NILE BASIN INITIATIVE
Initiative du Bassin du Nil

# PART II DSS CONCEPTUAL DESIGN

## ANNEX B: DSS Design Specifications

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Appendix B1 – Acronyms

Appendix B2: - Required and Desirable Features

| Versions | Submitted | Comments |
|---|---|---|
| Draft Annex B | 10 January 2008 | |
| Draft Final Annex B | 29 February 2008 | |
| Final Annex B | 17 March 2008 | |
| Final Annex B | 14 April 2008 | revised version considering additional comments made after 17 March 2008 |

# 1 Executive Summary – Nile DSS Design

The basic purpose of the Nile-DSS is to provide a framework for sharing knowledge, understanding river system behavior, designing and evaluating alternative development, investment projects, and management strategies. The main goal is to support informed, scientifically based rational cooperative decision making. The objective is to improve the overall net benefit from harnessing the Nile, and develop economically efficient, equitable, environmentally compatible and sustainable strategies for sharing the benefits. The DSS should help to *"enhance the capacity to support basin wide communication, information exchange, and identifying trans-boundary opportunities for cooperative development of the Nile Basin water resources"*.

The Nile-DSS design is based on three major functional components:

- An information system that provides a common and shared information basis for the planning and decision making processes, locally, sub-regionally, and basin wide, directly accessible for all stakeholders;
- A modular river basin modeling system built around a dynamic water budget model end economic evaluation, that helps to design and evaluate possible interventions, strategies and projects in response to the problems and challenges identified and prioritized in the stakeholder consultations;
- Tools for a participatory multi-criteria analysis to rank and select alternative compromise solutions for win-win strategies.

The DSS and its central river basin model system directly support an open and participatory multi-criteria decision making process. The initial first phase core model components are designed to address a basic set of main concerns and priority issues of efficient water resources management and allocation, water quality, extreme events (floods and droughts), agriculture, hydropower, and navigation as well as watershed management and erosion, considering simultaneously hydrological, environmental and socio-economic criteria and objectives.

The DSS components will be integrated in an open, hierarchical, modular and very flexible implementation to also facilitate information exchange with other models and tools used or developed within the basin. A key concept is the support of the analysis of local, national issues and specific projects, yet always to evaluate their overall downstream effects and basin wide impacts.

The major design principles for the Nile-DSS include ease of use, flexibility, modularity, scientific excellence and advanced ICT technology, openness, transparency, compatibility and interoperability, and cost efficiency to facilitate sustainable operation.

The main architectural features are a client-server implementation based on open source operating environments, standard interfaces, data formats, and communication protocols (e.g., http over TCP/IP, SQL, XML/HTML) that can exploit a wide range of hardware configurations but also the communication with any number of external information resources and the option for efficient web based access by a distributed user community.

The institutional structure of the implementation foresees one common set of software tools and shared, standardized common data sets that can be extended locally with data for individual scenarios, and optional problem specific add-on software, exploiting the modular architecture. These common tools and data are implemented at a central (NBI) location, two sub-regional locations (covering the White and Blue Nile sub-basins, respectively) and at the country level, together with the hierarchical data sharing, update, and access control mechanisms to ensure efficient yet safe and reliable use of the system.

The implementation process (scheduled over an initial 30 months) will use a rapid prototyping approach within an object oriented design paradigm that aims at an early operational prototype to ensure sufficient time for user feedback and extensive and independent testing, calibration and validation. Based on the open architecture and modular structure of the Nile-DSS, the basic system must be designed to be easy to expand to address a growing list of specific concerns beyond the initial shared basin wide priorities. This can be achieved by adding new functionality, models and tools, sharing the same basic utilities, data bases and core components, in later project phases and development cycles building on a robust and well tested initial core.

For the implementation of this core system, the direct involvement of the end users and future operators and managers of the system in the implementation and testing is an important principle here. This implementation process will also require a parallel open peer review process organized around a small set of directly relevant pilot applications and an associated training program to ensure control, responsibility and ownership as the basis for trust and acceptance by all riparian countries.

# 2 Concerns, Models and Data Requirements

## 2.1 Basin Concerns

### 2.1.1 Conclusions from Stakeholder Consultations

The NB DSS is designed to address common, shared problems and concerns of the riparian countries. These concerns may be:

- **Basin wide**, which refers to the impact of any specific action on the overall (downstream) basin;
- **Universal**, that is possible only of local, sub-catchment geographical scope but relevant everywhere, for all or several countries;
- **Specific**, of national and local/sub-catchment interest only.

These concerns have been identified and prioritized, considering the above classification, in the stakeholder consultations. A final priority list agreed upon in the second review workshop includes the following main concerns:

- Water resources development
- Optimal water resources utilization
- Coping with floods
- Coping with droughts
- Energy development (hydropower)
- Rainfed and irrigated agriculture
- Watershed and sediment management
- Navigation

Water quality and climate change have been identified as cross-cutting issues to be considered in addressing the above eight priority areas of concern.

These issues are addressed by a set of core models identified, with associated criteria for evaluation and ranking in the Multi-Criteria Analysis (MCA):

1. Water resources development and management: basic dynamic water budget model and economic evaluation; all hydrological and economic criteria.
2. Optimal water resources utilization: As above, with MCA tools supporting the evaluation of optimal utilization based on user-defined preferences and criteria, to be agreed upon through a participatory process;
3. Coping with floods: flood damage estimation in the water budget model, reach/routing results and control node based evaluation;
4. Coping with droughts: water shortage penalties computed by the core models, yield losses from the irrigation water demand model.
5. Energy development (hydropower): hydropower production as a function of reservoirs in the dynamic water budget model, economic criteria of the C/B analysis.

6. Rainfed and irrigated agriculture development: irrigation water demand model and farm/irrigation nodes in the dynamic water budget model, economic evaluation and criteria.
7. Watershed and sediment management: rainfall-runoff model including watershed erosion, non-point source input including sediment in the lateral catchment representation for reaches in the water budget model.
8. Navigation: addressed by reach level low-flow constraints in the dynamic water budget model, can be evaluated with user defined penalties for non-compliance at control nodes that monitor flow against minimum flow targets.

Cross-cutting issues:

9. Water quality: dynamic water quality model (DO/BOD, conservative tracers, first- and second order decaying substances) including basic sediment transport processes (turbidity, bank and bed erosion, siltation), that operates as a downstream model using the flow data from the water resources model.
10. Climate change: based on recent IPCC scenarios, the DSS (optimization) can be used to find robust solutions (strategies) that provide pareto-optimal (non-dominated) alternatives over all possible climate change scenarios.

Within these main concerns, typical questions that the Nile-DSS is designed to address and answer could be:

- What are the downstream effects and associated costs and benefits of a large reservoir/hydropower scheme like Karadobi, during normal operation, during start-up ? How do the costs and benefits of hydropower production, flood protection, enhanced temporal availability of water for irrigation, reduced downstream water balance ? Where do they accrue ?
- For any given investment project, is there an overall increase in basin-wide net benefits that can lead to a win-win strategy ?
- How would changes in the flow regime of the Sud (Jonglei canal) affect downstream water availability (temporal patterns and total water budget) and associated costs and benefits ?

### 2.1.2 Decision Support Requirements of NELSAP and ENSAP

These fields are in close agreement with the NELSAP and ENSAP projects. SAP projects follow a subsidiary approach that reflects countries' key interests with respect to the selection of water issues to be.

Programmes currently being implemented under NELSAP focus on transboundary integrated water resources management, energy (hydropower development and regional interconnection), and fisheries. Planned projects additionally include irrigated agriculture, watershed management, transboundary parks, navigation, re-afforestation, water hyacinth control, tourism management, flood and drought control, and wetland conservation.

ENSAP initiatives focus on integrated water resources / environmental management, energy (including regional power trade and transmission interconnection), flood preparedness and early warning, irrigation and drainage, and watershed management.

Most of these issues addressed by NELSAP and ENSAP are covered by the abovementioned "concerns", and in most case by the "key transboundary concerns". However, an exception is fisheries which has received less attention during the workshops, for reasons that are not entirely clear. As the presence of shared lakes is an important characteristics of the Nile Basin, in particular the Equatorial Lakes, sub-region, it has been decided to add fisheries to the list of concerns.

### 2.1.3 Regional Differences

The results of the stakeholder consultations were analysed for regional differences: Different sub-regional or national priorities might suggest the need for different regional configurations of the NB DSS:

However, there are no clear regional differences with respect to the ranking of the key transboundary concerns: They have been ranked high at virtually all the workshops, with few exceptions that were mainly related to problems of wording and aggregation of issues.

As to the other significant concerns, some regional differences can be found. For example, river navigation is only an issue in downstream countries (mainly Sudan and Egypt) while in the Equatorial Lakes region countries are less interested (and if so they refer to lake navigation). Wetland management is an important issue in Sudan but ranked much lower in other countries. Tourism is one of the main development potentials in the Nile basin area of DR Congo but less important elsewhere, etc. For this reason, and because of their quite specific local characteristics, these concerns will tend to be addressed in a more localised manner, i.e. by models more specifically developed and less directly integrated than for the key concerns.

On the other hand, all the models and tools needed to cope with the key transboundary concerns should be included in the core of the NB DSS modelling system: They need to be available for any part of the Nile basin, and need to be well integrated to ensure a smooth interaction between each other.

## 2.2 Identification of Models Needed

Table 2.1 below presents the results of the analysis of model needs. Models that are definitely required are highlighted green while models that are needed for in-depth analyses only are highlighted orange.

**Table 2.1 Models Needed**

| Areas of Concern | Water budget model (including groundwater interaction) | Meteorological models (pre-processor) | Rainfall/runoff | Flow routing, 1D hydraulic model | Reservoirs, hydropower | Watershed erosion, sediment transport | Irrigation water demand | Water quality | Economics, CBA | Water supply and sanitation | Biodiversity | Sediment transport / (3D model) | Wetland management | Groundwater (3D flow and transport) | Lake / reservoir water quality and ecology | Climate change (Downscaling) | Energy systems model | Regional development models | Macro-economic and sector models |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Water resources development | G | G | G | G | G | G | G | G | G | | | | | O | | | | O | O |
| Optimal water res. utilization | G | | | | G | | G | G | G | | | | | | | | | O | O |
| Coping with floods | G | G | G | G | G | | | | G | | | O | | | | | | O | O |
| Coping with droughts | G | G | G | | | | G | | G | G | | | | | | | | O | O |
| Energy development (hydropower) | G | | G | G | G | | | G | G | | | | | | | | O | O | O |
| Rainfed and irrigated agriculture | G | G | G | G | G | | G | G | G | | | | | O | | | | O | O |
| Watershed and sediment management | G | G | G | G | G | G | | | G | | | O | O | | | | | O | O |
| Navigation | G | | | G | | | | | G | | | G | | | | | | O | O |
| Water quality | G | | G | G | | G | | G | G | | | O | O | O | | | | O | O |
| Climate change | G | G | G | | G | | G | | G | | | | | | | G | O | O | O |
| Water supply and sanitation | G | | | | | | | G | G | G | | | | O | | | | O | O |
| Biodiversity conservation | G | | | G | | | | G | | | G | | G | | G | | | O | O |
| Wetland degradation | G | G | G | G | | G | G | G | G | | G | | G | O | O | | | O | O |
| Rainfed agriculture and livestock | G | G | G | | | G | G | | G | | | | | O | | | | O | O |
| Population structure / settlement patterns | G | | | | | G | | G | G | | | | | | | | | G | O |
| Tourism | G | | | | | | | G | G | | O | | O | | O | | | O | O |
| Water use efficiency / demand management | G | | | | | | G | | G | | | | | | | | | O | O |
| Aquatic weeds | G | | | G | | | | G | G | | | | O | | G | | | | |
| Fisheries | G | | | G | G | | | G | G | | G | | O | | G | | | O | O |
| Power trade | | | | | | | | | | | | | | | | | G | O | O |

The first nine model domains (encompassed cyan) cover the requirements of the “key areas of concern” (first eight lines of table 2.1). These models need to be included in the first phase core set of models. The table clearly shows that these “core” models are also required for most of the remaining concerns. It is therefore recommended to incorporate these models into a consistent, integrated core model system.

The water resources network model is understood to include dynamic water budgets, demand/supply data for water use, routing, confluence and diversions (including the representation of alternative water allocation strategies) as well as water use and conveyance losses (evaporation and seepage) and a simple (mass budget) representation of groundwater coupling and interactions, as well as a basic economic evaluation (CBA). Aggregation to different geographical and administrative units (riparian countries) is a requirement.

Among the remaining models two groups can be distinguished:

1. Models which are related to many concerns, but required for in-depth analyses only. In a number of cases the processes involved can be modelled either in a simplified manner or through complex, sophisticated modelling approaches. In these cases it is suggested to incorporate the basic routines in the core modelling system while the advanced models, which are difficult to integrate due to their complexity and considerable data requirements, will be optional stand-alone modules. Typically, the data required for these models are not readily available and specific development work is required. The need and the exact specifications need to be defined carefully. These cases include:
   - Energy/hydropower: Basis functions (e.g. the modelling of hydropower generation based on flow data) are simple, but a complex energy sector model is needed to address issues related to energy demand, dispatching, transmission, the use of alternative energy sources, etc.;
   - Sediment transport: Basic functions (e.g. soil erosion based on the USLE and basic transport processes) can be incorporated in the core, but advanced models are needed for 3D modelling;
   - Environment/biodiversity: A generic Environmental Impact Analysis tool may be adequate for many cases, but modelling of biodiversity (in terms of indicator species) needs specific research;
   - Economic analysis: Basic analyses (cost-benefit based) need to be included in the core, but for a full evaluation of indirect benefits, sectoral and macro-economic effects, a more comprehensive model ( input/output model, dynamic or equilibrium) is needed;
   - Water supply and sanitation: Processes related to water abstraction and wastewater effluents are included in the core; a specific model (and monitoring system) is required to address service coverage, public health issues etc.;
   - Wetlands: A certain number of issues will be covered by core routines (e.g. floodplain inundations, crop water requirements, etc.), but specific developments of complex models may be required to address all aspects of wetland management.

2. Models that are definitely required for certain issues, but need very specific local development, calibration and validation. These cases include
   - Biodiversity; and
   - Lake / reservoir water quality and ecology, including fisheries.

   These models need specific development work (and possibly original research) and will be developed as stand-alone modules for specific locations (e.g. Lake Albert), accessible from the core modelling system through an appropriate interface.

## 2.3 Data Availability Constraints

Data availability and data exchange are important issues in the Nile Basin. The analysis conducted during the Inception Phase (Inception Report, Annex A, chapter 5) revealed considerable gaps for various parts of the basin and for several types of data.

For the core models, the basic hydrometeorological and geophysical data are largely available from public sources (e.g., close to 40 runoff stations from FOA data sets with multiple decade coverage, global DEM, satellite imagery for landcover, climate and detailed meteorology (e.g., NOOA/NCEP: National Centers for Environmental Prediction), so that the basic dynamic water budget model can be calibrated and validated for the entire Nile basin and major sub-basins. These will be major tasks in the application building phase and testing of the DSS development

For specific models beyond the core, special data compilation exercises will be needed to obtain the data necessary to run, calibrate and validate these models; examples are data for 3D groundwater models or economic data beyond the basic techno-economic assessment. The following table shows types of data highlit blue which are required for the core set of models as defined in Chapter 4.

**Table 2.2 Data Needs and Data Availability**

Legend:

| | |
|---|---|
| | Data available / monitoring network existing |
| | Data needed partly available |
| p | Data collection planned |
| - | Data not available |
| ? | Situation not clear from the available information |

| **Data** | | Burundi | DR Congo | Egypt | Ethiopia | Kenya | Rwanda | Sudan | Tanzania | Uganda |
|---|---|---|---|---|---|---|---|---|---|---|
| Hydrological data | Streamflow data, daily | | - | | | | - | | | |
| | Streamflow data, hourly or shorter interv. | - | - | | ? | p | - | - | - | |
| | Real time data | - | - | | ? | p | - | - | - | - |
| Meteorological data | Precipitation (station data) | | - | | | | | | | |
| | Precipitation (grid data from meteorol. models) | | | | | | | | | |
| | Rainfall intensities (parametrized or hourly data) | | - | | | | | | | |
| | Other meteorological parameters | | - | | | | | | | |
| | Real time data | - | - | ? | - | - | - | - | - | - |
| | Climate change scenarios, GCM model results | to be derived from international sources | | | | | | | | |
| Hydrogeological data | Aquifer data | | - | | | | | | ? | |
| | Well data, pumping rates | | - | | p | | | | ? | |
| Water quality data | River water: DO/BOD, NH4, salinity, temp… | - | - | | ? | | - | - | | |
| | Lake water quality | | - | | ? | | | - | | |
| | Groundwater quality | ? | - | | ? | | ? | ? | | |
| | Drinking water quality | | - | | | | | | | |
| Sediment data | Suspended solids | - | | | | | - | | | |
| | Erosion data (watershed) | data from experimental plots, to be analysed | | | | | | | | |
| | Sediment deposition data, river bank/bed erosion | | | | ? | ? | | ? | ? | ? |
| Morphological parameters | Catchment parameters | to be compiled from DEM (GIS) | | | | | | | | |
| | Channel geometry | to be compiled from satellite imagery and other sources | | | | | | | | |
| | Floodplain topography | | | | | | | | | |
| | Reservoir / lake data | to be compiled from agencies | | | | | | | | |
| Water use data | Sectoral water use data | To be compiled from different sectoral institutions | | | | | | | | |
| | Inventory of abstraction points | | | | | | | | | |
| | Inventory of emission points | | | | | | | | | |
| | Hydropower generation data | | | | | | | | | |
| | Agricultural production data | | | | | | | | | |
| | Crop water requirements | | | | | | | | | |
| | Agricultural practices | | | | | | | | | |
| | Agro-chemical use data | | | | | | | | | |
| | Wastewater treatment data | | | | | | | | | |
| | Water supply and sanitation coverage | | | | | | | | | |
| GIS data | Digital Elevation Model | | | | | | | | | |
| | Land use data | | | | | | | | | |
| | Soil types | | ? | | | | | ? | ? | |
| | Location of consumers and polluters | Inventory to be made | | | | | | | | |
| | Distribution of population / settlements | To be prepared from satellite imagery | | | | | | | | |

| Data | | Burundi | DR Congo | Egypt | Ethiopia | Kenya | Rwanda | Sudan | Tanzania | Uganda |
|---|---|---|---|---|---|---|---|---|---|---|
| Financial and economical data | Unit investment costs, lifetime, discount rates | to be compiled for NB DSS | | | | | | | | |
| | Unit operational costs | | | | | | | | | |
| | Agricultural market prices | | | | | | | | | |
| | Energy market prices | | | | | | | | | |
| | Shadow pricing factors | | | | | | | | | |
| Demographic and socioeconomic survey data | Demographic data | | | | | | | | | |
| | Public health data | | | | | | | | | |
| | Employment, livelihoods, etc. | | | | | | | | | |
| | Sectoral economic records | to be compiled from sector institutions | | | | | | | | |
| | Fishery data | | | | | | | | | |
| Biodiversity data | Indicator species | - | - | ? | - | ? | - | - | ? | ? |
| Energy sector data | Energy demand, etc. | to be compiled from sector institutions | | | | | | | | |
| Macroeconomic data | | to be compiled | | | | | | | | |

The most significant data gaps vis à vis these requirements are identified as follows:

- Absence of hydrological monitoring networks in Rwanda and DR Congo, while network density and/or operation is insufficient Burundi, Sudan, Tanzania, and Uganda; in all these countries (except Uganda) there are no recording gauging stations; data quality is often moderate to unsatisfactory as the hydrological services do not have the appropriate resources for regular operation
- Insufficient network density of rainfall and meteorological stations in Burundi, Rwanda, Sudan and Tanzania
- General lack of data for the Nile basin area of DR Congo due to insecurity
- Lack of data on surface water quality, including suspended solids, in most countries (exceptions: Egypt, Kenya, Uganda; for suspended solids: Ethiopia)
- Lack of systematic surveys of sediment deposition in reservoirs

The following types of data need to be compiled from a variety of different institutions (sector agencies, etc.):

- Reservoir /lake characteristics
- Sectoral water use and related production data (agriculture, energy, etc.)
- Inventory of water abstraction and wastewater emission points
- Use of agrochemicals
- Financial and economical data (unit costs, market prices, etc.)

Data types which are relatively easy to access include:

- GIS data (e.g. Digital Elevation Models, grid rainfall, land cover), available from international public domain sources.
- Socioeconomic, demographic and health data: Surveys according to international standards have been conducted recently in most countries (except DR Congo, Sudan) and will be repeated regularly (also planned for these two countries)

The recommended measures to address these gaps are:

- Define a core network of NBI-DSS stations of regional importance. These stations should be linked to a NBI telemetry system which would be a key source of input data for an operational NBI-DSS. Data quality should be excellent, with supervision (quality assurance) provided at the regional or sub-regional level.

- Mobilise support for the re-establishment of hydro-meteorological services,; this could be done through SAP projects or by facilitating support from other agencies or international organisations.
- Sensitise national authorities to provide adequate means (recurrent budget) for keeping the hydro-meteorological services operational and producing reliable data.
- Promote the introduction of automated stations combined with telemetry equipment. This would have a number of significant advantages, including better data resolution (e.g. hourly data during floods), automated processing, prompt information about station failures at the centre, and real time data availability (for forecasting purposes). However, conventional equipment (such as staff gauges and rain gauges) needs to be kept in parallel as a more robust fallback solution if the modern equipment fails (due to energy failure, theft, etc.)
- Promote an integrated approach where all data that are relevant for decision making in water resources management are centralised in a river basin agency (similar to the model implemented in Kenya).
- Initiate and encourage data exchange arrangements and data harmonisation efforts.

# 3 System Requirements

## 3.1 General Requirements

The Terms of Reference (ToR) state that the Decision Support System for the Nile Basin

"…. is expected to provide the necessary knowledge base and analytical tools to support the planning of cooperative joint projects."……."An essential feature of the Nile Basin DSS should be that it is an agreed upon tool that will be accepted and used by all riparian countries in the management of the shared Nile water resources."

Essential components of the Nile Basin DSS are:

- Comprehensive Knowledge base
- River Basin Modeling System
- Set of tools, including those used for multi-criteria analysis
- Basin-wide communication system
- Human and institutional capacity strengthening targeted at enhancing capabilities of riparian experts on continued use and maintenance of the DSS."

The design phase of this present assignment has sought to develop the Nile Basin DSS in a manner that aims to ensure

- the continued existence and usefulness of the DSS;
- facilitation of common acceptance by all Nile Basin riparians and
- enhanced riparian cooperation.

The consultation and discussion with the contracting authority and stakeholders has resulted in the following recommended approaches, which are seen as particularly relevant, and in some cases essential.

**Enhance Ownership**
The DSS shall be owned by the Nile Basin riparians, a group of highly diverse nations and their water resources agencies. The enhancement of ownership will be effected through:

- Decision-maker participation in the overall development of the DSS throughout the process and especially during the execution of the respective consultancy.
- User participation in DSS design and technical development.
- Possibility of upgrading and adjustment according to evolving user needs by development of a modular, open-ended system.

**Clear Response to Perceived Needs**
Development of the DSS in response to clearly perceived needs at regional/sub-regional and national levels will enhance both ownership and sustainability of the system. It was clear from the start that while the DSS must first serve regional needs, it must also be perceived as useful for decision making at the national level.

**Ensure Transparency and Confidence**
To meet the expectations and to make best use of the investment all riparians must have full confidence that the system provides rational and objective support based on best available data,

information, and estimates. This requires that all assumptions, methodologies, and technical descriptions are agreed upon and readily accessible by the users and decision-makers.

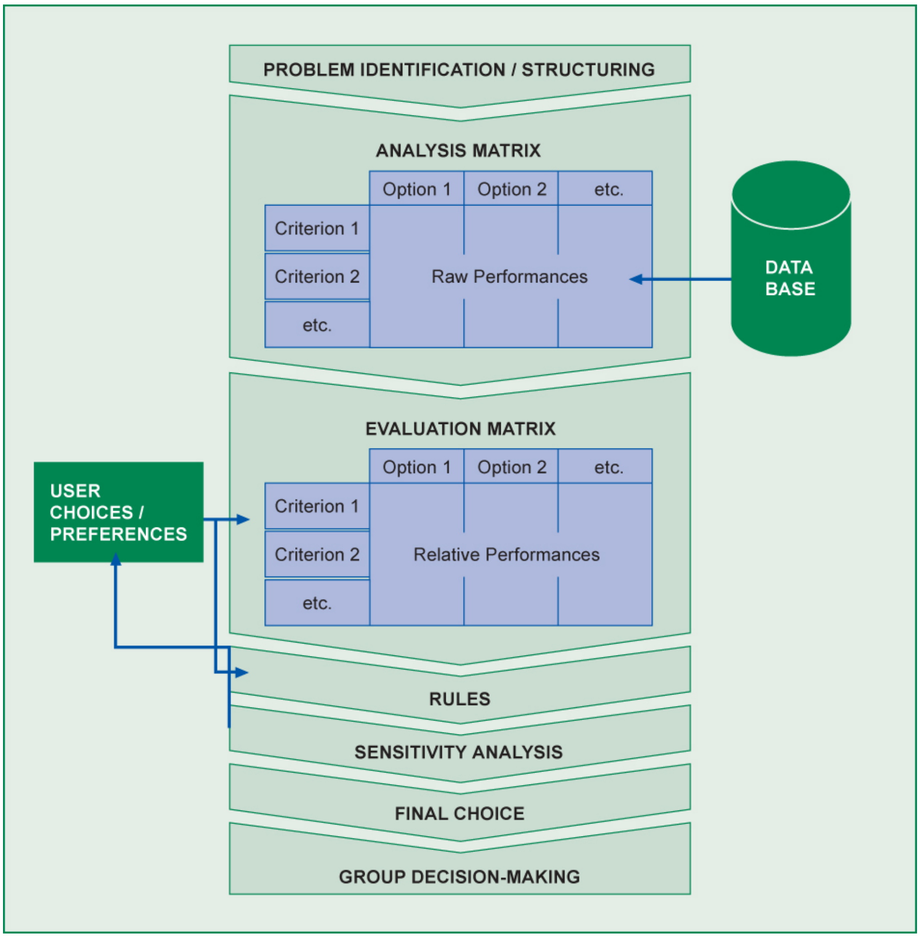
**Enhance Sustainability**
Sustainability is understood as the opportunity for the DSS to continue to function and be used within the framework of Nile Basin collaboration as well as at the national level. Sustainability relates to institutional, financial and technical aspects.

## 3.2 Purpose of the System

The basic purpose of the Nile-DSS is to provide a framework for sharing knowledge, understanding river system behavior, evaluating alternative development and management strategies, and supporting informed decision making. The objective is to improve the overall net benefit from harnessing the Nile river, and develop environmentally compatible, economically efficient, equitable and sustainable strategies. The DSS should help to *"enhance the capacity to support basin wide communication, information exchange, and identifying transboundary opportunities for cooperative development of the Nile Basin water resources"*.

The analysis matrix contains development and investment options which are described by values of criteria. This step does not include any kind of preferencies. Theoretically, the number of options and criteria are infinite; practically they are bound to possible solutions of e.g. potential investments. Users' choices and preferences are then applied to the each pair of options and criteria. E.g. rules for ranking of options against criteria need to be agreed; a sensitivity analysises help to understand the robustness of the results matrix.

**Figure 3.1** **Decision-Making Procedure in a Step-by-Step Flow Chart**
(adapted from "mDSS4 Decision Methods, 2006, Fondatione EMI ENRICO MATTEI, Venice, Italy)



## 3.3 Basic Questions

The basic questions related to the DSS design can be summarized as follows:

**What will the system be used for?**
A decision support system for integrated water resources management primarily has to support decision making processes. This includes the iterative steps of:

- Structuring the problem and providing a shared information background to all participants in the decision making process (stakeholders);
- Defining a preference structure, which involves the selection of (multiple) criteria, and the definition of (multiple) objectives and a priori constraints;
- Designing alternatives in terms of combinations of instruments (technological, economic, regulatory), that hold promise to meet the constraints and contribute to the objectives;
- Evaluate the performance of the system for these alternatives in terms of the preference structure (multiple criteria);
- Rank the alternatives, and eventually select a preferred (optimal, compromise) solution acceptable within the rules of the decision making process and its participants.

**What is the structure of the system?**
The system in structured in terms of its major functional components or modules, and their relationship with each other and the user. The structure of the DSS reflects the major elements of the decision making process. Technically, the Nile-DSS is structured as a client-server system using **http over TCP/IP** for any combination of local and remote access.

The three main groups of components are:

- The **information system (IMS)** represented by a set of (relationally) linked **databases** (RDBMS) that provide an object oriented and hyperlinked view of the Nile basin and its main functional components in hypermedia formats; the information systems includes a set of tools for data management, analysis, and display; most object (classes) in the system are geo-referenced, which makes a GIS a central component between the information system and the analytical tools. The information system also provides inputs to the analytical tools (model inputs, initial and boundary conditions) and manages model outputs, thus also supporting the cascading and nesting of models where the output of one model can (automatically) be used as the input for another.
- The **analytical tools or models**, that represent the basic functions of the river basin and will primarily be used for
  - Scenario analysis, answering WHAT IF questions;
  - for the automatic generation of alternatives (an automated scenario analysis, simulation based optimization in a two-stage procedure linked to the MCA below)

  including the evaluation of the alternatives in terms of the user selected criteria (hydrologic, socio-economic, environmental);
- The **DSS tools proper** that perform the ranking and selection of alternatives, and, depending on the MCA method used, the elicitation of preferences, support for group negotiations, analysis of robustness and sensitivity.

These three groups of components are embedded in a common user interface (based on httpd and a web server such as Apache), with common multi-layered access control. |The components exchange data automatically to eliminate the need for manual data processing tasks, and also are supported by a range of systems management, maintenance, and configuration tools.

**How will the user interact with the system?**
In the Nile-DSS there will be more than one group or class of users, who will perform different tasks. A hierachical structure of the interface and reports generated will provide different levels of detail and technicality for different users. All of them, however, will access the system through the same primary graphical user interface (GUI) and visualization tools (primarily graphs, diagrams and topical maps): interactive, menu driven (selection from pre-defined menus of context sensitive options, point-and-click, drag-and-drop interface, with distributed access (web browser as the primary client software).

Access to the user interface can be local (LAN or local PC/workstation/server) or remote through the Internet, but using the same standard protocol (http). The open interface will also support the use of external visualisation tools (including animation) such as VIS-5D (public domain) or similar commercial products. A web client (browser) as graphical user interface uses http as the (multi media/MIME type) data transfer protocol over the general Internet protocol layers TCP/IP. Within any HTML page (interpreted by the web client) other protocols such as ftp (for data transfer/upload), smtp(for asynchronous data transfer) or ssh (for secure remote login/erminal sessions/shell execution) or scp (for secure (encrypted passwords) remote copy) can also be used as required.

**What will be the output of the system and how it shall be used to serve the intended purposes?**
The output of the Nile-DSS corresponds to the basic components, which in turn mirror the main steps in the decision making process and MC analysis:

- Answers to any and all interactive queries put to the information system in the form of interactive designed reports including the possibility to export selected data sets for processing with (local) third party tools;
- Model generated scenarios/results including their evaluation, uncertainty and sensitivity analysis for model results;
- Ranking of alternatives for specific decision problems according to the user defined preference structure (MCA and decision support proper).

All these **information products** are designed (and can be configured interactively) to directly support the decision making process including the formulation of trade-offs, negotiation within cooperative games, and include tools for problem structuring and user to user communication, as well as optional tutorial and training components implemented in the same architecture (see below) as optional (web-based or local) computer assisted learning tools.

## 3.4 Water Resources DSS

The Nile-DSS is based on the concepts of Integrated Water Resources Management: „IWRM is a participatory planning and implementation process, based on sound science, that brings stakeholders together to determine how to meet society's long-term needs for water and coastal resources while maintaining essential ecological services and economic benefits" (USAID, http://www.usaid.gov/our_work/environment/water/what_is_iwrm.html). The **Global Water Partnership** describes IWRM as "a process which promotes the coordination of water, land, and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital eco-systems" (GWP 2000). These concepts are directly applicable to the Nile-DSS and reflected in its design.

The Nile-DSS design is based on three major functional components:

- An information system that provides a common and shared information basis for the planning and decision making processes, locally, sub-regionally, and basin wide, directly accessible for all stakeholders;

- A modular river basin modeling system built around a dynamic water budget model end economic evaluation, that helps to design and evaluate possible interventions, strategies and projects in response to the problems and challenges identified and prioritized in the stakeholder consultations;
- Tools for a participatory multi-criteria analysis to rank and select alternative compromise solutions for win-win strategies.

### 3.4.1 Information Management System

At the core of the DSS is a common, shared information management system implemented in one or several relations data base management systems (RDBMS) and related GIS with industry standard SQL network accessible interface. The data base design (data model) must directly reflect the object oriented design (OOD) of the DSS implementation and include OLAP (on-line analytical processing) capabilities for efficient data analysis. The data bases describe the geo-referenced physical and administrative elements of the river basin such as sub-catchments, dams and reservoirs including hydropower generation, aquifers and wells, open channels and pipelines, diversions and confluences, lateral catchments, and points of demand such as settlements, farms and irrigation districts, industries, or wetlands. Generic objects classes include crops or water technologies.

### 3.4.2 River Basin Model

The central analytical tool is a dynamic water budget model, implemented in an object-oriented network design (semi-distributed), that fits into the overall modular architecture: each of the nodes and reaches of the river basin representation can be hierarchically based on specific models for the corresponding object or processes, supporting the hierarchical linkage, cascading or nesting of several models. The basic model computes water supply and demand on a daily basis, can be aggregated to monthly and annual water budgets for any node, sub-catchment, or administrative grouping, and includes an embedded economic assessment. This basic core model interacts with logical pre-processors (hydrometeorological data management, time series analysis, rain-fall runoff model, irrigation water demand, watershed erosion) and in turn provides the inputs for a water quality model (DO/BOD, conservative substances, first order decay, turbidity/sediments including bank and bed erosion, transport and siltation processes) and the economic evaluation of demand and supply in a cost-benefit analysis. These models together generate the criteria describing the main issues and concerns as used in the subsequent multi-criteria analysis.

Interactive scenario analysis, but also the automatic generation of alternatives for sensitivity analysis and in a two stage optimization procedure (satisficing) or direct mathematical programming frameworks should be considered for implementation.

### 3.4.3 Decision Support Tools (MCA)

The analytical core directly and automatically exports the alternatives and their descriptive criteria (including costs and benefits) to the multi-criteria analysis tools. These will include several methods, from basic interactive implementation of the Pugh method (decision matrix) with user defined weights to reference point methodology (automatic normalization between Nadir and Utopia, preferences expressed by a reference point) and the linkage (open interface) to any number of commercially available tools for stakeholder preference elicitations and subsequent ranking and selecting, including group decision making and sensitivity analysis for robust decisions.

# 4 Nile DSS Functionality Design

The Design of the Nile-DSS describes the organization of the proposed Nile-Decision Support software system into

- the initial set of modules/components/classes or other units
- the behavior and functional responsibilities of units
- the interaction between these components, including the different users.

The DSS design, related architecture and implementation proposal (Implementation plan of the DSS Development plan and TOR inputs) are based on

- general considerations of the DSS processes the system will support (see Figure 3.1);
- the results of the project's Analysis phase, the main concerns (issues) identified by the stakeholders, and the institutional, technical, and data constraints that need to be considered.

## 4.1 Basic Principles of the DSS Design

The DSS Design described below is based on the following principles:

- **Ease of use**: the primary objective is to support decision making processes by diverse groups of stakeholders, which requires ease of use or useability. A consistent, intuitive, largely graphical, responsive user interface includes a fully interactive and menu driven implementation, easy to learn also for infrequent users, extensive (data driven) configuration and adaptation options, embedded help- and explain functions, error correcting (better: fail safe) or "intelligent" user support to minimize frustration when using complex tools (e.g., Raskin 2000). It should include the possibility for adaptation to different levels of user proficiency, hierarchically structured levels of output detail, support for different cognitive preferences, multiple output channels. In addition to information management and analytical tools, this also requires tools for "customer management" and the facilitation of user to user communication, and building a common knowledge base, sharing experience.
- **Flexibility**: A DSS supports individual and institutional learning processes, which implies continuous change of users and user requirements. Adaptability, customization, continuing development and support for easy upgrades are all required features. Flexibility also means that the system must be scaleable for a wide range of problems from local to basin wide while retaining the same logic and methods wherever possible,
- **Scientific excellence**: a key concern when using complex software tools for decision support is **trust**. This must be based on access and openness for inspection, the ability to analyse any results in terms of the underlying, data, assumptions, and methods, full and easily accessible documentation (ISO 9000 series, e.g., Oskarson and Glass, 1996; and UML style documentation, e.g., Albir ,1998) but also the use of state-of-the-art models and tools, including tools for and validation, data assimilation calibration, and built in quality control and assurance wherever possible.
- **Openness, transparency**: also related to the issues of trust, but equally to ease of use and the shared information basis for all stakeholders and participants in the decision making process (empowerment by information, Agenda 21, chapter 40) is the principle of openness. All data, assumptions, and processes used must be open for inspection and sufficiently documented. Ideally, ever results, conclusion or inference generated by the

system can be explained with a detailed backtracking or trace function; this also includes the requirement for a complete log of all user interactions and specifications.

- **Modularity**: the above requirements necessarily lead to a high degree of modularity, with multiple, alternative and complementary tools, models and methods, easy to exchange or add, but also the possibility to customize different versions of the system for different|(local) use easily with different sets of components. While tightly integrated, these components also can operate in a stand-alone mode. The requirement for individual semi-independent modules also corresponds to a component-based design methodology (Lepreux S., Kolski C., Abed M., 2004) that facilitates both development and testing.
- **Advanced technology**: as a complement to scientific excellence of the methods and tools, the use of advanced yet appropriate technology is the basis for the usability requirements. The very rapid development of ICT makes a forward looking strategy mandatory. What may be perceived as a technical constraint today (e.g., limited Internet connectivity, massive computational and storage requirements) is virtually guaranteed to disappear within the foreseeable future.
- **Compatibility, interoperability**: integration of components, and interoperability with external information resources, models, tools, data bases, monitoring networks etc. All require adherence to industry standards. The use of industry standard where applicable, including basis such as OSI and standards of communication protocols and data formats, but also more specific application oriented standards such as OpenGIS, OpenMI, Dublin Core Metadata, etc. is an important element to guarantee interoperability in an open architecture. For the design and software development itself, that also includes adherence to the ISO9000 family of standards (Oskarson and Glass, 1996).
- **Cost efficiency**: this is a major prerequisite for the **sustainability** of any ICT solution. This includes not only the basic hardware and development or license costs, but more importantly the costs of continuing training, maintenance, further development. Systems architecture, the implementation strategy and process, and continuing operation have to also consider costs. However, the most expensive system (by the hour) is one not being used.

### 4.1.1 Project Characteristics, Guiding Software Design and Development

The choice of software design and development methodology for the Nile-DSS development and the corresponding systems architecture and implementation is based on the Requirements and constraints derived from the stakeholder workshops and interviews, and basic project characteristics as described below.

Project characteristics of the Nile-DSS as a software development project can be summarized in four important dimensions, namely

1. project size,
2. application domain,
3. criticality, and
4. innovation.

The position of Nile-DSS as a software development project (which covers just one, but certainly a central aspect of the entire project activities and objectives) is summarized in the Table below:

| | |
|---|---|
| Project size | large to very large |
| Project domain | environment, DSS |
| Project criticality | medium to low |
| Project innovation | high to very high |

**Project size**

This not only measures the size of the resulting product in terms of lines of code or Megabytes of data, but primarily the complexity of the system, the number (and nature) of its main components, interactions, and, importantly, the size and composition (and location) of the institutions involved, but also the shee physical size of the application domain (3,000.000 $km^2$). With a possibly distributed and international design development team with various levels of background (in formal software engineering projects), and the size and complexity of the main project components like the dynamic, distributed simulation models, a label of large to very large is justified.

**Project domain**

Here we mean not only the domain of environmental management which is inherently complex and ill-structured, but also the characteristics in more technical terms: real-time (use of on-line information), interactive GUI (a necessary DSS feature), distributed (client/server architecture with both LAN and WAN elements), decision support objective. All these components involve major uncertainties (which are also reflected in the vague initial user specifications) that lead to the conclusion of an ill-structured problem domain.

**Project criticality**

As a system oriented to scenario analysis, planning, management (including the possibity to expand towards real-time operational flood forecasting) and decision support in an important domain that has demonstrated impacts on human health, Nile-DSS project would be of high criticality. However, the time horizon and typical response times of forecasts are in the order of days and hours, not minutes and seconds (compare, for example, the typical time characteristics and response time requirements in a power plant control system or a flight traffic control system).

Also, model-based forecasts like those generated by Nile-DSS are inherently uncertain. Their primary objectives is to explore a problem domain and help design and evaluate management alternatives, with the ultimate choice made by the human user, and not by the system automatically. This is equally true for the real-time forecasting of pollution levels, where the appropriate management response is decided and initiated by a human operator.

**Project innovation**

As a development project, that integrates a number of state-of-the-art yet proven (at least in the proposed integration) elements into a complex system that spans at least nine countries and numerous stakeholder institutions, Nile-DSS is of high innovativeness. The distributed nature, based on LAN and WAN communication, on-line integration of optional HPCN for optimization, and monitoring, complex 3D dynamic simulation (e.g., for regional downscaling of global weather forecasts), interactive GUI and GIS and multi media element, and finally multi-criteria DSS concepts all have exploratory element that lead to an innovation ranking of very high.

### 4.1.2 Software Development Approach

The choice of approach for software development is based on the main characteristics of Nile-DSS, which include:

- participatory implementation and a high degree of innovation,
- a heterogeneous and distributed group of stakeholders,
- approximate initial user specifications from a diverse user group,
- a complex and ill-structured application domain, and
- the non-commercial nature of the product.

The basic software development methodology adopted for the Nile-DSS demonstrator development and integration is **rapid prototyping** within an **object oriented design and development methodology** as described in Rumbaugh OMT (Rumbaugh et al., 1991).

**Prototyping** is preferably used as a development method in cases where the users find it difficult to explain what is required of the software in a sufficiently technical language to allow precise interpretation. While the User Requirements Analysis (see Annex A) provides general and high-level guidelines, in particular on aspects of required (and also desirable but not essential) functionality related to key concerns, and describes application scenarios (interventions) in some detail, it lacks the technical details that could be used as the basis for a more structured design approach (for example, object oriented design (OOD) methods such as Rumbaugh OMT, Booch, Shlaer-Mellor, Coad-Yourdon, or Martin-Odell).

**Rumbaugh OMT** provides appropriate concepts to guide the development methodology, and the standard terminology of Shlaer-Mellor for Objects, Classes, and Instances should be adopted.
The basic approach foresees a sequence of prototyping cycles, starting from the initial user requirements, where each cycle is used as the basis for a refinement of the specifications and subsequent modification of the functionality and/or implementation. In this approach, prototype development is primarily seen as an information gathering approach to elicit more detailed functional specifications from the user group. The prototype provides the language for these refinements.

The important focus of the design process, for a modular implementation strategy which continues as **concurrent engineering** during the implementation phase in the prototyping cycles, is to ensure that the final system:

- meets the functional specifications (support of scenario analysis and forecasting as specified in the initial users requirements document);
- fits the runtime time and space constraints (better-than-real-time performance for forecasting);
- can be implemented within the resource constraints (time, space, material, existing components, legacy software, people);
- is designed with longevity and easy maintainability in mind (requirements of the exploitation plan).

### 4.1.3 Development Standards

The requirements of ISO 9000-3 for software design are straight forward and rather general:

- The activities should be carried out in a disciplined manner.
- Input and output should be specified, and design rules and internal interface definitions should be examined.
- A systematic design methodology appropriate to the type of software being developed should be used (application specific methodology).
- Past design lessons learned should be used, and past mistakes avoided.
- Product design should facilitate testing, maintenance, and use.

- The product of the design phase should be subject to review.

While these requirements are easy enough to accept, they provide little or no practical guidance for the design process. The same is true for implementation, which in ISO 9000-3 clearly refers to coding (implementing the design) and producing a test-ready product:

- The activities should be carried out in a disciplined manner.
- Rules and standards (e.g., coding standards, language choice) should be specified and observed.
- Methods and tools should be appropriate to satisfy user requirements.
- The product of the coding phase should be subject to review.

The software development method and approach proposed for the implementation phase, including the subsequent validation phase, is therefore in full compliance with the relevant **ISO 9000-3** requirements.

As a much more comprehensive and detailed document, ESA PSS-05-0 Issue 2, February 1991, the ESA SOFTWARE ENGINEERING STANDARDS ISSUE 2 (The CEO's chosen Software Engineering Standard Document), prepared by: ESA Board for Software Standardization and Control (BSSC), are consulted for detailed guidance.

#### 4.1.4 System Components: OOD

The main components of the system can be grouped into

- Objects (data) organised in a set of object oriented data bases (implemented in industry standard RDBMS) and
- Services (functions) that operate on these objects and produce derived information products.

An object oriented design (OOD) provides a wide range of concepts such as class/member relations (parent/child) and inheritance, dynamic instantiation and overloading (see Appendix B for details) that helps to efficiently structure the information content with minimal redundancy and describe the logical relationships between the elements. The simplest data model for a flexible object representation consists of triplets of the form

```
Object_ID, property_name, property_value
```

While this data model is very generic, and most appropriate for the interactive creation of new objects and their attributes, for very large data sets of complex (nested) queries in SQL (structured query language) it becomes inefficient, so that data tables with a predictably fixed structure can be implemented in a multi-column format with pre-defined column names and interpretation.

#### 4.1.5 Object Classes

The object classes that define the core of the information system content directly represent the real-world objects in the river basin. They also relate to the main elements of the core models like Nodes (including sub-catchments) and Reaches (river segments). A major feature (see “flexibility” above) is that the list of object classes is open, new classes and their list of attributes (and certainly new instances within a class and their attribute values) can be dynamically configured (data driven without any changes to the code) to guarantee an open data base structure and flexible interface for any and all optional third party components.

Typical examples of basic IWRM object classes that directly relate to the basic core of models include a set of geo-referenced classes:

- (sub)catchments or watersheds
- Aquifers, and associated springs (natural flow), wells, well fields (pumped);
- River segments or reaches, pipelines; (gravity flow or pumped) associated data are cross-sections, roughness (routing parameter) and rating curves.
- Reservoirs (natural lakes or with an-made storage dams) with their associated geometry
- Monitoring stations and associated time series of observations (hydrological, meteorological, combined); from the monitoring data, model input time series can be extracted, edited (e.g., scaled) and used in the models as named data sets as part of a model scenario.
- Hydraulic structures (weirs, confluences, …)
- Settlements, farms, irrigation districts, industries/enterprises, tourist resorts
- Water and waste-water treatment plants.

Generic (non-georeferenced) object classes include, for example:

- Crops (with their physiological and economic/yield data)
- Water technologies (the technical elements and their techno-economic data that make up the Interventions to generate alternatives for the DM process);
- Pollutants (and their model relevant attributes like solubility, partition coefficients, persistence, toxicity)
- Aquatic species, wetland fauna and flora
- Variables (attribute definitions with name, synonyms, display name, unit, legal value ranges and definition, explanation, questions in support of editing functions, modification dates, source, ownership/access class, et.c) and optional Rule references (see below) for dynamic instantiation (estimation by rule-based inference);
- Rules. First order production rules of the form

```
IF   condition
     [AND/OR condition]
THEN conclusion
```

  that can be used for inference with a simple backward chaining inference engine for the estimation of values from circumstantial (indirect) evidence, classification tasks, symbolic modelling, etc.)
- Problem and error reports, FAQ, manual pages
- User profiles, access information and privileges, access rights
- Distance learning resources (lectures, tests, evaluations)

Each of these classes maintains an open list of attributes that can be numerical, symbolic, or both (hybrid). Each class, and each instance (member such as a specific reservoir) is defined by the values of these attributes, where the structure (set of attributes) is inherited from the parent class. A special set (and TABLE in the data base) corresponds to the META data for each object and attribute; typical META DATA elements (like for any other attribute, the list is open and can be configured at the application level, data driven).

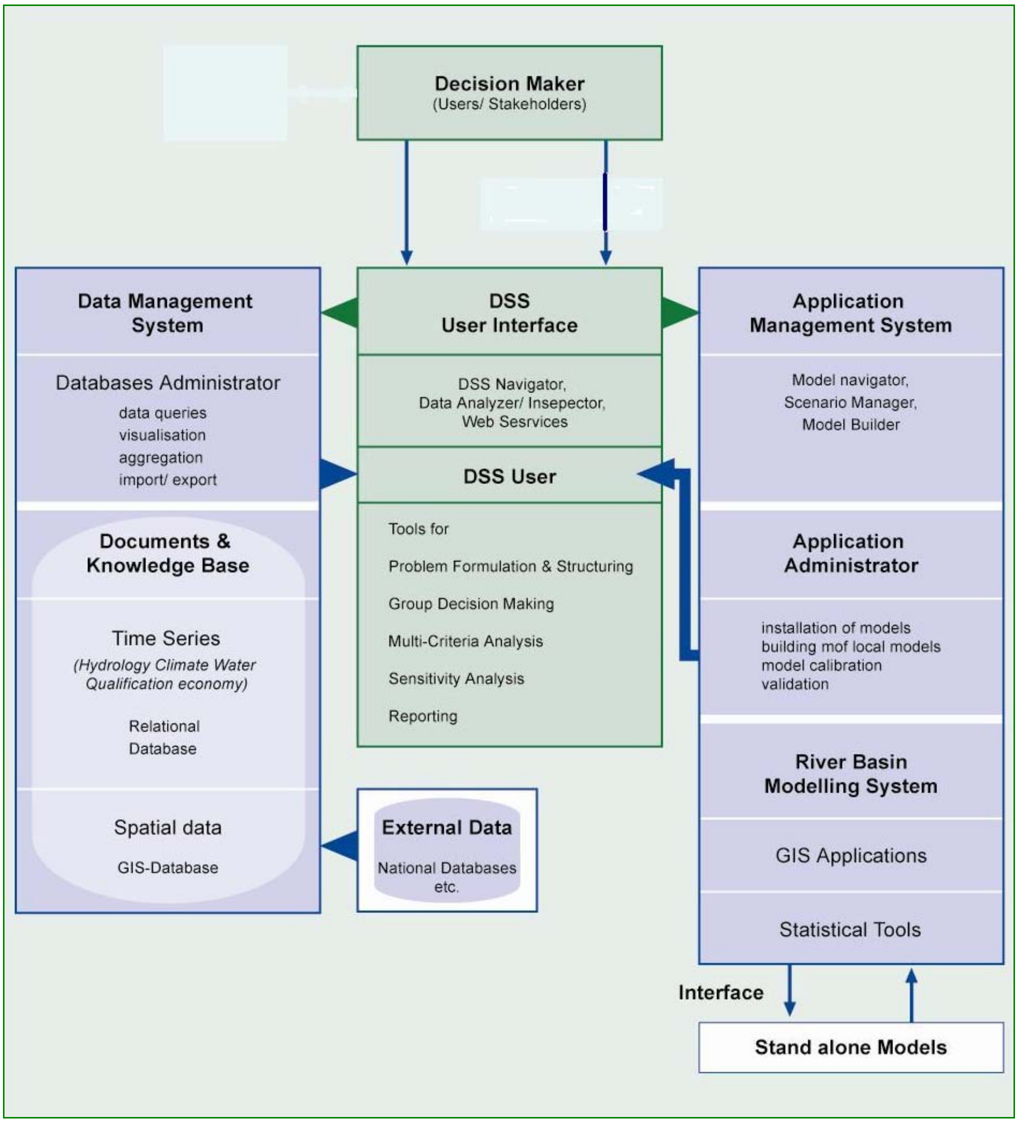
### 4.1.6 Components and Interactions

The basic components of the Nile-DSS (implemented as objects) can be grouped into three main function blocks, shown in figure 4.1 below:

- The **central DSS component** with tools for the structuring of the problems, elicitation of preferences, and the MCA, all designed to support a participatory decision making process;
- The **information system (data management system)** consisting of data bases and GIS that manage background information including reports, observation data including optionally real-time monitoring, and the model inputs, outputs and scenarios;
- The analytical **core of models** and tools with the two main sub-components, the fully integrated set of embedded models and tools that comprise the river basin modelling system, and a set of external models linked to this core for specific applications.

The primary communication between linked (cascading) models is through the shared data base: models results can be exported to the data base, model inputs can be retrieved from the data base. The management of the data sets including model scenarios (compound data sets that include (network) configuration information, model and scenario specific parameters, GIS data (fields) and numerous time series which are either derived from monitoring time series (observed or synthetically generated) or produced by other models or pre-processors.

**Figure 4.1** **The Basic Components of the Nile-DSS**



### 4.1.7 Connectivity, Communication, Protocols

The **Open Systems Interconnection Basic Reference Model** (OSI Reference Model or OSI Model ) define a layered, abstract description for communications and computer network protocol design. The OSI Model consists of seven layers, namely the Application, Presentation, Session, Transport, Network, Data Link, and Physical layers. Layer are collections of related functions that provides services to the layer above it and receive services from the layer below it, fully compatible with the (hierarchical) OOD paradigm introduced below. More recently, IETF (Internet Engineering Task Force) and , IEEE (Institute of Electrical and Electronics Engineers) have in part extended and superseded the original OSI model with many of the core protocols in use on the Internet today derived from the TCP/IP standard.

## 4.2 System Architecture

The proposed architecture is **Client-server** with http as primary communication protocol (Figure 4.2); server side tools include PHP and numerical models and tools in any language that can either

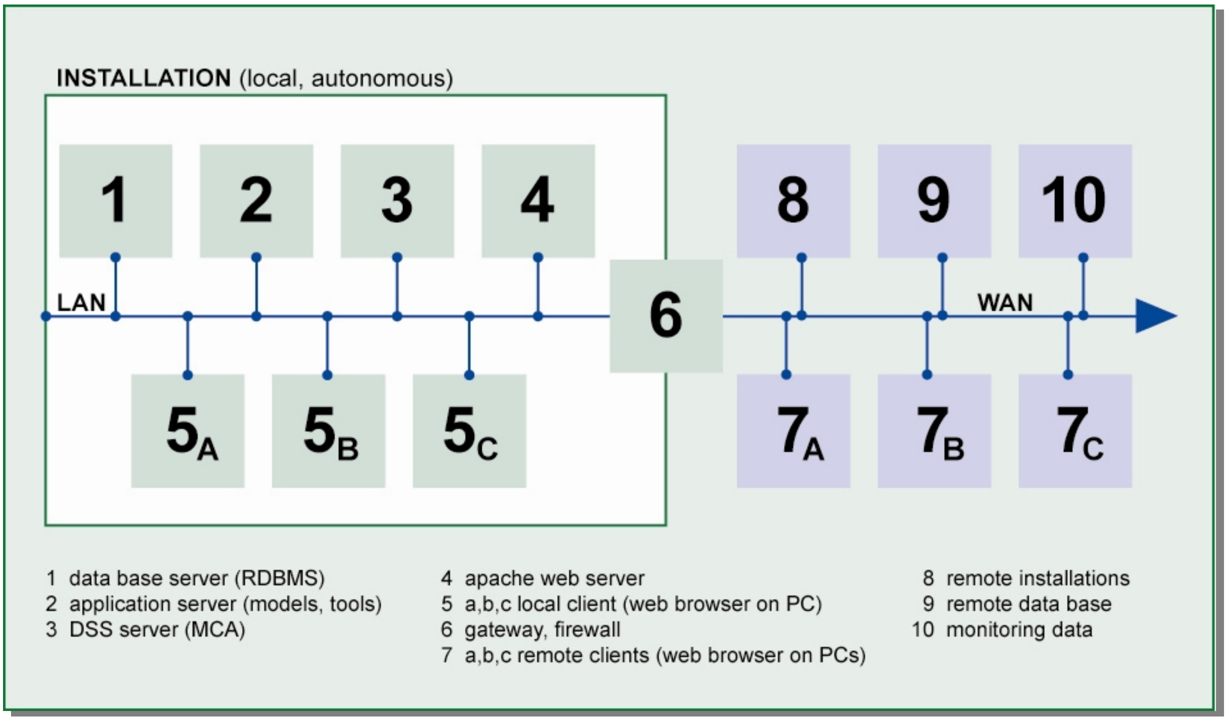
- Communicate with the **shared data bases through SQL**, including a blackboard (also implemented on the common RDBMS) for the coordination of interactive sessions in a multi-user environment);
- Generate HTML code for the client (standard PC with any standard web browser like MS Internet Explorer of Mozilla/Firefox), directly through cgis in C/C++ or PHP (server side); where appropriate, Java applets can be used for increased client side (graphic) interaction. Client pages in dynamic HTML include Javascript code for local interaction beyond HTML.

Use of standard PCs as clients facilitates integration of all Office (MS Office or OpenOffice) applications through **cut and paste** operations in addition to the possibility of **server-side integration** through:

- Data import/export in Office compatible formats such as CSV;
- Direct access of client-side applications to the SQL data bases with ODBC;
- Server side integration through standard interfaces, shared data base, cgi wrappers that execute third party (binary) code;

.

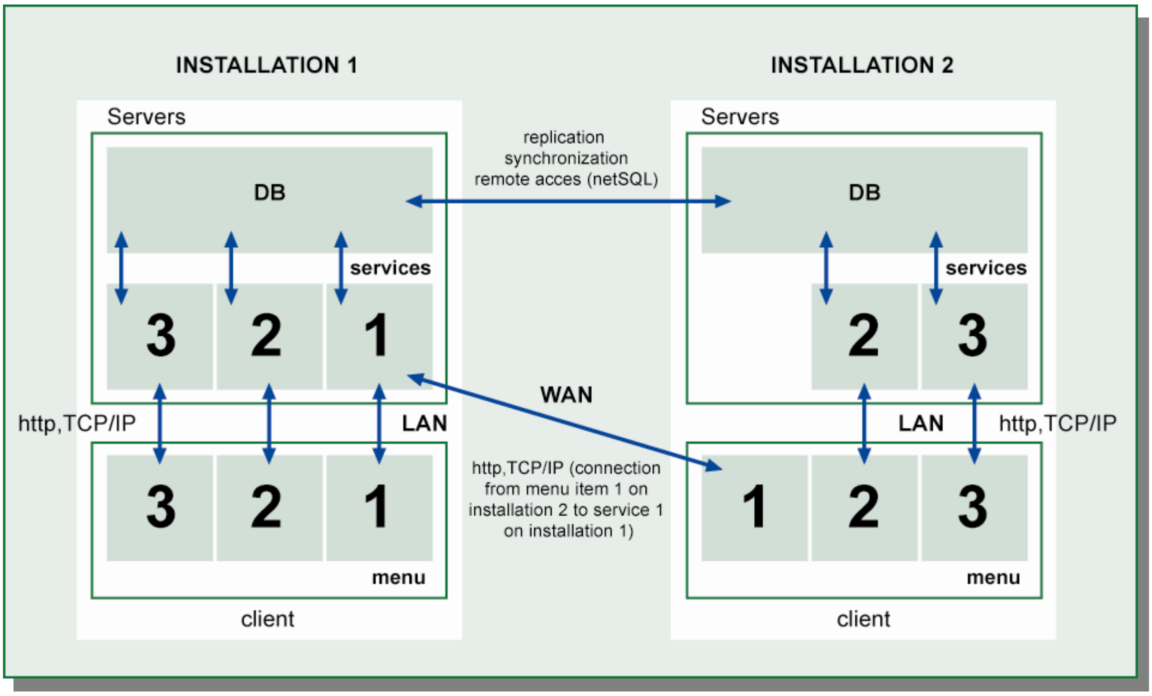
**Figure 4.2 A Web-based Client-Server Architecture**




Access to interactive application and their interfaces through embedded OS emulators like VMware (virtual machine and virtual server) that basically can provide a web-accessible multi-user Windows environment on any (platform) server including a local machine with a non MS operating system

All **information resources** in the system are defined as objects which provides for a unified management of data and functions (models, tools). They are identified by a URL (universal resource locator) so that they can be configured (data driven) on any installation and flexibly accessed from different location (Figure 4.3):

**Figure 4.3** **Optional Sharing of Services between Installations**

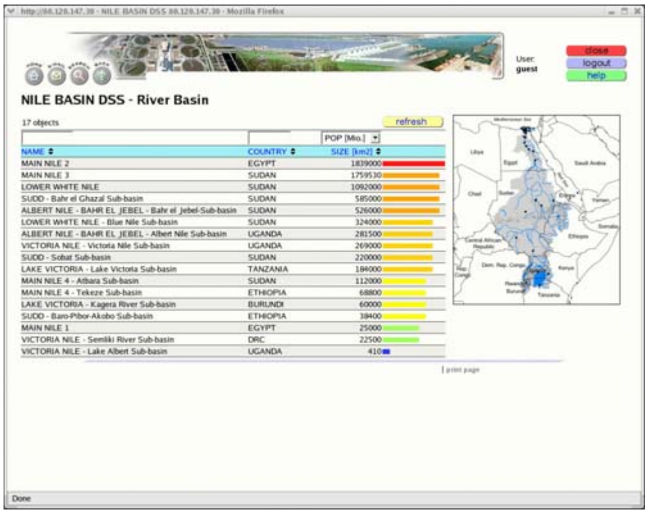


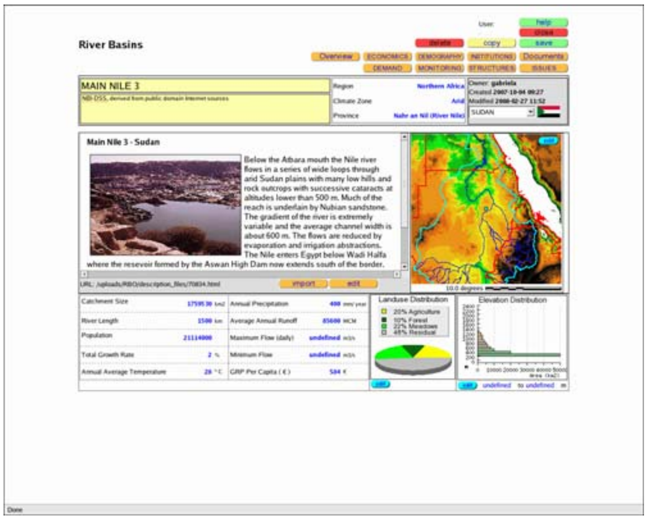

- The immediate local (stand alone) system that in this case operates as both server and client;
- A local area network (LAN Intranet) from a local database of web server;
- The Internet or WAN at any arbitrary (server) location that is network accessible.

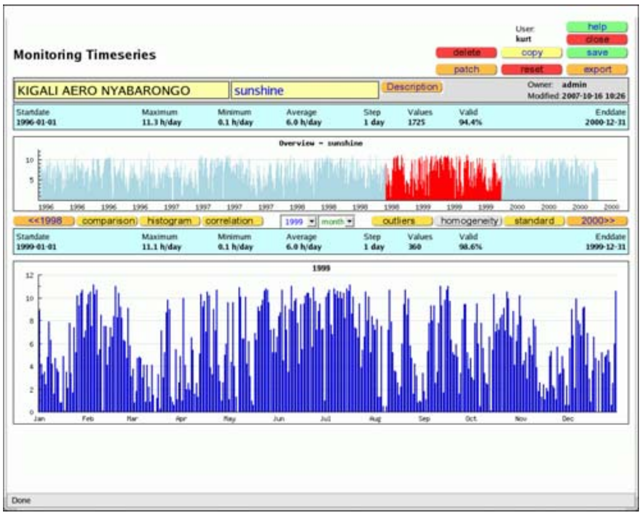
This basic **architecture meets all the basic design concepts** enumerated above. It can be implemented both as a local, stand alone system, as a central powerful server/cluster for remote access and use by any web client, or as any combination of local and remote (in possibly several locations) information resources, data sets and models. However, any one of the installations share exactly the same code (all or a clean subset), the only differences are in the configuration data that define the locations (URL) of individual information resources (local or remote).
The implementation uses a number of (logical) server than be implemented on one single or several (possibly distributed) CPUs in one or more computers (clusters); these logical or software servers include:

- Object data base server (any industry standard RDBMS supporting SQL);
- Web server such as Apache (platform independent)
- Application server consisting of a set of cgi (common gateway interface) programs for the individual models and tools.

## 4.3 Information Management System




The information management of the NB DSS is based primarily on a common data base, implementing and object oriented design (OOD) on any industry standard relational database management system (RDBMS, e.g., ORACLE, Sybase, MySQL, PostgreSQL).
The data base is used to

- Store all shared, common basin data, GIS layers, time series data, and links to the Document Management and Information System; a set of basic object to be represented and related to the water budget Model's network architecture is described above;
- Any local data sets beyond the common, shared core data.
- Model scenarios, parameters, model results; while primarily produced "locally" they can be exported for analysis at the next higher (sub-regional and basin wide) level, or provide inputs for any downstream scenarios;
- User management and access information and control;
- Coordination between cascading models and data within a given interactive session (maintaining multi-user capabilities) using a blackboard architecture.

### 4.3.1 Synchronization between Installations

The NB DSS is planned as a single, common shared software system and common data base, with software copies and data replica at the national level, at the regional level and at the basin level. This requires careful consideration of the synchronization of any updates and modifications using the following principles:

- Common data sets, once approved by an editorial process to be defined, are distributed as read-only from the central NBI installation to sub-regional and national, basin level systems;

- Local data sets can be freely added and edited, including model scenarios; for the systems can be remotely accessed, all data sets are strictly controlled by user/owner and group access privileges, i.e., read-only for any and all external/guest users; users (data owners) can freely determine access to their own data sets (data sharing).
- Any data or model scenarios/results that are to be included in the common approved, read-only shared data set have to be submitted to the next higher level for approval in an editorial peer review process before distributing them to all installations.
- Depending on the communication network capabilities, these synchronization tasks can be network based and fully automatic (updates are subject to the approval/acceptance of the respective local systems administrator) or by conventional distribution of electronic update media such as DVD.

## 4.4 River Basin Model System

The central modelling component is a dynamic water budget and linked water quality model including economic evaluation of the costs and benefits of water supply and use at different levels of temporal and spatial aggregation.

The central model uses a topological network representation of a river basin and any number of sub-basins or catchments, defined as NODES and REACHES (segments) (see Figures embedded in Chapter 4.4.1). Nodes and reaches are objects, their behaviour is described by data set from the information system, linked core models, and the basic dynamic water resources model itself.

The main advantage of the network representation is in its flexibility to adapt to arbitrary size catchment; possible strategies include the ability to integrate nested models in order to analyze the basin at different levels of detail in a given application. The management of cascading or nested models and their respective scenarios is based on the object-oriented design and implementation (see above). All components, i.e., models, (user specific) scenarios, and data sets (model inputs and outputs) are objects that share the same descriptive elements (Meta-data) so they can be visualised, selected, imported and exported between the functional components (models and analytical tools) including the MCA.

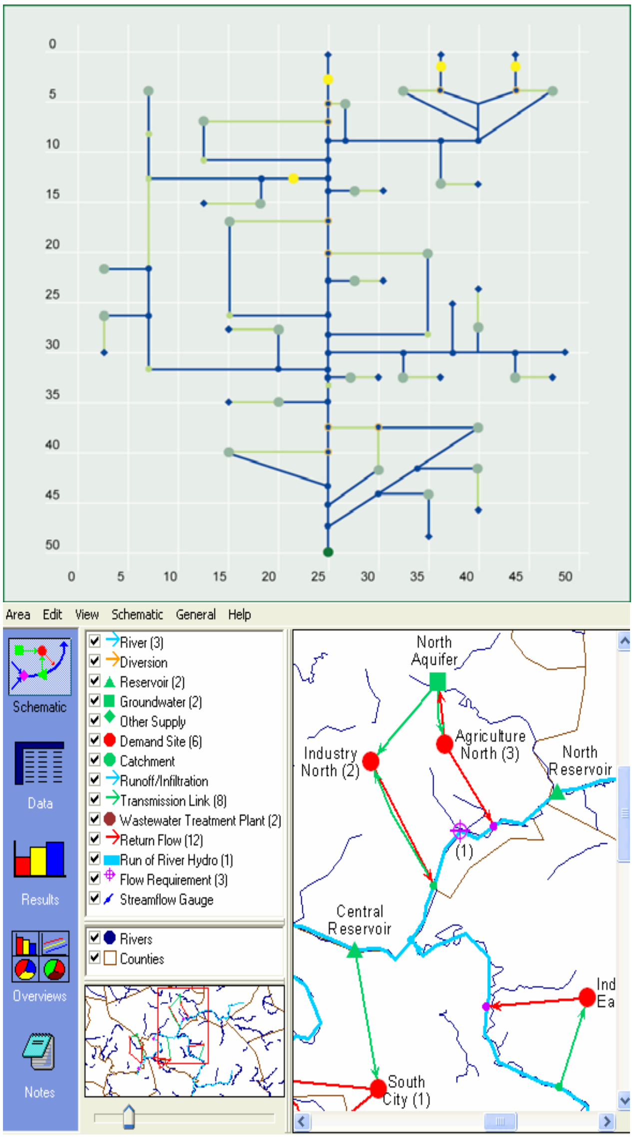
Model nesting: this refers to a method where the aggregated output from one model (application) of high resolution is used as the (point) input of another application of the same model with lower resolution but wider (spatial) coverage, i.e., a zooming in and out possibility to maintain both detail and coverage at workable levels over a large area. As an example, consider a detailed water budget mode of a sub-catchment represented by numerous nodes; the (aggregate) output (runoff) from that subcatchment can be introduced as a single (sub-catchment or start node) in a model of a larger downstream basin.

Cascading of models describes the linkage of different models, where, for example, the output from the rainfall-runoff model is used as an input to the water budget model.

Since NODES of the network are represented as objects, this provides the possibility to add new methods of analysis (within the existing modeling environment as (user selected) alternative methods to "instantiate" the objects in the current (scenario) context. Since in the proposed client-server architecture this can be done by reference to any (user defined and provided) URL, the system is open for any additional method that interacts with the base model through the shared data base.

### 4.4.1 Network Representation

While the detailed list of functional components that constitute a network representation of a river basin (dynamic water budget model) is adaptable, the list below provides some indicative examples and a minimal core of (object) components:




- Start or input nodes, that can represent
  - Sub-catchments (One more linked Hydrological Response Units, defined by time series of runoff which can in turn be generated by the linked rainfall-runoff model;
  - Desalination, water harvesting;
  - Springs, wells and well fields.
- Demand nodes, representing areas of water use:
  - Settlements
  - Agricultural use (irrigation districts, livestock farming)
  - Commercial and industrial uses
  - Wetlands
  - Associated (waste)water treatment plants
- Structural components:
  - Confluences
  - Abstractions or bifurcations
  - Dams and reservoirs (with multiple abstractions/outflow for multi-purpose use including hydropower production) or natural lakes;
  - Falls and cataracts (relevant for navigation and water quality)
  - Geometry node (for geo-referencing and diagram design)
- End nodes (outflow from the basin simulated)
- Reaches (open channel) and associated lateral catchments, floodplains, pipelines (supporting pumped flow and negative slopes)
- Aquifers (underlying any number of nodes and reaches that can interact by seepage, extraction, infiltration and exfiltration); groundwater recharge (artificial)

### 4.4.2 Embedded Models (Core)

The embedded models are directly linked to the dynamic water budget model; they can generate output directly used as input data for nodes in the network, or can be linked dynamically to represent dynamic node behaviour.

The set of tightly integrated models is implemented with a common (style) user interface, shared variable (including the criteria for the MCA) definitions, scenario management, and post-processing, directly and transparently coupled with

- The information system for the management of all model inputs, outputs, and scenarios;
- The DSS tools proper (MCA) for the ranking and selection of model generated alternatives (scenarios).

The minimal set of (initial) models that constitute the tightly integrated core of simulation tools will consist of the following components:

**Water resources network model including economic evaluation, reservoir management and hydropower generation**

The dynamic water resources network model with embedded **economic evaluation**, generating dynamic water budgets, demand/supply data for distributed and sectoral water use. This basic, main or core dynamic water budget model system includes a number of components as embedded process models such as **direct rainfall and evapotranspiration, routing** (open channel and pipelines, gravity flow and pumped), **confluence and diversions** (abstraction points) including the representation of alternative water allocation strategies, **storage and reservoir release, water use** and **interaction with groundwater** such as conveyance losses (evaporative and seepage at demand nodes) etc. These processes are transparently embedded with the model system and accessible through the menu driven interface system (the model manager, see below).

While a simple (mass budget) lumped or semi-distributed representation of groundwater coupling and interactions (conjunctive use scenarios, seepage, infiltration and exfiltration processes) must be included to complete the water budget approach more complex 3D groundwater flow and transport models can be linked as external components (see below). Aggregation to different geographical and administrative units (sub-catchments and riparian countries) as well as economic sectors is an important requirement.

Data requirements: The basic data requirements of the core dynamic water budget model are:

- Daily rainfall and temperature, daily flow data (optionally calculated for sub-catchments with the rainfall-runoff model
- Daily flow time series for all start nodes
- Daily water demand for all demand nodes, optionally computed for irrigation districts with the irrigation water demand estimation models
- Reservoir characteristics (geometry) and release rules
- Reach data (connectivity, basic geometry (minimally: length, average width and depth at mean flow, reach type or roughness; slope can be calculated from the node elevation and reach length).
- Techno-economic data for all structures and demand nodes, including annualized investment and operating costs, benefits from water demands satisfied including hydropower production benefits.
- Costs and benefits for compliance with or violations of constraints at the control nodes.

The basic dynamic water budget model includes reservoirs and multi-purpose reservoir management (represented by multiple, individually controlled abstractions or outflow) as well as hydropower production at a planning level (daily timestep with optional monthly aggregation).

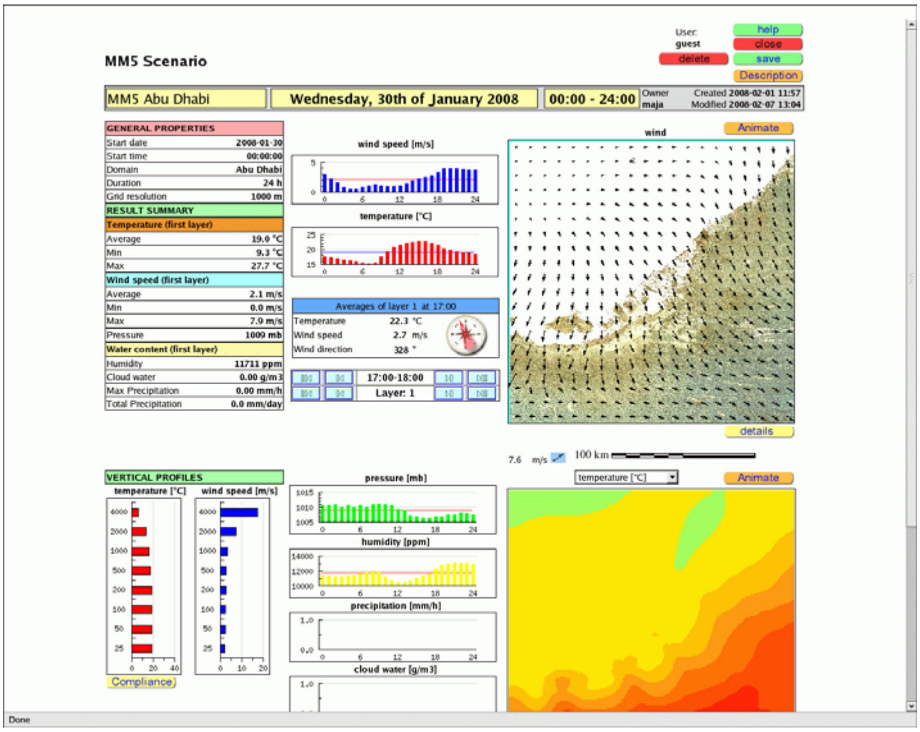
**Rainfall-runoff model**

Dynamic model that provides inputs to nodes representing sub-catchments, or lateral inflow to reaches. The model will include lumped, semi-distributed and gridded (GIS based) options. These inputs consist of one or more time series of flow; they also include estimates of **non-point source pollution** in particular **sediment erosion from upstream catchments**. The same modelling approach can be used to represent lateral inflow to the reaches of the primary network water resources model. In its embedded version, a lumped representation for each lateral catchment based on a runoff-coefficient and empirical methods like the Universal Soil Loss Equation (USLE) in its numerous variants can be used. A closely related topic here is **flood management**, prediction of flood plains and inundation areas. Relevant concepts include flood damage based on GIS overlay analysis with land use, and the extent of the flood plain, duration of the flooding; related aspects include inundation fisheries and agricultural use of the receding flood. This in turn is thematically linked with any specific wetland management simulation, see below. Operational real-time flood forecasting is beyond the scope of the basic model set (primarily due to the real-time data requirements) but can be linked through the external model integration strategies.

Data requirements: For each HRU (hydrological response unit): daily precipitation and temperature, elevation distribution, land use/land cover, soil characteristics, channel network, groundwater system (two-layer non-linear reservoir), observed flow for calibration.

**Meteorological pre-processor and models**

The required meteorological models generate distributed hydro-meteorological data or forecasts. These can be either a simple statistical method (distance weigthed averages, Thiessen polygons) While the basic geo-statistical tools for spatial interpolation are part of the core and covered by basic GIS functions, diagnostic and prognostic models will be part of the external models. Sharing the same data structures, they can be easily linked to the core data base and set of tools.




Data requirements: The data are either derived from observation stations (daily resolution

**Water quality model**

An associated network wide dynamic **water quality model** (DO/BOD, conservative tracers, first- and second order decaying substances) including basic **sediment transport** processes (turbidity, bank and bed erosion, siltation) that operates as a downstream model using the flow data from the water resources model; please note that the details of turbidity erosion (bank, bed) and sediment transport including (reservoir) siltation will require a dedicated external modelling approach with considerable data requirements.

Data requirements: Flow data are taken from the dynamic water budget model. Additional data include point sources of pollution (daily time series for each substance considered, associated with the demand nodes of the network representation).

**Irrigation water demand**

Irrigation water demand estimation/scheduling (provides input to nodes representing irrigation areas) and associated crop data (FAO CROPWAT or similar dynamic models based on crop specific water use).

Data requirements: These models require descriptions of the local meteorology (minimally temperature and precipitation, optionally wind, humidity, solar radiation for EVPT estimates; crop and soil data, irrigation technology, associated costs and benefits of production.

Within the basic DSS, **climate change** scenarios and their direct comparison can be based on alternative sets of adjusted hydro-meteorological input time series

### 4.4.3 External Models

The **specific (external) models** discussed in this section extend the basic river basin modelling functionality but are not directly required as "embedded" functions of the river basin simulation system. They can therefore be implemented either as specific developments (tightly coupled) or as third party external software solutions using any one of the integration methods described. The decision on the level of integration must be based on a careful analysis of stakeholder requirements, but also of considerations on costs and data availability. In many cases, a scientifically credible treatment of the problems and processes listed below will require some research and development effort, and dedicated data compilation.

These optional external models include:

- **Detailed reservoir management and optimization**, including specific tasks related to hydropower generation (e.g. hourly operational scheduling and control, power distribution systems). Please note that the basic planning level representation of reservoirs and hydropower production is already included with the core dynamic water budget model.
- **Urban/industrial water demand** (activity based including medium to long-term prediction capabilities based on growth rates for socio-economic driving forces), water distribution, sanitation;
- **Water and wastewater treatment**, related sewer systems, coupled to the river and lake/reservoir water quality models (see above). Treatment efficiency can be modelled as treatment technology specific removal efficiency by substance with a hydraulic constraint on treatment plant capacity.
- Near-field **water quality** downstream of major point sources such as major cities or wastewater treatment plants, also for highly transient (spill) events (e.g., flash floods in mining areas). Possible candidate model in the public domain that can easily be integrated with the network representation is the USGS BLTM (Branched Lagrangian Transport Model).

- **Groundwater flow and transport** model (e.g., 2D vertically integrated finite difference; complex 3D codes such as the “standard” MODFLOW can be considered as external third party codes, see below);
- **Lake (or reservoir) water quality**, nutrient cycle, primary production including algae and macrophytes (papyrus, water hyacinths), fish population dynamics, which would be the basis for any fisheries management models; they will require the integration of a semi-distributed or fully 3D hydrodynamic model with an ecological model which in turn could be linked to a model for (economic) fisheries management. One of the most attractive options here is the integration and use of the Lake Victoria Water Quality Model developed during the Lake Victoria Environmental Project I.
- **Wetlands**: while basically included in the main river basin model as a demand node (similar to an irrigation district) or a lake (but with increased evapo-transpiration rates due to intensive macrophyte vegetation) additional aspects and process for wetland management, e.g., linked to biodiversity, and embedded in a framework of socio-economic pressure, will warrant a specific wetland model. Due to the combination of complex biophysical processes with both ecological and socio-economic variables, a semi-quantitative approach such as cross-impact modelling (e.g., K-SIM) or generic model systems like STELLA could be used.
- Complex **meteorological pre-processors** (models): while basic statistical interpolation methods are part of the core, these include diagnostic (statistical pre-processors) or prognostic (non-hydrostatic) 3D dynamic models; in particular for the regional to local downscaling of global scale climate change models (based on IPCC scenarios), a 3D prognostic model (e.g., MM5, WRF) will be required, but can also be integrated as an external code or computational service (see below); the use of meteorological for medium term forecasts is related to the management of droughts, together with methods of alternative supply and demand management. Depending on the scale and time horizon, this is positioned between the interpretation of internal hydro-meteorological data fields and the more long term climate scenarios and impacts (see below). The input data can be derived as dynamic boundary conditions from global data sets (NOAA, global dataset from NCEP FNL on resolution 1°x1° with 6 hourly outputs), with the optional use of local monitoring data for data assimilation.
- **Climate change** impacts: this primarily involves the downscaling of global climate change (GCM) model results to regional and local scales. Using any one of the numerous CCM models that simulate the IPCC development scenario, their output will be used as initial and dynamic boundary conditions for prognostic (non-hydrostatic) hydro-meteorological model systems such as MM5 or WRF. They generate detailed fields of hydro-meteorological data that can drive the rainfall-runoff models and river basin modelling system described above.
- **Sediments** (erosion / sedimentation): Basic erosion and sediment transport processes will be included in the core model through semi-empirical models of catchment erosion and turbidity in the open channel flow (using a non-linear threshold equation for bank- and bed erosion and sedimentation including siltation of reservoirs). Detailed treatment of these processes will require external tools, including 3D hydromechanical modelling tools and detailed distributed GIS based modeling (based on any one of the extension of the USLE or one of the many non-point source pollution and erosion models such as ASNWERS, CREAM, etc)
- **Biodiversity** is of obvious concern in the Nile Basin. However, a realistic simulation of impacts of water resources development project on biodiversity is beyond the current state of the art in environmental modelling, beyond a simple relationship with ecological niches (defined by any or all of the state variables of the models listed, i.e., water budget elements and water quality) empirically related to individual species. Only qualitative approaches (see SIA/EIA below) seem feasible with the information available.

- **Impact assessment** (SIA, EIA): Strategic and Environmental Impact Assessment is a major tool for the analysis of water resources management projects, in fact mandated by most countries and all donor agencies. Support for at least screening level EIA based on checklists and linked to the data bases is a mandatory component. A range of typical methods and a rule-based approach using intelligent checklists (web-based) are described in the references below.
- **Regional development, demographics**. A final topic that covers the major socio-economic driving forces is regional development modelling, demographics, and input-output modelling; this can provide estimates on water demand as well as waste water generation tat directly feed into the water resources and water quality models. Again, a very wide range of possible model approaches and solutions exists, and will require a dedicated research and development effort.

### 4.4.4 Model Applicability by Basin

The Nile basin covers an extreme range of hydro-meteorological conditions. The models proposed, however, are all physically based and can thus be calibrated for this range of conditions, even though specific area like the Sud may require special adaptations of standard model constructs such as a linear reservoir model or open water (pan) evaporation estimates.


The range of applicability of the core models will be tested extensively during the pilot test application in the implementation phase with calibration and validation exercises against standard data sets. Where necessary, adaptations of the basic model representation will have to be developed to address non-standard conditions.

### 4.4.5 Model and Scenario Management and Interface

Wherever the results of one model can be used by another one, these results (mainly time series of hydro-meteorological variables, water supply and demand data, water quality data) they can be exported as a named data set (with automatically generated Meta-data) to the common data base. For the use of any downstream model, they are retrieved (multi-attribute ranking, filtering, and selection, parallel map display for georeferenced objects) from the data base by the common (model and scenario management) tools that organize the data and scenario objects. Examples of these links are:

- Hydro-meteorological time series (primarily temperature, precipitation) from the meteorological models (diagnostic pre-processor, prognostic forecasting model) to the rainfall-runoff, water resources, and irrigation water demand model;
- Time series of runoff from the semi-distributed rainfall-runoff model to the water resources model
- Water demand time series from the irrigation model to the water resources model
- Distributed pollution load and erosion from the catchment model to the water quality and water resources models
- Flow field (time series of flow for all network reaches) from the water resources model to the water quality model.

One important link is the automatic export of alternatives (summary of model results in terms of the user defined criteria) to the DSS tools (MCA). These alternatives can be generated individually by scenario analysis. Alternatively, simulation based multi-stage optimization tools can run the river basin model system with automatically generated parameter combinations (representing alternative sets of decision variables or instruments) using Monte Carlo simulation, adaptive heuristics, or genetic algorithms to generate large sets of alternatives. Feasible alternatives (meeting all a priori specified constraints) are then exported to the MCA tools for a second, participatory ranking and selection procedure.

There are numerous readily available software tools and models in the water resources management domain, both in the public domain and commercially. Any and all of them are candidates for integration if there is a well defined demand related to a specific problem that can not be covered by the embedded model system described above. Third part models and software and in particular commercial software that is only available in binary form, has its own interfaces and data formats. However, these tools can also be integrated and linked with the core models and the data bases with a variety of technologies, depending on their respective architecture and implementation platform.

Based on an open, standard interface definition for the data bases, the shared data base is used as a communication blackboard. External modules either conform to one of the standards supported such as such OpenMI or OpenGIS, will require a wrapper (cgi) to convert their data to the Nile-DSS data formats. Modules only available as executable code and have their own interface that is not web based can be run within a local window system or on a remote server (depending on model platform and server operating system) in native mode or through virtual machine (OS emulation) and virtual server technology.

## 4.5 Decision Support Tools (MCA)

### 4.5.1 Criteria to be considered

The NB DSS includes specific MCA tools. The main concern here is their integration with the simulation models, so that model generated alternatives can be exported for further processing the MCA automatically, transparently and error free.
The criteria to be considered must be computed by the core models, or easily derived from the model outputs. The criteria to be used with the MCA tools will be selected from an agreed upon master list of (a) bio-physical/environmental and (b) socio-economic criteria. Aspects of water quality, social and environmental components can be represented by defining benefits and costs (penalties) for meeting or exceeding reference value and standards at control nodes. An indicative example of an initial criteria list is given below:

**Bio-physical and environmental criteria:**

- **Supply/Demand ratio**: total ratio of all water supplied to demand nodes over the sum of demands; aggregated for the entire basin, sub-catchments, countries, or economic sectors.
- **Reliability of Supply**: the percentage of (daily) events summed of any and all demand nodes where the demand is being met; a user defined threshold of tolerance can be used.
- **Reservoir performance**: the percentage or ratio of schedules target release or storage level against the actual release or storage over time.
- **Diversion performance**: the percentage or ration of schedules target diversions or downstream constraints actual release diversions or abstractions over time.
- **Allocation efficiency**: ratio or percentage of the amount of water delivered and used versus the total allocation, which may be more (leading to a spill) or less (leading to shortfalls);
- **Water Shortfall**: sum of all allocation deficits.
- **Content Change**: annual water budget, percentage change over one water year as a percentage of the initial water content of the system.
- **Flooding days**: total number of days when flooding conditions (maximum flow constraints at selected control nodes) have been exceeded.
- **Flooding extent**: total area (floodplain) and time flooded for the above flood conditions.

**Socio-economic criteria:**

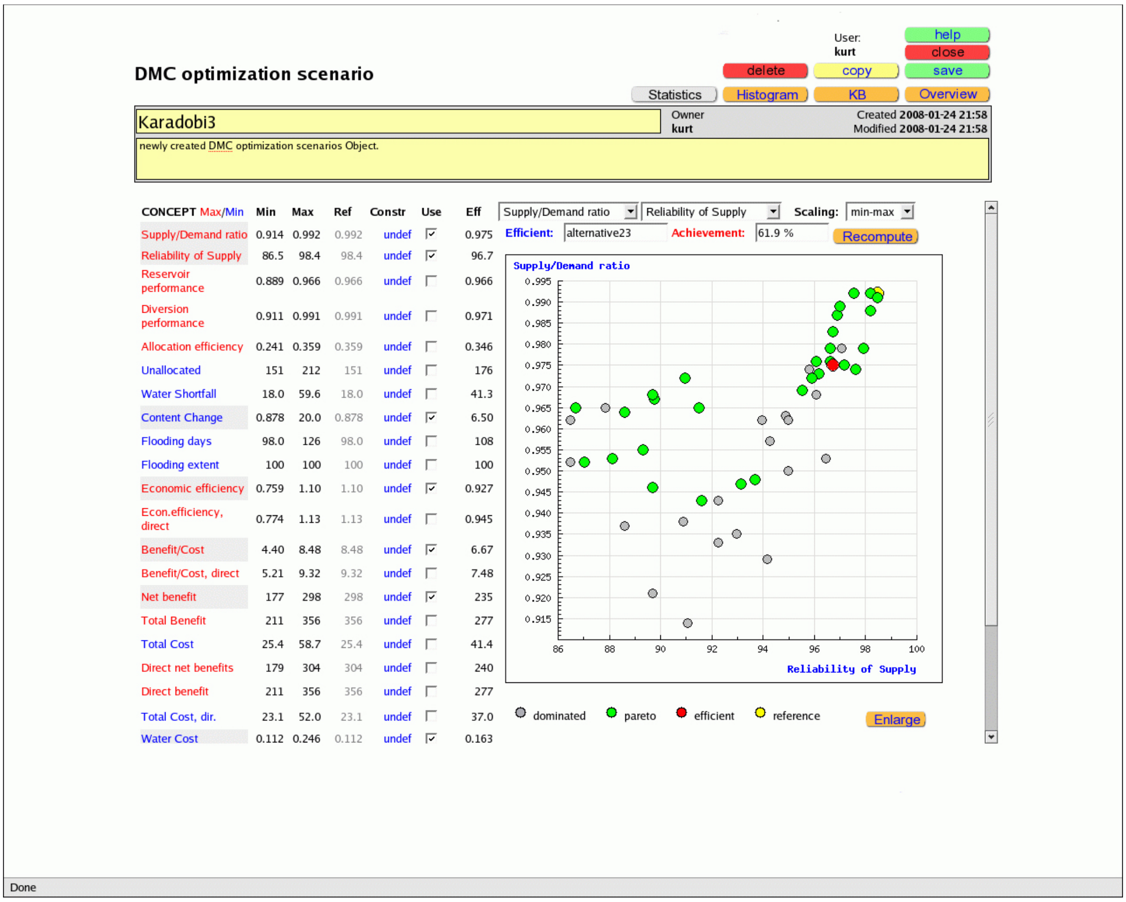
- **Economic efficiency**: total monetary benefit generated per unit water supplied to all demand nodes.
- **Benefit/cost ratio**: ratio of total benefits to total costs; can be computed both for direct (monetary) and including indirect (non-monetary benefits and penalties)
- **Net benefit**: total benefits (annual) per unit (entire basin, sub-catchments, country, economic sector), total or by country) minus total (annual) costs.
- **Total Benefit**: sum of all benefits over a one year run
- **Total Cost**: sum of all costs over a one year run; can be split into several cost components such as investment and capital costs, operating costs, indirect costs, damages, etc.

### 4.5.2 MCA Methods

A number of alternative MCA methods are described in the literature (see the references and selected Bibliography below). They maintain the necessary flexibility, and also support methodological pluralism, at least two methods that can be used efficiently independent on the number of alternatives and criteria are recommended for implementation:

- Basic decision matrix or Pugh Method (REF) with subjective, user defined weights on the criteria selected;
- Reference point methodology with automatic normalization between NADIR and UTOPIA, and implicit weights expressed by a preferred solution (reference point); the default reference point is UTOPIA (Figure 4.4)

**Figure 4.4** **Scattergram of Alternatives on two Criteria Axes, normalized between NADIR and UTOPIA, showing dominated (grey) and efficient Solutions (red)**




## 4.6 Linkages with other NBI Developments

*Quoted from: " Project Document, Eastern Nile Planning Model Project".*

The ENPM Project is very complex, involving the coordination of engineers, water managers, economists, sociologists, planners, computer scientists, etc. A primary requirement of the ENPM Project is to create an information management system that can deal with the data and information from these disparate disciplines and establish guidelines and procedures for storing, modeling with, and generating output from these data. Developing such an IMS, and ensuring that it is properly coordinated with and linked to the WRPMP's DSS will require particular care. The ENPM Modeling Office will liaise closely with WRPMP's DSS component. The ENPM database architecture and table definition will be closely coordinated with the DSS from the WRPMP system. The goal will be to ensure that the ENPM database emulates the design and structure of the DSS as much as possible. Maintaining consistency between the two databases will reduce duplication of effort, and allow for easier sharing of data. The ENPM IMS database will be designed also to reduce storage duplication between the two databases. DMIs will be developed to facilitate sharing and transfer of information and outputs between the two databases. The ENPM Modeling Office will work with the PMU for the WRPMP to explore ways to ultimately link the ENPM IMS with that of the DSS.

*Technical issues are at the heart of the ENPM Modeling System. These include:*

- *The ENPM knowledge base and models will be designed to be compatible with evolving concepts of the proposed Nile DSS.*
- *ENPM is one module of the NB DSS. The NB DSS has wider objective and focus. ENPM fits into NB DSS.*
- *ENPM is an investment-planning tool, not a full-scale DSS. ENPM could later grow into one of the components of DSS.*
- *Synergies between DSS Component and ENPM will be fully exploited and considered during the respective implementation phases to avoid duplication of efforts.*
- *ENPM's IMS will be a part of WRPMP's DSS.*
- *ENPM a part of DSS for institutional strengthening and training.*
- *ENPM and WRPMP both stress regional coordination and cooperation.*

The same strategy based on an open, modular architecture, shared data base, and a fully data driven implementation is also applicable to all other systems currently available or under development, such as the Mara river basin model, Kagera river basin model, Sio-Malaba - Malakisi basin model as well as the Lake Victoria Water Quality Model developed during the Lake Victoria Environmental Project I. These models and system can all be integrated through a shared data base (network accessible), common data formats and standards, and communcation protocols. These can either be built into the respective model implementations, or addressed by a set of model specific software wrappers that provide the necessary data translation and integration of the information flow and user interface.

# 5 Moving toward Implementation

The implementation of the NB DSS has to consider a number of constraints, primarily the very limited timeframe, but also the required participatory nature of the process. In consequence, the main elements of the implementation have to include:

- A rapid prototyping approach based on the adaptation and customization of existing software components, models and tools; a first operational prototype should be installed within one year of the implementation phase;
- Concurrent engineering, where different elements of the system can be developed in parallel, which requires a careful definition of all interface, data formats and protocols.
- A components based approach, where individual modules can be tested as fully functional tools in their own right to speed up development and testing.

## 5.1 Implementation Approach

The detailed description of the systems implementation plan and associated detailed technical specifications will be provided in a separate report (DSS Development Plan).

The procedure most appropriate for the implementation of the above architecture, but also a participatory approach with a maximum of user (stakeholder) involvement is rapid prototyping in a middle-out approach (e.g., Rumbaugh et al, 1991).

This aims at the development and test implementation of operational prototypes of the systems components starting with the very core as early as possible. This prototype is made available in pilot applications to all users, as a local copy and installation or over the web. User feedback from the initial users is collected and analyzed, and used for the next prototyping cycle. This guarantees that user specifications and requirements can be expressed efficiently in the concrete language the system itself provides. Rapid feedback enhances the users control, and ownership of and responsibility for the system as it develops with collective inputs. At the same time, early pilot applications that address local, sub-regional and common basin wide problems demonstrate the potential and benefits of the system, provide a common learning experience and on-the-job training opportunities,

The NBI-DSS technically consists of 12 or more installations of the same, common systems – 9 countries, 2 sub-regions and the NBI itself. On the one hand there is a hierarchical relation between these components, which would suggest a technical solution based on a centralised client / server architecture, with the NBI providing the more sophisticated components (e.g. database, GIS) to be used by its partners, with central administration, maintenance and development.

On the other hand there are several facts suggesting alternative solutions:

- Unpredictable quality of IT-connections (reliability, latency, bandwidth)
- demand for full-equipped systems on the national and sub-regional level for dealing with proprietary data
- complexity of managing the service of different system configurations
- decreasing costs of hard- and software components.

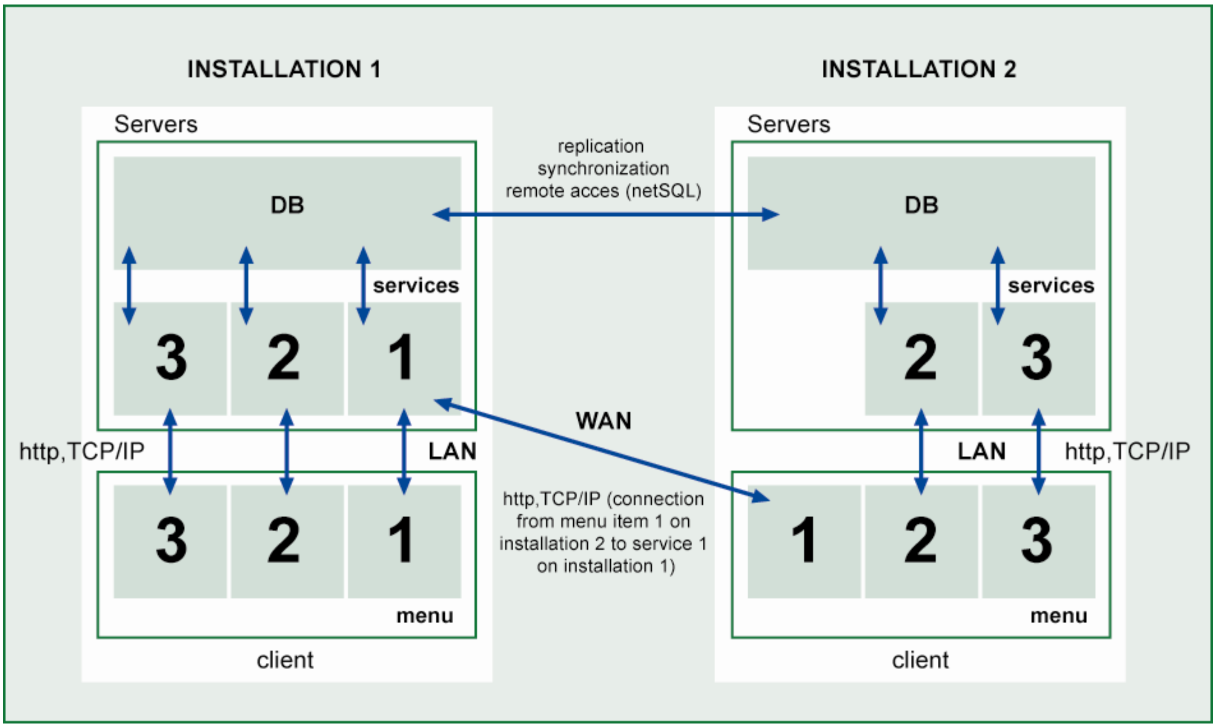
An alternative would therefore be to install 12 more or less identical systems at NBI, subregional and national levels. The principal configuration of these systems is shown below (figure 5.1).

However, to assure

- consistency concerning data, models and parameters throughout the NBI;
- quality control of NBI-wide used information; and
- general acceptance of NBI-DSS based decisions

these systems need a carefully replication, update and synchronization strategy based on a master-slave concept where the central server (at NBI) distributes any update.

**Figure 5.1** **Potential Configuration of Required Systems showing optional Linkages**




Sharing the same, identical client-server architecture, these systems can be operated as completely autonomous local systems, with data base (and optional software) updates from a central installation, or they can access any and all of the services from the central (or any other installation (Figure 5.1 above).

However, these requirements can better be met by one common system and a range of configuration options rather than by implementing different. The suggested workflow is shown below. The underlying principle is that there is a central master installation that at any time holds the one and only set of information (data, models, model parameters) valid for the whole NBI and this NBI-set is only distributed by the central NBI-DSS to the local installations.

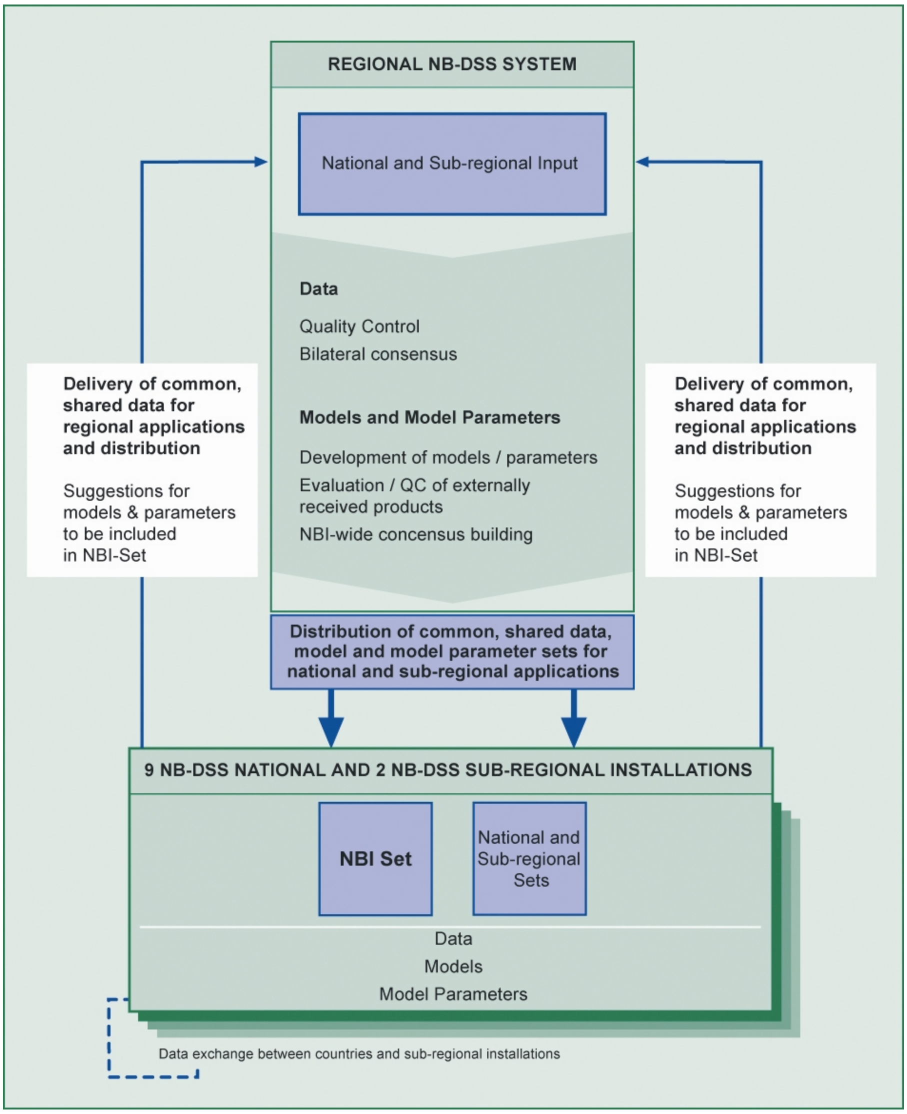
## 5.2 Data Flow, Exchange of Models and Model Parameters

The data of this common, central and authoritative NBI installation will be delivered mainly by the national authorities, but can also come from the sub-regions or maybe even the NBI itself, e.g., data obtained under the Data Sharing Protocol (under development). It will be the task of the NBI to check the quality (completeness, consistency, plausibility) of any data submitted with the tools of the data management system e.g., for statistical analysis including outlier detection, and reach consensus about necessary changes. Only quality assured data can then be made available for distribution/replication NBI-wide.

Models and tools can be developed by NBI staff, national authorities or external consultants. Again if they are meant to be used as "NBI-certified" they must go through an acceptance procedure at NBI. Again this implies an evaluation but also, and even more importantly, a NBI-wide consensus about the usage of these models and tools and any generic configurations must be achieved.

This work flow only applies to the shared and centrally common "NBI-set" of information. However the owners of the systems are free to use the whole potential of the DSS with other data, models or parameters for any other specific local purposes, applications and scenarios, based on the overloading principle of the underlying object oriented design.

**Figure 5.2** **Information Path: Distribution / Exchange of Data, Models and Applications**




All installations are structurally equivalent. They are identical in terms of their components, but can only use a clean subset of the master installation (at NBI).

Data bases include two major parts:

- shared, common content that is maintained at NBI and replicated, updated and distributed to all other installations;
- local content, that has the same structure, but is maintained at the local level.

Relevant parts of potential common interest of the local data content may be submitted to NBI for integration in the shared data base content.

## 5.3 Implementation Plan

The Implementation Plan for the Nile-DSS will be based on the Design principles and the Systems Architecture defined above. It will have to include a description of:

- **The Procedure.** A step by step guide to the process for using the method for design and implementation.
- **The Framework,** which refers to the set of available building blocks, the hardware and software environment used for the implementation.
- **Evaluation criteria**. The metrics, measures and design rules that are used to evaluate the design and implementation created using the procedure.
- **Notation and terminology** (ontology) providing a common, standard language and symbolism for the design and documentation process (such as UML, e.g., Albir 1998).

## 5.4 Risks

Risk in the implementation process are addressed in the implementation plan, they are primarily related to the long-term sustainability of the system in terms of licensing, documentation, support etc. Specific concerns include:

- Contractual possibilities of long-term support, maintenance, extended warranty beyond the basic project duration
- Access to source code for inspection, further development, under a non-disclosure agreement, as an “insurance” (put in escrow against consultant’s bankruptcy), etc.
- Integration of local staff in the development, consultants location versus on-the job-training for local staff.
- License requirements and possible constraints in distribution of software editions

These addressed primarily through the set of required features and criteria on the implementation plan and TOR.

While the use of Open Source tools may appear of great advantage, the integration of different models, tools, utilities into a well designed and consistent system with a common user interface is beyond the constraint of the time table specified (30 months).

Therefore, to start from a commercial product that meets the requirements of the core system and the overall open architecture as much as possible (according to the checklist of required and desirable features) it seems necessary, with additional developments to adapt to the specific NBI needs.

Maintaining open and well documented interfaces (as required) will make the future integration of Open Source tools easily possible; and (at least partial) access to the source code of any solution proposed for either future development or at least detailed documentation is one of the desirable features for the TOR.

## 5.5 Re-useable Components

The TOR has foreseen an overview of re-useable compoents to be used in te DSS design. However, as this would introduce very severe constraints on possible system configurations, as an alternative a list of desireable features of components of the system has been prepared that has been extracted from the set of known public domain components that could be integrated, subject to the main system framework, architecture, implementation platform etc, proposed by the successful bidder.

This list of required or desireable features is given in Appendix B2. These features are covered in more detail in the Implementation Plan and the contribution to the TOR for the system implementation.

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# Appendix B1

## Acronyms

| | |
|---|---|
| AHP | Analytic Hierarchy Process |
| BOD | Biological Oxygen Demand |
| BSSC | Board for Software Standardization and Control |
| CBA | Cost-Benefit Analysis |
| CBIS | Computer-based information systems |
| CCM | Community Climate Model |
| CMM | Cognitive Models and Metrics |
| COM | Council of Ministers |
| CPU | Central Processing Unit |
| CSV | Character Separated Values |
| CU | Coordinating Unit |
| DM | Decision Making |
| DO | Dissolved Oxygen |
| DPSIR | Driving forces, Pressures, States, Impacts and Responses |
| DSS | Decision Support System |
| EIA | Environmental Impact Assessment |
| EIS | Executive Information System |
| ELECTRE | Elimination et choix traduisant la réalité |
| ENCOM | Eastern Nile Council of Ministers |
| ENPM | Eastern Nile Planning Model |
| ENSAP | Eastern Nile Subsidiary Action Programme |
| ENTRO | Eastern Nile Technical Regional Office |
| ESA | European Space Agency |
| FAO | Food and Agriculture Organization |
| FAQ | Frequently Asked Questions |
| GCM | Global Climate Change Model |
| GDP | Gross Domestic Product |
| GIS | Geographic Information System |
| GRIB | GRIdded Binary |
| GUI | Graphical User Interface |
| HPCN | High Performance Computing and Networking |
| HTML | Hypertext Markup Language |
| ICT | Interactive Computer Technology |
| IEEE | Institute of Electrical and Electronics Engineers |
| IETF | Internet Engineering Task Force |
| IMS | Information System |
| IPCC | Intergovernmental Panel on Climate Change |
| ISO | International Standards Organization |

| | |
|---|---|
| IWRM | Integrated Water Resource Management |
| LAN | Local Area Network |
| M&S | Mathematical and Statistical |
| MAV | Multi Attribute Value |
| MCA | Multi-Criteria Analysis |
| MCAS | Multi-Criteria Analysis System |
| MIS | Management Information System |
| MM5 | Meteorology Model 5 |
| NB | Nile Basin |
| NBI | Nile Basin Initiative |
| NELCOM | Nile Council of Ministers |
| NELSAP | Nile Equatorial Lakes Subsidiary Action Programme |
| NGO | Non Governmental Organization |
| ODBC | Open Database Connectivity |
| OLAP | On-line Analytical Processing |
| OMT | Object Modelling Technique |
| OOD | Object Oriented Design |
| OpenMI | Open Modeling Interface and Environment |
| OR | Operations Research |
| OS | Open Source |
| OSI | Open Systems Interconnection |
| PIP | Participatory and Integrated Planning Procedure |
| PROACT | Problem, Objectives, Alternatives, Consequences and Tradeoffs |
| PSM | Problem Structuring Methods |
| RBMS | River Basin Modelling System |
| RDBMS | Relational Data Base Management |
| SIA | Strategic Impact Assessment |
| SOAP | Simple Object Access Protocol |
| SODA | Symbolic Optimum Deuce Assembly Program |
| SQL | Structured Query Language |
| SSM | Soft System Methodology |
| SVP | Shared Vision Programme |
| TAC | Technical Advisory Committee |
| TCP/IP | Transmission Control Protocol/Internet Protocol |
| TOR | Terms of Reference |
| UML | Unified Modeling Language |
| UPS | Uninterruptible Power Supply |
| URL | Uniform Resource Locator |
| USLE | Universal Soil Loss Equation |
| VM | Virtual Machine |
| WAN | Wide Area Network |
| WRF | Weather Research and Forecasting |
| WRM | Water Resource Management |
| XML | Extensible Markup Language |
| XPath | XML Path Language |
| XSLT | Extensible Stylesheet Language Transformations |

# Appendix B2

## Required and Desirable Features

This is a preliminary checklist of required and desirable features:

- **R**: required features
- **D**: desirable features

Please note: The classification in required and desirable features needs careful consideration by the client. It is unlikely that any available solution will meet all required features as listed here. The DSS Development Plan (with Implementation ToR) will provide further details and suggestions on the evaluation methodology.

| **Requirements and feature description (R: required; D**: desireable**)** | |
|---|---|
| **General, administrative requirements** | |
| **R** | Guarantee (> 12 months) , continuing support, maintenance options |
| **R** | Help desk (mail/web based) and error logging |
| D | Licensing scheme: unlimited institutional license within NBI |
| D | Source code access |
| **Implementation, architecture** | |
| **R** | Implementation platform (platform independent), |
| **R** | Client-server implementation |
| **R** | Web-based access (clients) |
| **R** | Modular implementation (easy exchange through standard interfaces) |
| **R** | Multi-level user access control, loging/monitoring |
| D | Operating system support (Open source) |
| D | Backup tools (embedded) and strategy |
| D | Modern coding style and languages (OOD, structured programming, C++) |
| **Documentation** | |
| **R** | User manuals (hypermedia and hardcopy): user, reference. Programmer's |
| D | Tutorial material, test data sets and example results |
| **User interface** | |
| **R** | Interactive, menu driven graphical |
| **R** | Web browser support |
| D | Multi-language support (English, French, Arabic) |
| **General utilities and tools** | |
| **R** | Model scenario management (common META data, search, retrieval) |
| **R** | Embedded calibration methods, error statistics |
| D | Direct scenario comparison |
| D | Sensitivity analysis |
| D | Stochastic modeling |
| D | Simulation based optimization (automatic scenario generation) |

| | |
|---|---|
| **Information Management System, RDBMS** | |
| **R** | Database protocol/interface: SQL |
| **R** | Datamodel description explicit |
| **R** | Standard META data model (e.g., Dublin core) |
| **R** | User defined report generation |
| D | Database type: object oriented |
| D | Database design, documented Entity-Relationship model |
| D | Use of database normalization forms |
| D | OLAP support |
| **Data analysis** | |
| **R** | Embedded statistical methods and tools, external link/compatibility |
| **R** | Time series analysis tools, synthetic TS generation |
| D | Data quality assurance tools (patching, outlier detection) |
| D | Spatial analysis, interpolation (GIS links) |
| **Embedded GIS functionality** | |
| **R** | Support of industry standard formats |
| **R** | Data exchange, compatibility, OpenGIS compatibility |
| D | RS support, satellite image processing |
| **Dynamic Water Budget Model** | |
| **R** | Data driven, interactive network configuration |
| **R** | Geo-referenced network geometry |
| **R** | Temporal scope and time step: hourly to monthly, multiple years |
| **R** | Explicit mass budget, error statistics |
| **R** | Explicit groundwater representation, coupling |
| **R** | Reservoirs with multiple outlets, hydropower generation |
| **R** | Variable reach geometry, support for rating curve/ flow data conversion |
| D | Open (user defined) list of node types |
| D | Model nesting, hierarchical linkage of networks |
| D | Economic valuation of structures, supply/demand balance |
| D | Lateral inflow, lateral catchments, floodplain representation |
| D | User defined reports, data export (CSV) |
| D | Yield analysis for reservoirs and catchments |
| **Hydrological processes** | |
| **R** | 1D hydraulic models |
| D | Multiple routing methods (data dependent) |
| D | Multiple EVTP estimation methods (data dependent) |
| D | Support for defined process representation/algorithms |
| **Core process models (liked to the water budget model)** | |
| **R** | Meteorological pre-processor: statistical |
| **R** | Rainfall-runoff models (lumped, semi-distributed) |
| **R** | Irrigation water demand estimation, crop production model |
| **R** | Water quality model (DO/BOD, conservative, decay, sediments |
| **R** | Erosion modelling: catchment, river bank and bed, transport/siltation |
| D | Rainfall-runoff model: fully distributed |
| D | Meteorological pre-processor: diagnostic |
| D | Meteorological pre-processor: prognostic |

| | |
|---|---|
| D | Meteorological modelling\|: GCM downscaling, CC scenarios |
| D | Cost-Benefit analysis (basin wide, by sector, by country) |
| **MCA, DSS tools** | |
| **R** | Multiple MCA methods (minimally: Pugh and Reference Point) |
| **R** | User defined open list of criteria |
| **R** | Automatic model linkage (alternative and criteria export) |
| D | Support for participatory decision making |
| D | Support for group decision making |
| D | Preference structure sensitivity analysis |

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