and populated areas located in areas where recession agriculture is practiced • New irrigation schemes
Legislation and Policy	Refer to NBI and local country policies
Policy Relevance	Refer to NBI and local country policies
Spatial Scale	Local and Regional and Nile
Temporal Scale	Construction and Operational Phase of irrigation schemes and dams/reservoirs
Method of calculation	Refer to Environmental Indicators for : • Floodplain Wetland Areas Inundated • Erosion Risk Calculate new irrigation scheme footprint
Frequency of calculation	Once-off for scenario assessment
Measurability	Moderately Easy
Data source (s)	Impact on recession agriculture: Refer to Environmental Indicator: • Floodplain Wetland Areas Inundated • Erosion Risk Data on new irrigation scheme sizes and footprints
Timing (specific time of year)	Once-off calculation for scenario assessment
Limitations	The number of households that practice recession agriculture and the

	relative importance of recession agriculture to livelihood strategies are likely to vary from area to area. Proxy Environmental Indicators do not provide information on the number of households that practice recession agriculture and or the importance of recession agriculture to local livelihood strategies. The significance of the impact on recession agriculture may therefore vary from community to community. The increase in food production associated with irrigation schemes may be related to food that is exported and or sold outside the local area. This will not result in an improvement in food security at a local level. Local communities may also not be in a position to afford food produced at irrigation schemes. The Proxy Economic Indicators will not be able to provide details on this issue.		
Rating (Refer to Environmental and Economic Indicators)	5	Very High	
	4	High	
	3	Moderate	
	2	Low	
	1	Negligible	
	0	Zero	
	-1	Negligible	
	-2	Low	
	-3	Moderate	
	-4	High	
	-5	Very High	
Geo-Reference (regions of applicability as per legend below)	Ratings for respective regions (if relevant)		
Responsible Entity	GIS specialist, hydrologist, ecologist and social specialist		
References	NBI and local country policies		

The environmental indicators linked to potential fisheries production have been used as a proxy for Fish Production.

Food Security: Fish Production Indicator

INDICATOR	FOOD SECURITY: FISH PRODUCTION
Type	Impact
Issue (s)	• The impact on fish production in local rivers due the change in flow regimes and flood lines in the areas downstream of dams and irrigation schemes • Increase in fish production associated with the establishment of new dams
Objective (s)	• To minimise the impact on fish populations and fish production in rivers located downstream of irrigation schemes and or dams • Introduce indigenous fish species to dams and increase fish production
Target (s)	• Maintain ecological integrity of rivers downstream of dams and irrigation schemes; • Establish local fishing initiatives within 3 years of completion of dams.
Definition	• Change in fish productivity levels in dams; • Change in fish productivity along river reach downstream of dams
Units of Measurement	• SO9-1: Proxy Environmental Indicator: Increase in fish production-EN3: • SO9-2: Proxy Environmental Indicator: Biological Production –EN6:
Monitoring Sites	• Selection of settlements and populated areas located in areas where fishing is practiced • New dam sites
Legislation and Policy	Refer to NBI and local country policies
Policy Relevance	Refer to NBI and local country policies
Spatial Scale	Local and Regional and Nile
Temporal Scale	Construction and Operational Phase of irrigation schemes and dams/reservoirs
Method of calculation	Refer to Environmental Indicators:

	• Biological Production • Fish Productivity Levels		
Frequency of calculation	Once-off for scenario assessment		
Measurability	Moderately Easy		
Data source (s)	Impact on fish production: Refer to Environmental Indicator: • Biological Production • Fish Productivity Levels		
Timing (specific time of year)	Once-off calculation for scenario assessment		
Limitations	The number of households that rely on fishing and the relative importance of fishing to livelihood strategies and local food security are likely to vary from area to area. Proxy Environmental Indicators do not provide information on the number of households that are involved in and or the importance of fishing to local livelihood strategies. The significance of the impact on fish production may therefore vary from community to community. A large percentage of the increased fish production associated with dams may be exported and or sold outside the local area. This will not result in an improvement in food security at a local level. Local communities may also not be in a position to afford to buy the fish. The Proxy Economic Indicators will not be able to provide details on this issue.		
Rating (Refer to Environmental and Economic Indicators)	5	Very High	
	4	High	
	3	Moderate	
	2	Low	
	1	Negligible	
	0	Zero	
	-1	Negligible	
	-2	Low	
	-3	Moderate	
	-4	High	
	-5	Very High	
Geo-Reference (regions of applicability as per legend below)	Ratings for respective regions (if relevant)		
Responsible Entity	GIS specialist, hydrologist, ecologist and social specialist		
References	NBI and local country policies		

The definition of Employment Rate as per the Inception Report refers to the percentage of the economically active population in the Nile Basin that is formally employed. The large number of economically active members of the community that live in the Nile Basin and who are involved in subsistence or small scale commercial farming would not fall within this definition as they are not formally employed. This indicator would therefore exclude a large percentage of the Nile Basin community that stand to be impacted by the proposed dam and irrigation schemes. This would in turn hinder the ability of the indicator to inform the assessment and comparison of different scenarios and this indicator is therefore not quantified.

The Inception Phase definition of Household Income as an indicator for Livelihoods is the "income levels of households (USD) residing in the districts/ provinces located inside the Nile basin. This indicator is dependent on an economic indicator and assumes that a change in household income levels is related to those households". This indicator is likely to be difficult to measure and would require detailed household level information. The use of an economic indicator as a proxy is therefore proposed. Another indicator which was proposed during the Inception Phase for the quantification of livelihood impacts is the availability of Natural Resources defined as "the percentage of land within the districts/ provinces inside the Nile basin that is suitable for the collection of natural resources". This indicator takes into consideration the footprint required for the development or irrigation schemes, the construction of dams/

reservoirs and the wetland and other areas that may become inundated as a result of a direct intervention or water resource management option, and assumes that the availability of natural resources impacts on the population's livelihoods. For the dam site or area affected by an irrigation scheme, the Environmental Indicator associated with the impact on indigenous vegetation associated with the area of inundation represents the proxy indicator.

The social indicators reflecting potential livelihood benefits is therefore be based on proxy environmental and economic indicators linked to Livelihoods. For Site specific impacts, these include the impacts on natural resources as reflected in the Environmental Indicator: Environmentally Sensitive Area. For downstream impacts, Environmental Indicators linked to Floodplain area inundated, bank stability and abundance of pest blackflies (to assess impact on livestock).

Livelihoods Indicators

INDICATOR	LIVELIHOODS
Type	Impact
Issue (s)	• The site specific issues associated with the establishment of irrigation schemes, dams/reservoirs and or canals includes loss of agricultural land (crops and grazing) and natural resources and the impact that these loses will have on local livelihoods • The establishment of irrigation schemes can also create employment and generate income which would benefit local livelihoods • The downstream impacts on livelihoods are closely linked to the impacts on food security, and include impacts on recession agriculture and potential for increased incidence of black pest flies during low flow conditions and the impact on livestock
Objective (s)	Improve the livelihoods of communities affected by irrigation schemes and dams and communities living downstream of dams and irrigation schemes
Target (s)	Improve the livelihoods of communities affected by irrigation schemes and dams and communities living downstream of dams and irrigation schemes and in the Nile Basin as a whole
Definition	• Loss of or access to productive agricultural land (crops and grazing) • Loss of and or access to natural resources • Increase in food production due to establishment of irrigation schemes • Change in fish productivity levels associated with dams • Prevalence of disease affecting livestock resulting from pest species • Impact on recession agriculture due to change in flood regime – floodplain inundation • Impact on recession agriculture due to change in flood regime –bank stability • Change in fish productivity along river reach • Increase in food production associated with establishment of new or expanded irrigation scheme
Units of Measurement	Indicators: Site specific: • SO10: Productive land (crops and grazing) in dam / irrigation scheme / canal foot print area • SO7: New Irrigation scheme footprint area • SO9-1: Proxy Environmental Indicator: Increase in fish production-EN3: • SO3: Proxy Environmental Indicator: Abundance of pest black flies-EN7 Indicators: Downstream • SO8-1: Proxy Environmental Indicator : Floodplain Area Inundated – EN4-1 • SO8-2: Proxy Environmental Indicator : Bank Stability – EN8 • SO9-2: Proxy Environmental Indicator : Biological Production- EN6 • SO7: New Irrigation Scheme Footprint Area
Monitoring Sites	• All settlements and populated areas located within the inundated area, proposed irrigation scheme and the expanded flood lines

	• Selected settlements and populated areas located downstream of irrigation schemes and dams/reservoirs		
Legislation and Policy	International Finance Corporation (IFC) Performance Standard (PS) 5: Land Acquisition and Resettlement World Bank Operational Policy (OP) 4.12: Involuntary Resettlement		
Policy Relevance	IFC PS 5 and World Bank OP 4.12 both state that resettlement and impacts on livelihoods should be avoided or minimised. Both also state that the livelihoods of resettlement communities should be restored to a condition that is better than the state they were in before resettlement.		
Spatial Scale	Local and Regional and Nile		
Temporal Scale	Construction and Operational Phase of irrigation schemes and dams/reservoirs		
Method of calculation	Site specific impacts Estimate the area of agricultural land (crop and grazing) area affected by the proposed irrigation scheme or dam/reservoir by using Google Earth images of the site with the area affected superimposed on the image. Review existing baseline socio-economic data for the study area and the site if it is available. Refer to Environmental Indicator, Footprint Areas: • Environmentally Sensitive Areas (ha) Downstream impacts Footprint area for irrigation schemes Refer to Environmental Indicators: • Floodplain wetland inundated • Bank Stability • Abundance of pest blackflies		
Frequency of calculation	Once-off for scenario assessment		
Measurability	Moderately Easy		
Data source (s)	Refer to hydrological data and models		
Timing (specific time of year)	Once-off calculation for scenario assessment		
Limitations	The determination of the altered flood lines are dependent upon the accuracy and reliability of the hydrological data for the affected rivers and catchment areas		
Rating (Refer to environmental and economic ratings)	5	Very High	
	4	High	
	3	Moderate	
	2	Low	
	1	Negligible	
	0	Zero	
	-1	Negligible	
	-2	Low	
	-3	Moderate	
	-4	High	
	-5	Very High	
Geo-Reference (regions of applicability as per legend below)	Ratings for respective regions (if relevant)		
Responsible Entity	GIS specialist, hydrologist, ecologist and social specialist		
References	International Finance Corporation (IFC) Performance Standard (PS) 5: Land Acquisition and Resettlement World Bank Operational Policy (OP) 4.12: Involuntary Resettlement		

Estimates of loss in productive land (SO10) were made by calculating areas within new reservoir inundation areas, irrigated areas and/or canal servitudes associated with the subset of land cover classes shown in the following table and contained in the Global Landcover (GlobCover) database. Adjustment factors were used to reduce the areas of composite landcover classes.

GLCFID	Landcover Class	Percentage of
11	Post-flooding or irrigated croplands (or aquatic)	100
12	Post-flooding or irrigated shrub or tree crops	100
13	Post-flooding or irrigated herbaceous crops	100
14	Rainfed croplands	100
15	Rainfed herbaceous crops	100
16	Rainfed shrub or tree crops (cash crops, vineyards, olive tree, orchards…)	100
20	Mosaic cropland (50-70%) / vegetation (grassland/shrubland/forest) (20-50%)	60
21	Mosaic cropland (50-70%) / grassland or shrubland (20-50%)	60
30	Mosaic vegetation (grassland/shrubland/forest) (50-70%) / cropland (20-50%)	35
31	Mosaic grassland or shrubland (50-70%) / cropland (20-50%)	35
32	Mosaic forest (50-70%) / cropland (20-50%)	35

Wetland areas and conservation areas within new reservoir inundation areas, irrigated areas and/or canal servitudes database were used to approximately quantify loss of access to natural resources (SO11).

Community Health and Safety

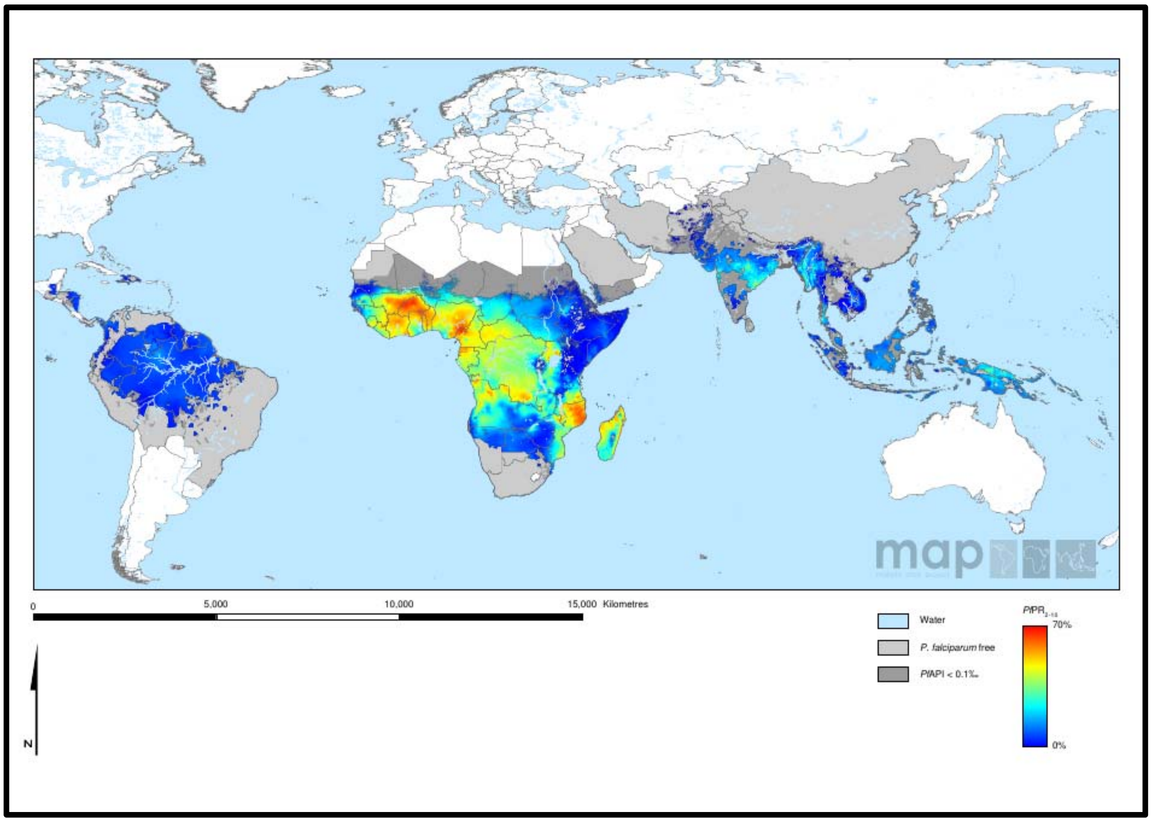
The impact on Community Health and Safety will be felt both at the proposed dam site and also downstream of the dam.. In the Final Inception Report, indicators for quantifying community health were the prevalence of waterborne diseases and the prevalence of diseases resulting from pest species. A key criteria for both waterborne and pest related diseases, as per the Inception Phase definition, is the percentage of individuals residing within a 1km buffer of a river, stream, irrigation scheme or dam located within the Nile basin that have contracted a waterborne disease. As in the case of water availability, there is limited data on the percentage of households residing within 1km of a river or stream in the Nile basin. Secondly, accurately determining how many of these households have contracted a waterborne disease requires a detailed survey. The definition also assumes that the majority of community members report cases water borne diseases to relevant medial authorities and that this data is captured. In remote, rural areas this is unlikely. However, impact on community health and well-being is recognised as a key social issue. The proxy environmental indicator that has been identified to provide information on the potential social consequences associated with waterborne and pest related diseases are the potential risk of an increase in black flies.

Community Health Indicator

INDICATOR	COMMUNITY HEALTH		
Type	Impact		
Issue (s)	• The potential impact on human health resulting from an increase in the prevalence of waterborne diseases associated with irrigation schemes (malaria) • Potential impact on human health resulting from prevalence of pest species associated with changes in flow regimes		
Objective (s)	To minimise the impact on human health due the establishment of irrigation schemes and changes in flow regimes		
Target (s)	Improve the levels of community health affected by irrigation schemes and communities living downstream of dams and irrigation schemes		
Definition	• Susceptibility of irrigation schemes to result in an increase in incidence of malaria • Impact on humans resulting from pest species • Water pollution downstream of urban areas		
Units of Measurement	• SO2: WHO malaria incidence map of Africa • SO3: Proxy Environmental Indicator: Abundance of pest black flies-EN7 • SO4: Defined load factors; Constituent loads/concentration in river; biological decay relationships		
Monitoring Sites	• All settlements and populated areas located near new irrigation schemes • Selected settlements and populated areas located downstream of irrigation schemes and dams/reservoirs		
Legislation and Policy	NBI and country community health policies		
Policy Relevance	Refer to NBI and country community health policies		
Spatial Scale	Local and Regional and Nile Basin		
Temporal Scale	Construction and Operational Phase of irrigation schemes and dams/reservoirs		
Method of calculation	Site specific impacts Assess susceptibility of area to malaria based on malaria incidence map for Africa. Downstream impacts Refer to Environmental Indicators: • Abundance of pest blackflies (Index)		
Frequency of calculation	Once-off for scenario assessment		
Measurability	Moderately Easy		
Data source (s)	Refer to Environmental Data and World Health Organisation (WHO) Malaria incidence map for Africa		
Timing (specific time of year)	Once-off calculation for scenario assessment		
Limitations	The WHO malaria map for Africa is based at a very broad level and can only be used to give an indication of which areas are more prone to malaria. This does not mean that in those areas that are less prone that the significance of the impact associated with the establishment of an irrigation scheme will be low		
Rating (Refer to Environmental Indicator Ratings)	5	Very High	n/a
	4	High	n/a
	3	Moderate	n/a
	2	Low	n/a
	1	Negligible	
	0	Zero	
	-1	Negligible	
Low Negative	-2	Low	
	-3	Moderate	
	-4	High	
	-5	Very High	
Geo-Reference (regions of applicability as per legend below)	Ratings for respective regions (if relevant)		

Responsible Entity	GIS specialist, hydrologist, ecologist and social specialist
References	WHO malaria map for Africa

Community Health will also consider the prevalence of malaria in the Nile Basin as a whole and the potential for proposed dam and or irrigation projects to create conditions that would be conducive to an increase in the prevalence of malaria. The WHO malaria map for Africa is based at a very broad level and can only be used to give an indication of which areas are more prone to malaria. This does not mean that in those areas that are less prone that the significance of the impact associated with the establishment of an irrigation scheme will be low.



Malaria Risk Areas (low risk areas shown as blue)

In the Final Inception Report, the indicator for quantifying community safety was linked to the percentage of population living in the flood line. The definition was based on “the percentage of the districts‟/ provinces‟ population that resides inside the flood line” and considers the safety of populations both downstream dams and alongside rivers, and assumes a change in flood lines as a result of direct interventions or water management options. As indicated above, the quantification of this indicator depends on detailed demographic data and hydraulic modelling in order to determine the percentage of the population that resides below the flood line.

Community Safety Indicator

INDICATOR	COMMUNITY SAFETY		
Type	Impact		
Issue (s)	• Potential safety risk posed by flooding and dam breaks to communities living downstream of dams. • Assumptions which have been made: ➢ The flood line downstream of dams will be lower than the current natural state flood line ➢ No flood plain encroachment will occur ➢ No dam breaks will occur ➢ An effective flood warning system will be implemented as part of the dam operating procedure • It is therefore assumed that the establishment of dams will not impact on the safety of downstream communities • Increased risk of drowning associated with dams and canals.		
Objective (s)	• To minimise the safety risk to downstream communities posed by dams and altered flood regimes		
Target (s)	• Refer to dam operation procedures		
Definition	• Drowning risk due to open water bodies • Households located within the 100 year flood line		
Units of Measurement	• SO6: Uninterrupted length of open canal and dam inundation area • SO5: 100 year flood envelope		
Monitoring Sites	• Selection of settlements and populated areas located in downstream of dams		
Legislation and Policy	Refer to NBI, local country policies and dam operating procedures		
Policy Relevance	Refer to NBI, local country policies and dam operating procedures		
Spatial Scale	Local and Regional and Nile		
Temporal Scale	Construction and Operational Phase of irrigation schemes and dams/reservoirs		
Method of calculation	Refer to hydrological data and models		
Frequency of calculation	Once-off for scenario assessment		
Measurability	Moderately Easy		
Data source (s)	Refer to hydrological data and models		
Timing (specific time of year)	Once-off calculation for scenario assessment		
Limitations	The determination of the altered flood lines are dependent upon the accuracy and reliability of the hydrological data for the affected rivers and catchment areas		
Rating (Refer to hydrological data and models)	5	Very High	
	4	High	
	3	Moderate	
	2	Low	
	1	Negligible	
	0	Zero	
	-1	Negligible	
	-2	Low	
	-3	Moderate	
	-4	High	
	-5	Very High	
Geo-Reference (regions of applicability as per legend below)	Ratings for respective regions (if relevant)		
Responsible Entity	GIS specialist, hydrologist, ecologist and social specialist		
References	NBI and local country policies		

APPENDIX B

ENVIRONMENTAL INDICATORS: BACKGROUND INFORMATION

EN1 Ecologically Sensitive Areas

Indicator	**Ecologically Sensitive Areas**
Type	State.
Issue(s)	Protection of ecologically sensitive areas will serve to protect the biodiversity and ecosystem services associated with such areas.
Objective(s)	To minimise direct and permanent impacts on Ecologically Sensitive Areas and associated biodiversity and ecosystem services.
Target(s)	(green) No Impact: None (yellow) Warning: Cat III to VI (red) Red Card: Cat 1 or II
Definition	Ecologically Sensitive Areas refer to those areas located within the primary impact zones that have been, or could potentially be, classified into one of the IUCN protected area management categories (www.iucn.org). The IUCN categories provide a global standard for defining and recording protected areas and are increasingly being incorporated into government legislation (www.iucn.org). The IUCN Protected Areas Categories System are as follows: • Category Ia – Strict Nature Reserve • Category Ib – Wilderness Area • Category II – National Park • Category III – Natural Monument or Feature • Category IV – Habitat / Species Management Area • Category V – Protected Landscape • Category VI – Protected area with Sustainable Use of Natural Resources Areas that could potentially be classified using the IUCN classification were based on the following considerations: • ***Wetlands***. Points identified as wetlands of international importance (www.ramsar.org). • ***Birds***. Points identified as Important Bird Areas (www.birdlife.org)
Units of Measurement	IUCN Classification and Square kilometers (km^2)
Monitoring Sites	N/A.
Legislation & Policy	Convention on Biological Diversity (UNCBD) Ramsar Convention IFC Environmental Performance Standard 6 (IFC 2012).

	African Development Bank Policy on the Environment (ADB 2004). NEPADS's Environmental Programme and Action Plan (2003) Transboundary Integrated Water Resources Management of the Kagera River Basin (TIWRM) Lake Victoria Basin Commission (LVBC) Lake Victoria Environmental Management Plan
Policy Relevance	Environmental policies of the IFC/World Bank and African Development Bank do not support projects that would lead to the significant loss or degradation of such areas.
Spatial Scale	Local (primary footprint area).
Temporal Scale	Long-Term (>10 yrs).
Method of calculation	EN1 = EN1.1 + EN1.2 where EN1 = IUCN Classification and Size of Ecologically Sensitive Areas for each proposed scheme EN1.1 = IUCN Classification and Size of Ecologically Sensitive Area within inundation area(s), (mapped at FSL). EN1.2 = IUCN Classification and Size of Ecologically Sensitive Areas within proposed irrigation area footprint (s). Wetlands of international importance (Ramsar Sites) and Important Bird Areas (IBAs) that fell outside of protected areas, but within primary impact zones, were classified as equivalent to IUCN Categories I & II (i.e. rating 5).
Frequency of calculation	Once-off for each proposed scheme.
Measurability	Easy.
Data source(s)	• Full Supply Level (FSL) of proposed impoundment(s) • Aerial extent of proposed irrigation area(s) • IUCN Protected Areas (www.protected planet.org) • Ramsar wetlands of international importance (www.ramsar.org) • Important Bird Areas (Birdlife International and NatureServe 2011)
Timing (specific time of year)	Once-off calculation.
Limitations	The assessment of this indicator was based on available spatial coverages, which is suitable for strategic planning only. Reasonably detailed spatial data were available for protected areas, but available data for Ramsar sites and Important Bird Areas (IBAs) were point data only, with no information

on the spatial extent of these areas. The significance of this limitation was generally low, as most Ramsar sites and IBAs are formally protected and therefore already incorporated by the IUCN coverage and classification. However, there were a few locations within the basin that fell outside of areas that are formally protected.

Biodiversity hotspots were not included because of the limitations of available data and the variability in spatial resolution of available data. Biodiversity data were available on mammals and amphibians from the IUCN database, but there were no uniform data available on groups that are likely to be more sensitive to impacts of water resource developments, such as plants, fish and aquatic invertebrates. Biodiversity is complex and any attempt to reduce the available data into a simple and transparent statistic that could be used to compare water resource developments at the scale needed for this DSS is certain to be fraught with problems and inconsistencies. It was therefore considered appropriate to exclude biodiversity and to rather address this during later and more detailed stages of the development process.

Rating

IUCN Category	Size within Direct Impact Zone (km^2)				
	> 100	10 - 99	1 - 9	0.1 - 9.9	0.01 – 0.9
I & II	-5	-5	-5	-5	-5
III	-5	-4	-4	-4	-4
IV	-5	-4	-3	-3	-3
V	-5	-4	-3	-2	-2
VI	-5	-4	-3	-2	-1

Responsible Entity

Ecologist.

References

African Development Bank (ADB) 2004. African Development Bank Group's Policy on the Environment. February 20094.

Birdlife International. Important Bird Areas Programme. (www.birdlife.org).

International Finance Corporation (IFC). 2012. Performance Standard 6. Biodiversity Conservation and Sustainable Management of Living Natural Resources.

NEPAD 2003. Action plan for the environment initiative of the New Partnership for Africa's Development (NEPAD).

Ramsar (www.ramsar.org).

BirdLife International and NatureServe (2011) Bird species distribution maps of the world. BirdLife International, Cambridge, UK and NatureServe, Arlington, USA.

EN2 Carbon Emissions

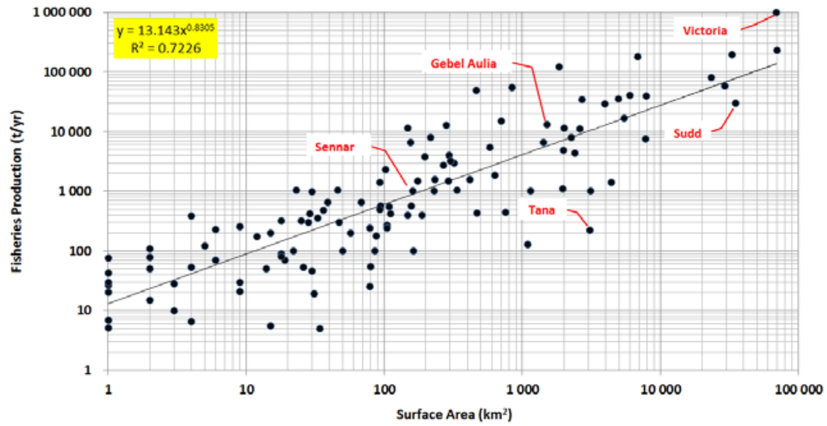
Indicator	**Carbon Emissions**
Type	Impact
Issue(s)	This indicator refers to the abundance of woody vegetation located within the area of inundation, or irrigation development, which would lead to the generation of greenhouse gasses. Emissions of greenhouse gasses from impoundments are usually low, but sometimes the emissions may exceed those of thermal alternatives (WCD, 2000). Increasing international concerns about greenhouse gas emissions provide sufficient incentive to include this as a key indicator (Scanlon *et al*., 2004).
Objective(s)	To minimize carbon emissions.
Target(s)	No Impact: <0.3 million tons Warning: 0.3 to 3 million tons Red Card: >3 million tons
Definition	The quantity of biomass inundated is proportional to the quantity of greenhouse gasses generated by impoundment. The values are presented as the total tons of carbon that are expected to be emitted. For hydropower plants these values can be expressed in terms of carbon generated per unit of electricity generated, and this provides a useful comparative index.
Units of Measurement	Tons of Carbon.
Monitoring Sites	All proposed impoundments.
Legislation & Policy	• UN Framework on Climate Change • Convention on Climate Change and its Kyoto protocol • World Commission on Dams Report (WCD 2000) • International Hydropower Association Sustainability Guidelines (Scanlon *et al*. 2004) • International Finance Corporation Environmental Health and Safety General Guidelines (2007) • African Development Bank energy sector policy (ADB Draft).
Policy Relevance	Various development guidelines specify the need to consider the emission of greenhouse gases when planning the construction of large dams.
Spatial Scale	Regional.
Temporal Scale	Long-Term (>10 yrs)
Method of calculation	Potential carbon emissions from woody biomass flooded by impoundment, as well as clearing and burning of woody biomass for irrigation development, were based on maps of carbon emission potential in Africa, developed by the Carbon Dioxide Information Analysis Center in

<table>
<tr><td></td><td>Tennessee, USA (Gibbs and Brown 2007). Estimates of woody biomass were based on forest inventory data contained in the Global Land Cover 2000 Database (GLC2000). The data sets include estimates of biomass in woody vegetation and biomass carbon found in woody vegetation, which were both expressed in Mg/ha (= tons/ha). The cellsize for these data was 0.045 decimal degrees.</td></tr>
<tr><td>Frequency of calculation</td><td>Once-off.</td></tr>
<tr><td>Measurability</td><td>Moderate confidence from available studies, but this indicator is likely to underestimate contributions of greenhouse gases because carbon sources are not restricted to decomposition of vegetation within the FSL. Another main source of carbon inputs is associated with sediment accumulation, which is not considered using this indicator.</td></tr>
<tr><td>Data source(s)</td><td>• Location of proposed impoundment
• Full Supply Level (FSL)
• EDF (2007)
• Gibbs and Brown (2007)</td></tr>
<tr><td>Timing (specific time of year)</td><td>Once-off calculation.</td></tr>
<tr><td>Limitations</td><td>This indicator considers total carbon emissions only, and does not differentiate between carbon dioxide or methane, and does not consider any of the other potential greenhouse gases, such as nitrous oxide and ozone. Furthermore, this indicator does not consider other potential sources of greenhouse gas emissions, such as:
• sediment accumulation within reservoirs
• methane generation from anaerobic decomposition.
• concrete production and other civil works</td></tr>
<tr><td>Rating</td><td><table>
<tr><td>0</td><td>Zero</td><td>0 to 9,999 tons</td></tr>
<tr><td>-1</td><td>Negligible</td><td>10,000 – 69,999 tons</td></tr>
<tr><td>-2</td><td>Low</td><td>70,000 – 149,999 tons</td></tr>
<tr><td>-3</td><td>Moderate</td><td>0.15 – 0.49 million tons</td></tr>
<tr><td>-4</td><td>High</td><td>0.5 – 3.0 million tons</td></tr>
<tr><td>-5</td><td>Very High</td><td>>3.0 million tons</td></tr>
</table></td></tr>
<tr><td>Responsible Entity</td><td>Ecologist.</td></tr>
</table>

References	African Development Bank (ADB) undated draft. Energy Sector Policy of the African Development Bank Group. EDF 2007. Prefeasibility study of Mandaya Hydropower Project, Ethiopia. Eastern Nile Power Trade Programme Study. Module M5. Report prepared by EDF and Scott Wilson for the Eastern Nile technical Regional Office. Gibbs, H.K. and S. Brown. 2007. Geographical Distribution of Woody Biomass Carbon in Tropical Africa: An Updated Database for 2000, NDP-055b. Available at [http://cdiac.ornl.gov/epubs/ndp/ndp055/ndp055b.html] from the Carbon Dioxide Information Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee. doi: 10.3334/CDIAC/lue.ndp055.2007. Global Land Cover 2000 Database. European Commission, Joint Research Centre, 2003. http://www-gen.jrc.it/glc2000. Scanlon, A., Kile, R., and Blumstein, B. 2004. Sustainable hydropower - guidelines, compliance standards and certification. United Nations Symposium on Hydropower and Sustainable Development, Beijing 27-29 October 2004. Hydro Tasmania, Australia. World Commission of Dams. 2000. Dams and development a new framework for decision-making. The Report of the Word Commission on Dams. London: Earthscan Publications, Thanet Press.

EN3 Fisheries Production

Indicator	**Fisheries Production**
Type	Pressure
Issue(s)	This indicator refers to areas that will become inundated through impoundment, and therefore represents the additional fish habitat created by impoundment. This indicator was chosen because of stakeholder concerns over fisheries production, and the importance of fisheries for sustaining livelihoods in the basin.
Objective(s)	To maximize fisheries production.
Target(s)	(green) No Impact – Increase in fisheries production (yellow) Warning – Fisheries production drops by <100 t/yr (red) Red Card – Fisheries Production drops by >100 t/yr
Definition	Fisheries production was based on catches from lakes and impoundments throughout Africa.
Units of Measurement	tons/annum.
Monitoring Sites	Impoundments & Wetlands.
Legislation & Policy	Ethiopia: Agricultural Led Industrialization Policy Egypt: Law No 124/1983 on fishing, aquatic life and the regulation of fish farms. General Authority for Fisheries Resources Development (GAFRD), Ministry of Agriculture. Uganda. 2004. National Fisheries Policy. Department of Fisheries Resources, Ministry of Agriculture, Animal Industry and Fisheries. DRC Decree on fishing and hunting (1937, amended in 1957, 1958, 1960) FAO: various initiatives throughout the basin.
Policy Relevance	Policy is unlikely to make significant difference to what happens in the field because of the difficulties of enforcement.
Spatial Scale	Local (inundation footprint).
Temporal Scale	Long-Term (>10 yrs).
Method of calculation	$y = 13.143\ x^{0.8305}$ where y = fisheries production (tons/a); and x = median area of inundation over simulation period (km^2).

	 **Figure X. Relationship between impoundment Surface Area and Fisheries Production. Data were based on measured catches from lakes and impoundments throughout Africa, extracted from the FAO database (2007) and Witte *el al* (1990).**
Frequency of calculation	Once-off.
Measurability	Easy.
Data source(s)	Summary of fish landings of main water bodies in the Nile catchment after the 1990's (Witte *et al.* 2009), and data on fish catches from lakes and reservoirs throughout Africa, extracted from the African Water Resource Database (FAO 2007).
Timing (specific time of year)	Once-off calculation.
Limitations	Many factors influence fisheries production, such as water temperature, water clarity, water depth, water quality and fish species. However, a simple equation based on the surface area of the waterbody alone was used to predict fisheries production. This simple approach was justified on the basis of a previous detailed investigation of potential fisheries production in 103 waterbodies in Africa (Hall 1999). The study concluded that the variation in potential yield was best explained by the waterbody surface area. The same study found that fisheries production potential was not significantly correlated with shoreline complexity, soil fertility, natural vegetation density, or water temperature. Mean potential yield per unit area was estimated at 65 $kgha^{-1}y^{-1}$ irrespective of the type of waterbody (Hall 1999). The 95% confidence intervals around this estimate (51 to 83 $kgha^{-1}y^{-1}$), indicates that potential production is relatively consistent (Hall 1999). A more recent study of global fisheries statistics showed that fish catches appear to have increased significantly since the 1950's, despite reports of falling catches caused by environmental degradation and overexploitation (Welcomme 2011). The apparent increase in production was attributed to

	improved collection of relevant data rather than increased production. The study highlighted the limitations and reliability of available data. No consideration was given to separating production of different fish species on the grounds that such level of detail is unnecessary for the purposes of this project, and any attempt to do so would be fraught with uncertainty. For example, Lake Victoria alone supports over 500 species of endemic fish and production figures for most of these are unknown. Even if one were to focus on the commercial species, their populations and production changes significantly as fishing effort and other driving variables change over time. It was therefore considered appropriate to consider total production only. Another limitation of this indicator is that there can be significant differences between potential production and actual production. For example, the potential fish production for the Sudd wetland was estimated at 140,000-150,000 tons per annum, whereas actual catches were estimated at 12,000-18,000 tons per annum (Bassa 1986). The difference was attributed to limited government intervention and problems related to transport, storage and processing (Bassa 1986). This indicator also does not address the disruption of upstream migration of fish (i.e. the rivers upstream of a proposed dam whose fish stocks may be reduced because of a migration barrier).

Rating

5	Very High	>1,000 tons increase
4	High	300 to 1,000 tons increase
3	Moderate	50 to 299 tons increase
2	Low	10 to 49 tons increase
1	Negligible	1 to 9 tons increase
0	Zero	0
-1	Negligible	1 to 9 tons decrease
-2	Low	10 to 49 tons decrease
-3	Moderate	50 to 299 tons decrease
-4	High	300 to 1,000 tons decrease
-5	Very High	>1,000 tons decrease

Responsible Entity	n/a.
References	Bassa, G. K. 1986. Fishery resources of Southern Sudan. In A.B. Zahlan (ed.): The Agricultural sector of Sudan: Policy and systems studies, 291-299. London (UK), Ithaca Press. Food and Agricultural Organisation of the United Nations (FAO) 2007. African water resource database. GIS-based tools for inland aquatic resource management. 2 Technical manual and workbook. CIFA Technical Paper 33/2. Halls, A. S 1999. Spatial Models for the Evaluation and Management of Inland Fisheries. Final Report. FIR Plansys 23220 01 20, MRAG Ltd. London. Welcomme, R. L. 2011. An overview of global catch statistics for inland fisheries. ICES Journal of Marine Science 68(8): 1751-1756. Witte, F., de Graaf, M., Mkumbo, O. C., El-Moghraby, A. I. and Sibbing, F. A. 2009. Fisheries production in the Nile System. Dumont, H. J. (ed.). The Nile: origin, Environments, Limnology and Human Use. Springer. Monographiae Biologicae 89: P 723-747.

EN4_1 Floodplain Area Inundated

Indicator	**Floodplain Wetland Inundated**
Type	State
Issue(s)	This indicator was chosen because of the significant ecosystem services that floodplain wetland areas provide, including biodiversity support, nursery areas for fish, and production of various natural resources, including timber, thatching grass and medicinal plants.
Objective(s)	To maintain spatial extent of seasonal inundation.
Target(s)	(green) No Impact: < 10% reduction (yellow) Warning: 10 to 50% reduction (red) Red Card: > 50% reduction
Definition	This indicator was based on the percentage change in the median wet season low flow, which was used as a surrogate and preliminary indicator to quantify potential impacts on floodplain wetland areas downstream of proposed impoundments or diversion schemes.
Units of Measurement	% change in median wet season low flows compared to baseline.
Monitoring Sites	n/a
Legislation & Policy	n/a
Policy Relevance	n/a
Spatial Scale	Regional.
Temporal Scale	Long-Term (>10 yrs).
Method of calculation	$y = (a-b)/b * 100$ where y = percentage change compared to baseline a = median wet season low flow for Scenario (m^3/s) b = median wet season flow during for Baseline (m^3/s) Median wet season low flows were calculated by selecting the median monthly flows for one month on either side of the month with the highest flow. This method was used because i) it enables comparable wet season low flows to be extracted from a monthly time series ii), it can be easily automated for time series that have more than one wet season..
Frequency of calculation	Once-off.

Measurability	Easy, but indirect (see limitations)
Data source(s)	Median monthly discharge (m^3/s)
Timing (specific time of year)	Once-off calculation.
Limitations	Ideally, the spatial extent and temporal duration of wetland inundation are needed to assess the extent to which development scenarios could impact on floodplain wetlands. However, such calculations need daily flow data and detailed hydraulic data (cross-sectional profiles; channel roughness etc), neither of which are available at the time of writing this report. Instead, a surrogate (preliminary) indicator was chosen to provide a comparable measure of potential changes in high flow events. The indicator chosen provides a comparative measure of the annual flood event, which is suitable for comparative purposes, but the indicator does not reflect the area or duration of annual wetland inundation.
Rating	See rating table below

5	Very High	>100% gain
4	High	25 to 100% gain
3	Moderate	10 to 24% gain
2	Low	5 to 9% gain
1	Negligible	<5% gain
0	Zero	0
-1	Negligible	<5% reduction
-2	Low	5 to 9% reduction
-3	Moderate	10 to 19% reduction
-4	High	20 to 49% reduction
-5	Very High	>50% reduction

EN5 Ecological Stress

Indicator	**Ecological Stress**
Type	State
Issue(s)	This indicator was chosen because of the importance of wet and dry season low flows and within year flow variability in defining instream ecological processes and associated river health. Aquatic biota have evolved life history strategies to cope with the natural stress regime, and any changes to the natural stress regime (increase or decrease) tend to reduce biodiversity because these changes produce conditions suitable to a few taxa only.
Objective(s)	To maintain the natural stress characteristics of the flow regime.
Target(s)	No Impact – Zero to moderate rating (0-3) Warning – High negative rating (-4) Red Card – Very High negative rating (-5)
Definition	This indicator refers to the availability of instream habitats during low flow conditions. This indicator aims to describe the present-day ecological stress characteristics at each hydrological node (or river type), against which the stress characteristics of a modified flow regime can be compared.
Units of Measurement	Percentage change seasonal (within year) variation in wet and dry season low flows compared to baseline,
Monitoring Sites	n.a
Legislation & Policy	The development and management of water resources have led to the alteration of the natural flow regimes of many rivers around the world and this has led to growing concern regarding the deterioration of river environments. These concerns have been expressed in various policy and guideline documents, including the World Commission of Dams (WCD 2000), and World Bank Policies on environment (World Bank 2001; Hirji and Panella 2003).
Policy Relevance	Environmental flow assessments aim to predict the environmental impacts associated with water resource developments and to provide information on the amount and frequency of managed flows which are required to maintain a river in a pre-determined, environmentally acceptable condition.
Spatial Scale	Regional.
Temporal Scale	Long-Term (>10 yrs).

Method of calculation	**EN 5.1: Dry Season Low Flow** y = (a-b)/b * 100 where y = percentage change compared to baseline a = median flow in the lowest 3 consecutive months during dry season for Scenario (m^3/s) b = median flow in the lowest 3 consecutive months during dry season for Baseline (m^3/s) **EN 5.2: Wet Season Low Flow** y = (a-b)/b * 100 where y = percentage change compared to baseline a = median low flow during wet season for Scenario (m^3/s) b = median low flow during wet season for Baseline (m^3/s) Median wet season low flows were calculated by selecting the median monthly flows for one month on either side of the month with the highest flow. This method was used because i) it enables comparable wet season low flows to be extracted from a monthly time series ii), it can be easily automated for time series that have more than one wet season. **EN 5.3: Dry Season Low Flow Level** [When cross sections and stage-discharge relationships are available, convert EVN5.1 into corresponding water levels.] **EN5.4: Wet Season Low Flow level** [When cross sections and stage-discharge relationships are available, convert EVN5.2 into corresponding water levels]. **EN5.5: Flow Variability** y = (a-b)/b * 100 where y = percentage change compared to baseline a = median annual flow amplitude for Scenario (difference between max

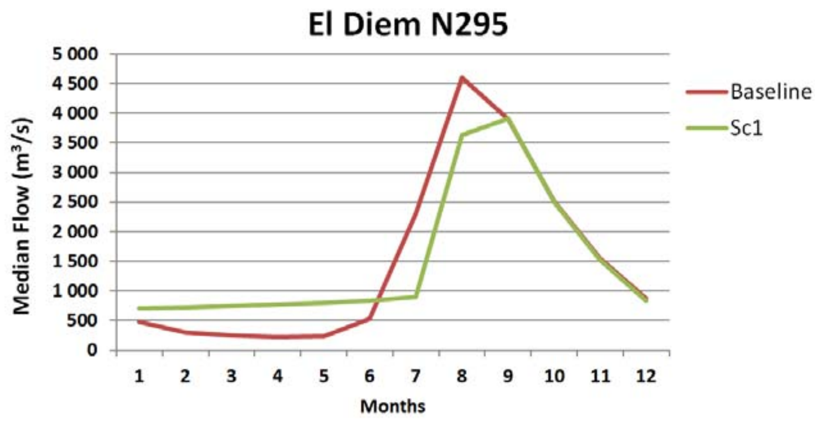
	and min monthly flow rate for each year) b = median annual flow amplitude for Baseline (difference between max and min monthly flow rate for each year).
Frequency of calculation	Once-off.
Measurability	Easy.
Data source(s)	Monthly flow (in Mm^3)
Timing (specific time of year)	Once-off calculation.
Limitations	This indicator could be expressed as an Ecological Stress duration curve, but this level of detail was unnecessary for the purposes of this project and the median stress was used for comparative purposes. An alternative indicator for a similar concept is the "duration of zero flows" (measured in days), but this could not be measured with the available monthly flow data.
Rating	(see table below)

		ENV5.1+5.2 Low Flows	EVN5.5 Annual Flow variation
0	Zero	0	0
-1	Negligible	<20% gain <17% drop	6 - 10% gain 5 - 9% drop
-2	Low	20 - 49% gain 17 - 34% drop	11 - 24% gain 10 - 19% drop
-3	Moderate	50 - 99% gain 35 - 49% drop	25 - 99% gain 20 - 49% drop
-4	High	100 - 149% gain 50 - 59% drop	100 - 399% gain 50 - 79% drop
-5	Very High	>150% gain >60% drop	400>% gain <80% drop

Responsible Entity	Ecologist.
References	Hijri, R., and Panella, T. 2003. Evolving policy reforms and experiences for addressing downstream impacts in World Bank Water Resources Projects. Rivers Research & Applications 19: 667-681. World Bank. 2001. Making Sustainable Commitments: An Environment Strategy for the World Bank. World Bank: Washington, DC. World Commission on Dams. 2000. Dams and Development: A New Framework for Decision Making. Earthscan Publications: London.

EN6 Biological Production

Indicator	**Biological Production**
Type	Impact
Issue(s)	Floodplain wetlands provide important nursery areas for fish and are therefore key components that define the magnitude of secondary production in many river ecosystems, and the associated goods and services that river and floodplain ecosystems provide.
Objective(s)	To maintain duration of inundation and associated biological production.
Target(s)	(green) No Impact – <60% reduction (yellow) Warning – 60-79% reduction (red) Red Card – >80% reduction
Definition	This indicator refers to the duration of the wet season.
Units of Measurement	Percentage change in duration of wet season (days) compared to baseline.
Monitoring Sites	n/a
Legislation & Policy	n/a
Policy Relevance	n/a
Spatial Scale	Regional.
Temporal Scale	Long-Term (>10 yrs).
Method of calculation	$y = (a-b)/b * 100$ where y = percentage change compared to baseline a = wet season duration for Scenario (days) b = wet season duration for Baseline (days) Duration was estimated graphically from median monthly flow, as illustrated in the example below (Figure xx).

	 **Figure xx. Median monthly flow at El Diem for Baseline and Sc1, showing a reduction in the duration of the wet season from 4.5 to 3.9 months.**
Frequency of calculation	Once-off.
Measurability	Moderately easy (see discussion under limitations).
Data source(s)	Median monthly flows at key locations.
Timing (specific time of year)	Once-off calculation.
Limitations	The duration of the wet season was estimated from the available monthly data, so the accuracy of this indicator was poor, but adequate for broad comparative purposes. In addition, a linear relationship was assumed between the duration of the wet season and the associated "biological production". Biological Production in the context of this project incorporates a number of attributes that could not be measured at the scale of this project, such as instream and riparian health, habitat diversity and biological diversity.
Rating	5 Very High >400% gain 4 High 150 - 399% gain 3 Moderate 40 - 149% gain 2 Low 10 - 39% 1 Negligible <10 % gain

0	Zero	0
-1	Negligible	<10% reduction
-2	Low	10 - 29% reduction
-3	Moderate	30 - 59% reduction
-4	High	60 - 79% reduction
-5	Very High	>80% reduction

EN7 Abundance of Pest Blackflies

<table>
<tr><td>Indicator</td><td>Abundance of Pest Blackflies</td></tr>
<tr><td>Type</td><td>State</td></tr>
<tr><td>Issue(s)</td><td>Pest blackflies occur throughout the Nile River Basin upstream of Lake Nasser, and periodic outbreaks have been reported in many parts of the basin, including the Nile River at Jinja and Khartoum (McCrae, 1977). Winds associated with the Intertropical Convergence Zone can transport the adult flies far into the Sudan dessert from breeding sites along the Nile River (Lewis, 1948). This indicator was selected because of its direct and well-known association with regulated rivers, and because of its potential impact on human well-being.

Blackfly larvae are aquatic and are found in flowing water only. The larvae feed by filtering fine particulate material from the water column, and the high numbers typically found downstream of dams are associated with elevated populations of plankton that are discharged from impounded water. Adult females need a blood meal to develop eggs, and some species can be particularly troublesome to livestock. In addition, there are two groups that transmit a nematode that causes eventual blindness among humans in the Nile Basin. Both groups of vectors are complexes of several genetically distinct, but morphologically similar species. Members of the Simulium damnosum complex breed in large rivers of Uganda, southern Sudan and south-western Ethiopia (inter alia), and are responsible for transmission of the most pathogenic form of river blindness (WHO, 1989). The Simulium neavei complex, by contrast, breeds in streams of hilly and mountainous areas in the Tanzania, Uganda and southern Ethiopia (WHO, 1989).</td></tr>
<tr><td>Objective(s)</td><td>To minimise blackfly outbreaks.</td></tr>
<tr><td>Target(s)</td><td><table><tr><td></td><td>No Impact</td><td></td></tr><tr><td></td><td>Warning</td><td></td></tr><tr><td></td><td>Red Card</td><td></td></tr></table></td></tr>
<tr><td>Definition</td><td>EN7.1: Peak HP Releases

Peak HP releases typically create short-term fluctuations in flow in which few flow-dependent invertebrates can survive, so blackfly outbreaks are unlikely under these conditions. However, peak hydropower releases are unlikely when a dam is spilling, so this indicator is only effective in reducing the risks of blackfly outbreaks when the dam is not spilling. Blackfly larvae position themselves for optimal feeding, so short-term variations in hydraulic conditions lead to sub-optimal feeding conditions. Specimens usually drift downstream, and in the process make themselves vulnerable to predation. The overall effect of increase short-term variation in flow is a reduction in abundance. The available flow data could not be used to</td></tr>
</table>

	quantify daily or sub-daily variations in flow, so peak HP power releases were used to define this indicator, with or without a regulating structure. **EN7.2: Dry Season Low Flow** Outbreaks of blackflies are typically associated with river regulation, and in particular, elevated dry season low flows (Palmer, 1997; Palmer *et al.,* 2007). The magnitude of the dry season is critical in defining the amount of blackfly larval habitat, and the size of the blackfly population that is able to provide recruitment for the following season. This indicator was based on changes in dry season low flow, expressed as a percentage change from baseline. **EN7.3: Wet Season Low Flow** Blackfly populations respond quickly to elevated flows in the wet season, particularly when water temperatures are high. Phytoplankton discharged from impoundments creates ideal feeding conditions for blackfly larvae, and this will lead to a significant increase in abundance. This indicator was based on changes in wet season low flow, expressed as a percentage change from baseline. **EN7.4: Within Year Flow Variability** Within year (seasonal) flow variability provides a natural mechanism for ensuring that flow conditions do not remain optimal for any one species for long. Reduction in within year flow variability tends to create conditions that are suitable for a few species, and often such species attain pest proportions. Reduction in within year flow variability therefore increases the risks of blackfly outbreaks.
Units of Measurement	Blackfly Worry Index: 0 to -5
Monitoring Sites	n/a.
Legislation & Policy	n/a.
Policy Relevance	n/a.
Spatial Scale	Regional.
Temporal Scale	Short-Term (seasonal). Blackflies have short life spans and outbreaks are typically seasonal.
Method of calculation	**EN7.1: Peak HP Releases** HPP (Yes/No), with or without re-regulating structure.

	EN7.2: Dry Season Low Flow Median value of the lowest consecutive three-monthly flow rate during pre-defined dry season (in m^3/s), expressed as a percentage change from baseline. **EN7.3: Wet Season Low Flow** Median wet season low flows expressed as a percentage change from baseline. Median wet season low flows were calculated by selecting the median monthly flows for one month on either side of the month with the highest flow. This method was used because i) it enables comparable wet season low flows to be extracted from a monthly time series ii), it can be easily automated for time series that have more than one wet season. **EN7.4: Within Year Flow Variability** Median of annual flow amplitudes (difference between max and min monthly flow rate for each year), expressed as a percentage change from baseline. Note: Blackflies are not expected to occur in pest proportions where the river gradient is flat, as current speeds are likely to be too low to support high populations. Outbreaks of blackflies were therefore not expected where channel slope <0.0005.
Frequency of calculation	Once-off.
Measurability	Easy, provided hydrological data are available.
Data source(s)	Available monthly hydrological time series.
Timing (specific time of year)	Once-off calculation.
Limitations	The downstream attenuation of short-term flow variations was not considered. Furthermore, this indicator does not apply to the *Simulium neavei* group because of their unusual and exclusive association with specific species of crabs.

Rating

		7.2 + 7.3	7.4
0	Zero	0	0
-1	Negligible	<10% increase	<10% decrease
-2	Low	10 – 59% increase	10 - 29% decrease
-3	Moderate	40 – 59% increase	30 - 39% decrease
-4	High	60 – 100% increase	40 - 49% decrease
-5	Very High	>100% increase	>50% decrease

Responsible Entity

-

References

Lewis, D. J. 1948. The Simuliidae of the Anglo-Egyptian Sudan. Transactions of the Royal Entomological Society of London 99: 475-496.

McCrae, A.W.R. 1977. Intermittent Eradication of *Simulium damnosum* Theo. on the Nile from Jinja, Uganda 1951 - 1977. Medical Entomology Centenary Symposium Proceedings.

Palmer, R. W. 1997. Principles of Integrated Control of Blackflies (Diptera: Simuliidae) in South Africa. WRC Report No. 650/1/97. Water Research Commission, Pretoria, South Africa.

Palmer, R. W. and O'Keeffe, J. H. 1989. Temperature characteristics of an impounded river. Arch. Hydrobiol. 116(4): 471-485.

Palmer, R. W., Rivers-Moor, N., Mullins, W, McPherson V and Hattingh, L. 2007. Guidelines for Integrated Control of Pest Blackflies along the Orange River. WRC Report No. 1558/1/07. Water Research Commission, Pretoria, South Africa.

World Health Organisation (WHO). 1989. Geographical distribution of arthropod-borne diseases and their principal vectors. Unpublished document WHO/VBC/89.967. Geneva: World Health Organization.

EN8 Bank Stability

Indicator	**Bank Stability**
Type	State.
Issue(s)	This indicator refers to the increased risk of bank erosion that is associated mainly with increased variation of short and medium-term flow fluctuations, and discharge of clear, "sediment hungry" water from impoundments. This indicator was selected because of the significant impacts of bank collapse on ecological integrity and associated goods and services.
Objective(s)	To minimise river bank erosion.
Target(s)	(green) No Impact | | (yellow) Warning | | (red) Red Card | |
Definition	Bank stability was determined from a combination of channel sinuosity, distance from impoundment and flow variation.
Units of Measurement	Ratio
Monitoring Sites	Hydrological Nodes
Legislation & Policy	International Erosion Control Association USDA National Soil Erosion Laboratory The Soil and Water Conservation Society International Soil Conservation Organization
Policy Relevance	African Development Bank 2000. Policy for Integrated Water Resources Management.
Spatial Scale	Regional.
Temporal Scale	Long-Term (>10 yrs).
Method of calculation	Bank Stability = SD x (10*S/D) Where SD = Standard deviation of monthly flows S = Sinuosity, measured as the main channel distance (km)/Straight line distance (km), measured over 10 km D = Distance from impoundment (km)

Frequency of calculation	n/a
Measurability	Moderate
Data source(s)	• GIS: Soil resource Loss Analysis • GIS: Aerial extent of proposed irrigation area(s) • Google satellite image assessment • Location of proposed impoundment (and downstream areas) • River network
Timing (specific time of year)	Once off calculation.
Limitations	This indicator was based on available desktop information and does not consider several factors that could be important for predicting stream bank erosion, such as soil particle size, soil depth, bank vegetation, channel slope, channel width and bed roughness. Many of these factors were assumed to be incorporated in the sinuosity index, which provided a single statistic that was easy to measure, yet provided a simple method of identifying areas of potential bank instability.
Rating	see below

5	Very High	n/a
4	High	n/a
3	Moderate	n/a
2	Low	n/a
1	Negligible	n/a
0	Zero	
-1	Negligible	
-2	Low	
-3	Moderate	
-4	High	
-5	Very High	

•

Geo-Reference	xxx
Responsible Entity	River geomorphologist (or equivalent)
References	Ahmed, A. A. and Ismail, U. H. 2008. Sediment in the Nile River System. UNESCO International Hydrological programme. International Sediment Initiative. Bashar, K. E, Eltahir, E. O., Fattah, S. A. Ali, A. S., Musnad, M., Osman, I 2010. Nile Basin Reservoir Sedimentation Prediction and Mitigation. Nile Basin Capacity Building Network. UNESCO-IHE Institute for Water Education, Delft, The Netherlands (UNESCO-IHE). Ahmed, A. A., Ibrahim, A. A., hamed, S. E., Saad, S. I. 2005. Towards the improvement of the protection methods against bank erosion. Nile Basin Capacity Building Network. UNESCO-IHE Institute for Water Education, Delft, The Netherlands (UNESCO-IHE).

EN9 Recovery Distance

Indicator	**Recovery Distance**
Type	State
Issue(s)	Altered conditions downstream of impoundment, including: • **Terrestrialisation of floodplain wetland,** caused by bed armouring (erosion) and channel incision from the release of "silt-hungry" water, leading to reduced frequency of floodplain inundation and consequent terrestrialisation; • **Migration barrier,** caused by impoundment, leading to reduced riverine fish stocks and genetic isolation of fish populations • **Increased prevalence of bilharzia,** caused by warmer winter water temperature. • **Altered water quality,** caused by impoundment and associated stratification. Changes include elevated concentration of manganese and increased populations of phytoplankton and zooplankton.
Objective(s)	To minimise the recovery distance.
Target(s)	(green) No Impact: < 5 km (yellow) Warning: 5 – 100 km (red) Red Card: >100 km
Definition	The distance downstream of impoundment where instream conditions approach the conditions expected for an unimpounded river.
Units of Measurement	Kilometers.
Monitoring Sites	All proposed impoundments.
Legislation & Policy	World Bank Environmental Health & Safety Guideline (2007).
Policy Relevance	-
Spatial Scale	Regional.
Temporal Scale	Long-Term (>10 yrs).
Method of calculation	Recovery distance was based on expected changes in water temperature downstream of proposed impoundments, expressed by the equation $y = 35.5 \ln(x+1)-11.8$, where x = median discharge (m^3/s) and y = thermal

recovery distance (km) (Palmer and O'Keeffe 1989). This relationship was based on a global review of thermal recovery distances measured downstream of impoundments.

The distance to the next significant tributary was also considered as a potential method for quantifying recovery distance based on available desktop information, but there was insufficient flow data on tributaries to use this method consistently. Furthermore, the middle and lower Nile have insufficient tributaries for this method to be feasible.

Recovery distance cannot be greater than the distance to the top end of the next impoundment or lake, and these maximum recovery distances for each proposed impoundment are shown in the table below.

Name	Distance to next impoundment (km)	Name of downstream impoundment or lake
Itang	None	
Dumbong	24	Unnamed existing impoundment
Gilo 2	None	None
Baro 1 MPurpose	38	Tams
Geba A	97	Geba R
Birbir A	40	Birbir R
Gumero	50	Tams
Birbir R	26	Tams
Sor	28	Geba A
Tams	55	Itang
Geba R	19	Tams
Karadobi	108	Mandaya
Mandaya	68	Border
Border	60	Roseires (current)
Border	41	Roseires (heightened)
Roseires heightened	None	Sennar too small to impact

	Rumela at Atbara	42	Kashmire El Girba
	Rusumo	72	Lake Ihema
	Murongo (Kishanda Scheme)	39	Kakono West High
	Murongo (Kishanda Scheme)	163	Lake Victoria
	Baro 2 MPurpose	22	Tams
	Tekeze TK 04B	107	TK7
	TK 7	231	Rumela at Atbara
	TK 16	None	
	TK 22	189	Rumela at Atbara
	TK 21 Angereb	132	Rumela at Atbara
	Kakono West High	117	Lake Victoria
	TK5	?	

Frequency of calculation	Once-off.
Measurability	Easy.
Data source(s)	• Location of proposed impoundments • Areas of inundation of downstream lakes and impoundments • Median discharge from proposed impoundment
Timing (specific time of year)	Once-off calculation.
Limitations	This indicator does not address the disruption of upstream migration of fish (i.e. the rivers upstream of the proposed dam whose fish stocks may be reduced because of a migration barrier).

Rating

0	Zero	0 km
-1	Negligible	<5 km
-2	Low	5-25 km
-3	Moderate	25-100 km
-4	High	100-200 km
-5	Very High	>200 km

Responsible Entity	Hydrologist & Ecologist.
References	Palmer, R. W. and O'Keeffe, J. H. 1989. Temperature characteristics of an impounded river. Arch. Hydrobiol. 116(4): 471-485. Ward, J. V. and Stanford, J. A. 1983. The Serial Discontinuity Concept of lotic ecosystems. In: Fontaine, T. D and Bartell, S. M. (eds). Dynamics of lotic ecosystems. Michigan, Ann Arbor, 29-42 pp.

EN10 Seasonal Shift

Indicator	**Seasonal Shift**
Type	State.
Issue(s)	This indicator was chosen because impoundments tend to modify the natural seasonal flow pattern, and this can have significant downstream ecological implications. Impoundments typically delay or even eliminate the onset of the wet season because the first runoff of a season is stored in the impoundment, so spillage only takes place once an impoundment is full. The ecological implications of such changes are not well understood and differ from place to place, but they are likely to be significant. Generally there is a decline in freshwater biodiversity in regulated river systems where groups are adapted to naturally strong seasonal flow regimes. Changes in the timing of the wet season can affect a range of important ecological processes, such as hatching of eggs, and migration and spawning of fish.
Objective(s)	To mimimise changes to the natural timing of the onset of the wet season.
Target(s)	No Impact: <3 month delay Warning: 3-4 month delay Red Card: > 5 month delay
Definition	Seasonal shift refers to temporal delay of the onset of the wet season, and in extreme cases, the elimination of the wet season.
Units of Measurement	Days.
Monitoring Sites	-
Legislation & Policy	-
Policy Relevance	-
Spatial Scale	Recovery Distance (see EN9)
Temporal Scale	Seasonal in the short-term, but impacts are likely to be cumulative in the long-term (>10 yrs).
Method of calculation	Number of days that the onset of the main wet season is modified from baseline, where the onset of the main wet season is a predefined threshold that is set for each hydrological node.
Frequency of calculation	-

Measurability	Easy.		
Data source(s)	-		
Timing (specific time of year)	-		
Limitations	-		
Rating	5	Very High	n/a
	4	High	n/a
	3	Moderate	n/a
	2	Low	n/a
	1	Negligible	n/a
	0	Zero	
	-1	Negligible	
	-2	Low	
	-3	Moderate	
	-4	High	
	-5	Very High	
Responsible Entity	-		

EN11 Phytoplankton Growth Potential

Indicator	**Phytoplankton Growth Potential**
Type	State
Issue(s)	This indicator was chosen because retention time is easy to measure (in days), and because it is directly related to the potential for phytoplankton biomass and algal blooms, such as potentially toxic blue-green algae (cyanobacteria), *Microcystis*. Rivers usually do not support large populations of plankton, except in their lower reaches, where current speeds are slow. The development of plankton populations is generally associated with standing water. Impoundments provide ideal conditions for the development of plankton, which respond rapidly to changes in flow conditions on account of their rapid life histories, which are typically measures in days or weeks. The availability of nutrients decreases as retention time increases, so small impoundments with short retention times can cause water quality to deteriorate for downstream users, whereas impoundments with long retention time can serve to improve water quality for downstream users.
Objective(s)	To minimise the risks of nuisance blooms of phytoplankton.
Target(s)	<table><tr><td>(green)</td><td>No Impact</td><td></td></tr><tr><td>(yellow)</td><td>Warning</td><td></td></tr><tr><td>(red)</td><td>Red Card</td><td></td></tr></table>
Definition	Water retention time refers to the average length of time that water is expected to remain in each reservoir.
Units of Measurement	Probability.
Monitoring Sites	n/a.
Legislation & Policy	World Bank Environmental Health & Safety Guideline (2007).
Policy Relevance	-
Spatial Scale	Regional.
Temporal Scale	Long-Term (>10 yrs).
Method of calculation	$y = 0.13*0.99^{x} \times 1.59$ where y = phytoplankton growth potential (%) x = retention time (days), calculated from the median annual storage divided by mean annual inflow into reservoir. These values are calculated separately for the baseline and each scenario,

<table>
<tr><td></td><td>and normalized against the baseline.

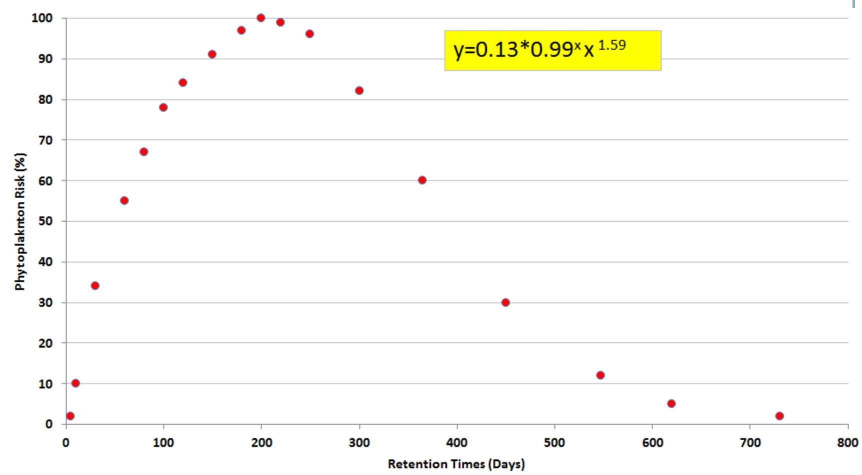



Figure X. Conceptual relationship between retention time (days) of water in reservoir and phytoplankton growth potential. [Based on Conveney 2011 and Wagner-Lotkowska 2004].</td></tr>
<tr><td>Frequency of calculation</td><td>Once-off.</td></tr>
<tr><td>Measurability</td><td>Easy.</td></tr>
<tr><td>Data source(s)</td><td>Hydrological characteristics (mean storage capacity and inflows).</td></tr>
<tr><td>Timing (specific time of year)</td><td>Once-off calculation.</td></tr>
<tr><td>Limitations</td><td>This indicator considers the long-term implications of retention time on nutrient availability, once an impoundment has matured. The indicator does not consider the short-term implications from arising from the decomposition of flooded vegetation or leaching of salts from newly inundated areas.

Furthermore, this indicator does not distinguish between evaporative loss and discharge, or any of the other factors that could affect nutrient status, such as proximity to human development and natural characteristics of the ambient water quality.</td></tr>
<tr><td>Rating</td><td><table><tr><td>0</td><td>Zero</td><td>0</td></tr><tr><td>-1</td><td>Negligible</td><td>< 20%</td></tr><tr><td>-2</td><td>Low</td><td>20 - 40%</td></tr></table></td></tr>
</table>

<table>
<tr><td></td><td><table><tr><td>-3</td><td>Moderate</td><td>40 - 60%</td></tr><tr><td>-4</td><td>High</td><td>60 - 79%</td></tr><tr><td>-5</td><td>Very High</td><td>> 80%</td></tr></table></td></tr>
<tr><td>Responsible Entity</td><td>n/a.</td></tr>
<tr><td>References</td><td>Coveney, M. F., J. C. Hendrickson, E. R. Marzolf, R. S. Fulton, J. Di, C. P. Neubauer, D. R. Dobberfuhl, G. B. Hall, H. W. Paerl, and E. J. Phlips. 2011. Chapter 8. Plankton. In: St. Johns River water Supply Impact Study. St. Johns River Water Management District, Palatka, FL, USA. St. Johns River Water Management District, Palatka, Florida.

Wagner-Lotkowska, K. Izydorczyk, T. Jurczak & M. Tarczynska, P. Frankiewicz 2004. Ecohydrological methods of algal bloom control. In: Zalewski, M & Wagner-Lotkowska (Eds). Chapter 12: Reservoir & lake management: Improvement of Water Quality. Integrated watershed management – Ecohydrology 7 Phytotechnology Manual. United Nations Environmental Programme.</td></tr>
</table>

EN12 Aquatic Macrophytes

Indicator	**Abundance of Aquatic Macrophytes**
Type	State.
Issue(s)	Construction of impoundments creates ideal conditions for prolific growth of aquatic macrophytes. Infestations of aquatic weeds can interfere with hydropower generation by clogging turbine impellers, and can prevent the passage of boats and interrupting economic activities. Furthermore, floating macrophytes reduce the availability of light and oxygen in the water, with detrimental implications for biodiversity. The plants provide ideal habitat for bilharzia snails, and also increases evapotranspiration losses. This indicator was chosen because of stakeholder concerns about invasive aquatic macrophytes in many parts of the Nile basin.
Objective(s)	To minimise macrophyte proliferation.
Target(s)	(Green) No Impact: <20% (Yellow) Warning: 20 to 80% (Red) Red Card: >80% growth
Definition	This indicator refers to the abundance of invasive aquatic macrophytes in general, but mainly refers to the water hyacinth *Echhornia crassipes*, which is one of the most aggressive and fastest growing aquatic weeds in the world.
Units of Measurement	Aquatic Macrophyte Growth Potential, expressed as a percentage (%).
Monitoring Sites	Agricultural return water discharge streams.
Legislation & Policy	Invasive species strategy, action plan and policy guidelines for Uganda (NARO 2008)
Policy Relevance	-
Spatial Scale	Regional.
Temporal Scale	Short to Medium (1 – 5 yrs).
Method of calculation	$y = 108/(1+x/2.29)^{-0.83}$ where y = aquatic macrophyte growth potential (%) x = total nitrate concentration (mg/l) These values are calculated separately for the baseline and each scenario, and normalized against the baseline.

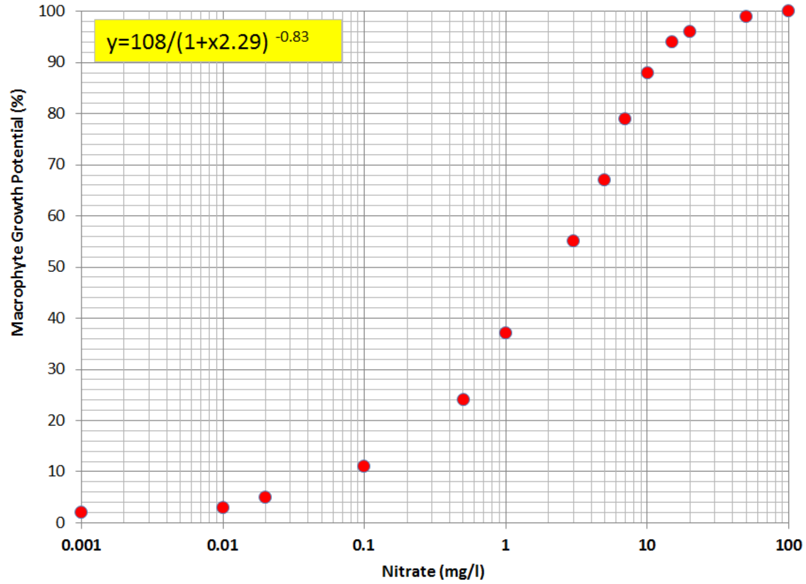


Figure X. Conceptual relationship between nitrate concentration in irrigation return water and macrophyte growth potential. [Data based on Byrne *et al.* 2010].

Frequency of calculation	Once-off.
Measurability	Easy, but unreliable because of other factors driving macrophytes growth (see discussion on limitation below).
Data source(s)	• Nitrate concentrations in receiving river immediately downstream of irrigation discharge points, based on: o expected total volume (budget) of nitrate from irrigation return flows, based on loading factor multiplied by the area of irrigation, and; • Specialist reports on aquatic weeds and associated phosphate and nitrate levels (e.g. Byrnes *et al.* 2010).
Timing (specific time of year)	Once-off calculation.
Limitations	Nitrate concentration was chosen as the driving variable for this indicator because nitrate is usually the most important variable affecting the proliferation of aquatic macrophytes. However, nuisance growth of aquatic macrophytes is determined by numerous others factors, including phosphate concentration, water temperature, day length, current speeds, herbivory and species of plant. Furthermore, the calculation also does not take into account the dilution of the discharge water when it enters the receiving river, partly because of the lack of data on ambient nutrient levels and the complications of cumulative effects of multiple irrigation developments. The calculation also assumes a single point discharge for

	each irrigation area. The values therefore represent the worst-case scenario that may arise in areas where dilution is minimal (i.e. quiet, standing marginal waters). The values presented are therefore hypothetical, but suitable for comparative purposes.
Rating	5 · Very High · >50% decrease 4 · High · 40 to 50% decrease 3 · Moderate · 30 to 40% decrease 2 · Low · 20 to 30% decrease 1 · Negligible · <20% decrease 0 · Zero · 0 -1 · Negligible · < 20% increase -2 · Low · 20 – 39% increase -3 · Moderate · 40 – 59% increase -4 · High · 60 – 90% increase -5 · Very High · > 90% increase
Responsible Entity	Ecologist.
References	Coetzee, J. A and Hill, M. P. 2012. The role of eutrophication in the biological control of water hyacinth, *Eichhornia crassipes*, in South Africa. Biocontrol 57: 247-261. Byrne, M., Hill, M., Robertson, M., King, A. J., Katembo, N., Wilson, J. Brudwig, R., Fisher, J. 2010. Integrated management of Water Hyacinth in South Africa. Development of an integrated management plan for water hyacinth control, combining biological control, herbicidal control and nutrient control, tailored to the climatic regions of South Africa. Water Research Commission Report No TT 454/10. Pretoria. National Agricultural Research Organization (NARO) 2008. The national invasive species strategy, action plan and policy guidelines for Uganda. Report submitted to CABI, under the UNEP/GEF Project: Removing barriers to invasive plant management in Africa (UNEP/GEF Project No GFL 2328-2711-4890.

APPENDIX C

ECONOMIC INDICATORS: BACKGROUND INFORMATION

INFORMATION TEMPLATES: ECONOMIC INDICATORS

Indicator	**Cost Benefit Analysis – Internal Rate of Return (IRR)**
Type	Expected return on investment
Issue(s)	• The efficiency of investment in irrigation and hydro-electricity schemes • The magnitude of the efficiency
Objective(s)	Determine the return on investment which the project is expected to achieve.
Target(s)	Establish only projects with an IRR that is greater than the discount rate or the target rate of return.
Definition	The IRR is the discount rate at which the present value of costs and benefits are equal .i.e. the rate at which the Net Present Value is zero.
Units of Measurement	Percentage
Monitoring Sites	Efficiency of the investment will be calculated for each focus area. The IRR is the net outcome for all the various focus areas, including the capital and operating cost of intervention.
Legislation & Policy	N/A
Policy Relevance	N/A
Spatial Scale	Regional (focus areas)
Temporal Scale	Over the project lifespan
Method of calculation	The capital and operational cost of intervention form part and parcel of the calculation to determine the efficiency of the investment.
Frequency of calculation	Once-off
Measurability	The net surplus per crop per focus area is the input for calculating the IRR.
Data source(s)	• Information by the agriculture departments of the NBI countries • International studies
Timing	Once-off calculation per intervention
Limitations	In situations where the stream of net befits over the assessment period changes its sign (positive and negative) it is not possible to calculate the IRR.

Indicator	**Cost Benefit Analysis - Net Present Value**
Type	US$ Financial Impact
Issue(s)	• The viability of the establishment for irrigation and hydro-electricity schemes by the construction of dams/ reservoirs • The magnitude (positive or negative of the intervention) of the financial surplus/profitability of the intervention
Objective(s)	Determine the financial viability of an intervention
Target(s)	Establish only projects that are financially viable
Definition	The difference between the benefits and costs (net benefits) in the specified year is discounted to the present by using the social discount rate. The discounted sum of all these net benefits over the economic project life is defined as the net present value (NPV).
Units of Measurement	US$
Monitoring Sites	Financial impact will be calculated for each focus area. The total NPV is the net outcome for all the various focus areas, incl. the capital and operating cost of the intervention.
Legislation & Policy	N/A
Policy Relevance	N/A
Spatial Scale	Regional (focus areas)
Temporal Scale	Over the project lifespan
Method of calculation	Due to the fact that the water usage in the Nile Basin is primarily for irrigation and hydro-electric generation purposes, the focus of the models for each focus area will be on the opportunities for irrigation and hydro-electric generation. Calculating the positive and negative financial impact of the change in water supply for various crops per focus area. The capital and operational cost of the intervention (dam/canals) are part and parcel of the calculation to determine if the positive effects (additional agriculture products and electricity sales) that flow from the intervention provide a financial viable option.
Frequency of calculation	Once-off
Measurability	Complex exercise. However, if the financial surplus (income less cost) per crop per focus area is calculated, this could be used for the modelling of various scenarios. The capital and operational cost have to be calculated for each intervention.
Data source(s)	• Information by the agriculture departments of the NBI countries • International studies
Timing	Once-off calculation per intervention
Limitations	Non-availability of crop production data. However, the Consultants have ample experience in this field, and reliable crop yield, price and operational cost figures can be developed in consultation with experts in the field.

Indicator	**Cost Benefit Analysis – Benefit Cost Ratio**
Type	Efficiency of investment
Issue(s)	• The efficiency of investment in irrigation and hydro-electricity schemes by the construction of dams/ reservoirs • The return per U$1 invested
Objective(s)	Determine the efficiency of the investment
Target(s)	Establish only projects that have a ratio greater than 1.
Definition	The ratio of the present value of benefits relative to the present value of costs. It indicates the return expected from a project for every $1 invested in the project.
Units of Measurement	Number/Ratio
Monitoring Sites	Efficiency of the investment will be calculated for each focus area. The BCR is the outcome of benefits compared to costs.
Legislation & Policy	N/A
Policy Relevance	N/A
Spatial Scale	Regional (focus areas)
Temporal Scale	Over the project lifespan
Method of calculation	The focus is on the benefits of the project relative to its costs. The net benefits (benefits less operational costs) of the project are divided by the capital costs of the project.
Frequency of calculation	Once-off
Measurability	The net benefits (benefits less operating costs) and the capital cost per crop per focus area are used for measuring the BCR.
Data source(s)	• Information by the agriculture departments of the NBI countries • International studies
Timing	Once-off calculation per intervention
Limitations	Non-availability of crop production data.

Indicator	**Cost Benefit Analysis - Water Development Cost for Agriculture**
Type	US$ Cost Impact
Issue(s)	• The water development cost for agriculture purposes • The level of water development cost for agriculture in relation to a specific application
Objective(s)	Determine water development costs for agriculture purposes
Target(s)	Establish only projects whose costs do not go beyond a certain level
Definition	The criteria that focuses on the development costs of water. If water development cost of water is beyond a certain level, it becomes obvious that the cost is too high for a specific application.
Units of Measurement	US$ per Mm^3
Monitoring Sites	Cost impact will be calculated for each focus area. The water development cost for each crop for agricultural purposes will be determined.
Legislation & Policy	N/A
Policy Relevance	N/A
Spatial Scale	Regional (focus areas)
Temporal Scale	Over the project lifespan
Method of calculation	Total cost of agriculture infrastructure in US$ million divided by total water used for irrigation and agriculture purposes in Mm^3.
Frequency of calculation	Once-off
Measurability	This criteria focus on the cost side of the development and not so much on the benefits that flow from the investment.
Data source(s)	• Information by the agriculture departments of the NBI countries • International studies
Timing	Once-off calculation per intervention
Limitations	Considers the cost side of the investment in isolation not in conjunction with the benefits expected to flow from it.

Indicator	**Cost Benefit Analysis – Water Development Cost for Hydro-electricity**
Type	US$ Cost Impact
Issue(s)	• The water development cost for hydro-electricity purposes • The level of water development cost for hydro-electricity in relation to a specific application
Objective(s)	Determine the water development costs for hydro-electricity purposes
Target(s)	Establish only projects whose costs do not go beyond a certain level
Definition	The criteria that focuses on the development costs of hydro-electricity. If water development cost of hydro-electricity is beyond a certain level, it becomes obvious that the cost is too high for a specific application.
Units of Measurement	US$ per Mm^3
Monitoring Sites	Cost impact will be calculated for each focus area. The water development cost for hydro-electricity purposes will be determined.
Legislation & Policy	N/A
Policy Relevance	N/A
Spatial Scale	Regional (focus areas)
Temporal Scale	Over the project lifespan
Method of calculation	Total cost of hydro-electricity in US$ million divided by total water used for hydro-electricity purposes in Mm^3.
Frequency of calculation	Once-off
Measurability	This criteria focus on the cost side of the development and not so much on the benefits that flow from the investment. It does not make reference to the benefit that will flow form the generation of electricity. It also does not take into account whether there is an off-set for the electricity that is generated.
Data source(s)	• Information by the agriculture departments of the NBI countries • International studies
Timing	Once-off calculation per intervention
Limitations	Does not take into account the benefits that flow from the investment. It also does not take into account whether there is an off-set for the electricity that is generated.

Indicator	**Macro-Economic Impact Analysis – Net Impact on GDP**
Type	US$ Economic Impact
Issue(s)	The impact on GDP reflects the magnitude of the values added to the economy by the irrigation and hydro-electricity schemes.
Objective(s)	Determine the economic contribution of the intervention
Target(s)	Establish only projects that increase the economic growth and welfare of the economy.
Definition	Measure of economic growth and welfare as it represents, among other criteria, remuneration of employees and gross operating surplus (profits). These are all components of the value added chains at all levels of the economy.
Units of Measurement	US$ million per annum
Monitoring Sites	Economic impact calculated for each focus area. GDP is the net value of the value added chain at all levels of the economy.
Legislation & Policy	N/A
Policy Relevance	N/A
Spatial Scale	Regional (focus areas)
Temporal Scale	Over the project lifespan
Method of calculation	A partial general equilibrium model based on Social Accounting Matrix (SAM)
Frequency of calculation	Once-off
Measurability	Components that add value to the economy should be calculated for each intervention. GDP is a good measure of economic growth and welfare as it represents, among other criteria, remuneration of employees and gross operating surplus (profits0 as components of value added at all the levels of the economy.
Data source(s)	• Social Accounting Matrix for the specific NBI country that is of relevance in the specific scenario.
Timing	Once-off calculation per intervention
Limitations	May not capture all value adding activities in the economy.

Indicator	**Macro-Economic Impact Analysis – Net Direct Employment Opportunities**
Type	Direct Employment Impact
Issue(s)	The magnitude of the direct employment creation of the intervention.
Objective(s)	Determine the extent that labour is effectively absorbed by the intervention
Target(s)	Establish only projects that effectively create direct employment opportunities.
Definition	Determines the number of direct employment opportunities that will be created by investment in the irrigation and hydro-electricity schemes. Furthermore, a distinction is made between skilled, semi-skilled and unskilled labourers.
Units of Measurement	Number of employment opportunities
Monitoring Sites	Direct employment opportunities for each focus area will be calculated. The total direct employment is the sum of direct employment opportunities for all various focus areas.
Legislation & Policy	N/A
Policy Relevance	N/A
Spatial Scale	Regional (focus areas)
Temporal Scale	Over the project lifespan
Method of calculation	A partial general equilibrium model based on Social Accounting Matrix (SAM)
Frequency of calculation	Once-off
Measurability	The direct impact is a more accurate figure and very area specific.
Data source(s)	• Social Accounting Matrix for the specific NBI country that is of relevance in the specific scenario.
Timing	Once-off calculation per intervention
Limitations	Does not take into account the downstream ripple effects of the intervention.

Indicator	Macro-Economic Impact Analysis – Net Total Employment Opportunities
Type	Total Employment Impact
Issue(s)	The magnitude of the total (direct, indirect and induced) employment creation of the intervention.
Objective(s)	Determine the extent that labour is effectively absorbed by the intervention
Target(s)	Establish only projects that effectively create employment opportunities.
Definition	Determines the number of total employment opportunities that will be created by investment in the irrigation and hydro-electricity schemes. These include employment opportunities directly created by the project and those indirectly created and induced by the project throughout the broader economy. Furthermore, a distinction is made between skilled, semi-skilled and unskilled labourers.
Units of Measurement	Number of employment opportunities
Monitoring Sites	Total employment opportunities for each focus area will be calculated. The total employment is the sum of all employment opportunities for all various focus areas.
Legislation & Policy	N/A
Policy Relevance	N/A
Spatial Scale	Regional (focus areas)
Temporal Scale	Over the project lifespan
Method of calculation	A partial general equilibrium model based on Social Accounting Matrix (SAM)
Frequency of calculation	Once-off
Measurability	The total impact takes into account the downstream ripple effects of the intervention.
Data source(s)	• Social Accounting Matrix for the specific NBI country that is of relevance in the specific scenario.
Timing	Once-off calculation per intervention
Limitations	May fail to account for all indirect and induced employment opportunities separately on each of the intervention.

Indicator	**Macro-Economic Impact Analysis – Net Impact on Low-income Households**
Type	US$ Financial Impact
Issue(s)	The magnitude of the changes that will occur to both household income and spending/savings pattern of low income households.
Objective(s)	Determine the impact on low-income households
Target(s)	Establish projects with a positive impact on poverty alleviation
Definition	The extent to which the project has a positive impact on poverty alleviation by measuring its impact household income, especially how the low-income households will benefit.
Units of Measurement	US$ million per annum
Monitoring Sites	Low households income and poverty alleviation will be calculated for each focus area. Total low-income household is the outcome of all various focus area.
Legislation & Policy	N/A
Policy Relevance	N/A
Spatial Scale	Regional (focus areas)
Temporal Scale	Over the project lifespan
Method of calculation	A partial general equilibrium model based on Social Accounting Matrix (SAM)
Frequency of calculation	Once-off
Measurability	The extent to which low-income households will be affected by the spin offs created by the total project.
Data source(s)	• Social Accounting Matrix for the specific NBI country that is of relevance in the specific scenario.
Timing	Once-off calculation per intervention
Limitations	N/A

Indicator	Macro-Economic Impact Analysis – Net Impact on Total Households
Type	US$ Financial Impact
Issue(s)	The magnitude of the changes that will occur to both household income and spending/savings pattern of all income households.
Objective(s)	Determine the impact on all income households
Target(s)	Establish projects with a positive impact on households income
Definition	The extent to which the project has a positive impact on poverty alleviation by measuring its impact household income and how the total households will benefit.
Units of Measurement	US$ million per annum
Monitoring Sites	Total households income and poverty alleviation will be calculated for each focus area. Total households income is the outcome of all various focus area.
Legislation & Policy	N/A
Policy Relevance	N/A
Spatial Scale	Regional (focus areas)
Temporal Scale	Over the project lifespan
Method of calculation	A partial general equilibrium model based on Social Accounting Matrix (SAM)
Frequency of calculation	Once-off
Measurability	The extent to which total households will be affected by the spin offs created by the total project.
Data source(s)	• Social Accounting Matrix for the specific NBI country that is of relevance in the specific scenario.
Timing	Once-off calculation per intervention
Limitations	May fail to account for medium and high income households separately on each of the intervention.

Indicator	**Regional Impact Analysis – Inter-active Impact (GDP) on other Nile Basin Countries**
Type	Distributional Impact
Issue(s)	The magnitude of distributional impacts of water on GDP on other Nile Basin countries
Objective(s)	Determine the distributional impacts of water on GDP on other Nile Basin countries
Target(s)	Establish projects with a positive distributional impact on other Nile Basin Countries.
Definition	Measures the distributional impacts of water on GDP, namely the direct sectoral impact relative to other sectoral impacts and the impacts that the project has on the primary country versus other areas/countries in the Nile Basin.
Units of Measurement	Percentage
Monitoring Sites	The impact will be calculated for each focus area. The total impact is the outcome of all the various focus area.
Legislation & Policy	N/A
Policy Relevance	N/A
Spatial Scale	Regional (focus areas)
Temporal Scale	Over the project lifespan
Method of calculation	Factor between the impact GDP has on the secondary NBI countries compared to the main impacted country for the specific scenario.
Frequency of calculation	Once-off
Measurability	Impact that the project has on the primary country compared to the other NBI countries.
Data source(s)	• The values are determined by economic models.
Timing	Once-off calculation per intervention
Limitations	N/A

Indicator	**Macro Economic Impact Analysis - Inter-active Impact (Employment) on other Nile Basin Countries**
Type	Employment Impact
Issue(s)	The magnitude of distributional impacts of water on employment on other Nile Basin countries
Objective(s)	Determine the distributional impacts of water on employment on other Nile Basin countries
Target(s)	Establish projects with a positive distributional impact on other Nile Basin Countries.
Definition	Measures the distributional impacts of water on employment, namely the direct sectoral impact relative to other sectoral impacts and the impacts that the project has on the primary country versus other areas/countries in the Nile Basin
Units of Measurement	Percentage
Monitoring Sites	The impact will be calculated for each focus area. The total impact is the outcome of all the various focus area.
Legislation & Policy	N/A
Policy Relevance	N/A
Spatial Scale	Regional (focus areas)
Temporal Scale	Over the project lifespan
Method of calculation	Factor between the impact employment has on the secondary NBI countries compared to the main impacted country for the specific scenario.
Frequency of calculation	Once-off
Measurability	Impact that the project has on the primary country compared to the other NBI countries.
Data source(s)	• The values are determined by economic models.
Timing	Once-off calculation per intervention
Limitations	N/A

Indicator	**Environmental Impact Analysis – Hydro-electricity Sales**
Type	US$ Financial Impact
Issue(s)	The viability of the saleable electricity generated
Objective(s)	Determine the financial viability of generating electricity for sales
Target(s)	Establish only projects that are financially viable
Definition	The difference between the benefits and costs (net benefits) of generating electricity.
Units of Measurement	Average GWh over the period
Monitoring Sites	Financial impact will be calculated for each focus area of hydro-electricity sales. Total impact is the outcome of the various focus area.
Legislation & Policy	N/A
Policy Relevance	N/A
Spatial Scale	Regional (focus areas)
Temporal Scale	Over the project lifespan
Method of calculation	The capital and operational cost of the intervention (hydro-electricity sales) are part and parcel of the calculation to determine if the positive effects (electricity sales) that flow from the intervention provide a financial viable option.
Frequency of calculation	Once-off
Measurability	Externalities associated with water development.
Data source(s)	• The values are determined by economic models.
Timing	Once-off calculation per intervention
Limitations	N/A

Indicator	**Socio-Economic Impact Analysis - Net Carbon Emissions**
Type	Environmental Impact
Issue(s)	The magnitude of the impact on the environment associated with water development and use.
Objective(s)	Determine the environmental impact of hydro-electricity
Target(s)	Establish only projects that have a minimal impact on the environment (low carbon emissions).
Definition	The externalities associated with water development and use. The environmental impact is only for hydro-electricity
Units of Measurement	Average MT over the period.
Monitoring Sites	Environmental impact will be calculated for each focus area. Total impact is the outcome of the various focus area.
Legislation & Policy	N/A
Policy Relevance	N/A
Spatial Scale	Regional (focus areas)
Temporal Scale	Over the project lifespan
Method of calculation	Econometric methodologies.
Frequency of calculation	Once-off
Measurability	Externalities associated with water development.
Data source(s)	• The values are determined by economic models.
Timing	Once-off calculation per intervention
Limitations	Difficulty in measuring the environmental impact

The Social Accounting Matrix

A Social Accounting Matrix (SAM) is a comprehensive, economy-wide database, which contains information on the flow of resources that take place between the different economic agents that exist within an economy (i.e. business enterprises, households, government, etc.) during a given period of time – usually one calendar year.

When economic agents in an economy are involved in transactions, financial resources change hands. The SAM provides a complete database of all transactions that take place between these agents in a given period, thereby presenting a "snapshot" of the structure of the economy for that time period. As a system for organising information, a SAM presents a powerful tool in terms of which the economy can be described in a complete and consistent way:

- Complete in the sense that it provides a comprehensive accounting of all economic transactions for the entity being represented (i.e. country, region/province, city, etc.), and
- Consistent in that all incomes and expenditures are matched.

Consequently, a SAM can provide a unifying structure within which the statistical authorities can compile and present the national accounts.

Like the traditional Input-Output Table, the SAM reflects the inter-sectoral linkages in terms of sales and purchases of goods and services, as well as the remuneration of production factors that forms the essence of any economy's functioning. What is also of importance is that a SAM reflects the economic related activities of households in some detail. Households are responsible for decisions that have a direct and indirect effect on important economic variables such as private consumption expenditures and savings. These economic aggregates are important drivers of the economic growth processes and ultimately the creation of employment opportunities and wealth. Private consumption expenditure, for example, comprises approximately 60% of total gross final domestic spending in the economy. By combining households into meaningful categories, such as a range of income levels, the impact on these households' welfare of a changing economic environment is made possible by the SAM.

It is clear from the above that because of the intrinsic characteristics of the SAM, once compiled, it renders itself as a useful tool for analytical purposes. Especially, based on the mathematical traits of the matrix notations that describe its structure, a SAM can be transformed into a powerful econometric tool/model. For example, the model can be used to quantify the probable impact on the economy of a new infrastructural project such as a new power station – both the construction phase and the operational phase will be modelled.

Thus apart from serving as an extension to a country's National Accounts, the SAM in its model form opens up many opportunities for the economic analyst to conduct rigorous policy and other impact analyses for the purpose of ensuring optimal benefit to the stakeholders concerned.

Application of a SAM

The development of the SAM is very significant as it provides a framework within the context of the International System of National Accounts (SNA) in which the activities of all economic agents are accentuated and prominently distinguished. By combining these agents into meaningful groups, the SAM makes it possible to clearly distinguish between groups, to research the effects of interaction between groups, and to measure the economic welfare of each group. There are two key reasons for compiling a SAM:

- Firstly, a SAM provides a framework for organising information about the economic and social structure of a particular geographical entity (i.e. a country, region or province) for a particular time period (usually one calendar year), and
- Secondly, to provide a database that can be used by a number of different macroeconomic modelling tools for evaluating the impact of different economic decisions and/or economic development programmes.

Because the SAM is a comprehensive, disaggregated, consistent, and complete data system of economic entities that captures the interdependence that exists within a socio-economic system, it can be used as a conceptual framework for exploring the impact of exogenous changes in such variables as exports, certain categories of government expenditure, and investment on the entire interdependent socio-economic system. In this regard, there exist sophisticated macro-econometric models, such as the Computable General Equilibrium models (CGEs). The SAM, because of its finer disaggregation of private household expenditure into relatively homogenous socio-economic categories that are recognisable for policy purposes, has been used to explore issues related to income distribution.

The SAM's main contribution in the field of economic policy planning and impact analysis is divided into two categories:

As a Primary Source of Economic Information

As a detailed and integrated national and regional accounting framework consistent with officially published socio-economic data, a SAM instantly projects a picture of the nature of a country or region's economy. It lends itself to both descriptive and structural analysis.

As a Planning Tool

Due to its mathematical/statistical underpinnings it can be transformed into a macro-econometric model that can be used to:

- Conduct economic forecasting exercises/scenario building.
- Conduct economic impact analysis both for policy adjustments at a national and provincial level and for large project evaluation.
- Conduct self-sufficiency analysis i.e. gap analysis to determine, with the help of the inter industry and commodity flows contained in the provincial SAM, where possible investment opportunities exist, and
- Calculate the inflationary impacts on provincial level of price changes instigated at national level (i.e. administered prices, VAT, etc.).

To summarise, the SAM mechanism provides a universally acceptable framework within which the economic impact of development projects and policy adjustments can be reviewed and assessed at both national and provincial/regional levels. It serves as an extension to the official National Accounts of a country's economy and, therefore, provides a wealth of additional information, especially when disaggregated to more detailed levels.

Magnitude of Economic Linkages

Formally, economists distinguish between direct, indirect and induced economic effects. Indirect and induced effects are sometimes collectively called secondary effects. The total economic impact is the sum of direct, indirect and induced effects within a region. Any of these impacts may be measured in terms of gross output or sales, income, employment or value added.

Direct Impacts

The direct impacts refer to the effect of the activities that take place within an industry. It refers to the income and expenditure that is associated with the everyday operation of each of the components of the industry. For instance if a factory is taken as an example the direct impacts refer to the total production/turnover of the factory; the intermediate goods bought by the factory; the salaries and wages paid by the factory; the profits generated by the factory.

Indirect Impacts

The indirect impacts refer to economic activities that arise in the sectors that provide inputs to the industry and other backward linked industries. For example, if the primary agriculture sector uses fertilizer, the indirect impacts refer to the activity (paying of salaries and wages; and profit generation) that occurs in the fertilizer sector as well as the sectors that provide materials to the fertilizer sector.

Induced Impacts

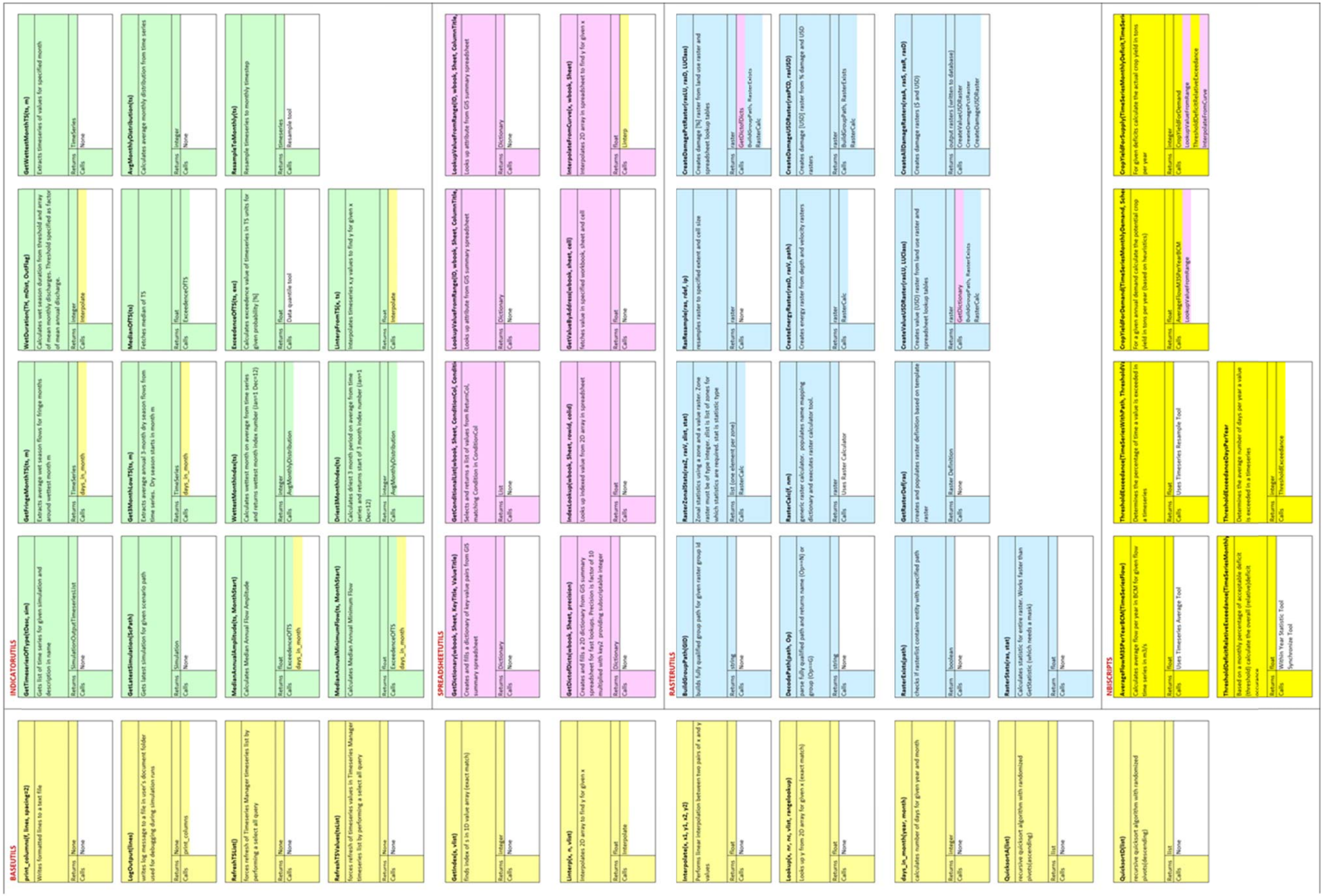
Induced impacts refer, inter alia, to the economic impacts that result from the payment of salaries and wages to people who are (directly) employed at the various stages an industry. In addition the induced impact also includes the salaries and wages paid by businesses operating in the sectors indirectly linked to the industry through the supply of inputs. These additional salaries and wages lead to an increased demand for various consumable goods that need to be supplied by other sectors of the economy that then have to raise their productions in tandem with the demand for their products and services.

These induced impacts can then be expressed in terms of their contributions to GDP, employment creation and investment or other useful macroeconomic variables.

Added together, the direct, indirect and induced impacts provide the total impact that an industry will have on the national and provincial economies.

APPENDIX D

SCRIPT STORAGES AND DEPENDENCIES


BASEUTILS
INDICATORUTILS
SPREADSHEETUTILS
RASTERUTILS
NBISCRIPTS

ENVIRONMENTALINDICATORS

EN1_EnvSensitiveAreas(RID, IID, CID)
Fetches pre-measured footprint areas from Indicator spreadsheets
Returns: float
Calls: LookupValueFromRange

EN42_WetlandArea(tsBCase, tsSC, outUnits)
Wetland area inundated: Calculates change in median inundated area relative to baseline
Returns: float
Calls: RefreshTSValues, MedianOfTS

EN7_BlackFlyRating(tsBCase, tsSC, Peaking, Reregulatior
Determines Blackfly risk rating (-5 to 0) from HP operation, changes in low flows and variability
Returns: integer
Calls: EN55_FlowVariability, EN51_DryLowFlow, EN52_WetLowFlow, LookupValueFromRange

EN3_FishProduction(ts)
Estimates Fish Production [t/annum] based on median reservoir area [km2]
Returns: float
Calls: ExceedenceOfTS, InterpolateFromCurve

EN11_EnvSensitiveRating(RID, IID, CID)
Determines impact rating (-5 to 0) for sensitive areas in footprints
Returns: integer
Calls: EN1_EnvSensitiveAreas, LookupValueFromRange, IndexLookup

EN5_EcoStressRating
Determines ecological stress rating (-5 to 0) from changes in low flows and variability
Returns: integer
Calls: EN55_FlowVariability, EN51_DryLowFlow, EN52_WetLowFlow, LookupValueFromRange

EN8_BankStability(RID, VegIdx, ts)
Calculates bank stability rating (-5 to 0) downstream of impoundment based on drawdown index, silt-clay content (critical shear stress) and bank vegetation index
Returns: integer
Calls: ResampleToMonthly, MedianAnnualMinimumFlow, MedianOfTS, LookupValueFromRange, IndexLookup

EN4_FloodPlainInundation(tsBCase, tsSC)
Calculates median flow for wettest month and compares with baseline
Returns: float
Calls: WettestMonthIndex, GetWettestMonthTS, MedianOfTS

EN12_HotspotRating
Determines impact rating (-5 to 0) for environmental hotspots in footprints
Returns: integer
Calls: LookupValueFromRange

EN51_DryLowFlow
Calculates dry season median flow for 3 driest months and compares with baseline
Returns: double
Calls: Driest3MonthIndex, Get3MonthLowTS, MedianOfTS

EN9_RecoveryDistance(ts, RID)
Estimates Recovery Distance [km] based on median discharge and distance to d/s tributary [km]
Returns: double
Calls: ExceedenceOfTS, InterpolateFromCurve, LookupValueFromRange

EN55_FlowVariability(tsBCase, tsSC)
Calculates median annual flow amplitude and compares with baseline
Returns: double
Calls: MedianAnnualAmplitude

EN2_Carbon(RID)
Fetches pre-measured footprint carbon tonnage from Indicator spreadsheets
Returns: float
Calls: LookupValueFromRange

EN52_WetLowFlow
Calculates wet season median flow for fringe months around wettest month and compares with baseline
Returns: double
Calls: WettestMonthIndex, GetFringeMonthTS, MedianOfTS

EN10_WetSeasonShift(tsBCase, tsSC, factor)
Calculates onset of wet season and compares with baseline
Returns: double
Calls: AvgMonthlyDistribution, WetDuration

EN6_WetDuration
Calculates average wet season duration (days) and compares with baseline
Returns: double
Calls: AvgMonthlyDistribution, WetDuration

EN11_PhytoPlankton(tsInflow, tsStorage)
Phytoplankton growth potential: Calculates reservoir retention time
Returns: float
Calls: None

EN12_AquaticMacrophytes(tsRec, CRec, tsReturn, IID)
Calculates time of decay (h) of mixed effluent returnflow and receiving river to acceptable coliform concentration and assigns maacrophyte growth potentail rating
Returns: integer
Calls: Driest3MonthIndex, Get3MonthLowTS, MedianOfTS, LookupValueFromRange

ECONOMICINDICATORS

EC1_Navigation(tsBCase, tsSC, thBExc, outUnits)
Impact on navigation: Calculates #days above baseline flow threshold or change relative to baseline
Returns: double
Calls: RefreshTSValues, ExceedenceOfTS, ThresholdExceedanceDaysPerYear, LogOutput

EC32_EvapLoss_System(ScenarioPath, UnitDivisor)
Calculates system wide average annual evaporatio in specified units. UnitDivisor converts to other units (eg. 1000 converts M to G)
Returns: double
Calls: GetLatestSimulation, GetTimeseriesOfType

EC51_FoodProductionSingle(tsDefB, tsDemB, IID)
Food production: Calculates actual crop yield (tonnes) adjusted for demand deficit.
Returns: double
Calls: RefreshTSValues, LogOutput, CropYieldForSupply

EC31_EvapLoss(tsEvap, UnitDivisor)
Calculates average annual evaporation from timeseries in specified units. UnitDivisor converts to other units (eg. 1000 converts M to G)
Returns: double
Calls: None

EC21_AverageEnergy(ts, UnitDivisor)
Calculates average energy [MWh] generated over simulation period. UnitDivisor converts to other units (eg. 1000 converts M to G)
Returns: double
Calls: None

EC32_EvapLoss_System_Compare(sPathBCase, sPathSce
Calculates system wide average annual evaporation in specified units (volume difference or % difference) and compares with baseline
Returns:
Calls: GetLatestSimulation, GetTimeseriesOfType

EC51_ProductionIncome(tsDefB, tsDemB, tsDefS, tsDem
Production income: Calculates income (Million USD) based on actual crop yield (tonnes) and compares with baseline to produce change in income (Million USD or %)
Returns: double
Calls: RefreshTSValues, LogOutput, LookupValueFromRange, CropYieldForSupply

EC51_FoodProduction(tsDefB, tsDemB, tsDefS, tsDemS,
Food production: Calculates actual crop yield (tonnes) adjusted for demand deficit and compares with baseline to produce change in crop yield (tonnes or %)
Returns: double
Calls: RefreshTSValues, LogOutput, CropYieldForSupply

EC22_AverageEnergy_System(ScenarioPath, UnitDivisor
Calculates system wide average annual energy in specified units. UnitDivisor converts to other units (eg. 1000 converts M to G)
Returns: double
Calls: GetLatestSimulation, GetTimeseriesOfType

EC4_FloodDamage(ras, Divisor)
Calculates flood damage (USD) for pre-generated infrastructure (Agric/Structures/Roads) damage
Returns: integer
Calls: RasterStats

EC51_ProductionIncomeSingle(tsDefB, tsDemB, IID)
Calculates income (Million USD) based on actual crop yield (tonnes)
Returns: double
Calls: RefreshTSValues, LogOutput, LookupValueFromRange, CropYieldForSupply

Returns:
Calls:

SOCIALINDICATORS

SO2_MalariaEndemicity(RID, IID)
Fetches pre-measured malaria incidence (% population) from Indicator spreadsheets
Returns: double
Calls: LookupValueFromRange

SO7_FormalIrrigation(IID)
Fetches pre-measured irrigation scheme areas from indicator spreadsheets
Returns: double
Calls: LookupValueFromRange

SO1_WaterAvailability(tsBCase, tsSC)
Proxy. Calculates dry season median flow for 3 driest months and compares with baseline
Returns: double
Calls: EN51_DryLowFlow

SO91_FishProductionDam(ts)
Proxy: Estimates Fish Production [t/annum] based on median reservoir area [km2]
Returns: double
Calls: EN3_FishProduction

SO4_UrbanPollution(tsRec, CRec, UID)
Caluclates time of decay (h) of mixed effluent returnflow and receiving river to acceptable coliform concentration
Returns: double
Calls: Driest3MonthIndex, Get3MonthLowTS, MedianOfTS, LookupValueFromRange

SO10_ProductiveLandUse(RID, IID)
Fetches pre-measured productive landuse from footprint spreadsheets
Returns: double
Calls: GetConditionalList, LookupValueFromRange

SO81_RecessionAgricFloodPlain(tsBCase, tsSC)
Proxy. Calculates median flow for wettest month and compares with baseline
Returns: double
Calls: EN4_FloodPlainInundation

SO92_FishProductionRiver(tsBCase, tsSC, factor)
Proxy: Calculates average wet season duration (days) and compares with baseline
Returns: double
Calls: EN6_WetDuration

SO5_HouseholdsFlooded(rasD, rasS)
Overlays structures raster with flood raster and calculates number of households in flooded area
Returns: integer
Calls: RasterCalc, LookupValueFromRange, GetConditionalList, RasterZonalStats

SO12_PhysicalDisplacement(RID, IID)
Fetches pre-measured population (households) from indicator spreadsheets
Returns: double
Calls: LookupValueFromRange

SO3_PestDiseasePrevalence(tsBCase, tsSC, Peaking, Rere
Proxy: Determines Blackfly risk rating (-5 to 0) from HP operation, changes in low flows and variability
Returns: integer
Calls: EN7_BlackFlyRating

SO11_LossNaturalResources(RID, IID)
Proxy: Fetches pre-measured environmentally sensitive areas from Indicator spreadsheets
Returns: double
Calls: EN1_EnvSensitiveAreas

SO6_DrowningRisk(CID)
Fetches pre-measured uninterrupted canal lengths from Indicator spreadsheets
Returns: double
Calls: LookupValueFromRange

SO13_EconomicDisplacement(RID, CID)
Calculates disruption of access as sum of dam fetch and/or canal length
Returns: double
Calls: LookupValueFromRange

SO82_RecessionAgricBank(RID, ts)
Proxy: Calculates bank stability rating (-5 to 0) downstream of impoundment
Returns: integer
Calls: EN8_BankStability

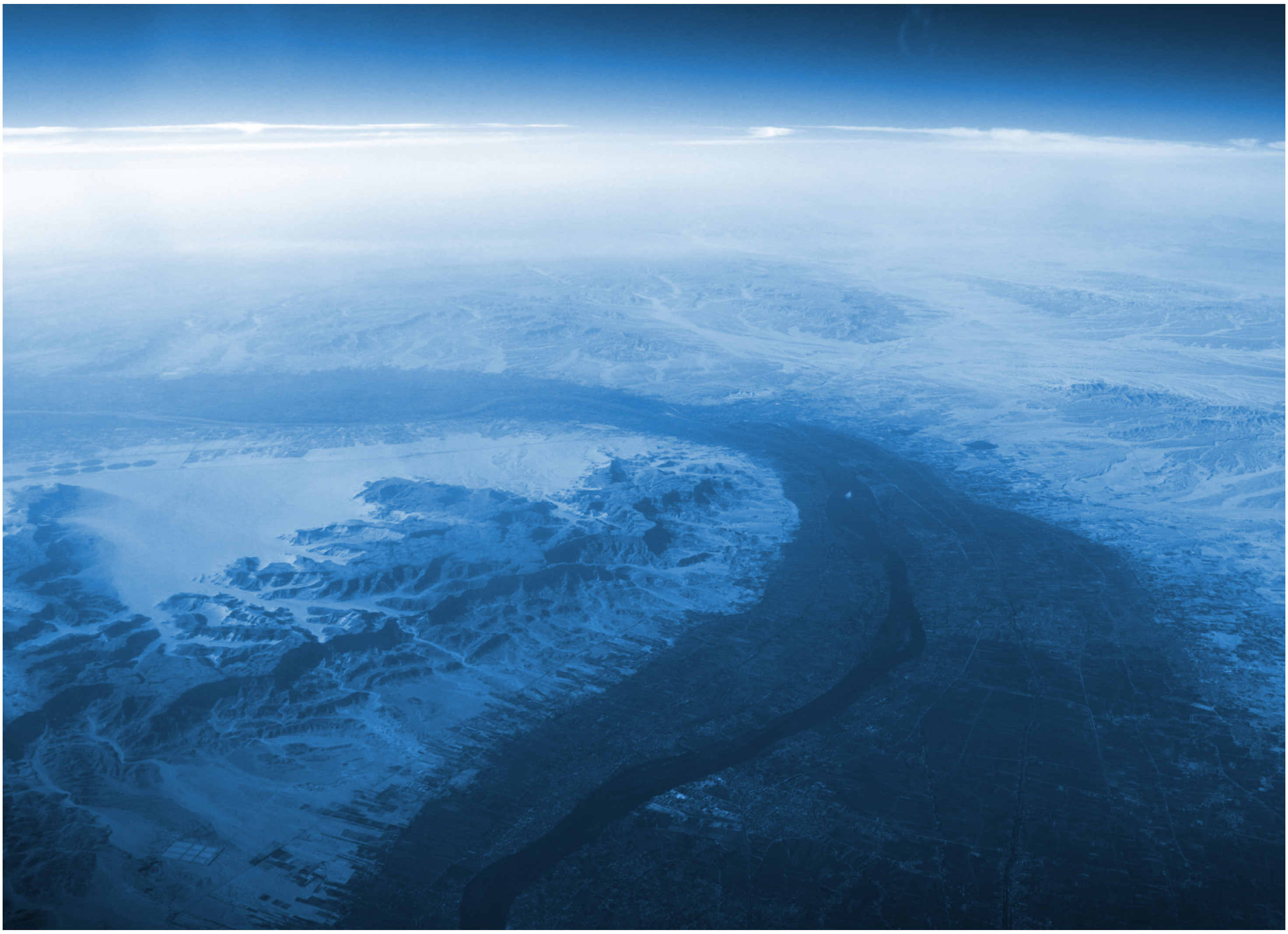


Photo: Shutterstock

ONE RIVER ONE PEOPLE ONE VISION

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