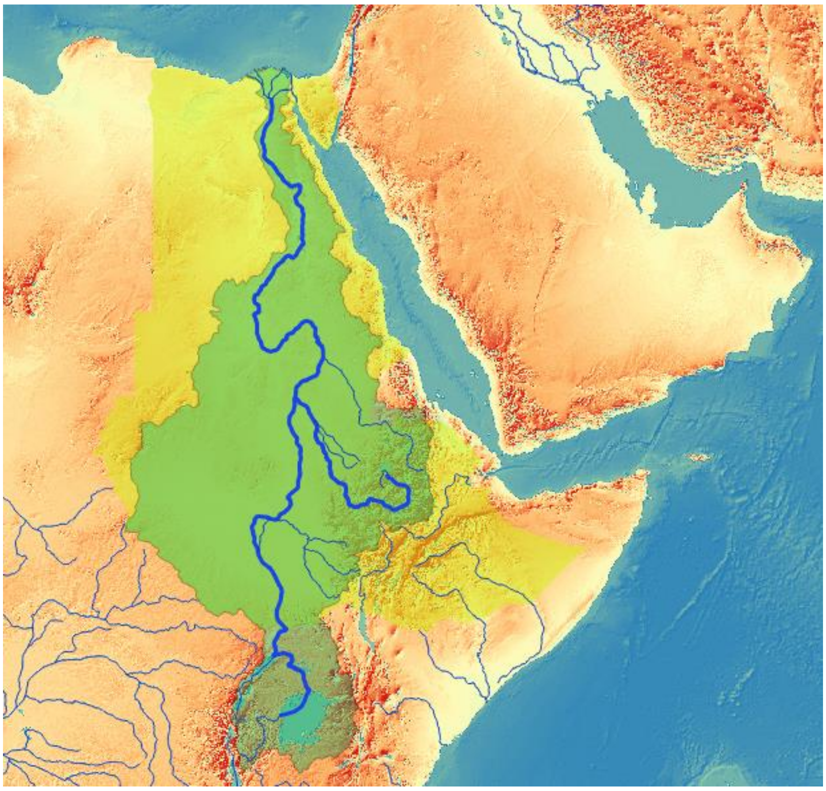
Roadmap



Nile Basin Initiative (NBI)
Eastern Nile Technical Regional Office (ENTRO)
Nile Cooperation for Results Project (NCORE)

Project Number	-
Project Name	Roadmap for Coordinated Operation of Transboundary Cascade Dams in Eastern Nile
Project Country	Egypt, Ethiopia, South-Sudan, Sudan
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List of Abbreviations

AfDB	African Development Bank
BCM	Billion Cubicmeter
CAR	Central Asia Region
CIWA	Cooperation in International Waters in Africa
DIU	Dam Implementation Unit
DRM	Disaster Risk Management
DSS	Decision Support System
EEP	Ethiopian Electric Power
EIA	Environmental Impact Assessment
ENDOC	Eastern Nile Dam Operation Capacity Building Centre
ENRES	Eastern Nile Reservoir System
ENTRO	Eastern Nile Technical Regional Office
EPC	Engineering, Procurement and Construction
EPP	Emergency Preparedness Plan
ESIA	Environmental and Social Impact Assessment
ESMP	Environmental and Social Management Plans
ESTAC	Ethiopian Sudan Technical Advisory Committee
FAO	Food and Agriculture Organisation
GERD	Grand Ethiopian Renaissance Dam
GoSS	Government of South Sudan
HAD	High Aswan Dam
HADA	High Aswan Dam Authority
HCB	Hydropower Plant Cabora Bassa
HEC-HMS	Hydrologic Engineering Centre Hydrologic Modelling System
HEC-ResSim	Hydrologic Engineering Centre Reservoir simulation model
HRC	Hydraulic Research Centre
ICU	Interim Coordination Unit
ICWC	Interstate Commission for Water Coordination
IWRM	Integrated Water Resources Management
LDC	Load Dispatch Centre
MAARI	Ministries of Agriculture, Animal Resources and Irrigation
MAFRARF	Ministry of Agriculture, Forestry, Tourism, Animal Resources and Fisheries
MCM	Million Cubicmeter
MEDIWR	Ministry of Electricity, Dams, Irrigation and Water Resources
MLHPP	Ministry of Lands, Housing and Physical Planning
MoWIE	Ministry of Water Resources
MRC	Mekong River Commission
MWIE	Ministry of Water Resources, Irrigation and Electricity
MWRI	Ministry of Water Resources and Irrigation
NBI	Nile Basin Initiative
NCORE	Nile Cooperation for Results
NCWR	National Council for Water Resources
NELSAP	Nile Equatorial Lakes Subsidiary Action Program
NELSAP-CU	Nile Equatorial Lakes Subsidiary Action Program Coordination Unit

NILE-SEC	Nile Secretariat
NMA	National Meteorological Agencies
NWRC	National Water Research Centre
RIBASIM	River Basin Simulation Model
SCADA	Supervisory Control and Data Acquisition
SMA	Sudan Meteorological Authority
SSUWC	South Sudan Urban Water Coordination
SWAT	Soil and Water Assessment Tool
Talsim-NG	Talsperrensimulation (River Basin Modelling) Next Generation
TWRO	Technical Water Resources Organ
UNECE	United Nations Economic Commission for Europe
USAID	U.S. Agency for International Development)

Roadmap

Document Information

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1 EXECUTIVE SUMMARY

This document presents a Roadmap for a framework on coordinated operation of reservoirs in the Eastern Nile region. The Roadmap was prepared based on results of the Situational and Gap Analyses plus considerations arising from international practices and experience in the field of cascade reservoir operations. It includes results from the consultation workshop held in Khartoum from November 22 to November 24, 2016. The roadmap was developed to ensure consistency with existing tools and frameworks which have been developed by Nile-Sec. or ENTRO in the past.

SITUATIONAL ANALYSIS AND GAP ANALYSIS

The Situational Analysis grounded on interviews and site visits in Ethiopia and Sudan backed by information from ENTRO, Nile-Sec and a literature review. Current institutional settings with the focus on reservoir operation were assessed, monitoring at dam sites and operation policies were compiled.

Desired or future objectives were defined and compared to the present situation in order to derive gaps. The Gap Analysis revealed issues concerning institutional as well as technical aspects. The main issues identified are:

- Regulations concerning evaluation, approval and review of reservoir operation are not existing
- Qualification and training of staff lacks clear regulations and procedures
- Supervision of reservoir operation is not clearly defined
- Cross-sectoral effects of reservoir operation are not assessed with the consequence that adverse impacts from operation of dams are not necessarily associated with reservoir operation
- Upstream-downstream data exchange to be used for operation is non-existent
- Data monitored at dam sites are not fully consumed for evaluation
- Coordination between cascade dams across borders does not exist

Impacts of reservoirs in the Eastern Nile Region on the hydrologic regime are huge and will increase in the future. The fact that effects and cross-cutting impacts of reservoir operation are not yet completely assessed and not included in considerations of operation poses a real risk. In conclusion, the need to identify impacts of reservoir operation and to fill the gaps accordingly is crucial.

INTERNATIONAL EXAMPLES

International examples were selected with various specifications in terms of coordinated operation of water infrastructure. The examples were chosen to demonstrate different levels of coordination ranging from exchange of data and information for decision-making up to an operational unit which bears the responsibility to operate water facilities in different countries. Examples were taken from the Mekong Region, Central Asia, Europe and Africa.

The evaluation of international examples confirmed the necessity to advance towards coordinated reservoir operation. In essence, the international examples show joint activities in the field of

- Capacity building and training
- Data sharing and generating joint data management systems
- Harmonised regulations concerning training, data exchange, even procurement
- Benefit sharing options and coordinated operation at different levels

Data sharing is considered as mandatory to create momentum. Cross-sectoral assessments are considered as unconditionally necessary when impacts of large dams are expected to have far-reaching consequences, in particular with an increasing number of dams or within a multipurpose reservoir system.

PROCESS FOR DEVELOPING COORDINATED OPERATION OF CASCADE DAMS

There is evidence that institutional aspects and governance progress slower than technical issues and thus can impede technical development, especially in regard to coordinated cascade reservoir management with a long tradition of controversial discussions. Hence, a technical framework should be developed first with a minimal institutional setup.

As a result, the guiding principle for developing the Roadmap is to create a minimal institutional structure to enable a technical framework. Such an approach of fostering a technical framework originates from experience and is recommended in [GWP (2012)]. Successful examples applying similar methodologies can be found in various UNECE guided projects [UNECE (2013)]. Working on technical aspects first often creates a momentum which can positively stimulate further effort to extend the institutional framework.

It is recommended to establish an Interim Coordination Unit (ICU) hosted by ENTRO. This unit should consist of members from all four countries and oversees and coordinates the development of coordinated operation of reservoirs. ICU is regarded as the voice of coordinated operation of dams and accompanies the technical framework.

Preparatory phase

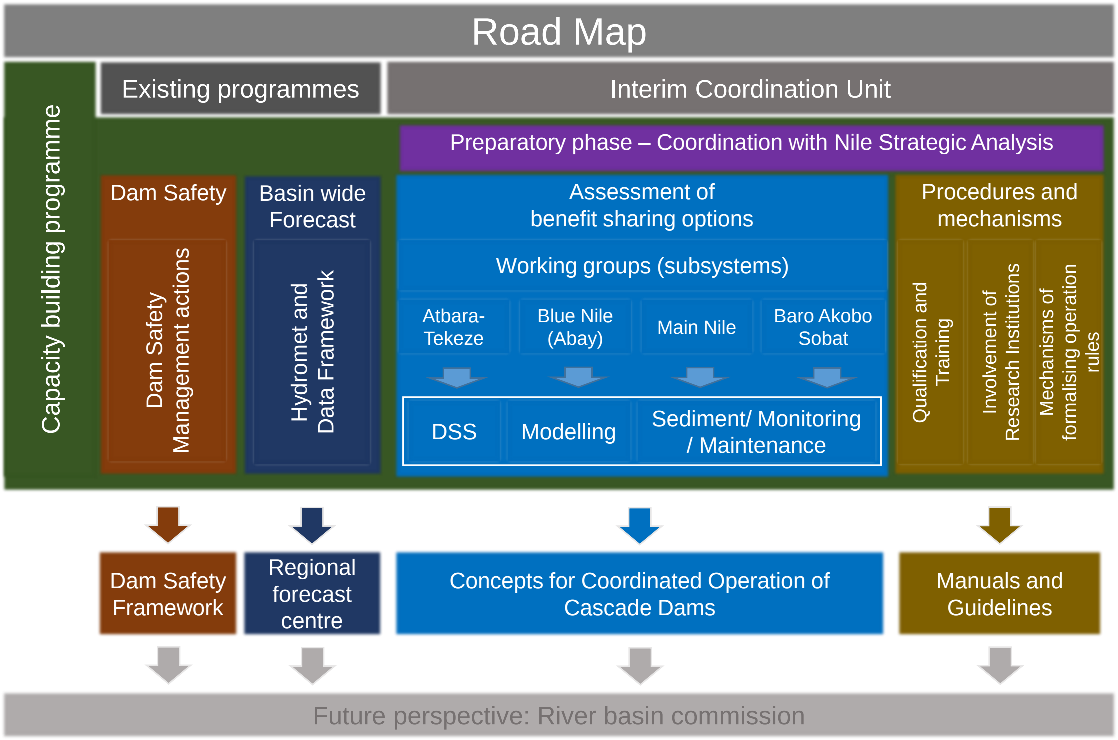
The Nile-Sec has conducted the Strategic Water Resources Analysis for the whole Nile River Basin. Phase I of the analysis dealt with establishing current (baseline) water demands and water use in the Nile Basin and was concluded in July 2016. Results demonstrated that there are risks that the growing water demands in the Nile Basin can surpass the available water. One of the options identified as a sustainable countermeasure was coordinated operation of storage reservoirs.

By introducing a preparatory phase into the process of advancing towards coordinated operation of reservoirs, the Roadmap and the Nile Strategic Analysis can be aligned and can benefit from each other. Scenarios with cascade reservoir operation could be combined with the baseline data from the Strategic Water Resources Analysis. Results could be presented in a visioning and scenarios construction workshop envisaged in June 2017. Options, benefits and risks of cascade dam operation could be demonstrated to the riparian countries by means of examples backed by cascade reservoir modelling. Apart from the advantage to make use of already compiled data, this also would meet the request of the riparian countries expressed during the consultation workshop in Khartoum in November 2016.

Pillars of the Roadmap

The concept of the Roadmap is based on four pillars:

- Procedures and mechanisms for harmonising reservoir operation
- Assessment of benefit sharing options leading to concepts for coordinated operation of dams
- Basin wide forecast as continuation of the Hydromet system which is in preparation by Nile-Sec
- Continuation of the Dam Safety programme to establish harmonised Dam Safety Management Regulations



Each pillar has clear goals which are:

- Procedures and mechanisms for harmonising reservoir operation
  This includes the development of common procedures and mechanisms for qualification, training and operation rules.
- Assessment of benefit sharing options
  The assessment of benefit sharing options demonstrates advantages arising from coordination but also consequences and risks if no coordination takes place in the future. The existing Decision-Support System developed by Nile-Sec. would be the ideal modelling framework.

The forecast and dam safety pillars are suggested as accompanying processes supporting the coordinated operation.

- Basin-wide forecast system
  The long-term goal of the Hydromet system and data framework pillar is to establish a Regional Forecast Unit. Short- and long-range forecasts are clear benefits for dam operation but also for other stakeholders and sectors, for example the agriculture sector. Thus, this pillar goes beyond the coordinated operation. The design for a basin-wide Hydromet systems has been prepared and first phase implementation is planned to start in 2017 so that the suggestions given in the Roadmap would supplement the process. Furthermore, the Flood Early Warning application at ENTRO could be taken up as starting point.
- Dam Safety
  In the long run dam safety procedures should arrive at a harmonised dam safety framework. This pillar is a direct follow-up of the draft Regional Dam Safety Framework. It complements the Regional Dam Safety Framework as it recommends also dam break studies, notification procedures, transnational inundation maps and joint preventive actions in case of emergencies.

Capacity building

An overarching element of the Roadmap is capacity building. It is recommended to establish a capacity building programme which accompanies all four pillars by means of training courses. The Roadmap suggests setting up an Eastern Nile Dam Operation Capacity Building Centre. This is regarded as a milestone for future dam operation in the Eastern Nile Region because of the massive impact dams will have in the future.

The vision of an Eastern Nile Dam Operation Capacity Building Centre (ENDOC) is to set up a centre with the assistance of international partners. Training courses held by practitioners from international dam owners and consultants need to be organised. This should be accompanied by site visits to dams in Europe, USA or elsewhere where upstream/downstream coordination plays a role. A period of four years seems to be sufficient to establish powerful training courses and to educate trainers from each country. The training centre aims at qualifying trainees in order to become trainers who are able to continue the training courses on their own. If sufficient local trainers have been qualified, the Training Operation Centre with international support could smoothly fade out and organisations in the countries take over.

ACHIEVEMENTS AND PERSPECTIVES

To achieve coordinated operation of cascade dams will take time. Working groups, data management, common procedures, regulations and finally operation rules must be established and brought into effect. The goal of the Roadmap is obtained, if the following achievements and perspectives are addressed step by step, continued and implemented.

- EN member states endorse actionable recommendations
  The documents, guidelines and manuals created by the Interim Coordination Unit with regard to training and mechanisms for reservoir operation rules are transferred into national policies.
- Linkages between water-, energy-, food security and ecology are assessed
  Effects of reservoir operation impacting on the water, energy, food security and ecosystems nexus are assessed. Coordinated reservoir operation will profit if a knowledge base is determined demonstrating the interplay between the sectors and reservoir operation.
- Collaborative monitoring and forecasts are in place
  The development of a forecast unit including a unified data framework and a harmonised data management system is a milestone not only for coordinated dam operation.
- Coordinated operation of cascade dams is implemented
  Based on the results of the benefit sharing option assessment, operation rules come into effect in the subsystems and finally for the whole Eastern Nile Reservoir System.

A long-term perspective for close cooperation between the countries is to establish a River Basin Commission dedicated to all or part of the management of shared waters between the countries.

2 INTRODUCTION

The Nile Basin Initiative (NBI) is an intergovernmental partnership established in 1999 for cooperative management and development of the Nile Water Resources. The Nile Basin covers an area of 3.1 million km² spanning the territory of 11 countries. Among others, the NBI implements the Nile Cooperation for Results (NCORE) project, shared by the three NBI centres:

- the Nile Secretariat (NILE-SEC) based in Entebbe, Uganda
- the Eastern Nile Technical Regional Office (ENTRO) based in Addis Ababa
- the Nile Equatorial Lakes Subsidiary Action Program (NELSAP) managed by its Coordination Unit (NELSAP-CU) located in Kigali, Rwanda.

The objective of the NCORE is to facilitate cooperative water resource management and development in the Nile Basin. Key areas addressed within NCORE are the enhancement of cooperation among the riparian countries, the provision of stakeholders with tools and knowledge for climate resilient water resources management and the promotion of sustainable water resources development. A crucial element in achieving cooperation among riparian countries and climate resilient water resources development is the coordinated operation of large dams in the Eastern Nile Region.

The Eastern Nile Region is home to a number of large dams. There are four existing cascade dams situated along the Abay/Blue Nile-Main Nile (Roseires, Sennar, Merowe, High Aswan Dam) with an aggregated storage capacity of 182 BCM which will be complemented by the Grand Ethiopian Renaissance dam (GERD) in Ethiopia, with a storage capacity of 74 BCM. Two cascade dams are in place along the Tekeze-Atbara Rivers (Tekeze, Kashim Al Girba). The Upper Atbara complex in Sudan, with a storage capacity of 8 BCM is almost completed. In addition, there are also other dams in the pipeline in Ethiopia and South Sudan.

At present, dams being in operation in Egypt, Ethiopia and Sudan are currently managed without cross-border coordination and only limited coordination at national level. In preparation for activities towards coordination of dam operation, a Roadmap addressing technical (e.g. water release and operation rules), institutional (e.g. responsibility and accountability of entities for coordinated management) and legal (e.g. treaties encoding coordination) aspects need to be considered.

Thus, the Eastern Nile Technical Regional Office (ENTRO) has launched the initiative to develop a

Roadmap for Coordinated Operation of Transboundary Cascade Dams in Eastern Nile

This report describes currently available data and information, contains a situational analysis, defines goals and compares the current situation with the goals in Section 6 Gap Analysis. It further describes steps the countries could undertake to achieve coordinated reservoir operation. This is supplemented by a time line and a work schedule outlining the major steps

3 OBJECTIVE AND SCOPE OF THE ROADMAP

The riparian countries operate a number of reservoirs independently of each other. Even within a riparian country coordinated dam operation is not fully developed or is not in place at all. The main reservoirs systems are illustrated in Figure 1.

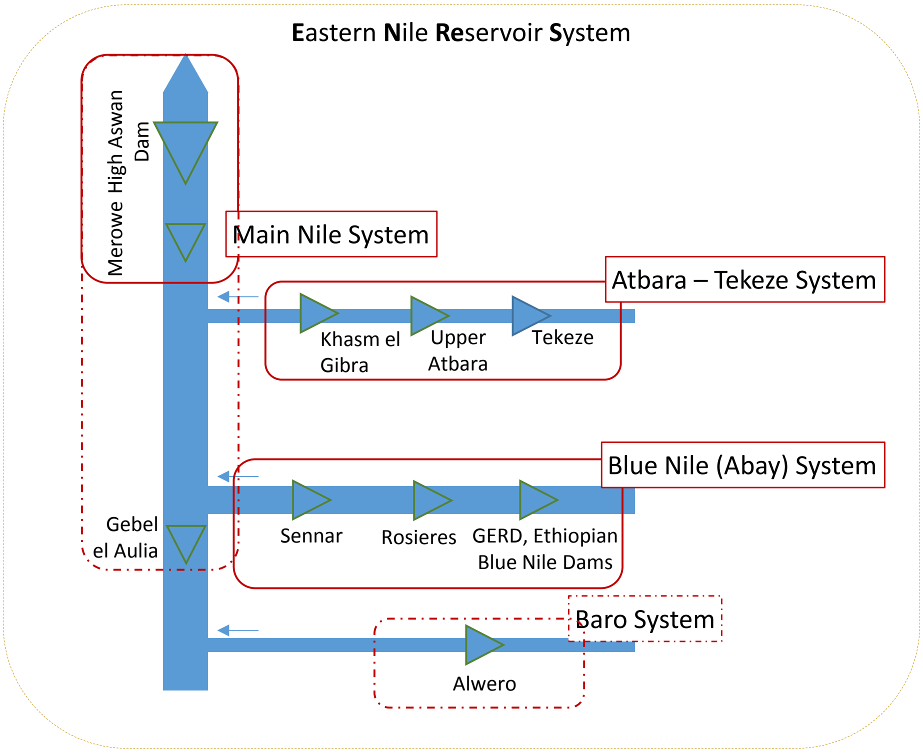


Figure 1: Main reservoir systems

All reservoirs together can be regarded as one large multipurpose, multi-reservoir system with mutual implications, the Eastern Nile Reservoir System (ENRES). A coordinated operation of ENRES or subsystems thereof requires awareness and dialogue among the Eastern Nile countries. Such a process can best be supported by means of a Roadmap which provides guidance and direction towards coordinated operation of a multi-reservoir system. Thus, the objective of this assignment is to accomplish a Roadmap so as to give recommendations for steps countries could take to develop coordinated operating rules and accompanying institutional mechanisms.

4 GEOGRAPHICAL SCOPE

The project area comprises the Eastern Nile Basin with the countries listed in direction of flow: Ethiopia, South Sudan, Sudan and Egypt. Although South Sudan does not have major reservoirs, its area, however, drains the Sobat River which originates with its tributaries from the Ethiopian Highlands.

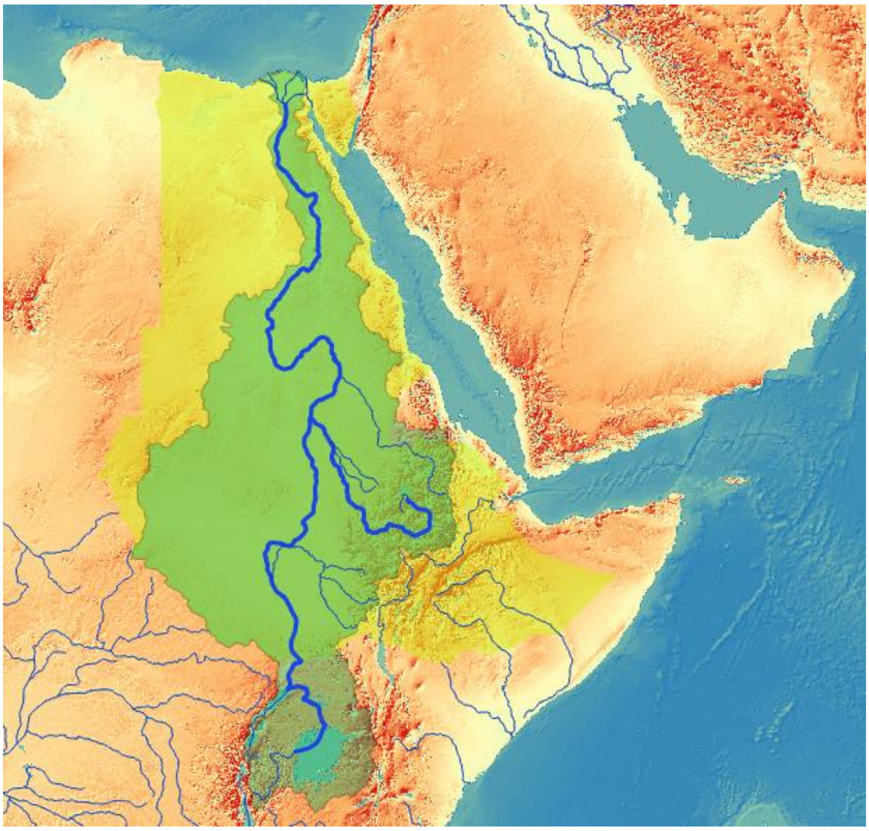


Figure 2: Project area, member countries and major rivers

The area of the four countries covers 4.856 Mio. km² according to [FAO Aquastat (2016)]. A schematic view of major rivers with the main gauging stations, adopted from [NBI (2012)], is illustrated in Figure 3.

4.1 Monitoring

The existing monitoring system with the most important gauging stations is depicted in Figure 3.

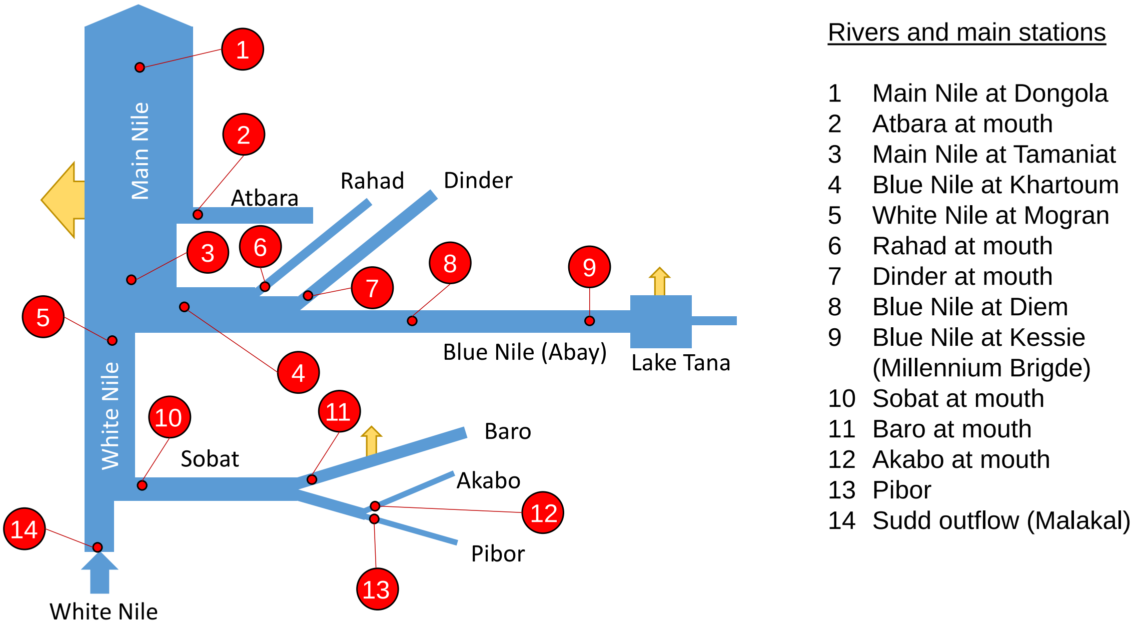


Figure 3: Schematic view of rivers and main gauging stations [modified from NBI (2012)]

4.2 Dams

The same schematic view is used to illustrate existing and planned reservoirs. All dams mentioned in Figure 4 were taken from [ENTRO Dam compilation (2016)].

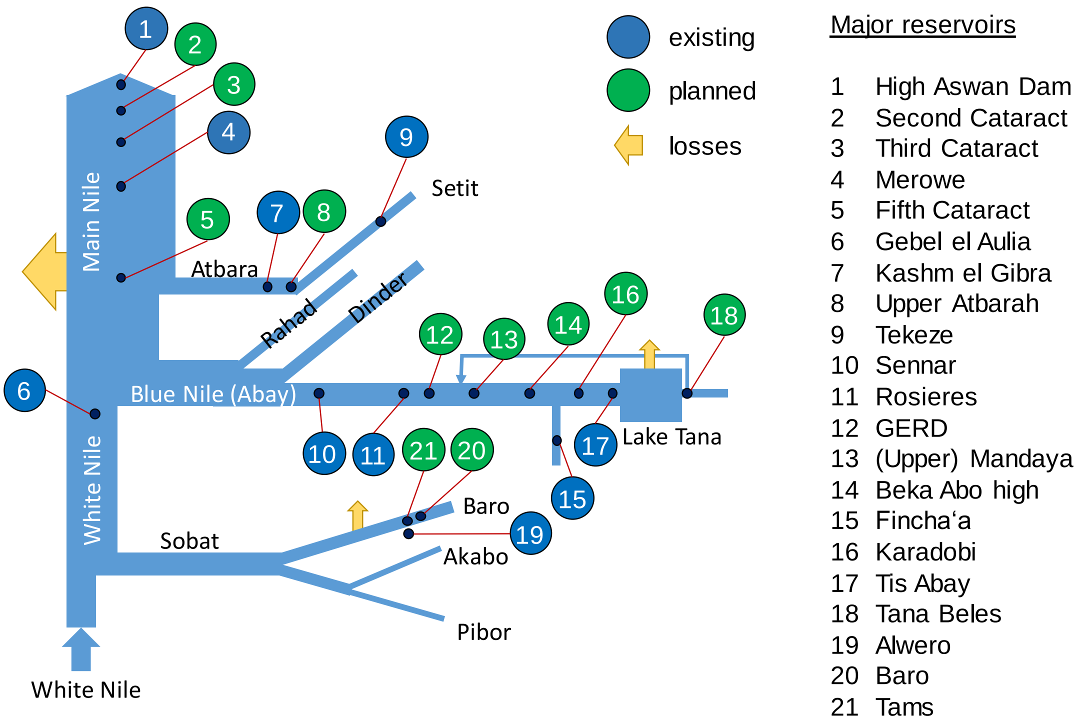
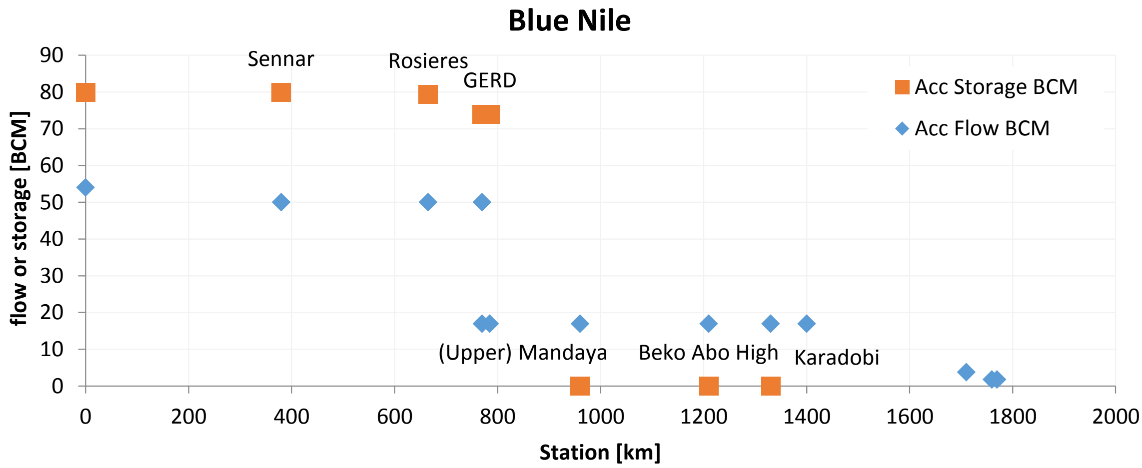


Figure 4: Schematic view of existing and planned reservoirs

The locations, names, purposes and elevation-volume-area curves of the existing and planned reservoirs were made available by ENTRO and were used to compare annual average flow with cumulated dam-regulated volumes disregarding dead storage. This is considered as an indicator for exploitation of natural resources and over-seasonal storage potential. The largest reservoirs along the Blue Nile are used only.



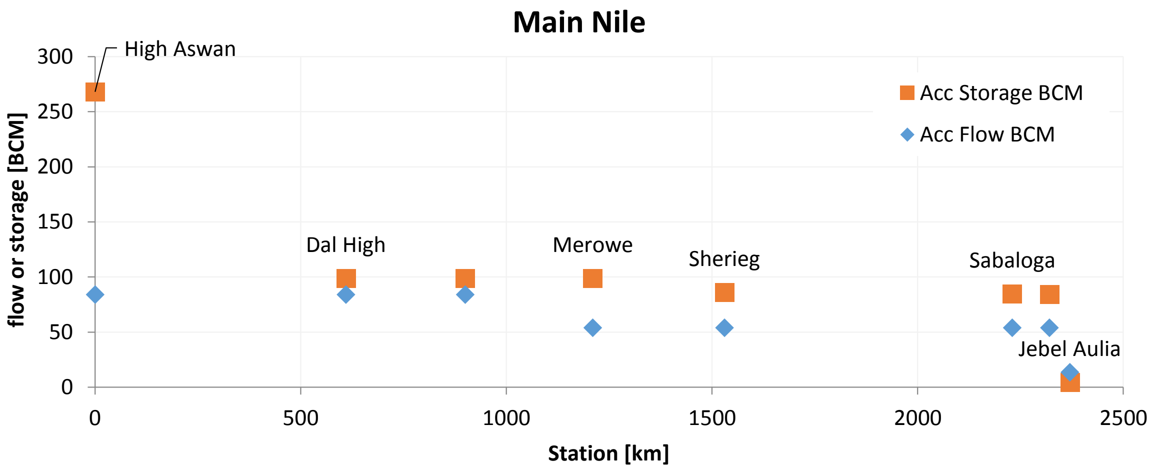
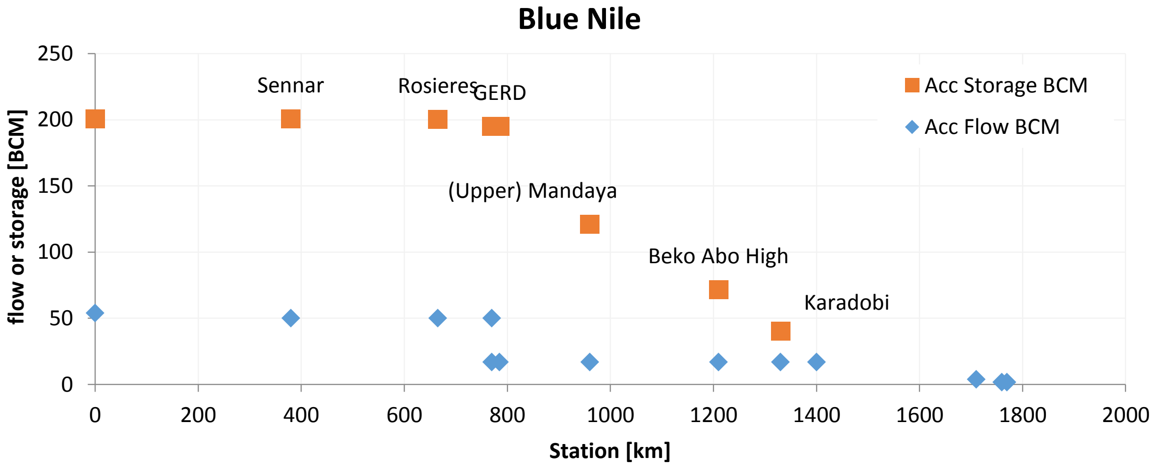


Figure 5: Annual average flow vs. existing cumulative reservoir volume (with GERD)

The Great Ethiopian Renaissance Dam (GERD) is already under construction and is included in the figure above. The influence of GERD is clearly visible and calls for any effort in terms of good reservoir operation. Further downstream the Main Nile there are two major dams already in operation, the Merowe and the High Aswan Dam.

The same figure can be produced including all planned dams (see Figure 6). On condition that all these dams are built, the annual flow of the Blue Nile at its confluence is exceeded by more than 300% by cumulated reservoir volumes. This gives strong evidence that managing the reservoirs will play a very important role and make the countries more resilient against adverse hydrologic conditions, proper operation assumed.



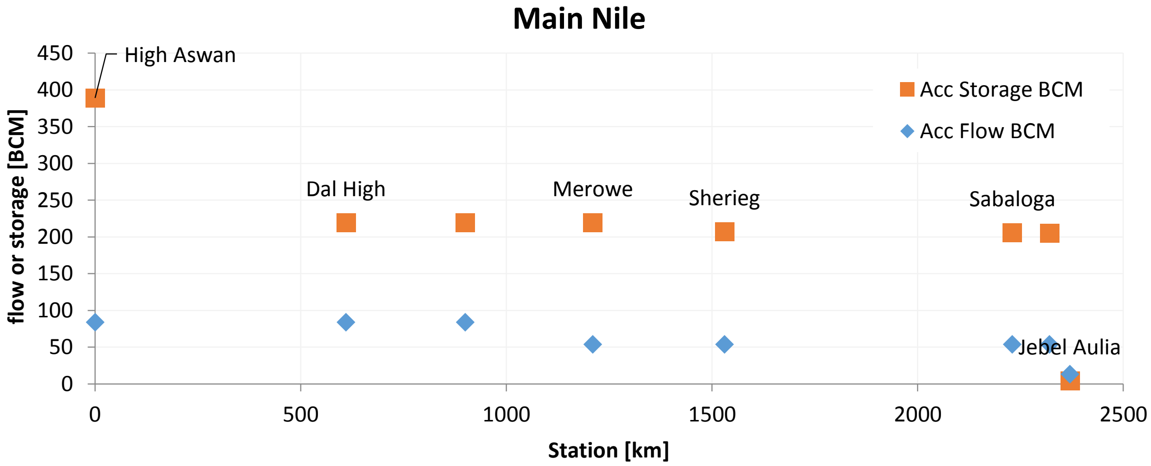


Figure 6: Annual average flow vs. existing and planned cumulated reservoir volume

Another indicator is the ratio between maximum storage volume and maximum water surface area. The indicators for selected reservoirs are given below.

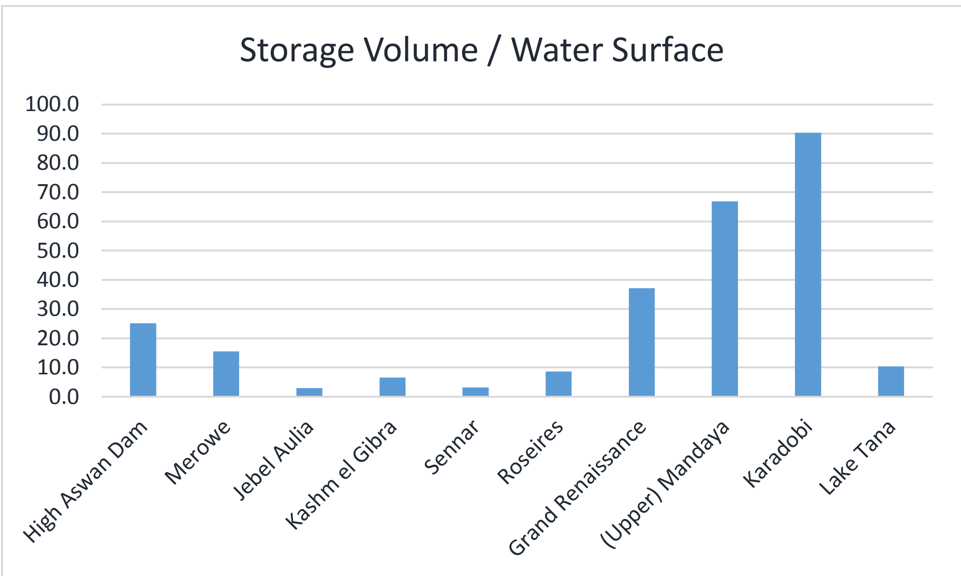


Figure 7: Storage volume vs. water surface as indicator for suitable topography

A large value indicates a favourable ratio between storage and water surface, that is, storage volume is available without covering a large area. A suitable topography indicates less evaporation losses per m^3 storage volume. In contrast, small values indicate a flat topography with high evaporation losses and thus less advantageous conditions. For example, the Merowe Dam, the latest and largest water infrastructure project in Africa in recent years, stores 15 MCM per square kilometre water surface, compared to values of > 30 for dams located in a more favourable topography in Ethiopia. This indicator creates a first objective with regard to coordinated reservoir operation: operation of cascade dams should aim at minimising losses due to evaporation.

4.3 Purpose of reservoirs in the Eastern Nile Region

There are five major topics pertaining to coordinated reservoir operation in the Eastern Nile Region:

- Flood and drought management
- Hydropower generation
- Irrigation
- Navigation and low flow augmenation
- Maintaining environmental flow

Flood and drought management is directly attributable to the scope of responsibilities of Ministries of Water Resources, it is also a cross-cutting topic which affects other ministries like infrastructure, environment, agriculture, economy and local governments at least from the view point of Disaster Risk Management (DRM). Thus, coordinated reservoir management with this topic in mind will have wide implications.

Maintaining certain levels of flow is an issue which serves different purposes:

- Water supply for human and livestock
- Water quality
- Minimum level for pumps intakes
- Fisheries
- Preserving ecosystems

Hydropower generation and irrigation affects other sectors like environment, energy, infrastructure, agriculture, food supply, economy, trade and socio-economic development. Low flow augmentation for navigation plays an important role downstream the High Aswan Dam but is also required along certain river reaches for transportation. A large number of ferries cross the rivers in many reaches and represent an important mean of transportation for local people where there are no bridges. This reflects the situation at least upstream Khartoum along the Blue Nile.

5 SITUATIONAL ANALYSIS

The section is structured to cover the following topics:

Institutional arrangements

- Institutional settings
- Roles and responsibilities

Monitoring

- Roles, responsibilities and course of actions
- Data management, archiving and data access
- Data sharing procedures

Operation Rules

- Evaluation
- Formulation
- Approval

Implementation

- Implementing agency
- Communication with stakeholders interacting with reservoir operation
- Documentation of operation
- Supervision of operation

Reservoir operation is affected by requirements and demands which originate from various sectors. It is important to understand the interplay between these sectors, their drivers and how they feedback into reservoir operation. Interactions between sectors can be expressed as cause-effect relationships. In essence, reservoir operation is affected by a network of causal-chains with partly interlinked and nested topics. This multi-dimensional and mostly complex structure has hydrologic, environmental and socio-economic roots. In order to assess effects of operation rules, it is necessary to know and evaluate the network in order to derive and determine relevant objectives, to identify constraints and finally to formulate operation rules. Having this in mind, the situational analysis tries to embed such a network but without evaluating it. It must be noted that assessing the causal-chains is beyond the scope of the Roadmap. However, this issue is key to successful cooperated reservoir operation and is taken up again in this report.

The information for the situational analysis was mainly acquired during interviews and meetings with ENTRO, representatives from various authorities in Addis Ababa and Khartoum, visiting and meeting managers and operation engineers at Beles Multipurpose Scheme, Lake Tana, Gebel Aulia and Sennar Dam in September 2016. This means that the level of detail is higher for Ethiopia and Sudan compared to Egypt and South-Sudan. Additional information was taken from documents provided by ENTRO and other sources compiled in Section 9.

5.1 Egypt

Egypt has a total area of about 1 million km² most of which is a vast desert plateau interrupted by the Nile Valley and Delta. The arable and cultivated strip along the Nile Valley covers approximately 4% of the area. The Nile Valley is incised and surrounded on both sides with large plains reaching 1000 masl in the east and about 800 masl in the west. The highest elevation is located at Mount Catherine in Sinai with 2629 m. The Qattara Depression in the northwest represents the lowest point in the country with 133 m below mean sea level. The population of Egypt has reached an estimated number of more than 85 million of which roughly 56% live in rural areas. More than 95% of all people live in the small green strip of the Nile Valley and the Nile Delta. This leads to a population density of more than 1000 inhabitants/km² along Main Nile compared to only 1 inhabitants/km² in the rest of the country.

Egypt has an arid climate with maximum temperatures reaching 38°C to 43°C during summer from May to October and daily means between 15°C to 21°C from November to April. Rainfall is very low, irregular and unpredictable. Annual rainfall is less than 200 mm in the north and decreases to nearly zero in the south.

Water resources in Egypt are more or less equivalent to Main Nile. An average annual volume of 84 km³ enters Egypt. There are no other significant water resources in Egypt. The areas outside the Nile Valley depend on scarce and fossil groundwater resources. The High Aswan Dam, constructed between 1960 and 1970 and finally filled in 1976, has a total storage capacity of 170 km³ and is by far the most important water infrastructure in the country. The dam provides water for irrigation along the Nile Valley, controls floods and is the main source of hydropower generation.

The Nile system below Aswan can be considered as a closed system, receiving inflow only from the High Aswan Dam. Outflows comprise crop evapotranspiration, non-recoverable municipal and industrial water consumption, evaporation, drainage of agricultural water to the sea, and non-recoverable inland navigation water released to the sea. In this perspective, groundwater extraction and reuse of drainage water can be considered as options for increasing the overall efficiency of the system and not as additional resources. The exact nature and details of these interrelations are not clear yet. A new factor that adds to the complexity of the issue is the change in water quality, which is the focus of research studies that are currently undertaken by the National Water Research Centre (NWRC).

The information about Egypt is based on documents provided by NBI and literature review. Sources are [ENTRO (2014), EMA (2016), Kamal, M.M. (2005?), NBI (2016), United Arab Republic (1959), Sutcliff, J.V., Parks, Y.P (1999), FAO Aquastat (2016), INECO (2009), USAID (2009), USAID (2008), USAID (2011)].

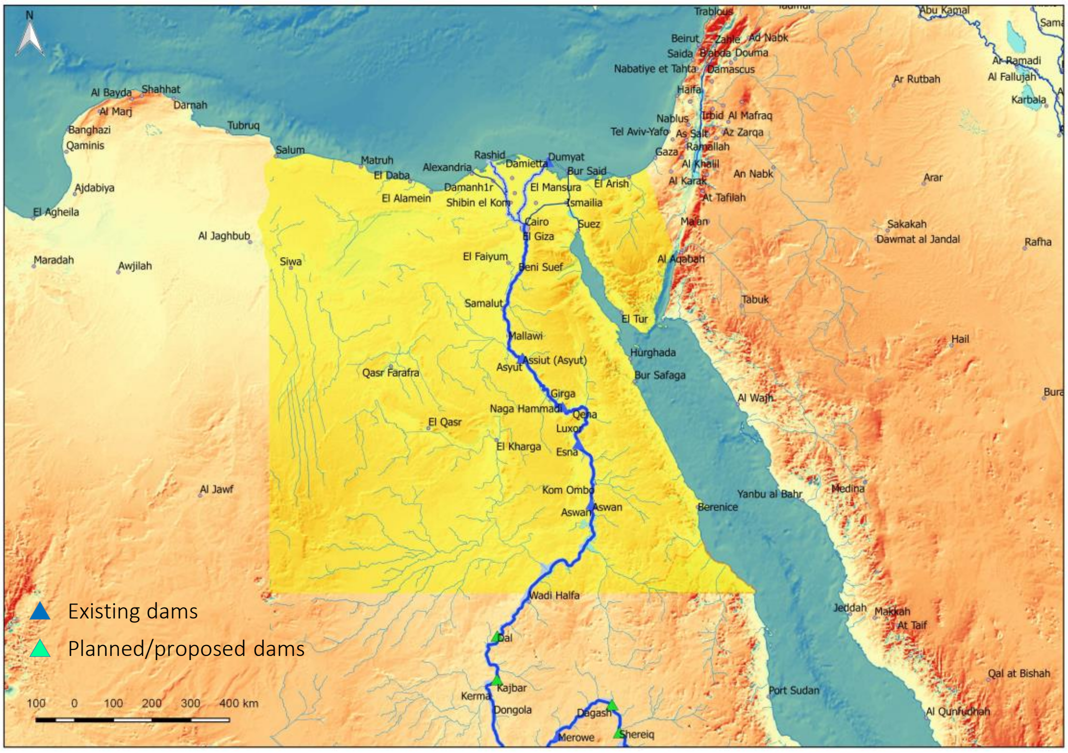


Figure 8: Overview of the Egypt with existing and planned dams

5.1.1 Institutional settings

Under law 12 of 1984, the Ministry of Water Resources and Irrigation (MWRI) has the overall responsibility for appropriating and distributing water and for managing drainage, groundwater and the Mediterranean coastline. In addition, under law 48 of 1982, the Ministry has the responsibility for controlling the inflow of pollutants into waterways. To undertake these responsibilities the MWRI has established a set of units and agencies illustrated in Figure 9 and Figure 10 [USAID (2008), USAID (2009)].

The Nile Water Sector is in charge of cooperation with Sudan and other Nile riparian countries. They oversee and execute the treaty with Sudan over the Nile water. Supervision of dams for irrigation are organised under the Irrigation Department. Their tasks concentrate on technical guidance and monitoring of irrigation downstream High Aswan Dam. The Planning Sector is responsible at national level for data collection, processing and analysis for planning and monitoring investment projects. Construction and maintenance of pumping stations for irrigation and drainage is in the hand of the Mechanical and Electrical Department.

The organisational structure of MWRI was taken from [USAID (2009)] and is shown below.

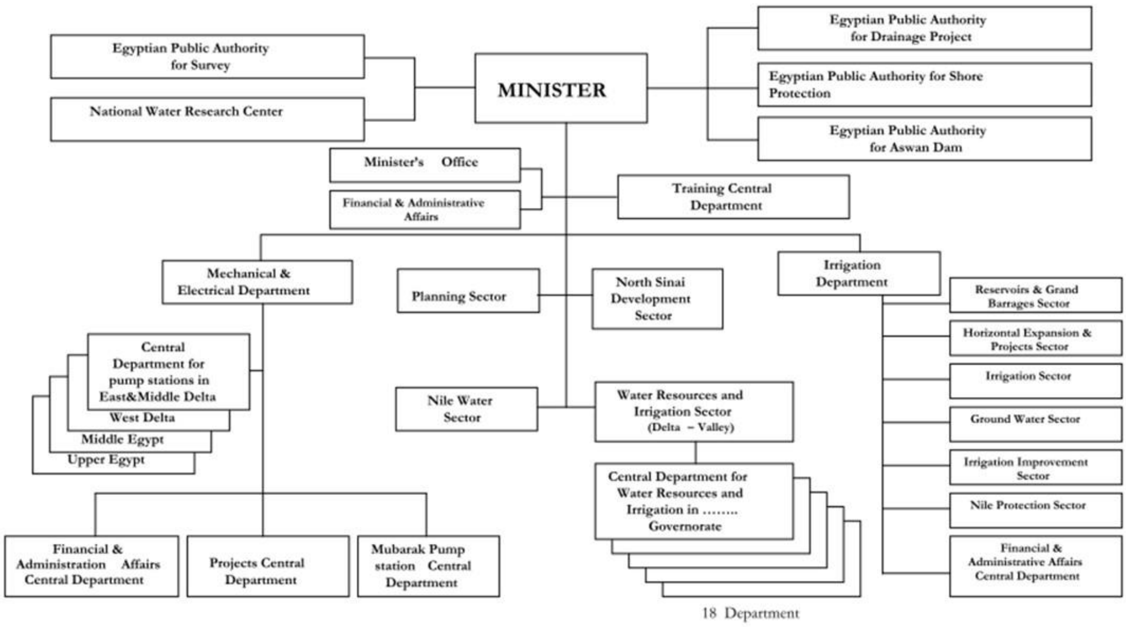


Figure 9: Organisational structure of MWRI (source [USAID (2009)]

MWRI is on the way to reorganise its institutional setting by considering

- sustainable economic growth through enhancing the role of the private sector
- decentralization and privatization of water management to the appropriate level to increase water use efficiency
- strengthen water quality protection and pollution control

The leading role of MWRI in terms of main supply facilities and water allocation policies, regulation and enforcement of water management remains under full control of the ministry [USAID (2009)].

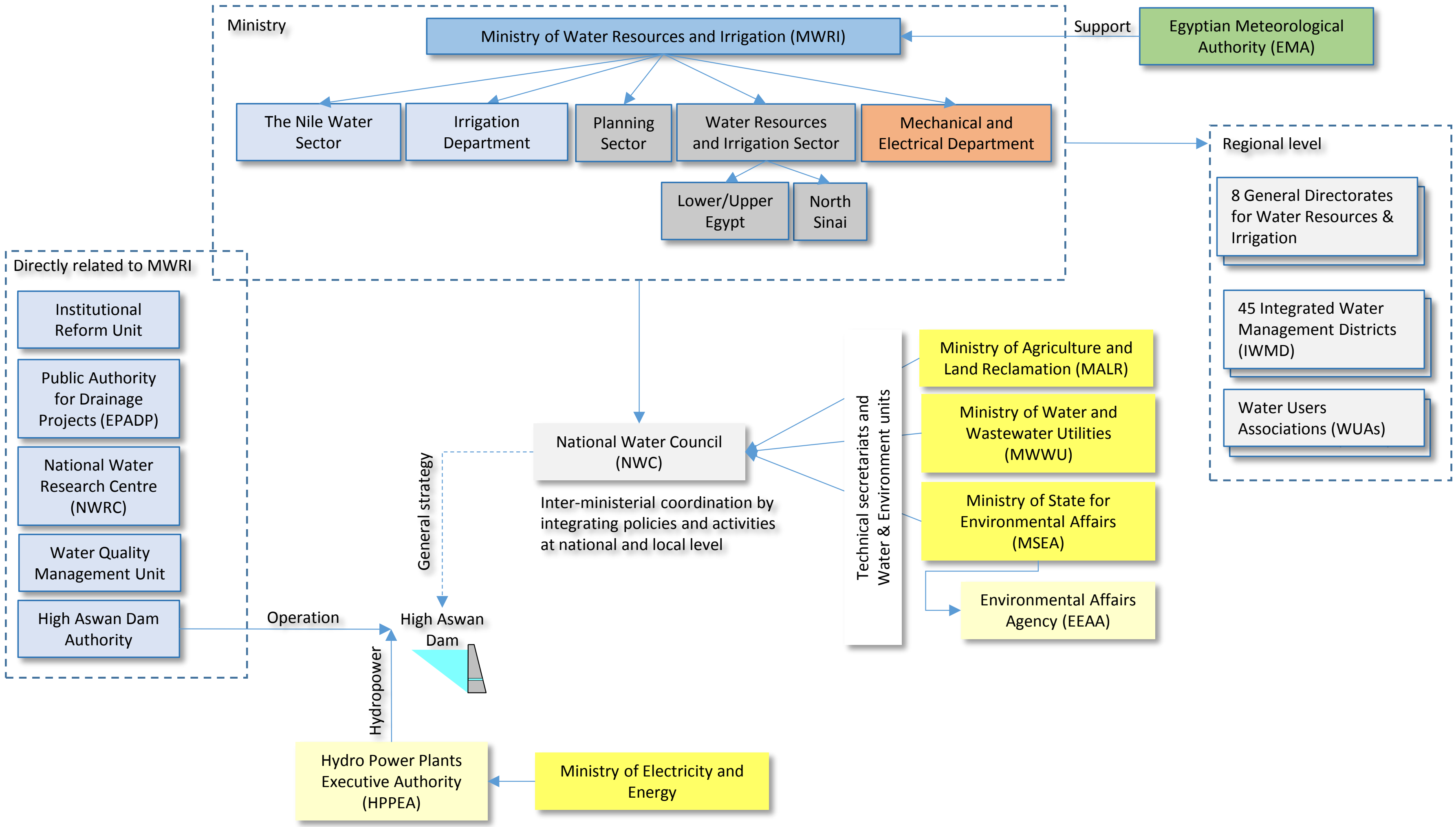


Figure 10: Institutional structure in Egypt with regard to reservoir operation

The High Aswan Dam Authority (HADA) has the responsibility of operating the High Aswan Dam (HAD). Concrete actions at the dam are undertaken by HADA, for example implementing operating or monitoring at the dam site.

5.1.2 Monitoring

Monitoring Nile Waters by Egyptians was performed since more than 2000 years. Nowadays it can be subdivided in monitoring the Nile in Egypt and monitoring upstream outside of Egypt. Apart from Ethiopia, Egypt conducts flow and water level measurements not only in Egypt, but also in all other riparian countries [ENTRO (2016)]. The observation station which is of interest within the scope of this project is the High Aswan Dam itself.

The lead institution responsible for the collection of surface water level and discharge within the Nile Basin is the Nile Water Sector at the MWRI. The Nile Water Sector is in charge of collection of rainfall and evaporation data within the Nile Basin. The Egyptian Meteorological Authority (EMA) collects meteorological data nationwide. The Ministry of Agriculture and the agricultural research stations collect agro-climate data. Data transmission for river stage and/or discharge is mostly manual but telemetric data transmission is being progressively introduced.

The unit in charge of monitoring at the High Aswan Dam is HADA and downstream the dam the Irrigation Department.

5.1.3 Operation rules

Operation of HAD is mainly to satisfy the demand for irrigation. This was the main purpose why HAD was built. Flood protection is another purpose of HAD. Rules on how to operate HAD during high flow situations were found in [Kamal, M.M. (2005?)].

Management and operation of the flood water quantities in Lake Nasser is based on the following rules:

- Water requirements for different requirements are released downstream High Aswan Dam and Old Aswan dam respectively.
- Additional quantities are released during the flood event on the condition that no damage is caused along downstream reaches. This requires the knowledge of critical flow capacities.
- The maximum water level in Lake Nasser must not exceed 182 masl.
- On the first of August the water in Lake Nasser must be controlled at 175 masl.
- Excess water beyond the Lake Capacity must be released over the spillways of the High Dam and Toshka spillway canal.

The dam gates are operated to keep the water level within minimum and maximum levels. Utilising the Toshka spillway depends on the storage capacity of the Toshka depression. The theoretical capacity of the Toshka depression is about 120 billion m³ at level 169.00 masl. However, the presence of an opening at the end of the fourth part of the Toshka Depression at level 150.00 masl leads to a drastic reduction of the actual capacity so that a storage volume of approximately 50 billion m³ is realistic. The water level of 175 masl at August 1st is needed to create a flood buffer as August marks the onset of the flood season.

Floods are classified into four classes:

- Low flood (inflow less than 60 billion m³)
- Medium flood (inflow ~84 billion m³)
- High flood (inflow ranges between 100~120 billion m³)

- Extreme flood (inflow greater than 120 billion m^3)

With the Merowe Dam, flood problems are alleviated to some extent. According to [NBI (2016)] and the Global Risk Data Platform of UNEP (http://preview.grid.unep.ch/), however, the flood risk downstream HAD is considered as very high which is attributable to densely populated areas directly located along the river banks.

5.2 Ethiopia

Ethiopia covers about 1.1 million km^2 with estimated more than 90 million people. The vast majority lives in rural areas (84%), only 16% in cities, of which approximately 4 Mio. are residents of Addis Ababa. Ethiopia is a Federal Democratic Republic composed of 9 National Regional states: Tigray, Afar, Amhara, Oromia, Somali, Benishangul-Gumuz, Southern Nations Nationalities and People Region (SNNPR), Gambella and Harari and two Administrative states (Addis Ababa City administration and Dire Dawa city council). The regional states as well as the two cities administrative councils are further divided in eight hundred Woredas and around 15,000 Kebeles (5,000 Urban & 10,000 Rural) (http://www.ethiopia.gov.et/de/regional-states).

Ethiopia owns a great geographical diversity. High and rugged mountains descend with steep slopes to semi-arid to arid plains. The elevation ranges from Ras Dashen with 4620 masl as highest mountain to the Danakil depression with 148 meter below sea level. One of the major features of the Ethiopian's landscape are large, incised rivers like Abay (The Blue Nile), Tekeze, Awash, Omo, the Wabe Shebellie and Baro-Akobo. (http://www.ethiopia.gov.et/de/regional-states).

Generally, Ethiopia is rich in water resources. Ethiopia has three distinct meteorological seasons: Belg (Feb. to May), Kiremt (Jun. to Sep.) and Bega (Oct to Jan). Belg is the small to moderate rainy season, Kiremt is the main rainfall season except for the lowlands and Bega is mainly referred to as dry season for the greatest part of Ethiopia.

Although irrigation demand is steadily increasing, the amount of water used for irrigation is small compared to the available water resources. Thus, water losses due to irrigation are almost negligible in comparison with the available water resources

On average, in the past Lake Tana drained about 120 m^3/s [NBI (2012)]) into the Blue Nile at Bahir Dar. Since 2010, after the Beles Project was commissioned, about 100 m^3/s are diverted from Lake Tana to feed the penstock of the Beles Project and only about 20 m^3/s remains for the Blue Nile (Abay).). After power generation, the Beles River rejoins the Blue Nile River just upstream of GERD. As a result, the discharge of the Blue Nile (Abay) directly downstream Lake Tana is kept on a minimal level to meet environmental requirements and for tourism. At the same time, the hydrological regime of the Beles River itself has changed.

However, the outflow of Lake Tana is not a major contributor for the Blue Nile (Abay) River. About 3.8 km^3 a year originate from Lake Tana in comparison to nearly 50 km^3 total flow volume per year at the border station Ed Diem.

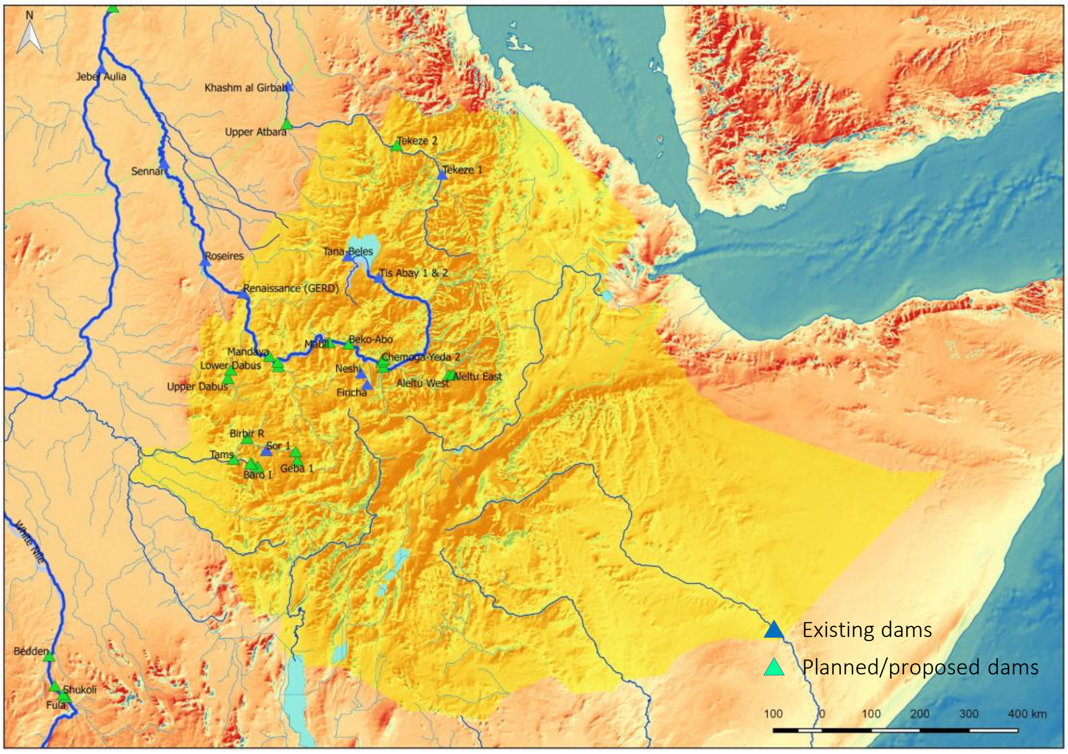


Figure 11: Overview of Ethiopia with existing and planned dams

5.2.1 Institutional settings

Overview

In 1992, Ethiopia shifted from a centralised to a decentralised system by establishing regional governments. The process of regionalization created nine regions, largely along ethnic lines, with power and administrative issues entrusted to these regional states. The regional governments have legislative, executive and judicial powers with respect to all matters within their geographical jurisdiction except for specific matters that remain under the authority of the Federal Government. The Federal States has the mandate to enact laws for land and water management. Specified in Article 51 of the Federal Constitution, the Federal level is the authority for waters linking two or more regional states and with an outlet outside the national territory [FDRE (1995)]. The regional states have the power to administer and manage land and water within their boundaries, and may issue laws for this purpose, provided they are consistent with federal laws [FDRE (1995), Haileslassie, A. et.al. (2008)].

Powers and duties with regard to water resources are determined in [Federal Negarit Gazeta (2005)]. Direct or indirect involvement in the development and management of land and water resources can be concluded from this source as follows: Ministry of Water Resources, Irrigation and Electricity MoWIE; Ministry of Agriculture and Rural Development; Ministry of Health; Ministry of Energy, Mines and Fuel; Ministry of Federal and Pastoral Affairs, Ministry of Livestock and Fishery Development and the Ministry of Environment and Climate Change.

Power and duties of the MoWIE related to coordinated reservoir operation are explicitly described in [Federal Negarit Gazeta (2005)] as:

1. undertake basin studies and determine the country's ground and surface water resource potential in terms of volume and quality, and facilitate the utilization of same

2. determine conditions and methods required for the optimum and equitable allocation and utilization of water bodies that flow across or lie between more than one Regional States among various uses and the regional States
3. undertake studies and negotiations of treaties pertaining to the utilization of boundary and trans-boundary water bodies, and follow up the implementation of same
4. cause the carrying out of study, design and construction works to promote the expansion of medium and large irrigation dams
5. issue permits and regulate the construction and operation of water works relating to water bodies referred to in (2) and (3) of this list
6. administer dams and hydraulic structures constructed by federal budget unless they are entrusted to the authority of other relevant bodies

According to the tasks, responsibilities for dams and reservoir operation are assigned to the ministry. The mandate for transboundary water bodies is included.

The organisational structure within MoWIE shows four entities which are in charge of dams and dam operation: The Ethiopian Electric Power (EEP), Dams and Hydropower Directorate, Hydrology and Water Quality Directorate and the Dam Safety Directorate. All entities are organised within MoWIE. EEP is in charge of construction, power generation, acts as operator and supervisor at the same time and can be seen as autonomous. All entities are closely linked together.

Decision-making happens in a very flat hierarchy, is mainly concentrated within EEP but is subject to agreements from a superior committee established under the Ministry to set up reservoir operation strategy once or twice a year. The committee has the responsibility to make strategic decisions aiming at policies, strategies, plans and the development of water resources to meet cross-sectoral needs. Member of the committee are:

- EEP
- Hydrology & Water Quality Directorate
- National Meteorological Agency
- Water Works Construction Corporation

The committee discusses and concludes suggestions on how to manage dams from an overarching and national viewpoint. The suggestions are subject to approval from the Minister. EEP dissect these specifications from national to reservoir level and brings them into operation on the ground.

Meetings of the committee are held at least once prior to each of the three hydrological seasons (Belg: Feb. to May, Kiremt: Jun. to Sep., Bega: Oct to Jan. Belg is the small to moderate rainy season, Kiremt is the main rainfall season except for the lowlands and Bega is mainly referred to as dry season for the greatest part of Ethiopia). Additional meetings can take place on demand depending on the hydrological situation.

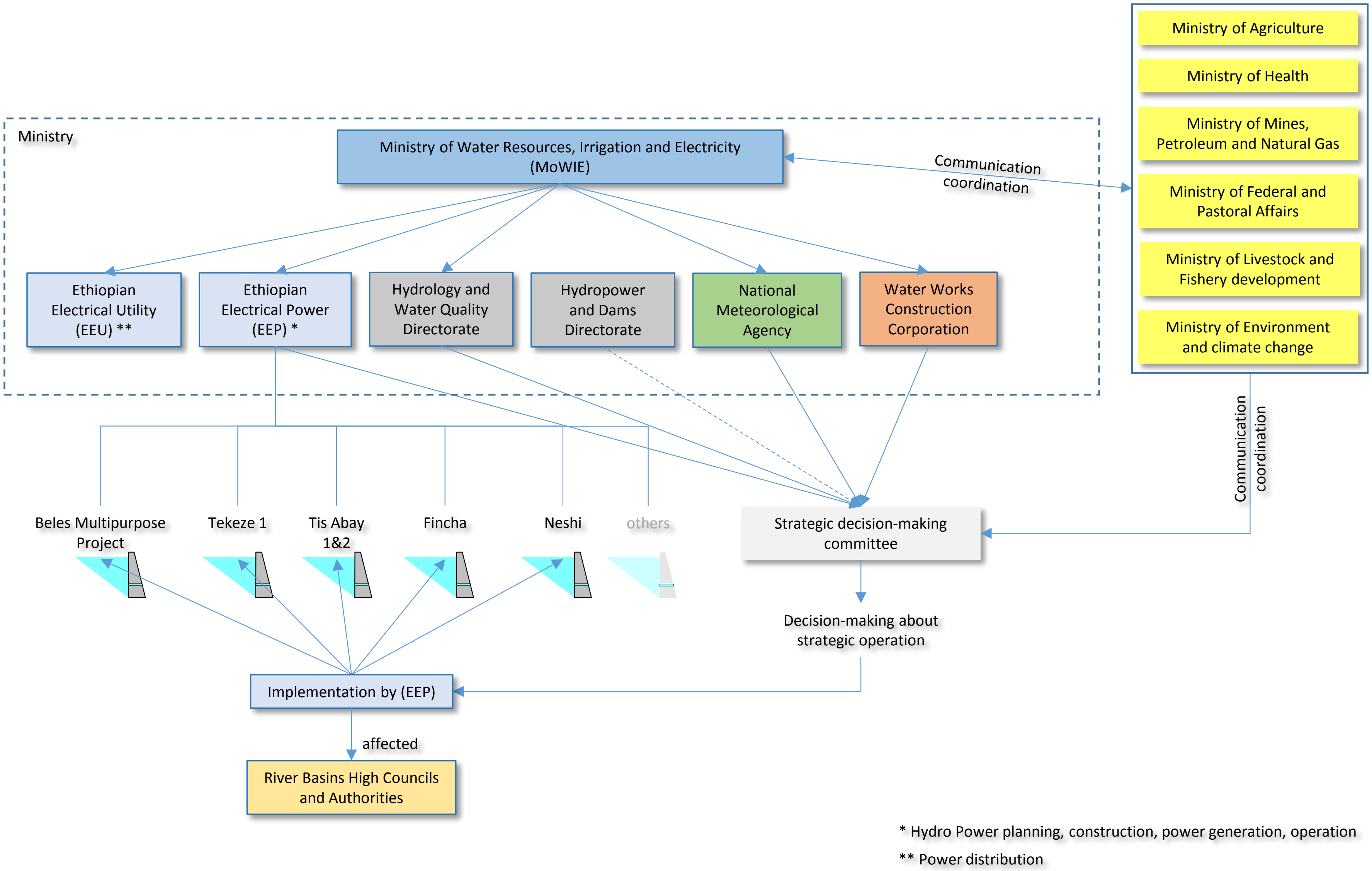


Figure 12: Institutional structure in Ethiopia with regard to reservoir operation

Details

The Beles Multipurpose Project is used as an example to outline details of an organisational setup of specific water infrastructure and how this fits into the overall institutional setting.

Beles river upstream | Beles river downstream the outlet

Figure 13: Beles river upstream and downstream the outlet of the Beles scheme

The hydropower plant receives water from Lake Tana. The intake, located at the western banks of Lake Tana, feeds the penstock with a capacity of up to 100 m^3/s. Four Francis turbines are installed with a capacity of 460 MW. The major features of the plant are: the intake at Lake Tana, the power house with the turbine hall and control centre, the 400KV substation, the outlet and the energy dissipation.

The Beles hydropower plant feeds into the national grid of Ethiopia. Releases are determined by electricity demand. This is reflected by the flow of information: The operation centre of the power grid of Ethiopia (Load Dispatch Centre, LDC) is directly in touch with the Beles control centre and gives instruction about the amount of power needed. Based on the instruction, adaptions are made at the Beles control centre accordingly. Adaptions can change several times a day.

The Beles control centre is the only permanently manned structure in the scheme. It is linked by landline with the management office and with the ministry in Addis.

In addition to hydropower, irrigation is part of the Beles scheme. Provision of infrastructure like pipelines, water diversion nodes is made but irrigation is of minor priority.

The fine-grained structure of the Beles scheme reveals that power demand is the driver for determining operation. The control centre and the management office can be seen as the prolonged arm of the LDC. As a result, decisions about operation are made by LDC. However, the water level of Lake Tana imposes constraints in form of minimum and maximum levels.

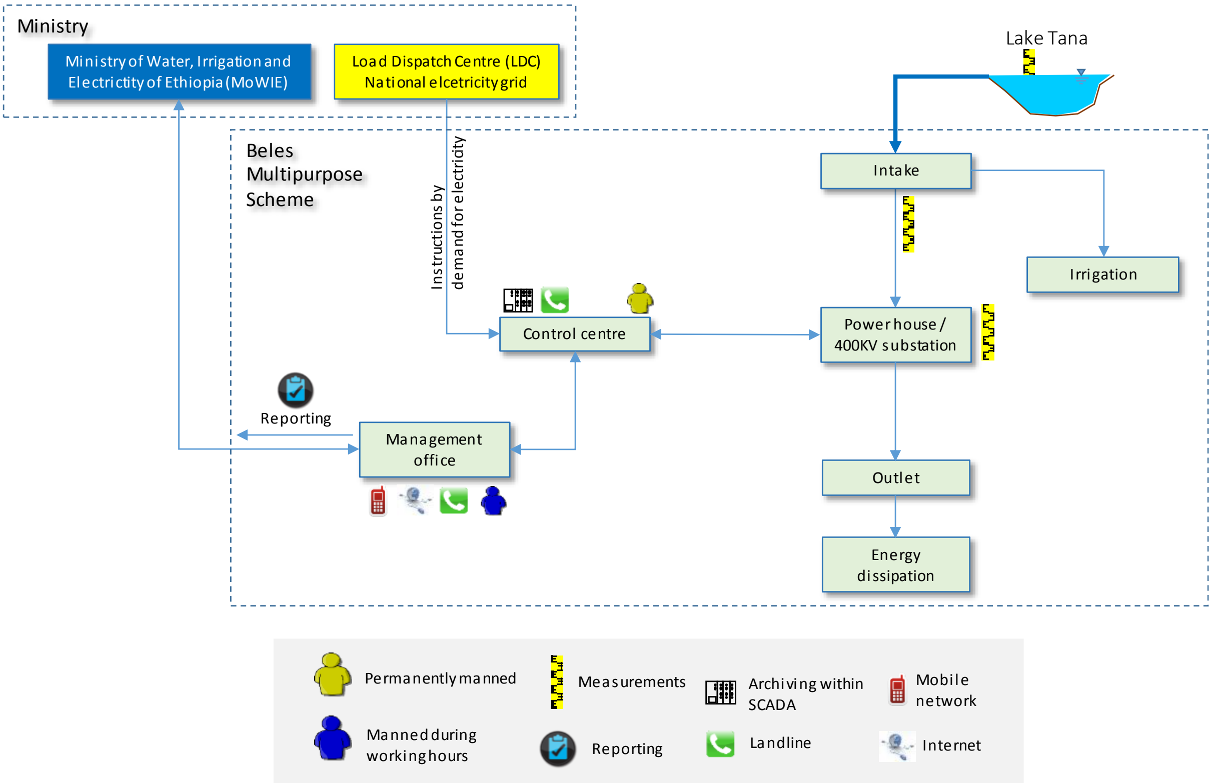


Figure 14: Beles Multipurpose Project's organisational structure

5.2.2 Monitoring

Overview

The Hydrology and Water Quality Directorate under the Ministry of Water Resources is the responsible unit for monitoring at national level. Data collection mainly concentrates on surface water resources comprising streamflow data, suspended sediments and water quality parameters. The Hydrology and Water Quality Directorate has the mandate to collect, analyse and disseminate records. The hydrological network for both streams and lakes consists of 560 gauging stations in 12 river basins of which 454 are at present operational throughout the country [http://www.mowr.gov.et/index.php].

The table of gauging station is taken from the ministries homepage.

Table 1: Hydrological gauging stations in Ethiopia

	Basin	Established	Operational
1	Awash	97	72
2	Abay (The Blue Nile)	160	131
3	Wabi-Shebelle	50	30
4	Genale_Dawa	38	36
5	Rift valley	70	54
6	Omo-Ghib	57	46
7	Baro Akobo	31	32
8	Tekeze	40	39
9	Dankile	12	11
10	Ogaden	-	-
11	Aysha	-	-
12	Mereb	5	3
	Total	560	454

In addition to the hydrological gauging stations, measurements at the dam sites are made. The EEP is in charge of controlling 8 dams, monitored and supported by telemetry systems at some of the dam sites. Other data collection systems like manual and automatic stations are in place as well. Observations comprise

- inflows to the reservoirs, derived from gauging stations upstream
- water level of reservoirs
- downstream releases
- withdrawals from reservoirs

Water diversion points like weirs are not integrated in the monitoring system and controlled independently by local operators.

All the time series data from the dam sites are kept in a data base administered by EEP. The data management system of the Hydrology and Water Quality Directorate and that of EEP are separated.

Data access by external users is not yet a topic for EEP for mainly two reasons. First, there is no need for coordination in terms of reservoir management as EEP is solely in charge of operation and second, no one requests information from EEP for the time being. In theory, data access is not restricted and could be made available by EEP. In practice, there is no need to further engage in that topic as long as no third party expresses interest in the data.

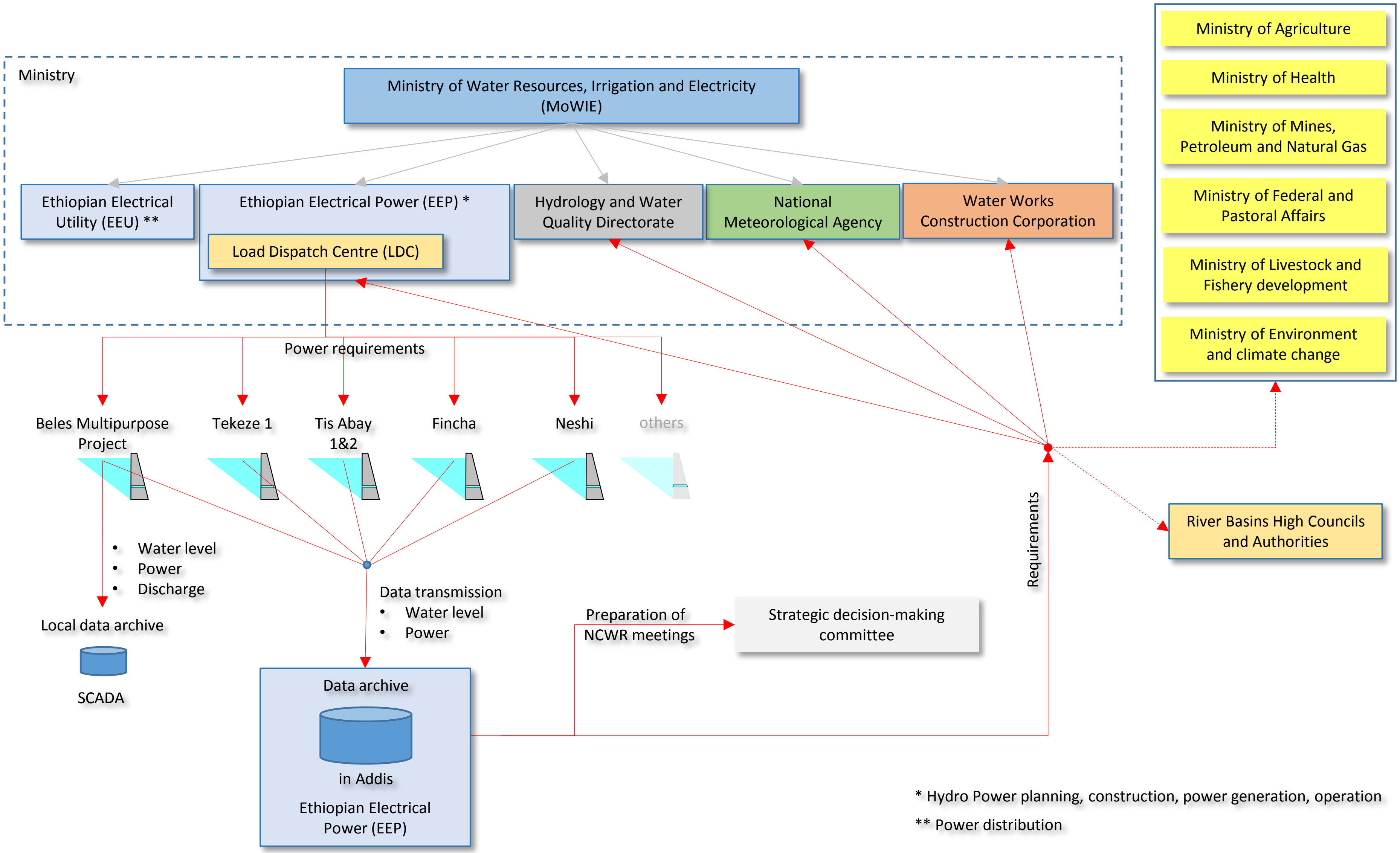


Figure 15: Data flowchart in Ethiopia with regard to reservoir operation

Details

The Beles Multipurpose Project is used as an example to outline details of monitoring.

Continuous measurements are carried out at the intake and at the power house. The water level of Lake Tana as well as generated power and discharge for each of the four turbines are permanently recorded. Water level and power data are transmitted to Addis whereas discharge is only archived at the site. Archiving uses a time step of 15 minutes during peak load hours. All other readings at off pick hours are taken at an hourly basis.

The SCADA system of Andritz Hydro is in use in the control centre. The SCADA is a closed system without any connection to the Internet or any other computer for safety reasons. This is intentionally done to protect the system and to prevent external interference. Data to be used at the management office come as hard copies from the control centre and requires retyping to store is digitally outside of SCADA. Evaluations and checks are performed at the management office. Reports about power generation are produced every day and sent to the ministry.

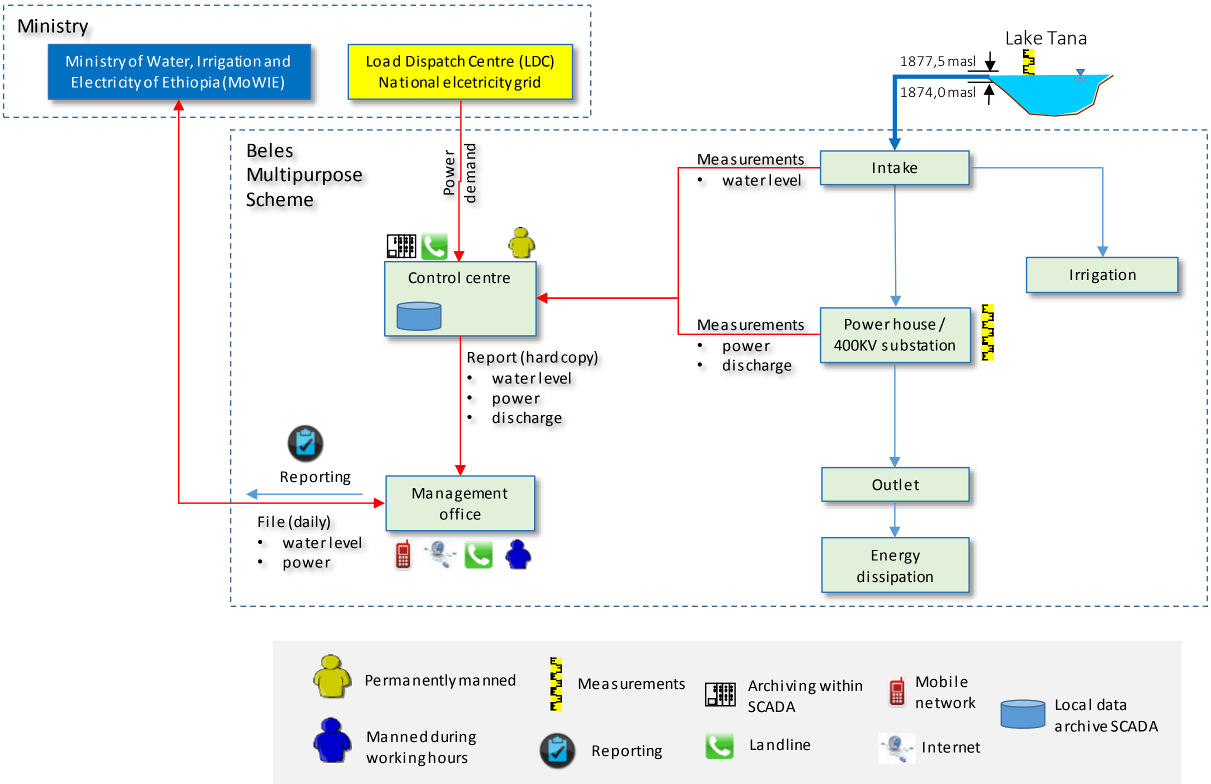


Figure 16: Beles Multipurpose Project's data flowchart

5.2.3 Operation

Overview

Dams in Ethiopia are mainly multipurpose focusing on:

- Hydropower
- Irrigation
- Water Supply
- Environmental flows

There are 8 dams in existence in the Nile Basin with the focus on hydropower and several dams are either being design, constructed or commissioned.

Table 2: Existing dams in Ethiopia

Existing Dams	
Name	Type
Tekeze Dam (TK 5)	Hydropower
Fincha Dam	Hydropower
Tis Abay 1 & 2	Hydropower
Chara Chara Weir	Hydropower
Neshi (+ Amarti diversion)	Hydropower
Sor 1	Hydropower
Alwero	Irrigation
Koga	Irrigation

Table 3: Dams under construction in Ethiopia

Dams under construction	
Name	Type
GERD	Hydropower

Table 4: Planned/proposed dams in Ethiopia

Planned / proposed dams		Planned / proposed dams	
Name	Type	Name	Type
Abobo	Irrigation	Geba 2	Hydropower
Aleltu East	Hydropower	Itang Dam	Hydropower
Aleltu West	Hydropower	Karadobi	Hydropower
Baro 1	Hydropower	Lower Dabus	Hydropower
Baro 2	Hydropower	Lower Didessa	Hydropower
Birbir R	Hydropower	Mabil	Hydropower
Chemoga Yeda 1	Hydropower	Tams	Hydropower
Chemoga Yeda 2	Hydropower	Tekeze 2	Hydropower
Dumbong Dam	Hydropower	Upper Dabus	Hydropower
Geba 1	Hydropower	Upper Mandaya	Hydropower

Prior to each hydrological season, the committee meets to make decisions about reservoir operation and general release strategies for the upcoming season. In preparation for committee meetings, reports are prepared by MoWIE explaining the current water resource situation with a special focus on currently available amount of water in the reservoirs. The committee determines priorities for water allocation under consideration of current water storage levels in the dams and flow predictions of the next 3 to 4 month. The rules undergo a review performed by MoWIE once a month.

Additional meetings of the commitee can be fixed on demand in case of exceptional hydrological conditions concerning both flood and drought. Identification of exceptional hydrological situations is autonomously executed by the Hydrology & Water Quality Directorate as part of MoWIE and discussions on adaptations of the operation schemes are approved together with EEP.

Excel is currently the means for executing scenarios concerning reservoir water management and supporting decision-making. No hydrological or water allocation models are in place in an operational mode, neither off-line nor online.

For the time being, no predetermined and comprehensively assessed operation rules are at hand. The current reservoir system is perceived as manageable. However, a gap concerning operation of dams due to the ongoing development of new dams in Ethiopia is recognised.

Details

The Beles Multipurpose Project is used as an example to outline details of operation. It must be noted that the Beles scheme is exceptional and does not represent a typical operational scheme of a dam.

The main objective of the Beles scheme is to provide power according to instruction of the Load Dispatch Centre in Addis Ababa.

Operation on the ground is performed with a 3 shift system. There are 5 shift attendants in each of the 3 shifts ensuring a 24/7 presence at the control centre and the power house. From the 5 shift attendants, one has a degree as engineer whereas the others are technicians. The maintenance and operation engineers, supervising the Beles scheme, are dedicated to stay in the management office. Both are supported by their respective department team members who are engineers and technicians. Additional engineers can be deployed to the management office in case of need.

Both the substation and the power house are equipped with a control room and a SCADA system. The SCADA system was introduced to the operators, but substantial experience was achieved by training on the job.

LDC determines power requirements for the whole of Ethiopia and the share for the Beles scheme. A maximum of 460 MW can be generated with the four Francis turbines installed. The share Beles should provide is dispatched to the control centre where the attendants at the centre make adjustments via the SCADA system to meet the demand. According to the adjustments, the SCADA system automatically adjusts flow until the requested power is reached.

There is one constraint affecting operation. The water level of Lake Tana sets two thresholds:

- Minimum water level 1784,0 m
- Maximum water level 1787.5 m

The SCADA system automatically stops all units if the pressure head in the penstock decreases below a predetermined threshold. This is the case when the water level of Lake Tana drops below the minimum level. Since 2010, the minimum water level was never reached. Except for 2015, the maximum threshold is regularly exceeded every year. In such a case, operation continues but discharge is limited to the maximum capacity.

Discharge recorded at the SCADA system is not cross-checked, neither in the outlet structure nor downstream at the energy dissipation weir.

Summary

It can be concluded that structures, having the priority of generating hydropower, are operated comparable to the Beles scheme: Requirements, formulated at LDC, are dispatched to the respective site where adjustments are made accordingly to meet the demand. However, dams are generally subject to a broader set of constraints as opposed to the Beles scheme. Dams might perform additional releases if the water level enters flood buffers, downstream needs have to be met, conflicts with other water consumers might occur. As a result, more complex operation accrues from mutually intervening purposes at a dam site.

Examining the process of developing operation rules revealed the course of action given in Figure 17. Information are based on [ENTRO (2016), FDRE (1997), AfDB (2001), AfDB (2009a), AfDB (2009b), EAWAG (2006), EEPCO (2009a), EEPCO (2009b)].

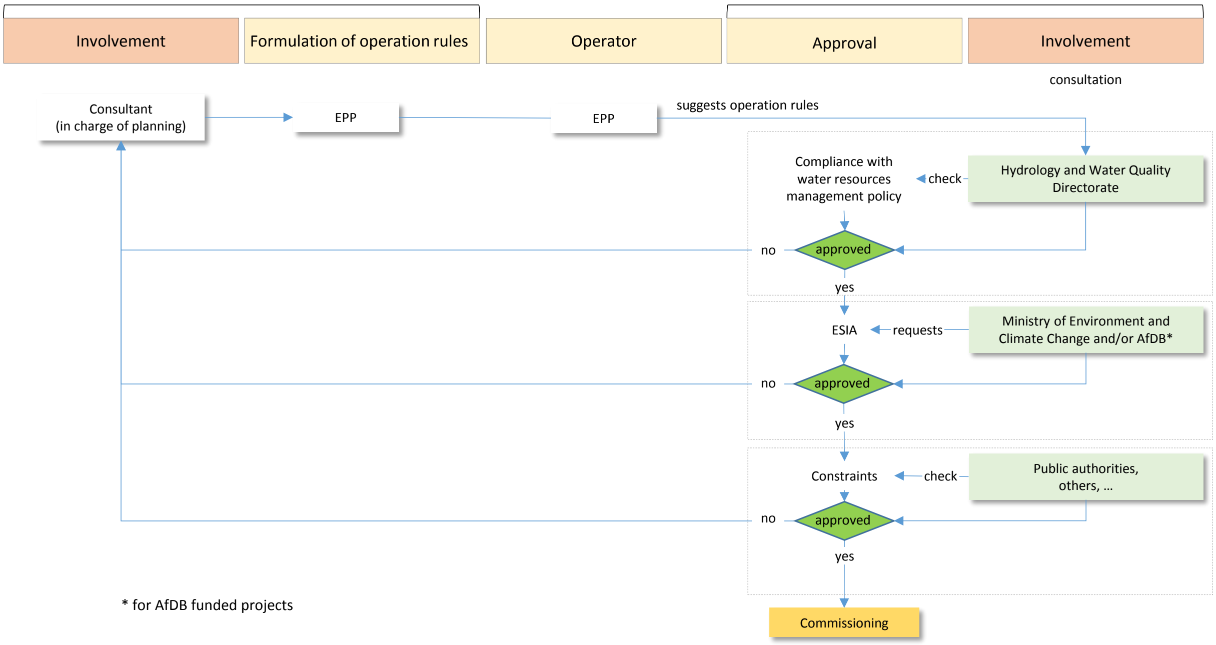


Figure 17: Development of operation rules associated with planning of a dam in Ethiopia

If a new dam site is under consideration, factors come into play which are set out in the guidelines of development banks like the World Bank or African Development Bank (AfDB). This entails two standards: Environmental and Social Impact Assessment (ESIA) and Environmental and Social Management Plan (ESMP). Both must be performed to be in accordance with international directives. The environmental policy of Ethiopia itself has adopted these standards [Federal Negarit Gazeta (1995), FDRE (1997)]. A premise of the environmental policy is to avoid or minimise harmful impacts on the environment in the process of developing infrastructure, especially projects which are expected to cause adverse impacts on the environment (Schedule 1 projects) [EEPCO (2009a), EEPCO (2009b)].

This means that effects of release patterns and operation rules are addressed and evaluated in terms of impacts on downstream river reaches as part of the development process. Thus, water management of a reservoir is embedded in the overall project planning approval. Formulating operation rules is usually commissioned to the consultant who is in charge of planning.

Once construction is finished and the infrastructure is in operation, changing operation rules is not considered as an act pertinent to further assessments. The environmental policy addresses projects in the sense of building something new. However, changing operation is seemingly not regarded as action necessitating impact assessment. Clarification on the subject of operation rules and when changing rules is worth the effort of conducting impact assessments are given in Section 6.1.3.

In conclusion, operation rules are assessed during the stage of planning but do not undergo an institutionalised process of periodic review during the life-time of a reservoir, even if boundary conditions might have changed substantially as time goes by.

5.3 South Sudan

South Sudan is the newest country in Africa. It emerged in 2011 after a civil war and a referendum in favour of secession. Southern Sudan covers an area of about 640,000 square kilometres with the whole area distributed in the southern plains of the White Nile and its tributaries. 10 states constitute South Sudan. Each state is further divided into counties, payams and bomas. South Sudan's population is 11.3 million in 2013 with an annual growth rate of 4.1% based on the period 2012-2013, which is the highest in Africa. 70 percent of the total population lives in rural areas.

The country has substantial water resources but these are unevenly distributed across the territory and vary substantially between years with periodic major flood and drought events. Annual rainfall range from 400mm in the northern parts to 1600mm in the southern parts distributed across three major River Basins, namely: Bahr el-Ghazal, Bahr el-Jebel and the river Sobat. Within the region are various surface water sources comprising perennial rivers, lakes and wetland areas; seasonal pools/ponds, rivers, torrents, streams and extensive floodplains (known locally as Toich); and cataracts/falls/rapids upstream of the rivers.

In South Sudan three major tributaries meet and flow into the White Nile, namely: Bahr el-Ghazal (comprising three sub-basins of Kiir, Loll and Jur); Bahr el-Jebel (comprising numerous tributaries such as Yei, Aswa and Kiit; in addition to branches such as Bahr el-Zeraf); and River Sobat (comprising three sub-basins of Pibor, Akobo-Baro; in addition to branches and Khors such as Machar and Adar River Systems and Khor Nyanding). Also, there are seasonal rivers and streams that originate and flow inside Southern Sudan, namely the Drainage of Eastern Equatoria Plateau (Kurun, Hoss and Keneti), system of rivers flowing out of Western Equatoria (Tonj, Naam and Gel). Finally, the main stem of the White Nile (from Lake No to Wun-Thou, north of Renk) receives large volumes of water from systems of Khors and Wadis (Fulus, Atar, Lolle and Yabus).

When high river discharges occur, water spills over the banks of rivers and floods large areas of land creating swamps with an area of approximately 3 million ha, 1.4 million ha are seasonal and the remaining 1.6 million ha are permanent wetland. Not all the water discharged into the swamp areas flows out, creating a permanent swamp and giving the region its name: Sudd (meaning barrier/blockage in Arabic). The swamps and marshlands of Sudd Region are characterised by high levels of vegetation cover. Altogether wetlands account for around 7% of the total land area of Southern Sudan.

The main watercourse of the country is the White Nile. The river enters the country in the utmost southern part at the Nimule National Part, passes Juba and continues north constituting the Sudd wetland. The Sudd wetland is the inland delta of the White Nile and one of the largest swamps worldwide. It is one of the most ecologically valuable areas in the Nile river basin and is listed as a Ramsar Wetland. It consists of lakes, marshes and extensive floodplains.

Southern Sudan possesses large areas of land underlain by rich aquifers, including the Umm Ruwaba formation. These water-bearing formations are recharged by seasonal rainfall and river flooding and in some cases extend across international boundaries. Information on the distribution, characteristics, annual extraction and recharge, depths, associated risks (sources of pollution and possibility of over-abstraction) and flow direction of these underground waters is scarce or inadequate.

The climate of Southern Sudan is generally seasonal with considerable annual variations and is characterised by a single rainfall season. The northern parts fall under the Sudano-Sahelian zone which is predominantly dry, sub-humid and semi-arid with extensive grazing. This zone is characterised by dry spells especially in the first months of the rainy season while the second half of the rainy season is marked by heavy and stormy rains of short duration. The southeast and eastern parts fall under dry sub-humid and semi-arid mountainous East Africa zone with potential for rain-fed crops. The southwest and western areas with good drainage conditions fall under the humid Central Africa zone, predominantly moist sub-humid and humid with a wide range of perennial tropical crops and extensive areas under forest. There is evidence to suggest that climate variability has increased in recent years. The average annual rainfall increases from north with approximately 700 mm/year to south-east and south-west with over 2000 mm/year. The mean temperatures in South Sudan are typically above 25°C and can rise above 35°C, particularly during the dry season, which lasts from January to April.

Dam capacity is limited in South Sudan. The Maridi dam, also called Kazana, was rehabilitated in 2010 for public water supply and irrigation uses. Feasibility studies have been contracted in 2008 for three medium-sized dams: the Sawa dam in Wau, the Baraj dam in Juba and the Kenti dam in Torit (respectively in Western Bahr El Ghazal, Western Equatoria and Eastern Equatoria states), aiming at fulfilling South Sudan's needs for electricity and clean water. In addition, the Bahr el Jebel hydropower cascade has also been proposed constituted by five projects in Fula, Bedden, Shukoli, Lekki and Juba yielding an estimate 2 590 MW compared to the current 22 MW available (for a demand of around 45 MW) [GOSS (2007), MWRI South Sudan (2011), FAO Aquastat (2016)].

Demand for water is expected to increase rapidly in future given projected population growth and economic development. The impact of human activities on the availability and quality of water resources is already evident in the form of increased pollution, reduced river flows, lowering of water table in urban areas and contamination of both surface and ground waters, and is a growing concern.

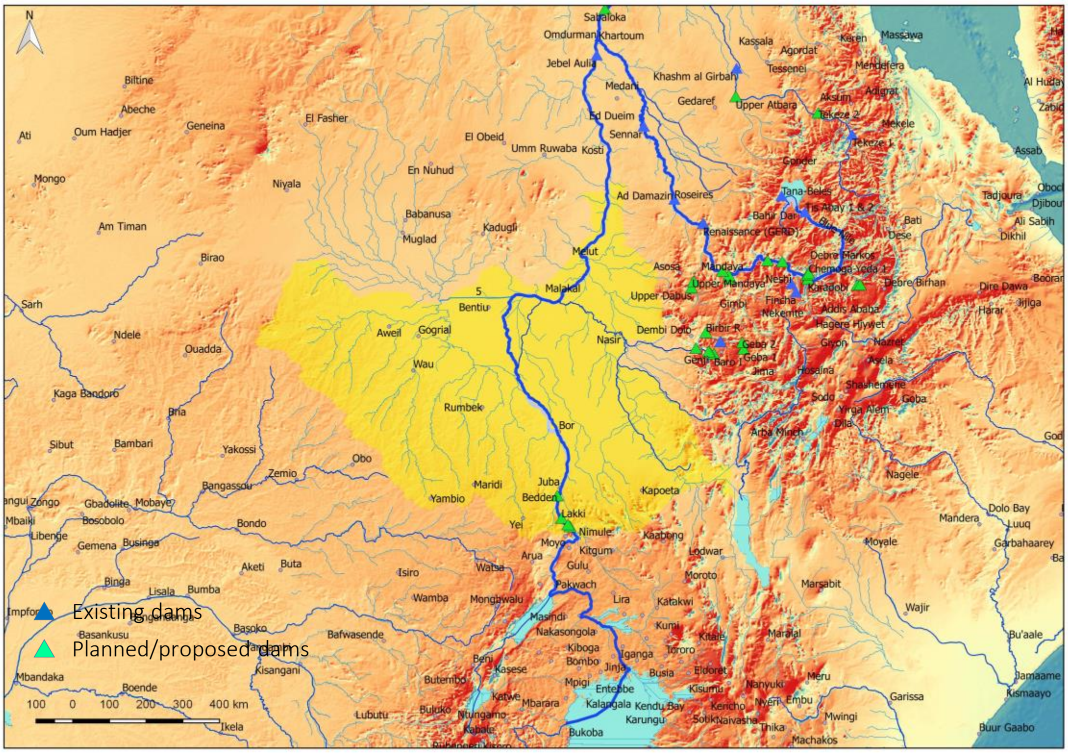


Figure 18: Overview of the South-Sudan with existing and planned dams

5.3.1 Institutional settings

The Water Council is the highest institutional body which takes responsibility of South Sudan's water resources. The Council is chaired by the Minister of Water Resources, Irrigation and Water and

Sanitation Services. The functions of the Council are explained in [The Republic of South Sudan (2013)] as the following:

i. Be the principal multi-stakeholder advisory body of the Water sector and advise the Cabinet on approval of new or amendment of legislation, policies and strategies;
ii. Act as an appeal and arbitration body for resolving disputes in the water sector;
iii. Oversee overall compliance with sector governance and coordination arrangements;
iv. Oversee, ensure coherence and advise on sector development and management plans;
v. Advise the Cabinet on major water investments and any submissions by the Water Resource Management Authority and the Safe Water Supply and Sanitation Services Regulatory Board;
vi. Issue guidance to the Water Resource Management Authority and the Safe Water Supply and Sanitation Services Regulatory Board;
vii. Recognize and promote good practices in the water sector ;
viii. Any other function or duties that may be assigned by the Cabinet.

Its main objectives are to formulate common water resources development policies, strategies, plans and legislation, guide and supervise their implementation, coordinate and integrate the activities of all the water sector agencies and stakeholders and preside over international affairs related to water.

The Council constitutes an Executive Secretariat, whose members are the Executive Secretary, the Director for Inter-Governmental Relations in the Office of the President, the Director General for Planning and Programming in the MWRI, Legal Counsel. It is supported by communication specialists, technical and support staff. Its main functions are to support the Council in the execution of its duties, provide technical expertise in water resources and water supply and sanitation, and obtain and provide such information and data as directed by the Council.

Water in South Sudan shall be managed by water sector stakeholders under the guiding principle of an integrated approach to water resources management. The organisational structure incorporates various levels and starts at the national level with the Water Resources Management Authority. This authority delineates river basins, catchments and sub-catchments and nominates Basin Water Boards, Catchment and Sub-Catchment Committees. Water users are encouraged to form Water Users Association in order to manage, distribute and conserve water under the regulatory framework outlined in [The Republic of South Sudan (2013)].

Concerning dams, the draft water bill [The Republic of South Sudan (2013)] roughly specifies that dam owners are subject to register their dam with the Basin Water Board.

5.3.2 Monitoring

At present, no comprehensive assessment of water resources quality, whether surface or groundwater, nor are adequate water quality monitoring systems are established [MWRI South Sudan (2011)].

The responsible government agency for surface water monitoring in South Sudan currently resides under the Directorate of Hydrology and Survey (DHS) under the Ministry of Electricity, Dams, Irrigation and Water Resources (MEDIWR). The South Sudan Meteorological Department (SSMD) under the department of South Sudan Civil Aviation Authority is responsible for meteorological monitoring. This institution resides within the Ministry of Transport, Roads and Bridges [NBI (2015)].

There are currently only 5 operational river gauging stations within South Sudan but a total of 71 historic locations that could potentially be rehabilitated. Data collection activities are carried out by river technicians with gauge readers recording stage on a daily basis. Data transmission is completed manually by phone and email and hard copies of recordings are sent to Juba. Microsoft Excel used for data archiving and analysis [NBI (2015)].

A formalised hydromet data sharing mechanism is not in place both at the ministry and meteorological department. User can make written requests to get available digital data and hard copy form. However, the SSMD is working on the formulation of data sharing policy and planning to charge data users [NBI (2015)].

5.3.3 Operation

Currently, no formal system for allocating water resources to sector or user exists [GOSS (2007)].

Concerning dams, there is only one small dam in place outside of the Eastern Nile Region. The Maridi dam was rehabilitated 2010. Apart from future plans about developing suitable sites like Fula 1 on the Bahr el-Jebel River or some other locations, no actions are being undertaken to develop hydropower.

In respect to safeguarding the environment, specific measures to preserve minimum flows of water required to maintain basic ecosystem functions are mentioned [GOSS (2007)] but not further specified.

Operation in the agricultural sector such as large scale irrigation is not yet developed. Historically, South Sudan relies on rainfed agriculture. Developments addressing irrigation by international cooperation organisations are currently put on hold.

5.4 Sudan

Sudan covers about 1.9 million km² with an estimated 35 million people. It is the third largest country in the continent. It stretches from the arid region in the north with almost zero rain to tropical savannah climate in the utmost southern parts along the border to South-Sudan and Ethiopia.

Khartoum is the capital with more than 4 Million inhabitants and largest city in the country together with Omdurman. Nyala, Port Sudan and Kassala follow in terms of population. About 11 Million people live in cities larger than 50,000 inhabitants, whereas the majority of more than 60% of the Sudanese population live in rural areas mostly along the Nile River and its tributaries.

Sudan is under federal rule with 15 States. Each State is governed by a Wali (Governor) with 7 to 10 State Ministers, 4 to 5 Commissioners for the different provinces and a number of localities. Each State has complete administrative and fiscal autonomy and its own State Legislative Assembly for legislative matters of the State [FAO Aquastat (2016)].

The terrain is generally flat plains, broken by several mountain ranges. The Deriba Caldera in the west hosts the highest mountain rising over 3000 masl. The Main Nile, Blue Nile and Atbara are the largest streams in the country. In the South-West of the Sudan the Bhar el Arab, which forms part of the border to South-Sudan, is a tributary of the Bahr el Gazal, is the largest river [FAO Aquastat (2016)].

Nile water is by far the most important water resource in Sudan. Groundwater is available to some extent but is not considered as a major source apart from supplying drinking water and in some areas for small scale irrigation. Approximately up to the latitude of Khartoum there is some amount of rain which sums up to 300 mm and increases to 600 mm a year towards south. North of Khartoum the rainfall decreases sharply up to almost zero at the border to Egypt.

The flow of the White Nile is almost equal for each month. There is no clear flood season visible in the monthly hydrograph, although October, November, December and January show the highest flow rates based on flow observations at Mogran. The flow volume of September is close to October. The long average annual discharge amounts to approximately 27 km³ at Mogran.

In contrast to the White Nile, the Blue Nile shows a distinct seasonal flow pattern. The annual flow of almost 50 km³ is mainly concentrated to four months. Starting in July with a noticeable increase in flow, discharge rises in August reaching the highest amount of water followed by September. In October the flow volume drops almost to the amount of July. This means that four month deliver roughly 85% of the annual flow volume. Concentrated on August and September only, both month provide 60% of the annual flow.

The seasonal pattern for the Atbara River in the east of Sudan is even more distinct. July to October sum up to roundabout 97% of the total flow volume of 12 km³, whereas August and September bring about 76% of the annual flow volume. All other months are more or less negligible. The Atbara River can run dry. However, since Tekeze Dam scheme upstream is in operation, the river carries water throughout the whole year.

The Gebel Aulia dam, which is the only dam site along the White Nile in Sudan, affects the flow by backwater for more than 600 km upstream at full water level. This results in a total water surface of 1700 km² and gives rise to high evaporation losses estimated to 2.5 MCM/year. Accurate figures are difficult to obtain because of the extent of the water surface. The bathymetry of the reservoir is calculated based on 8 water level stations equipped with elevation-cross section curves. The readings at the stations are made daily and transmitted by phone (landline). All observations are archived analogue. Responsibility for the 8 stations was handed over from Egypt to Sudan in 1977.

At the Blue Nile, on average, 30.5 MCM/day of the incoming flow is diverted into the Gezira scheme, which constitutes the largest withdrawal along the Blue Nile. The share for requirements downstream of Sennar Dam was increased from 7 MCM/day to 20 MCM/day as of 2012. The increase of releases from Sennar Dam was made possible by additional storage due to the hightening of Roseries dam completed in 2012. The increase had positive effects for downstream needs like ferry services, water abstraction schemes and water quality.

Concerning sediment load, the White Nile contains comparatively less sediment as the Sudd and Sobat Swamps behave as huge sediment traps. As opposed to the White Nile, the Blue Nile and the Atbara River transport huge amounts of sediments which, in turn, affects operation of dams. The problem of sedimentation along the Blue Nile becomes clear at Sennar dam. The bathymetry of the reservoir was surveyed regularly until 2010 showing a reduction of more than 50% of the storage volume from 0.93 BCM to 0.4 BCM. The present storage capacity of Sennar Dam can provide water for 10 to 15 days to meet the needs of Gezira.

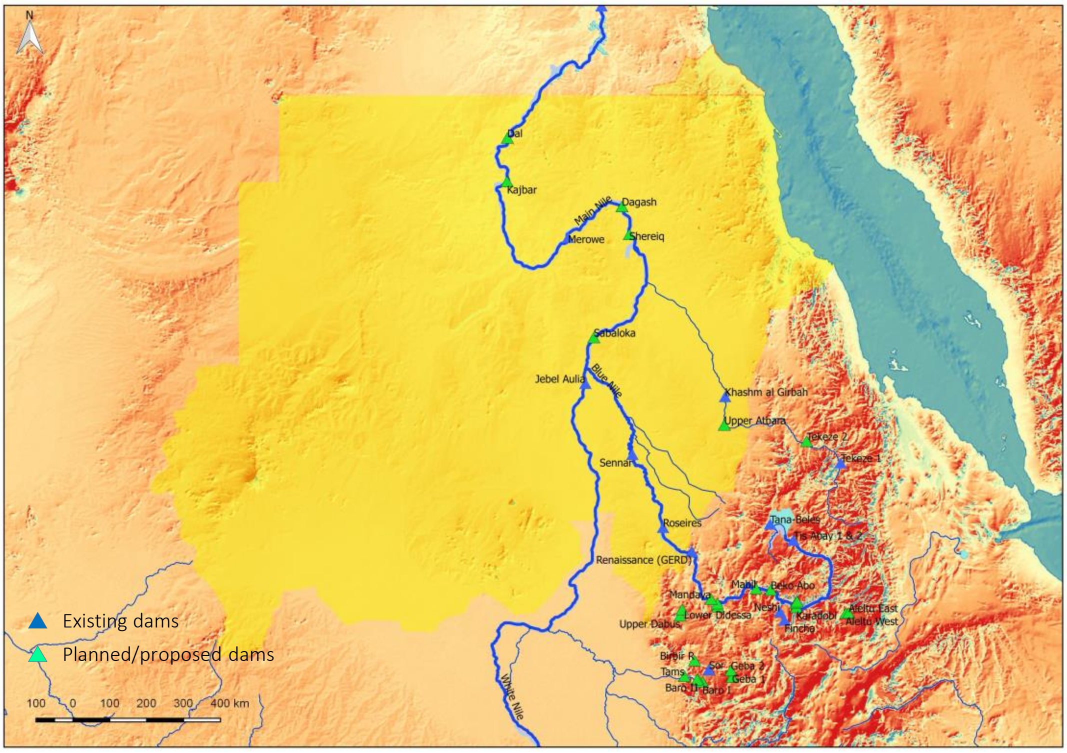


Figure 19: Overview of the Sudan with existing and planned dams

5.4.1 Institutional settings

Overview

The formation of the National Council for Water Resources (NCWR) was a step towards streamlining the country-wide decision-making with regard to water resources. The NCWR or Water Council is headed by the Minister of Water Resources, Irrigation and Electricity and includes representatives of stakeholders from the supply and demand sides.

The NCWR has given the mandate to the Ministry of Water Resources, Irrigation and Electricity (MWIE or MoWRIE) by constitutional documents to assume responsibility for water resources including dams and their operation. The main advisory bodies for dam operation along Blue Nile, White Nile and Main Nile set out be MWIE are:

- the Blue Nile Committee of Operation of Dams
- the High Committee of the Operation of Dams

Both committees constitute prior to the first filling phase of the dams which starts at the beginning of the recession of the flow at the end of the flood season. Meetings are regularly held on a monthly basis or in shorter intervals if need be. The Blue Nile Committee aims more at operational affairs and incorporates irrigation as a major purpose. The High Committee has the focus on hydropower and thus concentrates more on the Merowe Dam or Upper Atbara in the near future. Committee members stem from different entities. The structure is illustrated in Figure 20.

Both committees make strategic decisions about balancing different purposes and requirements. They receive requirements, demands from different units from within the ministry and other bodies which receive water from the river system. Both committees are supported by technical advisors who provide the committees with suggestions regarding dam operation. The advisors are usually recruited from within the ministry with in-depth knowledge of the dam system due to their former positions as directors of dam units or similar.

The MWIE incorporates all entities which have a share in dam operation. Additionally, directors from the Ministry of Agriculture and from the major Sugar Companies are not under the umbrella of the Ministry but participate in the Blue Nile Committee. In general, only governmental-owned entities are involved in dam related affairs.

Concerning transboundary water resources, the MWIE is already mandated to carry responsibility. There is a Permanent Joint Technical Committee on Nile between Egypt and Sudan which originates from the 1959 agreement. This committee discusses cross-border water affairs between both countries and holds meeting every 3 month or at least twice per year. Another committee dealing with transnational water affairs links Ethiopia and Sudan which is the Ethiopian Sudan Technical Advisory Committee (ESTAC).

In addition to the Sudanese organisational structure, Egypt operates independently own gauging stations in Sudan and South-Sudan to conduct measurements of flow along the Nile system. This is based on the 1959 agreement.

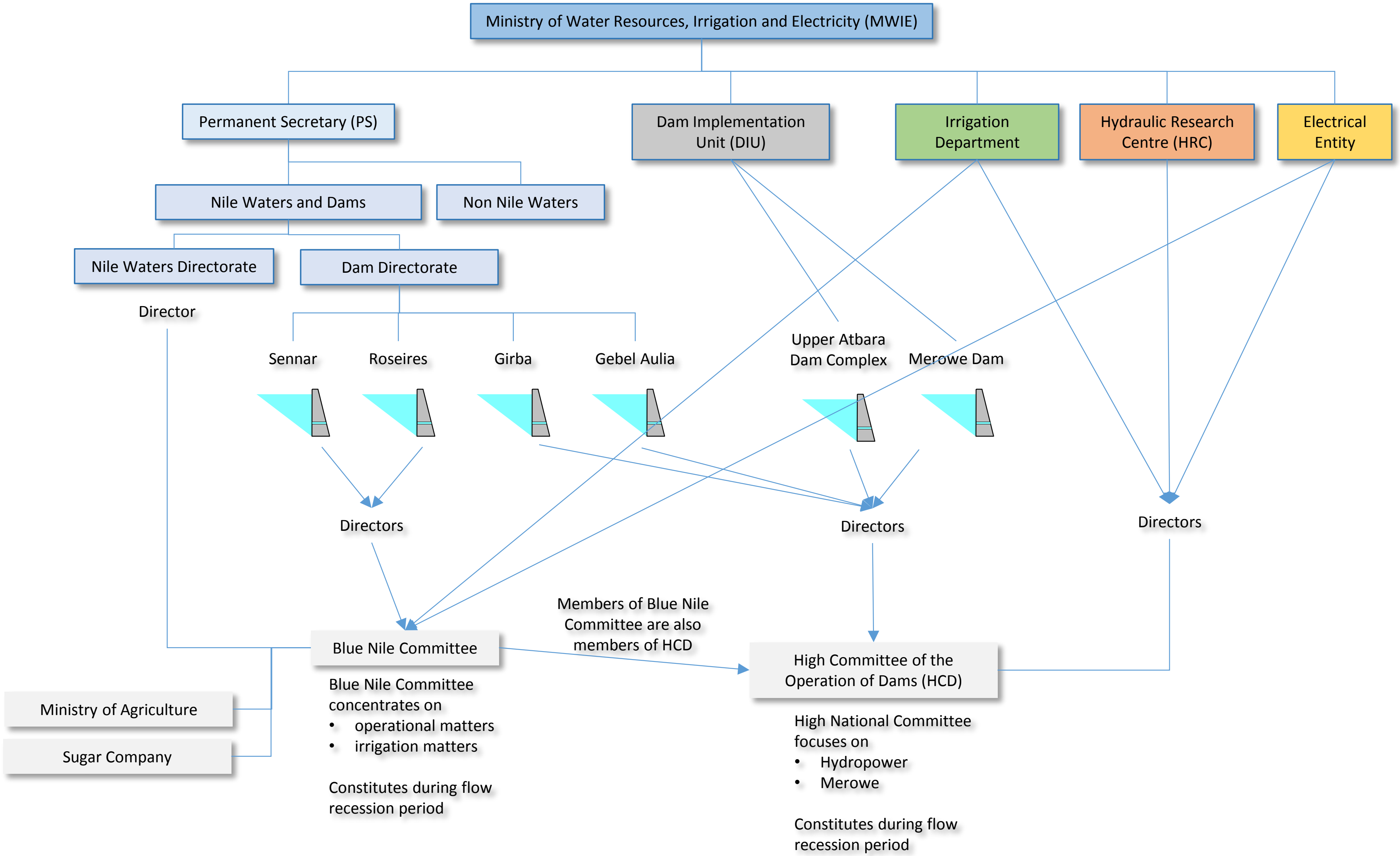


Figure 20: Institutional structure in Sudan with regard to reservoir operation

Details

The Gebel Aulia and Sennar Dam are used as representative examples to outline details of organisational setups of specific water infrastructure and how this fits into the overall institutional setting.

Gebel Aulia is located about 40 km upstream of Khartoum at the White Nile.

Gebel Aulia

Turbines at Gebel Aulia

Figure 21: Gebel Aulia at White Nile

The Gebel Aulia Dam is organised under the Dam Directorate which is part of MWIE. It is the only dam upstream of Khartoum along the White Nile within Sudan. Originally built 1933 to 1937 by Egypt to control flow, it was handed over to Sudan 1977 after the construction of the High Aswan Dam rendered Gebel Aulia useless for Egypt.

The dam management of Gebel Aulia is directly located at the dam site and is in touch with the Dam Directorate. Operation of the dam has to allow for varying flow of the Blue Nile and requirements – mainly flood protection – for Khartoum. Decisions about dam operation are made at the dam site following a concise rule curve for the water level (see Figure 2). However, exceptions are coordinated by the Dam Directorate in Khartoum.

From the view point of Sudan's coordinated reservoir operation, Gebel Aulia in conjunction with Sennar and Rosieres Dam can be seen as a reservoir system. Gebel Aulia Dam helps in flood protection, not only for Khartoum, but also in all the main Nile Downstream Khartoum. As of 2003, hydropower with a capacity of 30 MW was installed.

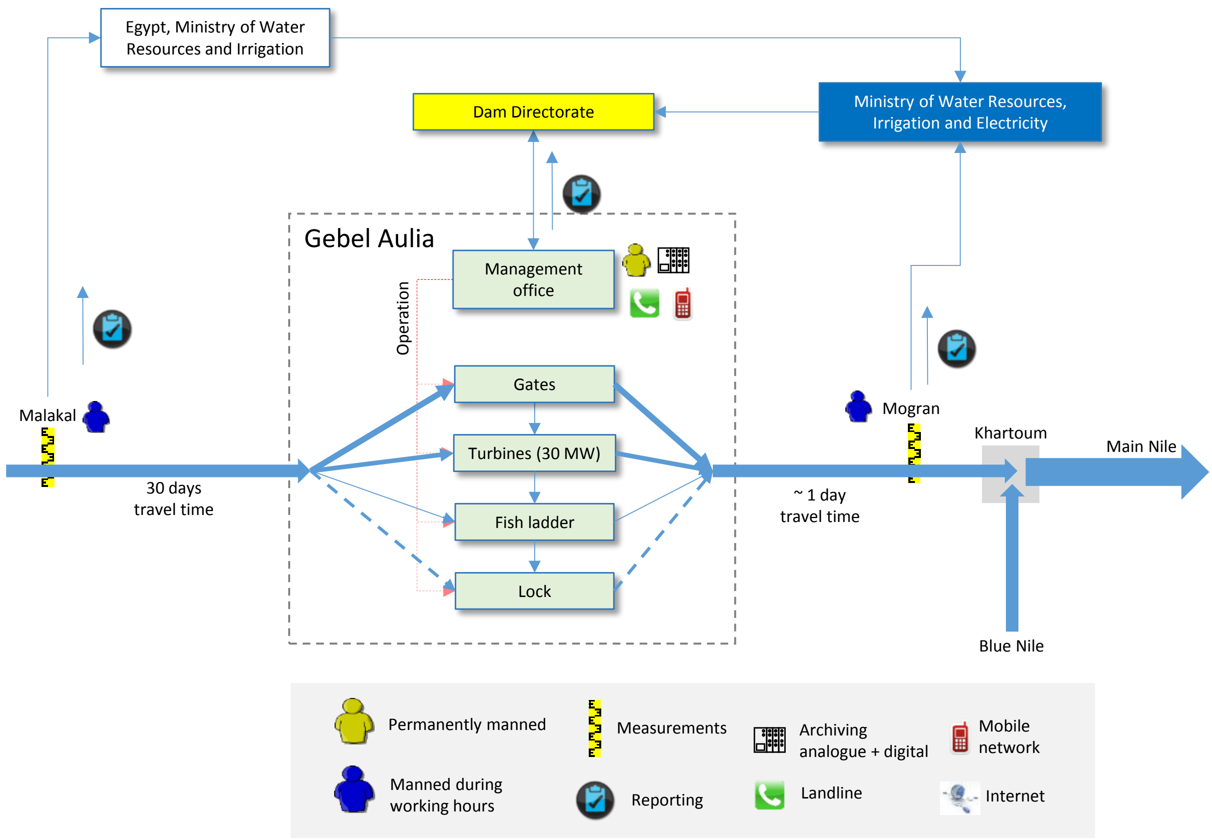


Figure 22: Gebel Aulia's organisational structure

The Sennar Dam is located about 300km upstream of Khartoum along the Blue Nile.

Figure 23: Sennar Dam at Blue Nile, view downstream

The Sennar Dam is organised under the Dam Directorate which is part of the Ministry of Water Resources, Irrigation and Electricity. Together with the Roseires Dam, Sennar Dam constitutes a cascade along the Blue Nile in Sudan. The dam was built 1925 as the main structure for providing water for the Gezira irrigation scheme. In the 1970s, pumps were built in for abstracting water for additional irrigation schemes outside of Gezira (Rahad with 125 Tsd. ha and Suki with 40 Tsd. ha). In 1962, turbines were installed to generate hydropower and as of 1962 to 1975, sugar companies emerged.

One sugar company (North-West Sinnar Sugar Company), developed in 1975, abstracts water directly from the reservoir. The Gunaid Sugar Company developed in 1962 Company abstracts water from the

Blue Nile about 160 km downstream the dam. The Gunaid pump station is one of the key players in deciding the minimum flow downstrean Sennar dam, as it requires some minimum level of the river for the pumps to be operated. Each sugar company operates roughly 15 Tsd. ha of sugarcane.

The dam management of Sennar Dam is directly located at the dam site. It is in touch with the Dam Directorate and Roseires Dam. Both dams constitute a cascade dam system and form a unit from the water resources point of view. This is institutionalised at both dams with aligned operating rules documented in one manual, the so-called red book. Operation engineers are in touch with each other. The organisation at Sennar Dam including the major stakeholders and their communication channels are illustrated in Figure 24.

Decisions about dam operation are made at the dam site following the red book. However, exceptions are coordinated by the Dam Directorate in Khartoum.

By far the most important purpose is water provision for Gezira. Operation of the dam has to allow for requirements of Gezira. Water demand of Gezira is calculated and collected autonomously within the Gezira scheme and transferred to the central communication unit for reporting procedures of Gezira. The operation engineer at Sennar Dam is directly in touch with the Gezira general communication unit about daily requirements. If water shortages arise at Gezira, complaints management goes directly from Gezira to the Dam Directorate because water management decisions are made based on a broader view. The Dam Directorate feeds their decision back to Sennar Dam.

From the view point of Sudan's coordinated reservoir operation, Sennar Dam plays a role in conjunction with Rosieres Dam and Gebel Aulia for Khartoum and downstream of Khartoum but has no distinct mandate for flood protection of Khartoum.

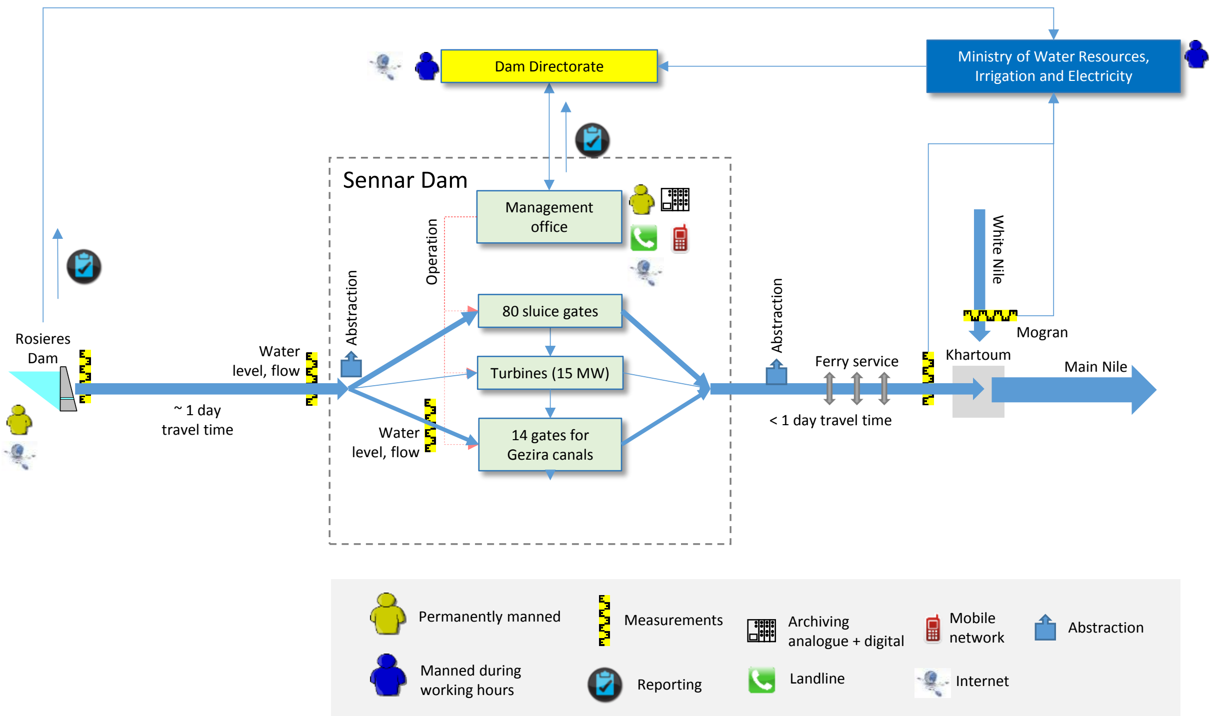


Figure 24: Senner Dam's organisational structure

5.4.2 Monitoring

Overview

Monitoring of flow has a long tradition along the Nile.

In Sudan recording flow of the Nile are mandated to the Nile Waters Directorate. They operate water level and discharge gauging stations. Time series are partly available over a period of up to 100 years.

At present, water levels and flows of all major gauging stations in the White Nile, Blue Nile, Main Nile and Atbara River are observed, transferred to and archived in Khartoum. Records are usually made on a daily basis. During flood events time intervals of readings can go down to 2h. The most important gauging stations are

- Malakal (White Nile) located in South-Sudan and operated by Egypt. Since 2013 out of operation due to the armed conflict in South-Sudan.
- Mogran (White Nile), located immediate upstream of Khartoum
- Blue Nile at Khartoum, upstream the confluence with White Nile
- Ed Diem (Blue Nile), immediate downstream the border to Ehtiopia
- Setit at Hiliew, immediate downstream the border to Éthiopia
- Atbara at Kubur, downstream the border to Ehtiopia
- 300km upstream of Merowe at the Main Nile
- Dongola (Main Nile), downstream of Merowe

In addition, for operating the Sennar Dam the releases of Roseries Dam are essential.

The readings of flow, made at 06:00 am, are delivered to the respective dam sites to facilitate operation. All dam sites have wireless connections with Khartoum's archiving unit. Water level, storage volume, releases and, if in existence, hydropower generation, are sent to Khartoum on a daily basis. Request for data for research, re-evaluation, statistics, etc. can be submitted to the archiving unit which provides the information accordingly. The data management and archiving system uses a database. Evaluations based on Excel including simple statistical evaluations are possible on the fly. In recent years, internet connections were installed at the gauging stations and the dam sites.

The Sudan Meteorological Authority (SMA), which runs under the Ministry of Environment, supports the MWIE with respect to dam operation. They provide descriptive short-term forecasts for all sites. 2 to 3 days streamflow forecasts are conducted in the Ministry and ENTRO and supplied to the respective dam sites.

Seasonal forecasts of the Blue Nile recession are conducted in the Ministry. All seasonal predictions are based on statistical approaches using the long time series of flow of the Nile as reference. Forecasts concentrate on the recession of flow as of October. Seasonal forecasts for the flood season as a whole are not in use.

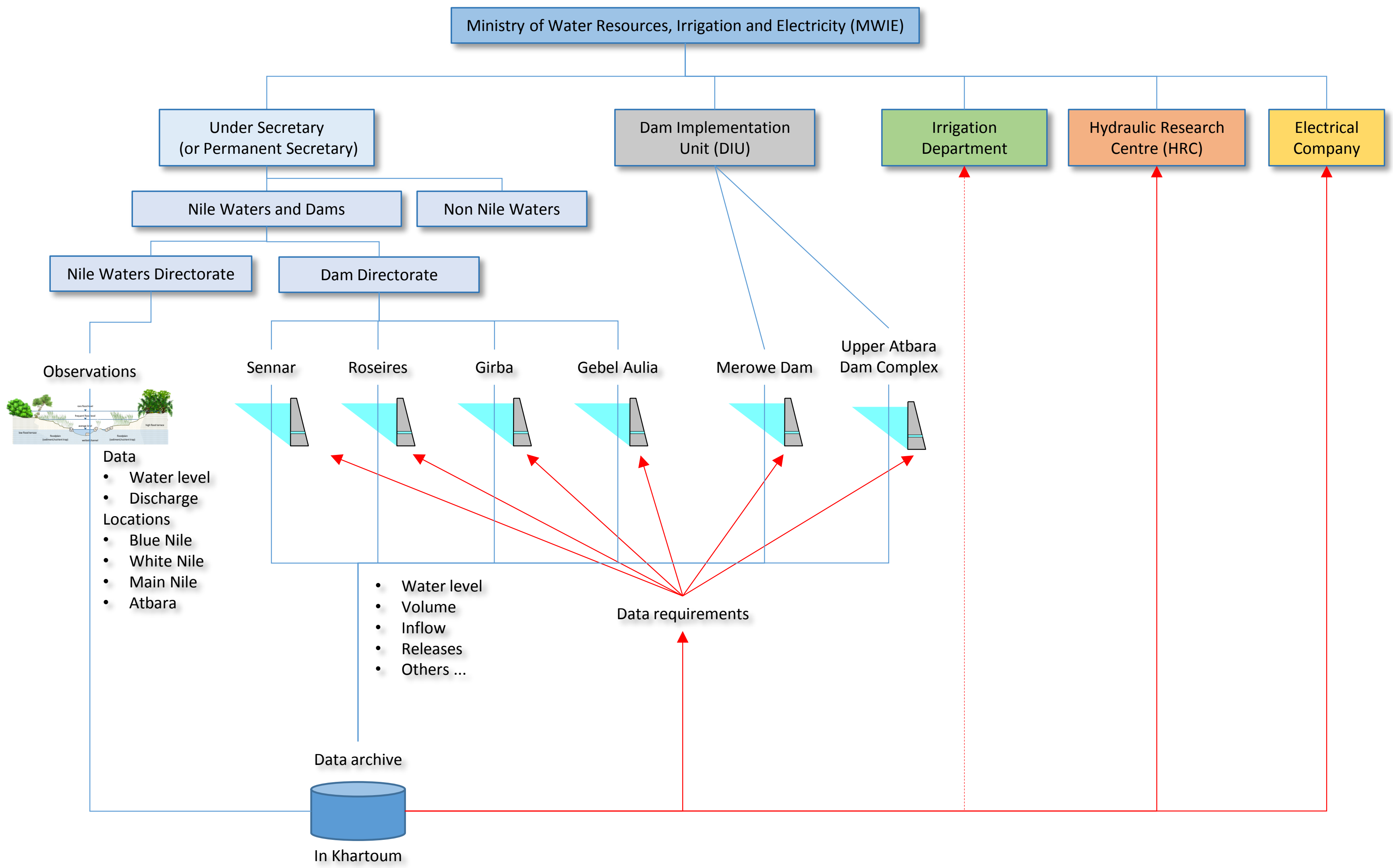


Figure 25: Data flowchart in Sudan with regard to reservoir operation

Details

Gebel Aulia and Sennar Dam are used as representative examples to outline details of monitoring.

Gebel Aulia:

Monitoring at the dam sites comprises the water level and generated power. Flow is observed upstream and downstream of the dam respectively, data are kept in analogue and digital form.

The upstream station, which is important for operation, is Malakal. This gauging station is located in South-Sudan and operated by Egypt. Observations are provided by Egypt. The lag time between Malakal to Gebel Aulia is roughly 30 days. Since 2013 the station has been abandoned by Egypt Engineers because of the civil war in South-Sudan. In addition to Malakal, Egypt operates own gauging stations along the Nile system in Sudan and South-Sudan. These are in addition to the stations which are operated by the two countries by themselves.

The essential station downstream Gebel Aulia is Mogran. It is located close to Khartoum upstream the confluence with the Blue Nile. The lag time between Gebel Aulia to Mogran is less than one day. Data exchange with Khartoum is performed on a daily basis.

Sennar Dam:

Monitoring at the dam sites comprises upstream and downstream water level, water abstraction for Gezira and generated power. Flow is observed upstream and downstream of the dam respectively, data are kept in analogue and digital form.

The upstream station and the water abstraction for Gezira is observed every day by the monitoring team at Sennar Dam and Egyptian engineers. No direct exchange between the measurements performed by Sudan and Egypt takes place.

The Sudanese observations are transferred and included in the monitoring system in Khartoum. Data exchange with Khartoum is performed on a daily basis. This ensures availability of water levels upstream/downstream at Sennar Dam for re-analysis or daily check-ups. The operation engineer has login credential to websites representing all major dam monitoring gauges and structures.

An additional but probably informal way of communication was established by means of WhatsApp. User groups have been established to link operation engineers from different dam sites. Since WhatsApp is not save, no confidential information are sent.

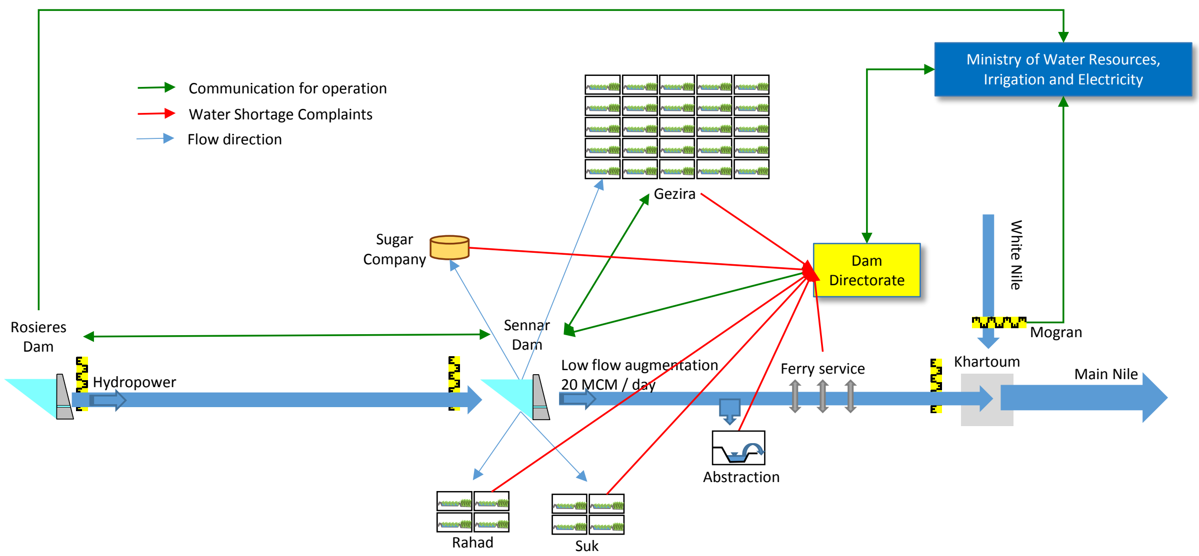


Figure 26: Sennar Dam data flowchart

5.4.3 Operation

Overview

Dams in Sudan are mainly multipurpose focusing on:

- Hydropower
- Irrigation
- Water Supply
- Environmental flows
- Flood control
- Navigation
- Water quality

Table 5: Existing dams in Sudan

Existing Dams	
Name	Type
Gebel Aulia	Hydropower, Flood protection
Khashm el Girba	Hydropower
Merowe	Hydropower
Roseires	Hydropower, Irrigation
Sennar	Irrigation, Hydropower

Table 6: Dams under construction in Sudan

Dams under construction	
Name	Type
Upper Atbara	Hydropower

Table 7: Planned/proposed dams in Sudan

Dams under construction	
Name	Type
Dagash	Irrigation

Dal High Dam	Hydropower
Kajbar Dam	Hydropower
Sabaloka	Hydropower
Shereig	Hydropower

The following major structures are located at:

- Rosieres and Sennar Dam along the Blue Nile
- Gebel Aulia at the White Nile about 40 km upstream of Khartoum
- Merowe at the Main Nile
- Khasm el Gibra and Upper Atbara (almost completed) at the Atbara River

All dams have operation rules in place. The Blue Nile and Atbara Dams follow an operation pattern which is shown in principle in Figure 28. In order to avoid sediment to be deposited in the reservoir, filling starts at the end of August and is completed in September. Filling can be suspended depending on current flow conditions (see dashed line in Figure 28). Hence, timing of the filling is a crucial operational aspect. Two components, which run diametrically opposed to each other, has to be achieved:

- Minimise sediment to be deposited in the reservoir
- Ensure the reservoir has reached full storage capacity before the dry season starts.

Gebel Aulia's operation is connected to the Blue Nile dam system and its filling pattern relates to. Gebel Aulia retains water during high flow of Blue Nile to accomplish flood protection of Khartoum and downstream for the Main Nile and sustains discharge during low flow conditions of Blue Nile. As such, there is already a coordinated reservoir system in place in Sudan which embeds White Nile, Blue Nile, Main Nile and Atbara River.

The central decision-making units for strategic decisions are the two committees which are: the Blue Nile Committee and the High Committee. Strategic decision-making is supported by a hydrological model based on Excel. The model was developed and is in use within the Ministry.

Daily operation, however, is accommodated by the Dam Directorate or Dam Implementation Unit (DIU). Concerning the Dam Directorate, information from all dam sites are received daily. During normal operation, decisions of releases are made at the dam sites based on general operation rules. These rules are referred to as "red books" at Sennar and Rosieres dam. During exceptional conditions the Dam Directorate in Khartoum can overturn decisions at the dam site and deploys new releases.

The DIU runs the Merowe Dam and in the near future the Upper Atbara complex. Links between operation at Merowe and all other dams are not yet developed, thus, Merowe is a single site reservoir with the major purpose of generating hydropower. To some extent, flood protection up to the border station at Wadi Halfa plays a role.

Apart from the overall objectives of balancing water for irrigation, flood protection and hydropower, water quality and environmental aspects as well as supply and sanitation must be considered. Such topics are under supervision of regional departments which may report to the Dam Directorate in case of need.

Assessment and formulation of operation rules is facilitated during the construction of the dam by the respective consultant. Over the years of operation adaptations of the rules take place but not as a formal process of reassessment and reformulation. Rules further develop by experience and are not comprehensively set out in writing.

Details

The Gebel Aulia and Sennar Dam are used as representative examples to outline details of operation.

Gebel Aulia:

The main feature for operating Gebel Aulia is a rule curve which determines the water level over the year. The rule curve is illustrated in Figure 27. The minimum and maximum water level to be kept span a range of 5 m and are 372.5 m and 377.4 m respectively. First filling starts usually on 1st of July and rises the water level to 376.5. Filling is suspended during August so as to keep a flood buffer of 1 m. On 3rd of September, usually, the second filling starts and is completed within September. The maximum water level is kept up to March. The water level is gradually lowered from March to April and kept on a minimum until July.

4 different structures need to be operated at Gebel Aulia:

- Gates for regulating flow
- Turbines for generating hydropower
- Fish ladder to allow fish to pass the dam from up- to downstream
- Lock for safe passage of ships

Staff at Gebel Aulia consist of

- 1 dam manager (civil engineer)
- 1 operation engineer (civil engineer)
- 1 maintenance engineer (civil engineer)
- 1 electro-mechanical engineer (mechanical engineer)

All are M.sc. holders. Either the dam manager or the operation engineer must be present in person at the dam site to guarantee a 24/7 accessibility. The dam manager as well as the operation engineer is in contact with Khartoum. 10 years of practical experience are minimum requirements for both. The operation of the turbines relies on separate staff but is supervised by both the dam manager or operation engineer.

There are three sugar farms on the White Nile upstream the Dam. They are the largest water consumers abstracting water out of the reservoir. Their pumps are installed below the minimum water level and are, average hydrological conditions assumed, not affected by the operation scheme.

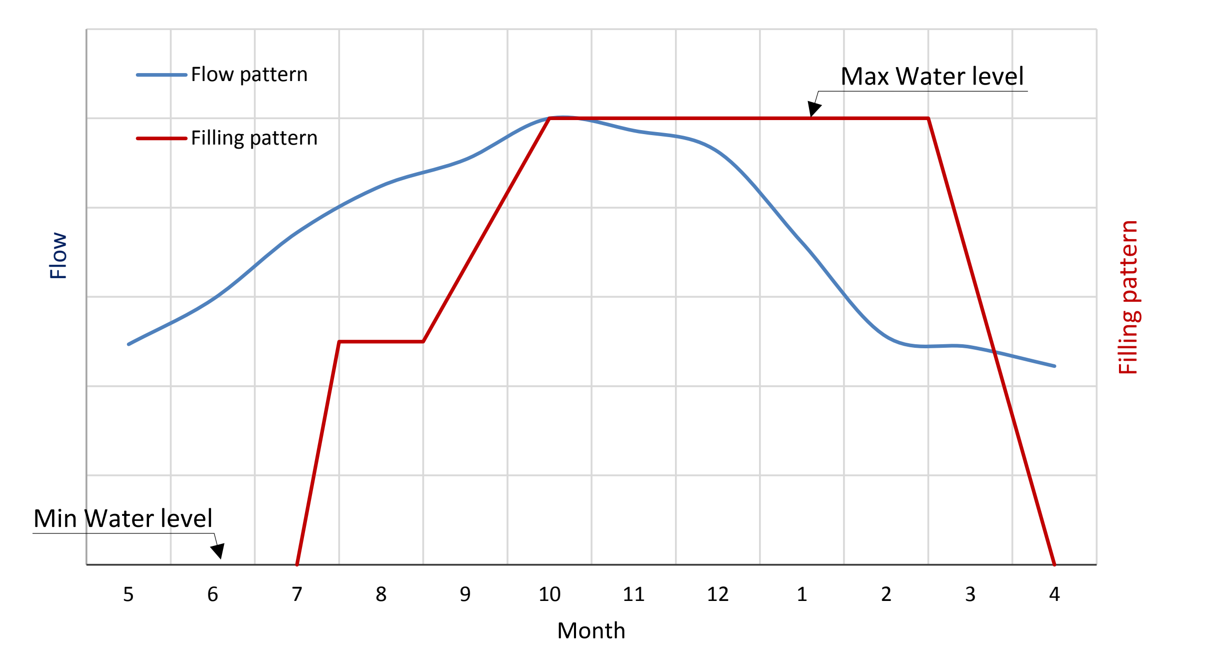


Figure 27: Filling pattern for Gebel Aulia dam

<u>Sennar Dam:</u>

Sennar Dam is the focal point for operation within the Sudanese reservoir system with regard to multipurpose operation. The dam must meet requirements arising from

- Irrigation (the largest and most important irrigations schemes in Sudan)
- Low flow augmentation for
  - ferries
  - water quality
  - abstraction (domestic water supply and a number of small scale irrigation pumps)
- Sediment management

Hydropower generation is a side function.

A rule curve for the water level is the governing element which determines the operation of the gates. Minimum water level is given to 417.2 m (415.0 prior 1970) and maximum water level is given to 421.7 m (420.7 prior 1951). Filling starts in August and is completed in September, subsequently the water level is kept until November when emptying gradually starts until March. The rule curve is illustrated in Figure 28. The minimum and maximum water level to be kept span a range of 4.5 m.

3 structures are in place at Sennar Dam:

- Gates for regulating flow
- Gates for feeding the Gezira canals
- Turbines for generating hydropower

Operating the gates to regulate flow is carried out with a crane. There are 80 gates in total. Each sluice gate is manually opened with the crane. Gate adjustments can take a whole day.

The adjustments for the Gezira canals, however, is automated. Opening and closing of all 14 gates is conducted at the control panel located on top of the dam.

Each activity in terms of changing flow, maintenance or any other dam related process is monitored and recorded in log books. Generally, adjustments are performed on a daily basis, but actions can be requested and implemented at any time. For example, releasing water into the canals sometime evolves into an iterative process since effects at canal junctions further downstream require re-regulating discharge.

The operation manual, indicated as red book, is at hand at Sennar and Rosieres Dam and contains rules for both dam sites. It was written in 1968 and not yet completely re-evaluated since then. However, in recent years a new operation scheme, giving priority to hydropower generation, came into being at Rosieres Dam. The capacity of the turbines at Rosieres is less than requirements at Sennar Dam. As a consequence, modified releases at Rosieres adversely affect operation at Sennar. Although operation at Sennar dam is dependent from releases at Roseires, no re-evaluation and impact assessment was carried out.

Problems regarding operation can also arise from supplying Gezira, if requested discharge exceeds the capacity of the main feeder canals. This imposes additional constraints for operating Sennar Dam as the responsibility of maintaining and operating the feeder canals goes halves to Sennar Dam and halves to Gezira. In addition, short-term needs from Gezira can occur during the rainy season which is supposed to be the period for rainfed agriculture. However, if rain suspends for a longer periods, irrigation schemes request water while the water level at Sennar is still lowest.

Further problems may arise during high flow in the Blue Nile which usually brings loads of debris. Debris flow can cause trouble for operating the gates, especially when the debris enters the pool from which the canals are supplied.

Staff at Sennar dam consist of:

- Director
- Deputy Director
- Operation engineer + assistant
- Mechanical engineer
- Maintenance engineer

Either the director or the deputy director must be present at the dam site. The same holds true for the operation engineer and its assistant. Apart from the mechanical engineers, all engineers are trained as civil engineers.

The monitoring team consists of 3 shifts with at least 3 technicians guaranteeing 24/7 standby.

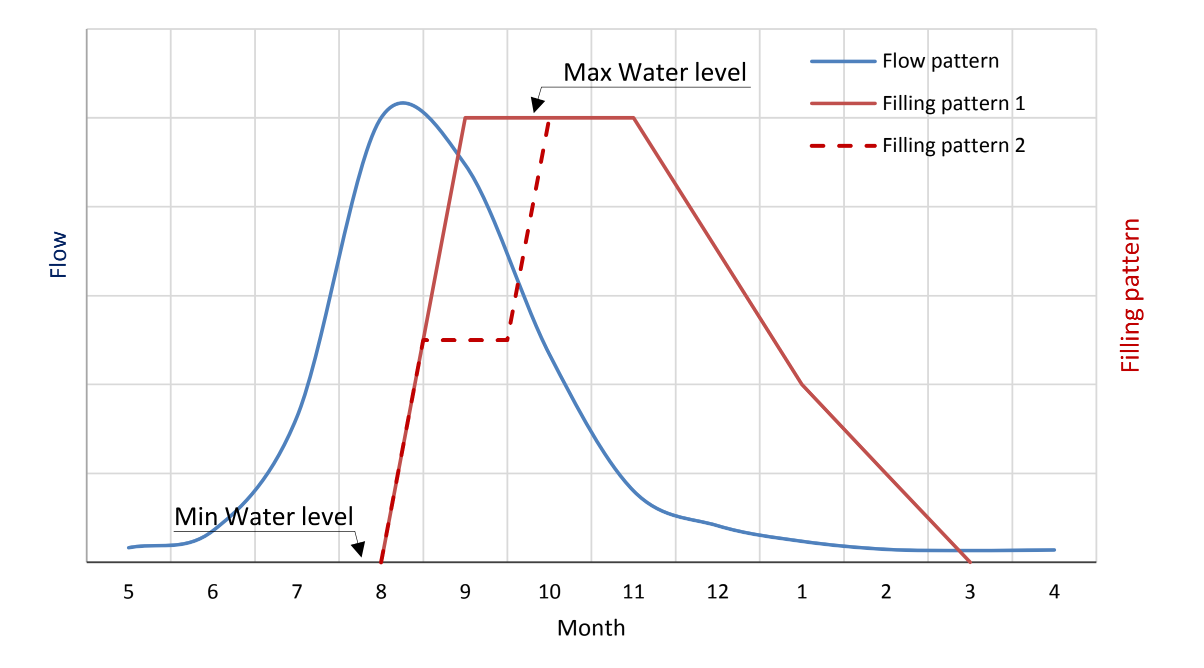


Figure 28: Filling pattern for Sennar dam

Summary

Reservoir operation for irrigation has developed over decades with Roseires, Sennar and Gebel Aulia as an example of coordinated reservoir operation with clear communication structures for both instructions for operation and data. However, with the advancing priority for hydropower, time-proven systems are at the verge of getting unbalanced. An example supporting this thesis is the cascade system Roseires and Sennar. While Roseires is changing the focus from flow augmentation for Sennar to optimise hydropower generation at its dam site, Sennar Dam is confronted with the problem of decreasing inflows and thus less supply safety for irrigation. This is due to the capacity of the turbines at Roseires which do not match the needs at Sennar. This reveals that with new circumstances and changing purposes, the necessity to invest in re-evaluating operation rules is crucial. This is backed by the fact that coordinated operation rules for Roseires and Sennar were not fully updated since 1968.

Site-specific benefits to enhance a single purpose can easily compromise the overall performance of a reservoir system or overproportionally impair other purposes.

In fact, examining the process of developing operation rules revealed that an assessment is usually carried out during the stage of planning but not institutionalised as a periodical process during the life-time of a reservoir, even if boundary conditions might have changed substantially (see the example above).

5.5 Regional Dam Safety Framework

Eastern Nile (EN) sub basin countries, that include Egypt, Ethiopia, South Sudan and Sudan, have made significant strides in strengthening Eastern Nile cooperation since the launch of the Eastern Nile Subsidiary Action Program in 1999, within the framework of the Nile Basin Initiative.

Development of large scale water infrastructure on trans-boundary Rivers requires careful coordination of dam operation and safety-related planning and management. Proper operations and maintenance of these large water infrastructures is vital to minimize the risks of a catastrophic disaster affecting populations residing downstream.

Despite the growing number of water resource infrastructure in Eastern Nile countries, complex hydro politics seems to be missing or there is inadequate capacity to properly manage safety of large and complex dams. Their location, type, age, complexity and the transboundary dimension of these dams demand the Eastern Nile countries to cooperate on safety management.

Recognizing this fact, Eastern Nile countries have initiated a Dam safety program in 2013. The objective was to take the initial steps, start conversation, create awareness and introduce basic concepts of dam design, construction, operation and safety of dams and in the long run to establish standard dam safety management practice in the sub basin.

The Situation Assessment was a comprehensive review of existing policy, legal, institutional framework and technical arrangements, and comparisons with international best practice and state of the art within and outside the continent. The situation assessment report reviewed the current dam safety management at national and trans-boundary levels and identified the following key challenges.

- Lack of proper documentation and baseline data;
- Aged dams in the basin which need close monitoring, inspection, maintenance and remedial works and improvement of instrumentation for safety monitoring;
- Limited technical, financial, legal and institutional capacity to handle safety of existing large and complex dams;
- Population growth; more development and expansion of urbanization d/s of dams;
- Neither regional (trans-boundary) nor national dam safety guideline and framework are available to manage safety of dams in the sub basin;
- Lack of regional cooperation on trans-boundary dam safety management;

As part of this program, the following key activities were accomplished [Abebe, M. (2016)]:

- Assessment of current dam safety practice in each country and identify key gaps;
- Provided technical trainings to Key stakeholders (dam owners, operators, regulators, decision makers, young professionals, etc);
- Developed a Roadmap for subsequent phases;
- Developed Regional Reference Dam safety guideline;
- Dam safety situation assessment on selected dam and

recently

- the countries have established dam safety units at national level and
- A Regional Dam Safety framework was developed at draft level

6 GAP ANALYSIS

A gap analysis is the comparison of a present situation with desired or future objectives. It requires the definition of goals in order to derive differences between the current and desired situation. A list of criteria was used to evaluate the current situation. The criteria are listed in detail in Annex 1.

It is important to keep in mind that this analysis aims at identifying gaps with regard to reservoir operation and not to evaluate gaps for water resources management as a whole.

The detailed gap analysis can be found in Annex 1. In the Roadmap only a summary for each country is given.

6.1 Definition of goals

6.1.1 Institutional setup

In this section goals concerning a basic institutional setup are given. It also contains the description of goals for capacity building and qualification of staff.

Basic institutional settings

Following the principles of Integrated Water Resources Management (IWRM), reservoir operation should be incorporated into river basin management where management of a basin is ideally organised according to watersheds rather than administrative or country borders. Main roles and responsibilities according to the main tasks for managing water resources are outlined in Figure 29:

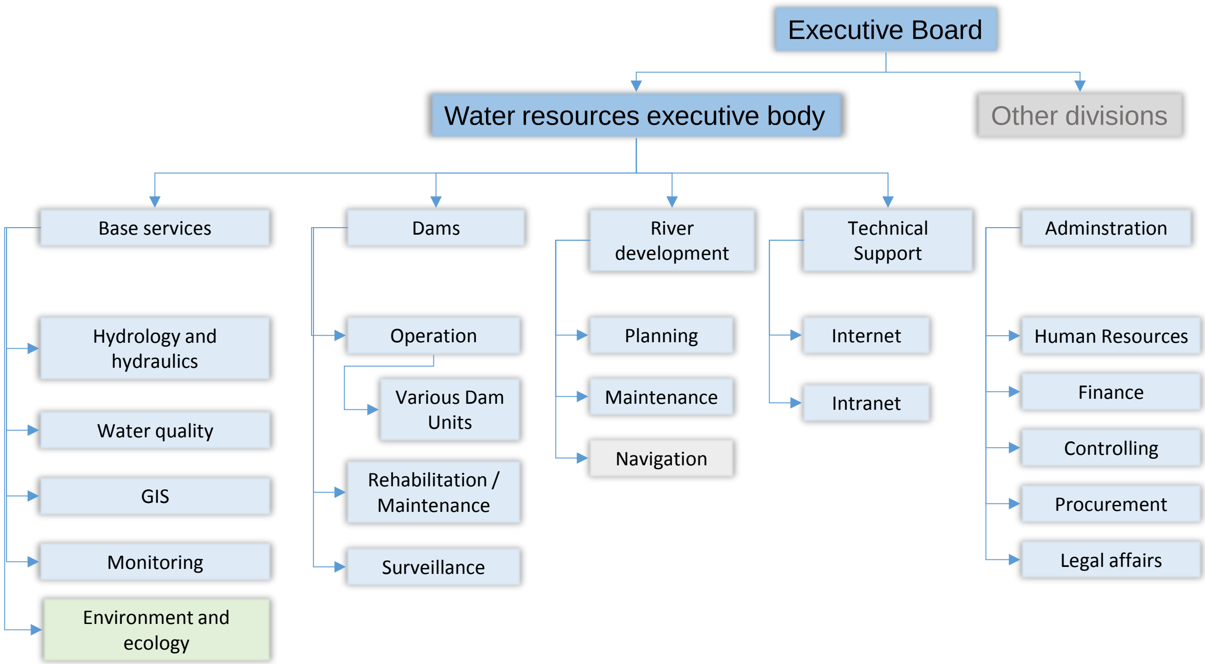


Figure 29: Organisational structure reflecting integrated water resources management

This structure of a water resources executive body responsible for operation on the ground is representative for many basin associations with the mandate to integratively manage water resources [UNECE (2013)]. Examples from Danube, Rhine, Save, Aral Sea, Central Asia, Mekong, East- and North-Europe are given in [UNECE (2013)] discussing the need for similar structures but also addressing difficulties and obstacles in achieving them.

The organisational structure in Figure 29 constitutes a favourite solution in which basic services like monitoring, management of data, hydrological, hydraulic, water quality, environmental assessments are separated from reservoir operation. Especially monitoring of water resources and dam sites needs full attention, time and funding as it requires implementation and maintenance of measuring stations, data collection, data processing and data management. This issue is often not fully recognized, underestimated and respective departments understaffed and underfinanced. As reliable data are obligatory for all dam related assessments this key-role needs capacity of human resources and sufficient financial resources. Dam surveillance and monitoring units are closely linked as to streamline data management procedures.

Summarizing organisational aspects, the following tasks can be associated to key-subdivisions:

- Bases Services - Water Resources Management [WRM]
  Acts as service partner for reservoir operation division
  Responsible for, but not limited to,
  - manage water excess and flood assessments
  - manage drought assessments
  - all kinds of hydraulic and/or hydrologic assessments
  - hydrologic and hydraulic modelling
  - assessments of ecosystems and ecological requirements
- Monitoring [MO]
  Acts as service partner for WRM and reservoir operation division
  Responsible for, but not limited to,
  - establishment of monitoring programs
  - set up and maintenance of measuring stations
  - data collection (catchment, reservoir, dam surveillance)
  - data processing, management and dissemination
- Dam safety and reservoir operation [DAM]
  Responsible for, but not limited to,
  - issue instructions to operation
  - liaise with authorities and stakeholders on dam operation
  - supervise and audit dam surveillance activities
  - manage emergency preparedness and response plans
  - manage program of external dam safety reviews
  - ensure that dam operation and safety records are maintained
  - establish procedures & standards for implementation of monitoring programs
  - assess failure modes and consequences
  - manage security and public safety at dam sites
  - maintain emergency response capability for dam facilities
  - prepare annual reports about operation
  - report emergencies to executive board and regulatory authority

Such a structure can be put in place at national level or transnational level. At national level, the river basin approach is not met but operation and actions are embedded in the national legal framework which satisfies rapid organisation and enforcement. At transnational level, the river basin approach is covered but enforcement and integration in different legal settings is more difficult and takes time.

As a short- to medium-term goal, it is recommended to separate operation and supervision. Supervision should also incorporate other sectors, at least environment, energy and agriculture as mainly affected sectors.

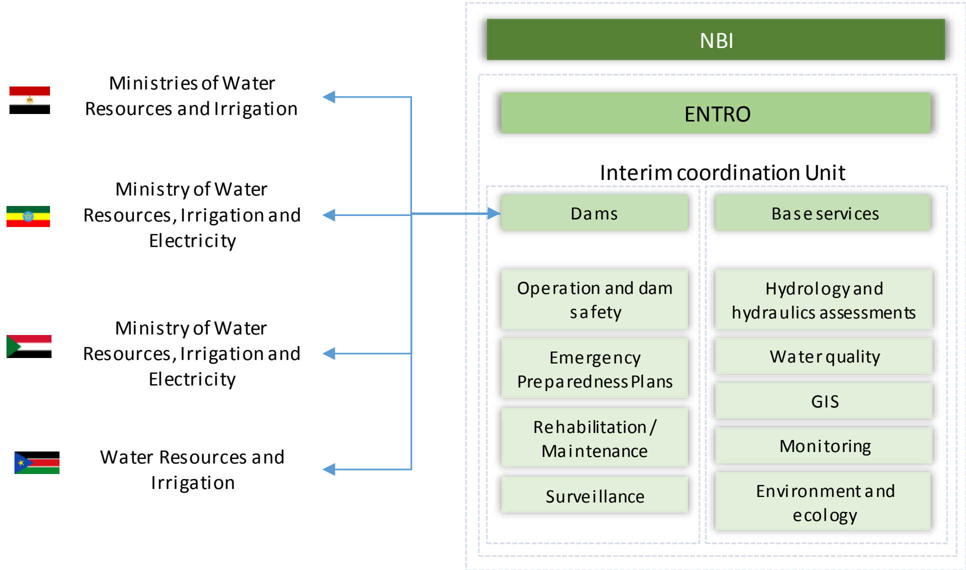


Figure 30: Proposed interaction with a transnational Interim Coordination Unit

ENTRO could play the role as host for a river basin Interim Coordination Unit in which ENTRO is organiser and each country participate with representatives. The objective of such a group should aim at aligning and coordinating regulations between the countries and to advocate for river basin management. It is common practice to circulate the chair of the group among the countries.

With such a structure in place, the switch to a river basin approach as long-term goal would be possible. The mandate of the Interim Coordination Unit could be amended to foster its position and responsibilities could gradually be carried over from national level to transnational level to accomplish a basin wide approach. The development of a common regulatory framework could be brought about in a coordinated way.

Qualification of staff

Implementing an institutional setup for both supervising agencies and operator requires appropriate education, knowledge and experience. The qualification required for reservoir operation is complex and depends on the position.

The operator of a dam system is responsible for its safe operation and is obliged to appoint suitable specialist personnel with adequate qualifications for its operation. An essential component of each dam operation concept is the professional qualification of the onsite-personnel employed for its operation and maintenance. It is therefore the responsibility of the operator to ensure that its personnel management is based on continual further training of the onsite-personnel [Fries (2010)].

The competence required for the onsite-personnel comprises hydrological and technical skills like:

- Basics about hydrology and reservoir operation rules
- Basics about construction and measurement and control technology
- Knowledge about dam surveillance and related equipment

It is of crucial importance that the staff at the dam site takes a high sense of responsibility and obtains regular training and professional development.

Concerning the water authority, essential prerequisites to promote the process of planning and supervising operation and to actively manage different operational situations is an in-depth knowledge of three components:

- Understanding the genesis of threats and risks for dam operation and dam safety
- Understanding the process of day-to-day-operation
- Understanding the wider implications of dams and operation rules

The first item indicates advanced training in regard to hydrological and dam construction related issues and natural hazards. Training about weather forecasts, their reliability, interpretation and how to utilize information derived from hydro-meteorological parameters, ensures that authorities and operators are able to interpret an upcoming situation. It is essential to keep abreast of latest hydro-meteorological developments which were rapidly developing in recent years and to avoid wrong expectations.

The second issue concerns the preparation of high quality standards for design, inspections and control of dams. Inspection and control means regular safety reports and annual dam audits. Especially the annual report deserved attention and should comprise:

- description of reservoir operation and special occurrences
- water yield of the hydrological year
- description of incidents
- evaluation of time series concerning
  - hydro-meteorology
  - discharge
  - hydraulic measurement
  - deformation measurements
- results of inspection
- functional exercises of hydraulic structures

The third issue is related to training in terms of the water resources and river basin process.

From ICOLD (2013)] the most important roles from the dam safety's and operational point of view are deduced as follows:

- Dam Safety Responsible Executive
- Responsible Executive's Dam Safety Advisor
- Manager Operational Dam Safety
- Manager of Operation

The main problem in staffing policy on-site is to perform the operational instructions and to avoid delays in taking actions in case of upcoming emergencies. Immediate response on-site is possible with a full shift organisation with one or more attendants at the dam throughout 24h of a day. In contrast, attendants organised in area shifts keep watch for more than one dam or location respectively. Partially attended schemes have one or more staff present during normal working hours and on call at home for the rest of the day. This means the dam is unattended at night, on weekends and during holidays. Area shifts or partially attended schemes must be accompanied by automatic controls of various degrees of complexity and a higher level of training. Schemes can vary depending on the season, i.e. a change to a full shift during the flood season and a partially scheme otherwise [ICOLD (1986)].

The organisational scheme at the dam site should be given in the operation manual with the consequences regarding expected travel time to the dam site if not permanently attended and a scheme about on call duties outside office-hours.

Capacity building

The operation managers and engineers and the staff on-site need different levels of training. Managers or engineers require training on dam design, basin management with reservoir operation and implications of dam operation respectively. Staff on-site should obtain practical training on monitoring, conducting readings, understanding operation manuals and maintaining appurtenant structures. Basic understanding of operation principles as well as dam related hazards are considered as necessary. Regular training for staff on-site is a prerequisite and needs attention also in providing sufficient financial resources.

6.1.2 Monitoring

Monitoring is mainly understood in reference to reservoirs. As such, a more limited sense of goals is applied although some criteria could also be transferred to a national wide network of gauging stations. Definition of goals with regard to monitoring comprises:

- Readings
- Data storage
- Data access

Readings

Readings are best made fully automated and are manually verified in fixed time intervals. An automated or semi-automated process of data validation should support the readings. From the view point of reservoir operation the following minimum set of parameters should be observed:

- Water level in the reservoir
- Temperature
- Rainfall at the dam site
- Releases (downstream)
- Abstractions from the reservoir

It is difficult to extend records to cover all abstractions which might be in place. Especially the range of users abstracting water from downstream reaches might be very divers and probably are not subject to regulations about maintaining observations.

Data storage

All parameters must be kept with meta-information, Meta-information is the set of attributes which are needed to understand and interpret values. Basic meta-information contains:

- physical source (station name, station id, sensor-id, etc.)
- origin (source: measured, derived, synthetic)
- interpretation (instantaneous values, cumulative, cumulative in a time step, mean values over a timespan, etc.)
- type (physical entity like precipitation, humidity, water level, humidity, flow)
- unit (mm, mm/h, m3/s, m/s, Mio.m3, etc.)
- status (original, user-defined, production, verified, obsolete, etc.)

It is paramount to keep two types of time series:

- Raw data
- Production time series

The meaning of raw data is self-explanatory whereas the term *production time series* describes processed and verified time series. Values undergo a pre-processing in regard to gaps, plausibility and verification checks so as to eliminate gaps and reading errors.

Data storage should be performed locally at the dam site and at a central monitoring unit. For efficiency reasons and to avoid redundant information, production time series best are processed and kept at the central monitoring unit and be made available from there.

Data access

Staff at the dam site should have read access to the local data base to retrieve data, make analysis, store files and to prepare reports. Only authorised staff should be given read-write access to administer the local data base. The central monitoring unit, which receives all raw data, is the focal point for data processing and disseminating data. The way how data are made accessible depends on the available technology. Web-based or even GIS-based interfaces are becoming more and more standard.

One of the most underestimated issues is data formats. It is mandatory for any efficient use of time series to have concise and homogeneous formats for data exchange. Surprisingly, to agree upon one data format among users in the water sector seems to be a major challenge. People are seemingly not very receptive to adopt a new standard and to drop their traditionally and proprietary formats.

6.1.3 Reservoir operation

Definition of goals with regard to operation of reservoirs encompasses

- Evaluation of operation rules
- Approval of operation rules
- Review of operation rules
- Operation rules and operation manual

Evaluation of operation rules

Procedures necessary to ensure a high quality of operation require a couple of steps and prerequisites.

- Geographical scaling
- Scoping
- Causal-chain analysis
- Operation policy options analysis
- Detailed assessment

<u>Geographical Scaling</u>

Geographical scaling defines the geographic boundaries to be analysed which is given by the watershed and additional determinations. Subsequently, sub-regions are identified as well as major features of the hydrosystem and economic activities.

<u>Scoping</u>

Within the scoping procedure critical topics and affected sectors must be identified. This starts mainly with an inventory of implications, beneficiaries, water resources, environment and socio-economic concerns. Considering the future, estimates of likely environmental and socio-economic perspectives must be determined. Scoping also includes the definition of a baseline scenario which represents the current situation so as to serve as a benchmark for all simulation with different operation policy options. In conclusion, scoping yields the objectives of reservoir operation, all boundary conditions and compiles sectors and stakeholders involved.

Causal chain analysis

Causal-chain analysis traces cause-effect relationships throughout the sectors of concern. Based on topics and issues identified during the scoping, cause-effect relationships first are derived as qualitative functions. Later on during the detailed assessment, each cause-effect relationships must be verified and developed quantitatively. If it cannot be verified it will be marked as irrelevant or negligible and sorted out.

Detailed assessment

The detailed assessment accompanies the scoping and causal chain analysis and is therefore not confined to one stage in the assessment process. Since it is an integral activity within the other components, it is carried out at several stages during the whole assessment process. It aims to substantiating conclusions from other components by identifying and documenting the nature and availability of information related to the selected priority concerns and issues. It also quantifies the relevance of selected concerns and issues. Hydrologic modelling is usually regarded as a core element. But also cause-effect modelling is required.

It must be noted that Detailed Assessment is mostly accompanied by a more or less intensive data gathering effort. Information may come from various sources like observations, previous assessments, research papers, scientific publications, surveys, government reports, status reports, EIA reports, economic reviews, etc. The major challenge during Detailed Assessment arises from the necessity to combine hydrologic modelling with often difficult to quantify socio-economic and environmental aspects. This is why the development of a sound basis of causal-chains lays the foundation for reliable results.

During the Detailed Assessment a more precise indication of geographical locations of major concerns and issues will emerge. Problems may be localized to a certain hot spot, a part of the river or other particular areas.

Operation policy option analysis

A policy option analysis indicates potential release strategies each of which are technically feasible according to the hydraulic structures, fulfil all objectives and meet all boundary conditions. The theoretically optimal solution is not always the one which scores highest in terms of practicability, desirability and preferability. If more than one solution can be found – which is usually the case – decision has to be made which will be prioritised and finally used.

Aforementioned steps clearly point at a tool which is capable of modelling river basins and generic cause-effect relationships incorporating uncertainties. In other words, hydrological modelling and generic cause-effect modelling must go hand in hand in one tool to streamline the evaluation process.

It must be noted, that the planner commissioned to perform detailed design or the constructor of dams is critical as partner for setting up operation rules in the sense of a comprehensive assessment as it is explained above. This is mainly due to three reasons:

Firstly, consultants for Engineering, Procurement and Construction (EPC) often underestimate the importance of operation rules and set their sights exclusively on issues concerning detailed engineering design.

Secondly, EPC consultants are often not forced to expend more effort because terms of references frequently lack clear duties and deliverables with respect to water management and operation.

Thirdly, reservoir operation, as explained above, usually affects different sectors and deals with impact assessment. As a consequence, it is split up into different tasks and thus assigned to a range of subjects, for example detailed design, EIA, socio-economic analysis.

An answer to the problem is to engage an independent consultant addressing the wide range of subjects exclusively. They should be tasked to perform operational assessment and link their work with detailed design, EIA and socio-economics assessments.

Approval of operation rules

International good practice is to separate the responsibilities of approval and operation. Hence, approving authorities and operators should be strictly separated and independent from each other. An ideal course of action can be depicted as given in Figure 31.

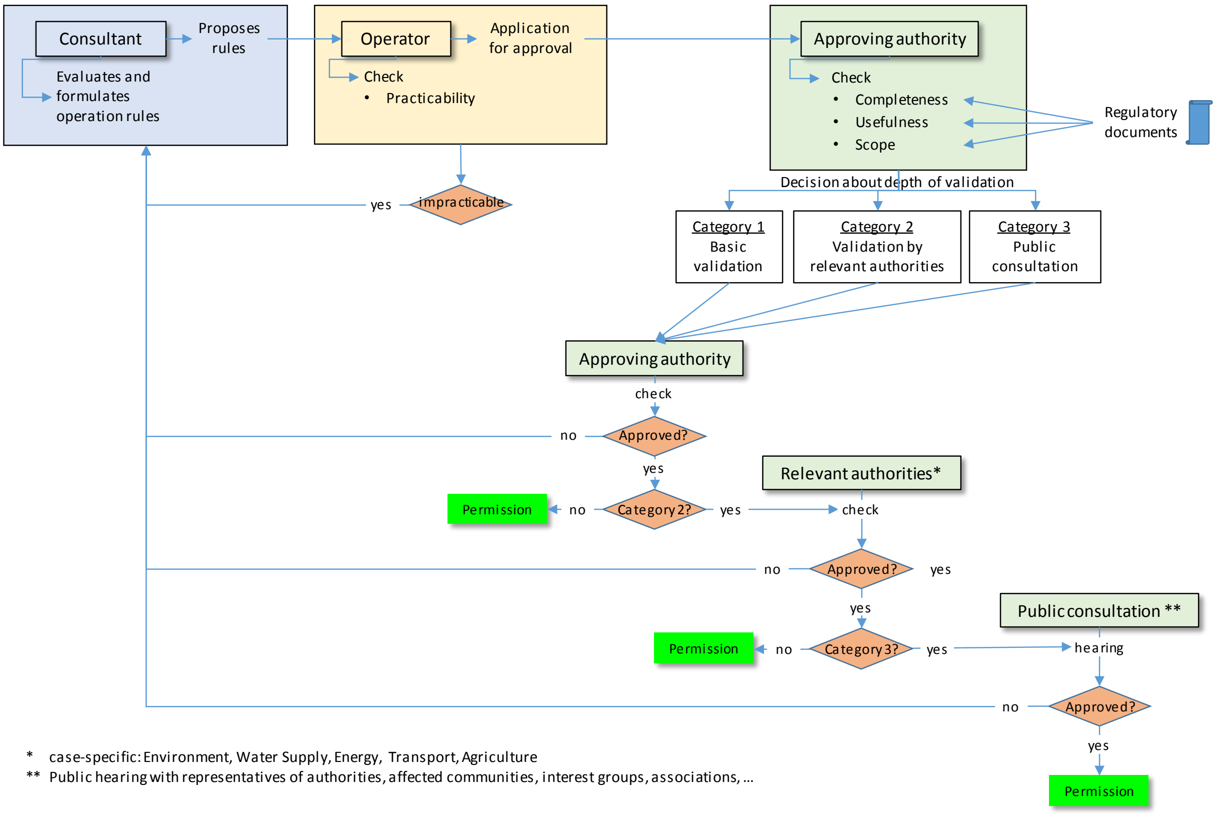


Figure 31: Course of action concerning approval of operation rules

A consultant or advisor, in close collaboration with the operator, explores suitable possibilities and proposes them to the operator who applies for approval. The approving authority conducts a minimum set of checks about completeness, usefulness and scope of rules whereupon the decision of the depth of the audit is made. A regulatory framework is required to ascertain reproducible decisions and to ensure that different operators obtain equal treatment.

Three categories of requirements and depth of investigation are considered as sufficient in order to reflect the range of impacts caused by operation rules.

Category 1 - Basic validation
Only the approving authority is involved and makes the decision. Examples of operation rules requiring basic validation are maximum drawdown velocities, reservoir zoning, annual filling patterns etc.

Category 2 – Relevant authorities
Authorities concerning environment, water supply, energy, agriculture are included case-by-case so as to determine boundary conditions, constraints, minimum requirements etc.

Category 3 – Public hearing
The highest category implies the highest level of detail concerning operation rules. It should come into effect during the planning process of a dam and during the life-cycle of a dam if operation undergoes substantial changes affecting at least two sectors, for example omitting or adding a new purpose like hydropower or irrigation.

The regulatory framework should contain a list of examples from which definitions about completeness, usefulness and scope can be taken and categorisation can be based on.

Review of operation rules

Referring to dam safety guidelines, a check every 5 to 10 years seems appropriate in case no incident or change of operation emerged. It will be sufficient to proof the performance by means of indicators like probabilities of supply safety. In case unprecedented hydrological events occurred or there is a request to change operation, a review must be commenced as follow-up.

Operation rules and operation manual

Operation rules are best illustrated in an operation manual outlining facts pertinent to the legal base, the dam, the operator and most importantly, the set of operation rules to adequately address all kind of hydrologic situations. Ideally, the operation manual contains and gives guidance to:

- Institutional framework
  - Legal base or concession for operation
  - Documents about approval
- Description of the dam and appurtenant hydraulic structures
- Description of the dam operator
  - Description of the operator and legal form of organisation
  - Organisation and staffing of the dam operator
  - Staffing at dam site
  - Qualification of personnel
- Review period and procedures
- Geographical scope of the reservoir and upstream
  - Extent of impoundment as a function of the water level
  - Distance and locations of backwater conditions as a function of the water level
- Geographical scope downstream
  - Distance where releases under different hydrological conditions are effective
  - Travel time of release under different hydrological conditions
- Environmental conditions
  - Minimum water level in the reservoir to maintain water quality
  - Minimum releases to maintain ecosystems (environmental flow)

- Hydrological regime and allocation of water
    - Release fluctuations and mitigation measures
    - Release rules as a function of purpose, date and water level (reservoir zoning)
- Basic safety rules and design floods with associated water levels
    - Spillway design flood
    - Check flood dam safety
    - Capacity of flood buffer
    - Probability of occurrence the flood buffer can compensate
    - Maximum drawdown velocity
- Monitoring
    - Sources of data,
    - Expected losses and accuracy
    - Reading intervals and how to retrieve the data
- Flood operation
    - Rules for identifying flood operation
    - Releases as function of water level and (if available) predicted flood
    - Downstream requirements and respective adaption of releases
    - Chain of notification (stakeholders to be informed)
- Drought operation
    - Rules for identifying drought operation and drought levels
    - Process description about how to escalate through drought levels
    - Releases and allocation rules as function of drought levels, purpose, water level and (if available) long-range predictions
    - Chain of notification (stakeholders to be informed)

The content of an operation manual as it is stated above is flexible depending on site-specific conditions. For example, a hydropower plant needs more emphasis on release fluctuations compared to a reservoir with irrigation and/or flood protection as main purposes. Part of the manual overlap with Emergency Preparedness Plans (EPP) and can be utilised for dam safety procedures as well.

6.2 Gap analysis for Egypt

The gap analysis of Egypt is based on secondary information and mainly builds on the findings of the USAID supports Integrated Water Management projects and the National Capacity Self-Assessment project from 2007, funded by the Global Environment Facility/ United Nations Development Programme and implemented by Egyptian Environmental Affairs Agency.

The IWRM project of USAID identified three major issues:

- increase water efficiency and productivity
- improve water quality
- provide a more equitable allocation of water resources

Capacity building was identified as an overarching issue. Providing graduate-level training opportunities for employees of the MWRI to improve management of water resources was stated as a major step forward.

From the water user viewpoint, participation by building capacity and supporting awareness of cost-sharing was concluded which could be accompanied by the formation of Branch Canal Water User Associations.

The capacity building assessment showed the need to establish training courses, staff performance assessment system and to create an incentive system for self-orientation and encourage career paths of employees. The lack of regulations and guidelines which point at non-formalised mechanisms for capacity building was mentioned. An important aspect was the fact that institutional performance criteria are needed to assess the effectiveness and efficiency of authorities to better direct actions in the future.

A general statement about monitoring was made in [USAID (2011)] aiming at the establishment of information management systems. Data which are collected need to be analysed to understand and improve water management.

[EMA (2014)] provides information about a gap concerning the need for knowledge and skills on drought management. Despite the existence of the HAD, difficulties in timely identifying droughts and their onset are considered as serious. This is important because the share for agriculture is gradually reduced under drought conditions. Identifying drought conditions as soon as possible and issuing warnings prevent farmers from selecting wrong crops. If water supply is reduced to counter drought conditions at a later stage adversely affects the yield and revenue of farmers. Furthermore, a lack of staff in the meteorology and irrigation sector gives rise to shortcomings regarding long-range forecasts of the flow of the Nile.

Drought management and the lack of a suitable long-range forecast system directly lead to reservoir operation. Warnings need to be issued by the Ministry of Public Works and Water and Irrigation to inform the Egyptian Ministry of Agriculture in order to make adjustments of agricultural and implementation plans. Warnings are also necessary to alert the Ministry of Industry and the Ministry of Electricity and Energy that during drought conditions the amount of energy generated from hydropower will be less than usual giving rise to extent the use of alternative energy sources.

6.3 Gap analysis for Ethiopia

The situational analysis constitutes the background for the gap analysis. The Beles scheme is used as an example from which a more generalised view was derived as far as possible. Details of the gap analysis are given in Annex 1 – Gap Analysis.

Capacity building for reservoir operation

Given the fact that new dams are emerging in Ethiopia, the reservoir system will become more complex and operation will be more difficult even without transboundary coordination. As a result, personnel at dam sites and dam managers will face a more complex working environment. Capacity building and training needs to be enhanced to cope with increasing demands and to ensure high qualification of both staff on-site and at the managerial level. This calls for appropriate training measures to ensure that staff can satisfy increasing requirements, in particular concerning multifaceted impacts of dams.

Hence, procedures for capacity building and training should be defined and anchored within the regulatory framework clearly specifying the course of action and requirements.

Universities with good reputations are in place in Ethiopia. As capacity building is their domain, it is obvious to take advantage of existing organisational setups and infrastructure. Training for trainers is needed to ensure that theory and practise of reservoir operation can be delivered. Universities should be encouraged and supported to establish a pool of long-term assignments with practitioners who conduct training courses. An organisational gap must be bridged concerning data. If training should be efficiently and effectively executed, mechanisms must be installed to facilitate exchange of hydro-meteorological and reservoir related data as smooth as possible.

River basin management plans and reservoir operation

The demand for energy in Ethiopia provides a momentum for developing hydropower. The trade-offs between energy provision, loss of storage capacity due to sediment, water quality and environmental issues call for strategic long-term planning to address risks and to develop comprehensive water management plans. It is obvious that reservoirs will play a crucial role. The challenge is to keep pace with current, fact-creating developments and to establish sustainable management plans and – above all – to put them timely into effect on the ground to avoid irreversible environmental damage. This requires experienced experts in integrated water resources management who are able to bring management plans into practice.

Evaluating, approving and reviewing operation of dams

Based on the principles of IWRM, the more complex reservoir system (and even the current situation) reveals the need to extent the view from focusing on hydropower generation to a river basin approach. A river basin approach safeguards all requirements arising from environment, downstream needs, flood protection, drought preparedness, dam safety, monitoring and maintenance.

The current institutional settings should be strengthened with the future multipurpose reservoir system in mind. An independent entity sufficiently staffed will very likely be needed in the long run to cope with the development of dams. The role of such an entity would be to oversee the process of evaluating, approving and reviewing operation of dams. Strengthening institutional capacity with regard to dam operation is strongly recommended in order to guarantee high quality operation rules with regular performance checks and to address adequately the complex nexus of reservoir operation - impacts on the environment - downstream riparians.

Monitoring of dam operation

The scope of parameters required to monitor reservoir operation is not stipulated. Operation of reservoirs requires monitoring at the dam site concerning dam surveillance, dam safety related observations and parameters concerning the reservoir itself, e.g. water level. This more limited sense of monitoring should be extended. A more integrative sense of monitoring would include hydro-meteorological parameters at the dam site as well as observations upstream and downstream like flow and water levels. In the near future it will be a necessity to cover water quality aspects to anticipate problems and to safeguard ecosystems. As a consequence, regulations which determine the scope of readings should be taken into account. In case the scope of readings is enhanced, a gap concerning staff for monitoring likely evolves.

Operation of water infrastructure, in particular hydropower generation, uses SCADA systems to control hydraulic appurtenances and physical states. One should keep in mind, that a SCADA system does not replace a hydromet system. The task of a SCADA system is to ensure safe operation. It is often installed as a closed system without connections outside the operational computer network. Some SCADA systems are equipped with data storage and limited evaluation features. However, these are side-functions of SCADA systems as opposed to a hydromet data management systems. Main features of a hydromet system are to obtain, store, evaluate, create and illustrate hydro-meteorological mass data and derivatives thereof. A core element of hydromet systems is data evaluation and dissemination and as such, special attention is paid to make such systems performant. This becomes more important the more dams will come into being with the need to exchange efficiently for analysis and optimisation of operation.

At present, data access is of minor importance as the user group is limited. In preparation for more data traffic in the future, web-based technology should be taken into account. Considering interactive and distributed data services, there is a need to comprehensively assess the IT environment needed to cope with requirements arising in the near future. Points to be discussed are but not limited to:

- Number of users
- Number of visits
- Data transmission rate
- Technology (GIS web-servers, FTP, web-services, …)
- User authorisation

Readings, data storage and data access are linked topics and should be treated as a unit together with monitoring, hydromet systems and tools for data management.

Reservoir operation

The current practise of establishing rules during planning and construction of a dam should be enhanced and strengthened by regular reviews. Environmental Impact Assessment (EIA), if executed, can indicate a framework for operating a dam, and thus builds up a knowledge base for impacts and interplays a dam constitutes to other sectors.

Cause-effect relationships or causal-chains are not in place, that is, effects directly or indirectly arising from dam operation are not clear or vague. In other words, understanding the nexus of dams, operation and affected sectors is a prerequisite for developing balanced and sustainable reservoir operation.

Detailed assessment is based on hydrological modelling techniques. Applying hydrological models without understanding the nexus described above often results in unbalanced water management.

The result of an unidentified nexus is a lack of awareness of some causal-chains. Thus, their consequences remain unknown and cannot be related to dam operation. Such hidden impacts are inevitably neglected when performance of reservoirs is evaluated. This should be kept in mind considering the raising number of new dams in Ethiopia.

6.4 Gap analysis for South Sudan

By judging the situation described in the documents mentions in Section 5.3, significant shortcomings exist in two fields.

- Institutional settings
  Specifications are in existence but with low impact on the ground. It lacks qualified staff and implementation of regulations; enforcement is weak or not existent.
- Monitoring
  Monitoring does not exist or is operated at an inappropriate level.

Reservoir operation is not a concern as no major dam exists in South-Sudan

According to [NBI (2014b), NBI (2015)], the major gaps regarding monitoring in South Sudan comprise:

- Identified gaps at the national level that also have implications for a regional network include capacity building among staff, rehabilitation of monitoring infrastructure, quality control of existing data, and provision of acceptable monitoring technologies.
- Existing operational network for river stage/discharge and precipitation/meteorological monitoring would need to be expanded for not only national but also regional monitoring purposes.
- There is no monitoring dedicated to water quality, sediment sampling, or groundwater within South Sudan.
- Substantial investment in both infrastructure and institutional development is necessary to create a national institution capable of contributing data to a regional monitoring network. The need to develop South Sudan's capabilities is magnified by its overall hydrologic significance to the entire Nile Basin.

6.5 Gap analysis for the Sudan

The situational analysis constitutes the background for the gap analysis. Remarks and colours are best estimated according to confirmed information and data [see ENTRO (2016), etc.]. Findings from Sennar and Gebel Aulia dams are used as examples from which a more generalised view was derived as far as possible. Details of the gap analysis are given in Annex 1 – Gap Analysis.

Alignment of operation

Operation of dams is split up in two organisations: the Dam Directorate and the Dam Implementation Unit (DIU). It cannot be excluded that both authorities apply different standards for executing, evaluating or monitoring reservoir operation. Attention should be paid to coordinate operation between the two entities to avoid discrepancies in dam operation. The example of Roseires and Sennar Dam in Section 5.4.3 illustrates the need for more coordination.

Enhancement of human resources for reservoir operation

Dam managers and operation engineers will need support in the near future, if coordinated and river basin oriented reservoir operation with more communicational effort and more tasks takes effect. Dam safety also requires attention and will consume time and effort of staff on site. It is foreseeable that reservoir operation will necessitate more human resources with the same qualification the current staff already has, above all having the importance of dams for Sudan in mind.

River basin management plans and reservoir operation

As is was stated above for Ethiopia, there is an emerging issue to provide enough qualified engineers to adequately tackle the rising challenge of multipurpose operation. The demand for energy in Sudan provides a momentum for developing hydropower. At the same time, the necessity to secure food production is vital, too. Both purposes are not necessarily contradicting each other but require close coordination. The trade-offs between energy provision, increase of irrigation areas, loss of storage capacity due to sediment, water quality and environmental problems call for strategic long-term planning to address risks and to develop comprehensive water management plans. It is obvious that reservoirs play a crucial role. The challenge is to keep pace with current, fact-creating developments and to establish sustainable management plans and – above all – to put them timely into effect on the ground to avoid irreversible environmental damage. This requires experienced experts in integrated water resources management who are able to bring management plans into practice.

The Hydraulic Research Center (HRC) could be a focal point to provide practical training accordingly. It might be advisable to group experienced trainers according to their expertise from different research organisations to make training function.

Monitoring and water quality

Performing observations is driven by the need to keep track of flow, losses, water abstractions and diversions along Blue Nile, White Nile and Main Nile. Thus, water quantity is the major focus and this is addressed by monitoring units established at dam sites and by the Nile Waters Directorate.

However, one future challenge will be to address water quality. Monitoring water quality requires both obtaining samples and subsequent analysis by laboratories.

Data access is essential for operation engineers for the day-to-day business. Solutions exist which enable the engineer, who is in charge of operation, to grasp the “big picture” of its dam and hydrological conditions. Concerning evaluation at the dam sites itself, however, more possibilities are desirable so as to perform quick and reliable evaluations addressing forecasts, releases and dam safety aspects. It seems that all technical prerequisites are already in place to facilitate data access for a wider group of users.

Evaluating, approving and reviewing operation of dams

At present, rules for reservoir operation are established during planning and construction of a dam and are not subject to periodical reviews. This is seen as critical and entails problems like those illustrated in Section 5.4.3. Even more serious problems will emerge when competing purposes come along with increasing water stress due to adverse hydrological conditions. Such situations are more likely in the future because of rising demands and climate change.

6.6 Conclusion from the Regional Dam Safety Framework

The main topics given as recommendations in the draft Regional Dam Safety Framework are:

- To develop a strong transnational working unit which tackles dam safety related issues and makes recommendations to the member countries and serves as a leader and coordination unit.
- To establish national working units for implementing regulations at national level
- To initiate capacity building and training and to formalise this by means of regulations
- To implement and harmonise dam safety regulations in each country

The results from the draft Regional Dam Safety Framework analysis were taken as a starting point for recommendations concerning coordinate reservoir operation. The main statements are used, incorporated and can be found in Section 8.

7 INTERNATIONAL EXAMPLES

A range of international examples was selected each of which has its unique specifications in terms of coordinated operation of water infrastructure.

The examples were chosen to demonstrate different levels of coordination ranging from exchange of data and information for decision-making up to an operational unit which bears the responsibility of operation of water facilities in different countries. At the end of this chapter, an overview showing their specific achievements is illustrated.

7.1 Mekong

The Mekong River Commission (MRC) is the only inter-governmental organisation that works directly with the governments of Cambodia, Lao PDR, Thailand and Viet Nam to jointly manage the shared water resources and the sustainable development of the Mekong River.

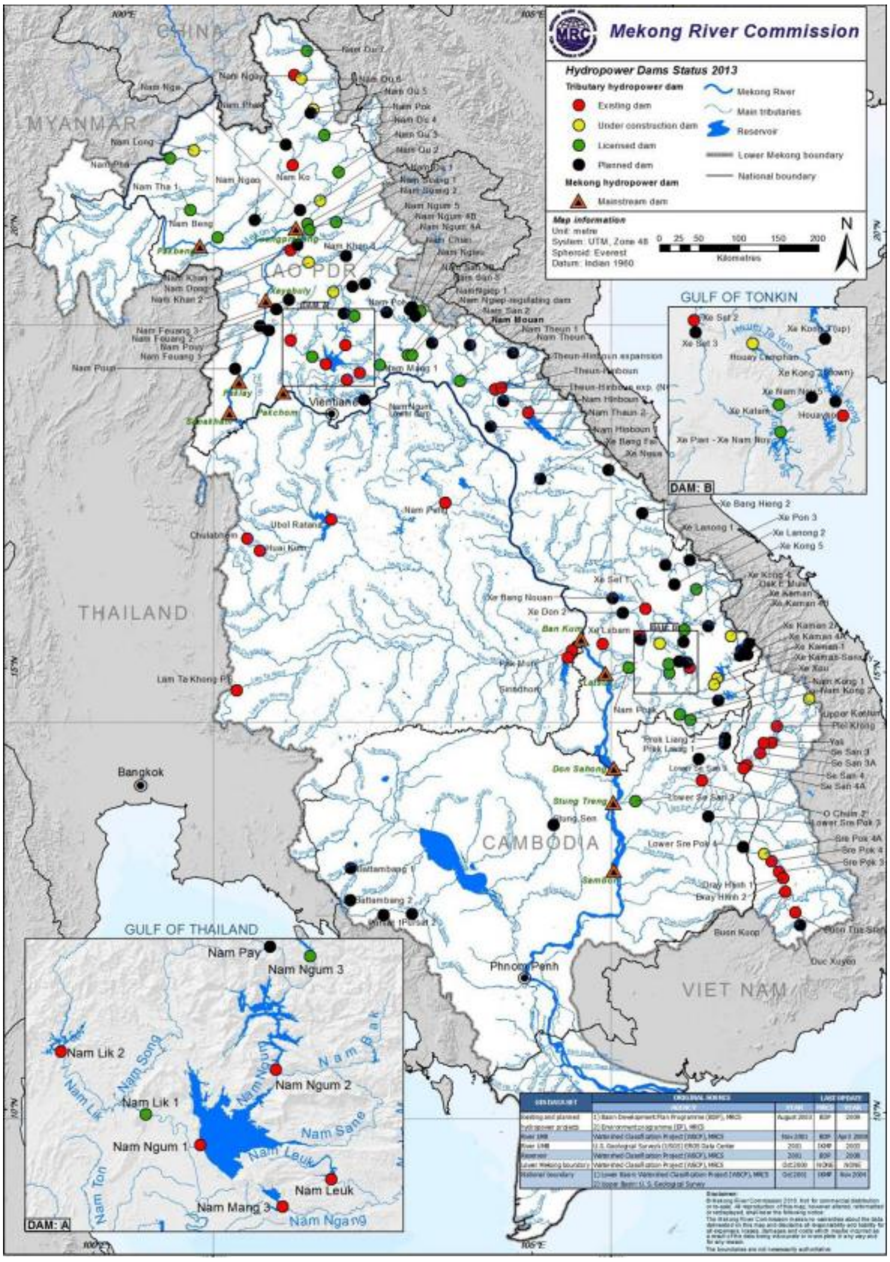


Figure 32: The Lower Mekong River Basin [MRC (2014)]

Since its establishment in 1995 by the signing of the Mekong Agreement, the MRC has adopted a series of procedures, namely the Procedures for Water Quality, Procedures for Data and Information Exchange and Sharing, Procedures for Water Use Monitoring, Procedures for Notification, Prior Consultation and Agreement and Procedures for Maintenance of Flows on the Mainstream, to provide a systematic and uniform process for the implementation of this accord.

At present, sustainable hydropower development is a major topic at MRC. Important steps which the member countries agreed upon were undertaken:

- Procedure for Notification, Prior Consultation and Agreement
  which has to be followed when any of the 4 countries plans a development that will have an impact on the Mekong mainstream
- Identification of ecologically sensitive areas for hydropower planning
- Multi-purpose and causal-chain evaluation of the effects of hydropower plans

- Benefit sharing options for hydropower
- Mitigation guidelines for sustainable hydropower practice including migration of fish
- Collection of improved environmental and socio-economic baseline information for planning of hydropower plants
- Rapid basin wide hydropower sustainability assessment tool

In contrast to the transnational agreements, reservoir development is solely the mandate of each member country at the national level. Member countries invite companies to make a bid and select the most attractive proposal without prior consultation of other countries.

At present, there is no official coordination between countries on dam operation. Discussions have started but have not reached concrete steps. A working group was established to evaluate possibilities of enhanced coordination based on the council study *Sustainable development of Hydropower development* [Manguerra, H. (2014)] prepared by the MRC.

National working groups were established to deal with sedimentation. However, MRC was not involved at the beginning. The basic trigger for MRC involvement is expected change of flow. That would generate prior consultation as per MRC procedure with the other member countries.

Capacity building is the task of MRC supported by the World Bank.

Concerning the development of hydropower dams, MRC has been working on Council Studies which serve as a knowledge base for each country in their decision-making and is a comprehensive cross-sector chausal-chain assessment. Council Studies are reviewed regularly and deal with the sustainable management and development of the Mekong River, including impacts of mainstream hydropower projects.

A core element of the MRC is the provision of streamflow forecasts for the mainstream Mekong. The Flood Management and Mitigation Team, located in Phnom Penh, runs an operational streamflow forecast centre with daily basin wide flood forecasts during the rainy season and weekly basin wide forecasts for the rest of the year. In 2016, a Roadmap for long-range, seasonal forecast (3 to 6 month) was finalised and is in the pipeline [MRC (2016)].

The MRC owns a data management system which is fully accessible by registered users and to obtain publicly available information via internet for external users. The flow of data starts at the national level where member countries run their own monitoring and gauging stations. Each country makes their observations at pre-selected stations available to MRC. MRC retrieves the data from the national monitoring centres and uploads them into their own data management system. Parameters are water level and rainfall.

In 2016, MRC and its dialogue partner China conducted a joint study on emergency water releases from China's cascade dams. After extreme drought conditions releases were initiated during the last dry season to increase the water level of the Mekong River. This helped alleviate the severe drought in the Lower Mekong Basin and is seen as a step towards integrating the upstream partner China.

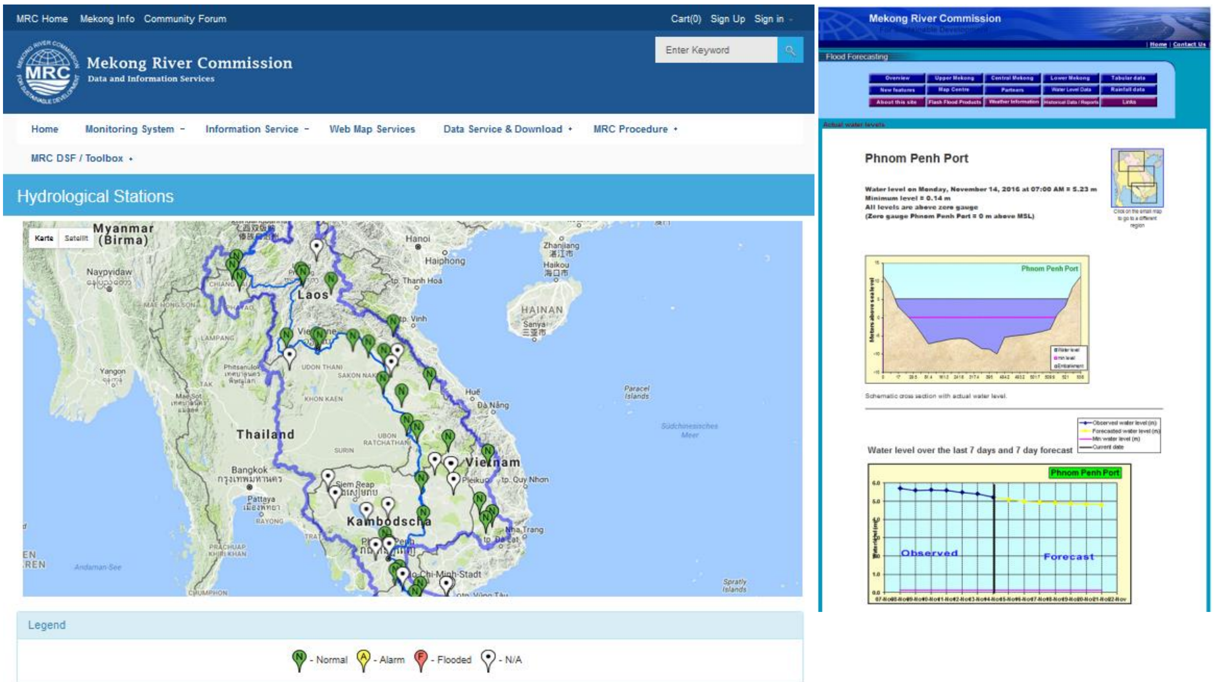


Figure 33: Data management system of the MRC [MRC (2014)] http://portal.mrcmekong.org/index}

7.2 Chu-Talas system

The Chu-Talas system joins the Kazakh Republic and the Government of the Kyrgyz Republic in Central Asia. Both countries worked closely together with UNECE and developed regional cooperation mechanisms concerning dam safety, capacity building and maintenance.

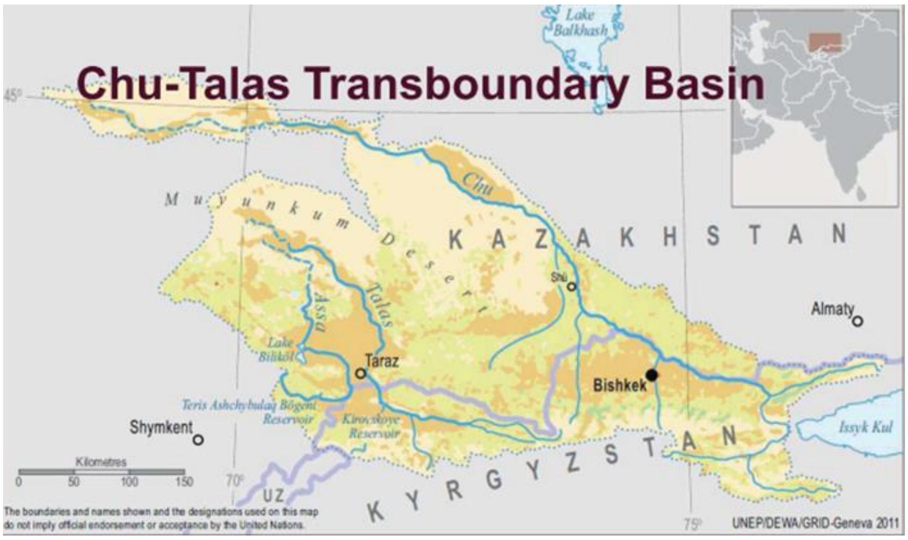


Figure 34: The Chu-Talas River system [Akbozova, I. (2015)]

The Chu and Talas rivers basins are located within the northern Tian Shan Mountains and the eastern margin of the Turan lowland. Formation of flow of the rivers stems entirely from within the territory of the Kyrgyz Republic.

Problems in the Chu-Talas river system prior to the transboundary agreement were:

- Talas River was a flood prone area with annual floods causing significant damage

- Kirov Reservoir built in 1975 with a capacity of 550 Mio.m³ was able to mitigate the flood problem to a certain extent
- Operation of the Kirov reservoir disregarded downstream needs which led to lower groundwater levels, causing ecosystem degradation and desertification in the lower reaches of the river

In order to tackle the problems and with support of UNECE, both countries embarked on cooperation and signed an agreement declaring that the use of water resources and operation of water management facilities of intergovernmental status shall be aimed at the achievement of mutual benefit on a fair and equitable basis. Major steps were:

- establishing a water allocation working group
- evaluating and finally changing operation rules of the Kirov reservoir
- sharing expenses for maintaining water management facilities to ensure reliable and safe operation

Main interstate water intake facilities are jointly operated and monitored with a SCADA automated control system. Water received by each country provides a formula for cost-sharing for maintenance.

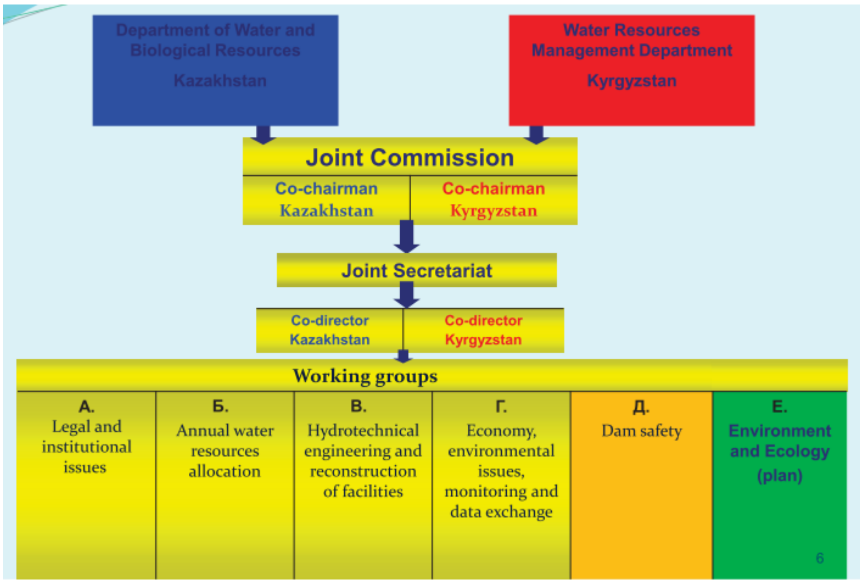


Figure 35: Organisational structure of the Chu-Talas Commission [Akbozova, I. (2015)]

The first step was to inventory water management facilities like dams, diversions, canals and hydroelectric power plants which are of transnational importance. The key section of their agreement is about compensation and sharing expenses to ensure reliable and safe operation of water management facilities. To achieve this, the parties shall share expenses connected with the operation and maintenance of water management facilities of intergovernmental status and with other mutually agreed activities pro rata according to the amount of water they receive. Permanent commissions to determine the working regimes and the range of necessary expenses for operation and maintenance were established. The allocation of necessary funding is assessed annually. This means that the water allocation working groups makes suggestions about sharing expenses to the joint commission who finally make decisions with are binding for both countries.

7.3 Zambezi

The Zambezi Water Commission is a river basin organization set up by countries that share the Zambezi River Basin. The Riparian States to the Zambezi River Basin are Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia and Zimbabwe. The Zambezi River has a catchment of 1 350 000 km² with a river length of 2650 km and a population of 40 Million (2000).

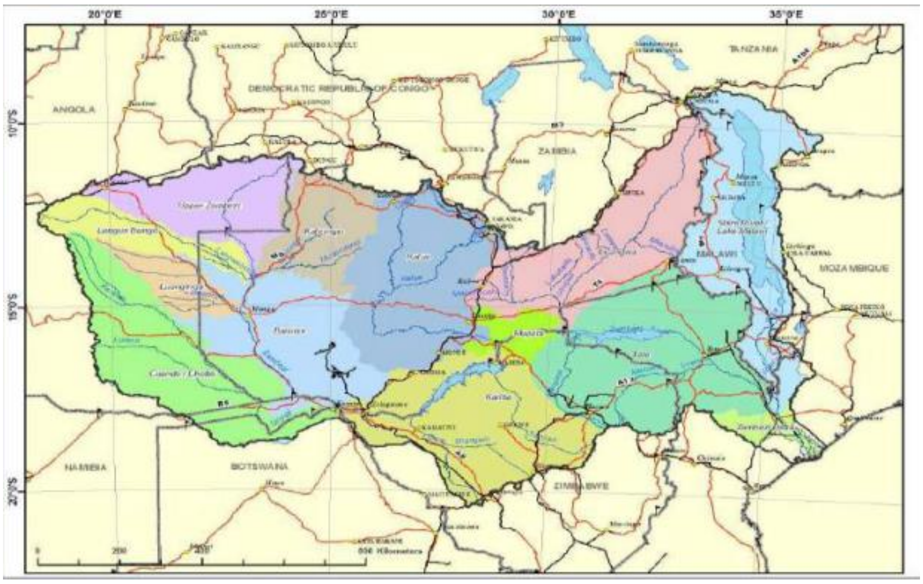


Figure 36: The catchment of the Zambezi River [http://www.zambezicommission.org/]

A *Dam Synchronisation Study and Flood Releases Study in the Zambezi River Basin Project* [SADC (2011)] was conducted which investigated coordinated reservoir operations. Results from this study indicated that timing of water releases from existing and proposed new dams can result in more collective win-win benefits. At present the predominant interest is on the hydropower generation investment sector.

The study assessed new operation rules which incorporated multiple objectives, like electricity production, agricultural demands, environmental flow, dam safety, flood protection. Large existing dams along the Zambezi River, however, have operation rules which only consider dam safety and the provision of water and adequate head for hydropower production. Other sectors are currently not included or underrepresented.

One major conclusion was to ease import and export of power between the countries. This will create more operational flexibility with benefits for all parties. The study showed also that flood management and environmental flows could be improved if releases are coordinated between the dams.

The study outlined the importance of a regional flow forecast system. To effectively manage storage and releases, the Zambezi system requires forecast of flows at given key locations. It is important to distinguish short, medium and seasonal lead time forecasts.

- Short lead time forecasts ► primarily on flood prone areas.
- Medium lead time forecast ► hydropower plants
- Seasonal lead time forecast ► major hydropower plants

Short term forecasts for floods and seasonal forecasts for environmental flows can be incorporated in reservoir operation decision-making as well.

Lacks and constraints were identified as the following:

- Zambezi riparian states' water sector Policies and Laws are not harmonized with each other's and/or with the ZAMCOM Agreement.

- Establishment of a permanent Zambezi Basin-wide management institution is needed.
- Weak national water management institutional capacity to perform river basin management tasks.
- Inadequate water resources knowledge base for basin-wide development and management.
- Inadequate effective stakeholder participation in water resources planning, development and management.
- Communication limitations in and amongst some Basin institutions.
- Inadequate financial resources to attract and retain skilled staff and to facilitate operations.
- Synchronized procedures and rules for data/information sharing, water infrastructure operation and management in the Zambezi River Basin.
- Lack of trust and confidence between countries

Issues in conjunction with data management were found as:

- duplications in mandates for data collection among different institutions
- incongruence of datasets collected from different sources
- incomplete time series and incongruent methodologies used for the same survey over time
- lack of a comprehensive Global Information System data depository
- granular but not systematic data on surface water pollution
- lack of comprehensive groundwater data (both in terms of quantity and quality)

Strong development of irrigated agriculture upstream of the basin and population growth at the current rate will decrease the total net benefits of the basin in the next 20 years, provided that the planned hydropower schemes will be implemented.

Hydropower is one of the major drivers for economic growth on both, the sub-basin scale as studied for the Kafue River, as well as for the entire Zambezi River Basin. Assessment of the economic costs of non-cooperation in the basin revealed a loss of 10% of the annual benefits of the basin system. It must be stressed that the distribution of gains and losses among riparian countries is uneven and constitutes a major obstacle towards efficient sharing of water resources. However, it might also be seen as an incentive for the development of adequate benefit sharing mechanisms.

Concrete cross-border operational aspects in the Zambezi basin were found as follows.

Decreased outflow of Cahora Bassa in dry months inhibits environmental demands of the Zambezi Delta	Restore floods in the Zambezi Delta by coordinating existing reservoirs: operate Kariba to supply downstream HCB during critical months. Discuss and implement adequate policies to share the corresponding benefits and costs.
The release of only oxygen or only nutrients from Itezhi-Tezhi Reservoir might inhibit the productivity of the wetland system downstream.	Release of nutrient-rich bottom and oxygen-rich surface water through turbines at 30 m and 13 m depths.
Delayed access of herbivores to the floodplains might have a disproportional negative effect on female and young lechwe.	Operation should be change to reduce flooding June-July
A too rapid flood rise inhibits the growth of new grass shoots in the floodplain, and thereby greatly reduces the food supply for herbivores in that year.	Monitor water levels, keep the water rise to a few centimetres per day.

[source: CCES/ADAPT (2013)]

7.4 Aral Sea

The Interstate Commission for Water Coordination (ICWC) of the Aral Sea was founded 1991 and extended 1992 between the countries Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, Uzbekistan. The commission was created on the request of the CAR countries itself.

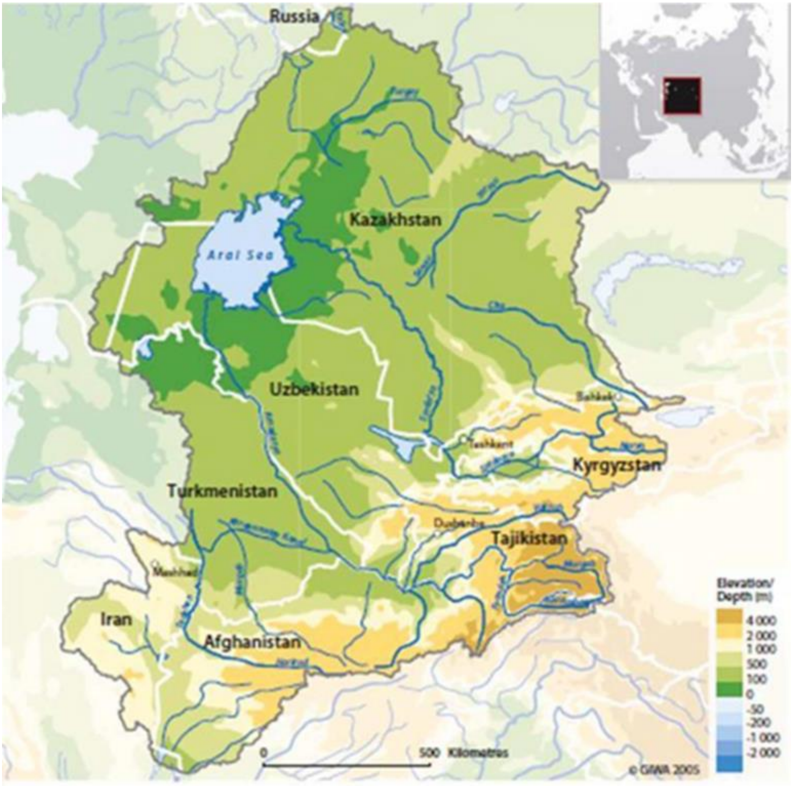


Figure 37: The Aral Sea system (http://www.icwc-aral.uz)

The Aral Sea system covers an area of 1 231 400 km² with the main rivers Sur Darya (annual flow 36.6 km³/a) and Amur Darya (annual flow 79 km³/a). The region provides home for a population of 43 Million.

The need to develop a joint approach was obvious as the Aral Sea is diminishing. Syr Darya and Amur Darya are the major tributaries. Both rivers faced tremendous water losses due to abstraction for agriculture, mainly cotton. This dates back to the former Soviet-era.

To prevent further conflicts on water, they embarked on joint activities in the following fields:

- Water allocation and daily operational management including extreme low flow conditions
- Installation of a forum for information exchange (cawater-info.net) and dialogue between the main bodies
- Automation of head water facilities
- Capacity building
- Joint research and projects

They agreed to install water bodies with have the mandate to perform operation. Each major tributary has an own operation unit coordinated by ICWC. A shortcoming identified by ICWC are sectors which are not yet taken into account, for example the energy sector.

The organisational structure is shown in Figure 38

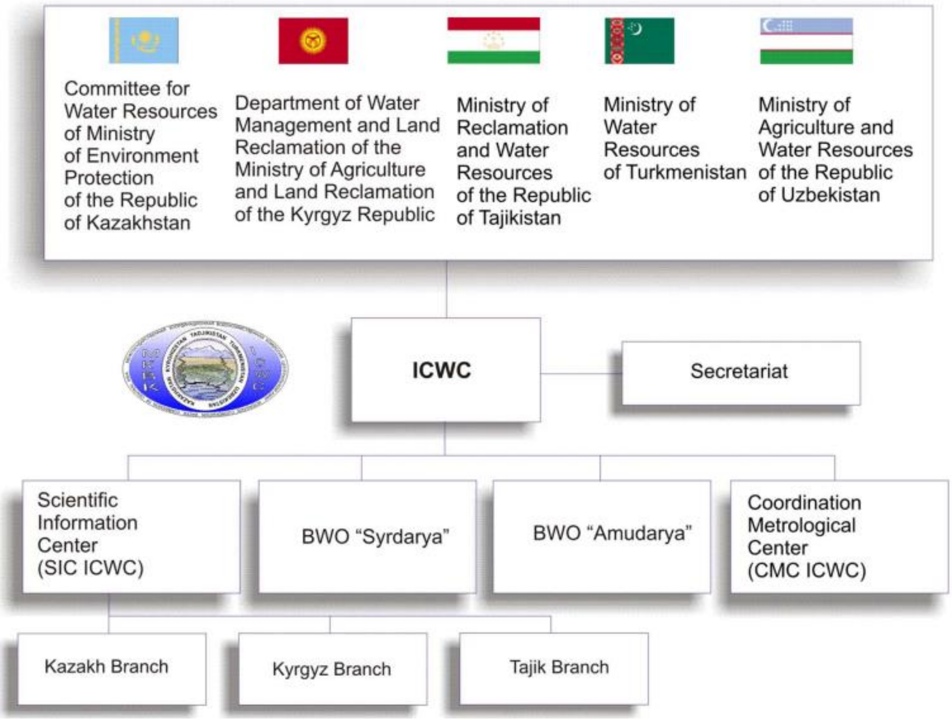


Figure 38: Main entities within the ICWC (http://www.icwc-aral.uz)

The BWOs (Basin Water Associations) are of particular interest.

Basin Water Association Syr Darya (BWO)

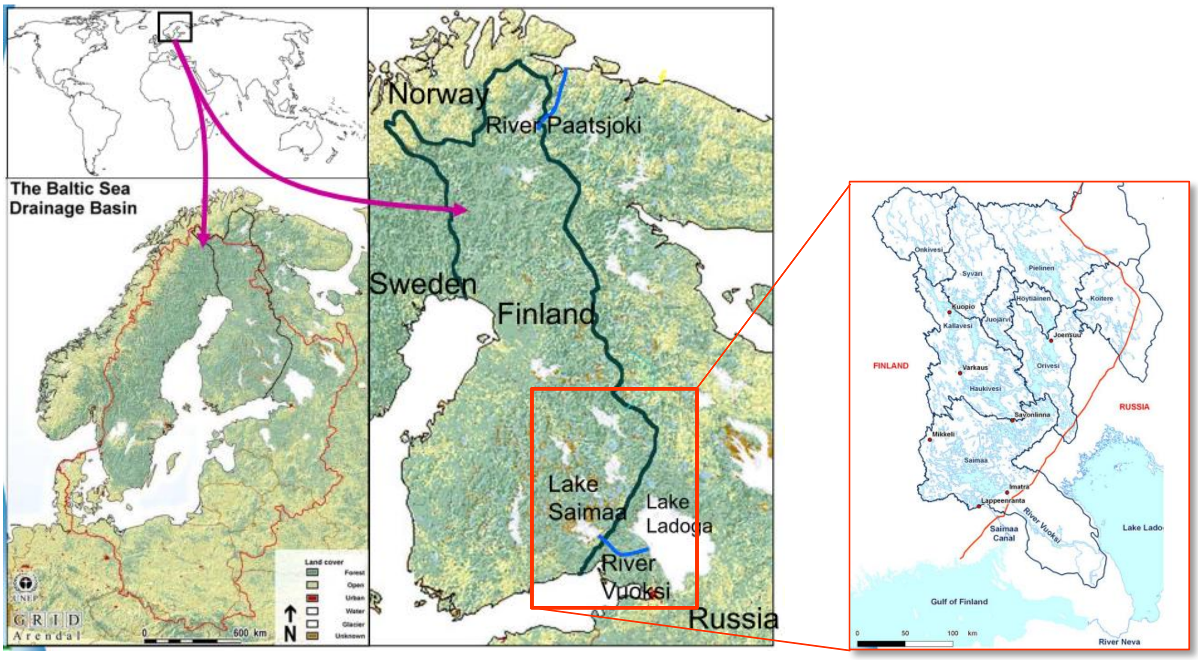
Figure 39: Catchment area of the BWO Syr Darya (http://www.icwc-aral.uz)

BWO is an executive and interdepartmental control body of ICWC of Central Asia republics and acts on the base of an intergovernmental agreement, financed by interested ICWC-members. BWO conducts Syr Darya basin water resources operative management and operates water-intakes, hydropower plants, reservoirs of common use, interstate canals. BWO also prepares and submits proposals to ICWC on water abstraction limits per year (divided into growing and non-growing periods) for each state on the base of jointly adopted decisions with regard to predicted water situation and releases to the Aral Sea and Syr Darya delta. The entity is also responsible for maintenance of water infrastructure and sets out safety rules.

The head of BWO appointed by ICWC has the right to approve plans on design, cost estimates, research and constructing works within the established limits. The head administrates BWO property according to actual legislation, signs agreements, acts and accounts within his competence and makes BWO's personnel arrangements. As a result, the BWO took over national tasks and brings them into transnational contexts on behalf of the countries.

7.5 Finland – Russia transboundary water cooperation

The Finnish-Russian Commission constituted to jointly manage the river Vuoksi and the Lake Saimaa system.



Source: UNECE 2013

Lake Saimaa River Vuoksi has a catchment of about 70 000 km^2 (Finland 77%, Russia 23%). Lake Saimaa has a water surface of 4460 km^2 and on average annual precipitation of about 600 mm/a. Natural mean discharge at the Vuoksi River runs up to 600 m^3/s, max 1170 m^3/s, min 220 m^3/s.

There is a joint commission which meets once a year. The topics of the commission are

Water Protection:

- Water quality monitoring
- Monitoring of pressures, particularly waste waters
- Intercalibration of laboratory analytics
- Information exchange on planned measures

Integrated water management:

- Discharge management
- Flood control and flood management
- Hydropower
- Fisheries and fish migration
- Information exchange on planned measures

A major task is data and information exchange. Both sides conduct measurements, water quantity and quality and exchange time series. Both sides also re-evaluate the data in order to calibrate their measurements. This is an approach which is to their mutual advantage as both countries obtain more reliable information about their water resources system and measurements. Exchange of data is performed via internet. Annual joint reports are prepared. One of the major tasks which requires attention in the future is fish migration.

7.6 Sava River Basin

The Sava River Basin Commission consists of Bosnia & Herzegovina, Croatia, Serbia, Slovenia. One main element of the work of the commission is to generate harmonised documents to be adopted by the countries:

- Staff regulations of the secretariat
- Main functions, structure of the secretariat and job description
- Rules for procurement
- Detailed regulations and procedures of financial affairs

The commission issues rules concerning budget, appropriations, guidelines on financial responsibilities, audits and how to conduct them are binding documents. Rules of procurement procedures were generated to address provisions of tender documents, time limits, procedures on evaluation and award and post award requirements.

7.7 Summary of international examples

Each of the international examples has a unique characteristic and coordination is performed at different levels. However, each example also demonstrates that some common rules for transboundary coordination are in place.

- All examples show the ultimate need for data/information sharing
- The level of river basin management is flexible and the process of developing cross-border coordination is dynamic and evolves over time
- Commitment of member countries is a prerequisite

Topic	Aral Sea	Finland-Russia	Chu-Talas	Mekong	Zambezi	Save River
Shared data/information management system	+	+	+	+	+	+
Joint monitoring and water allocation procedures developed	+	-	+	-	-	-
River basin-wide water management institutional structure	+	-	+	+	-	+
Common knowledge base for decision-making	+	+	-	+	-	-
Executive water association jointly operates water infrastructure	+	-	+	-	-	-
Basin-wide flow forecast system	+	-	-	+	-	(+)
Capacity building as function of the transboundary commission	+	-	-	+	-	+

Topic	Aral Sea	Finland-Russia	Chu-Talas	Mekong	Zambezi	Save River
Cost-sharing mechanisms established	+	-	+	(+)	-	-
Win-win situations identified	+	+	+	+	+	+
Harmonised administrative regulations	+	-	+	-	-	+

(+) in preparation

8 DEVELOPMENT OF THE ROADMAP

8.1 Conclusions from the gap analysis

The gap analysis revealed issues with different extent and urgency. There are institutional and technical gaps which require attention and may impact on coordinated operation. These gaps are used as guidance to suggest steps geared towards the development of an institutional and a technical framework. The major gaps concern:

- Lack of regulations concerning evaluation, approval and review of reservoir operation so that no consistent framework for reservoir operation rules is in place
- Supervision of reservoir operation is not clearly defined and coincides with the operator
- Qualification and training of staff lacks clear regulations and procedures
- Reservoir operation as part of river basin management is unresolved and comes along with a lack of training hereof
- Effects directly or indirectly arising from dam operation are not clear or vague
- Cross-sectoral effects of reservoir operation are not assessed with the consequence that impacts are not necessarily associated with reservoir operation
- Upstream-downstream data exchange to be used for operation is non-existent
- Data monitored at dam sites are not consumed to full extent
- Coordination between cascade dams across borders does not exist

8.2 Conclusions from the Consultation Workshop

A consultation workshop was held in Khartoum during November 22 to 24, 2016. The first day was scheduled as training course with international examples while day two addressed the presentation of the draft Roadmap. The third day was organised as group discussion which was closed by a summary representing the viewpoint of the delegates.

In general, the need for a regional coordination of dam cascades was perceived as necessary as well as the need for investing more in dam operation at dam site, basin, national and regional level.

Capacity building was prioritised as the most important component including modelling, data management but also practical components like dam operation on-site and provision of sufficient human and physical resources at both national and regional level. It was suggested that ENTRO could serve as a training and research centre and guide/develop training courses.

The existing regulatory environment and guidelines were mentioned as topics which need alignment between the countries and further improvement.

The basin wide streamflow forecast was consistently indicated as important both at national and transnational level. Performing forecasts as well as interpreting results was seen as crucial with a strong component of capacity building. Forecasts are intimately connected with data collection and dissemination so that data management and data exchange was unanimously regarded as key element.

Attention should be given to sediment monitoring and bathymetric survey for scrutinising coordinated operation scenarios. The concept of working groups and subsystems with the assessment of benefit sharing options was agreed and should be followed.

The riparian countries expressed the request to obtain more information about options, benefits and risk of cascade operation of reservoirs, for example by means of scenario development and modelling.

8.3 Preparatory phase

The Nile-Sec concluded the first phase of the Strategic Water Resources Analysis in July 2016. This work stream established the current (baseline) water demands and water use in the Nile Basin, developed projections of future water demands and supply based on national water resources plans of the riparian countries. The baseline water supply (availability), demand and use have been endorsed by the National Expert Group as the basis for future analytic work. The analysis demonstrated that there are risks that the growing water demands in the Nile Basin can surpass the available water. Based on the analysis, the National Experts Group identified a number of options for ensuring that growth in water demand can be addressed sustainably thereby reducing the risks of conflict due to shortage of water. One of the options identified was coordinated operation of storage reservoirs. In phase II of the strategic analysis, these options will be explored and the extent to which each option will contribute towards addressing the estimated water deficit quantified [Seid, A (2016)].

By introducing a preparatory phase into the process of advancing towards coordinated operation of reservoirs, the Roadmap and the Nile Strategic Analysis can be aligned and can benefit from each other. Scenarios with cascade reservoir operation could be combined with the baseline data from the Strategic Water Resources Analysis. This could be used to generate plausible options of coordinated operation of dams (existing and planned), assess their performance in terms of agreed upon metrics and prioritize a set of options as most promising. These options could support the second phase of the Strategic Water Resources Analysis together with other options to develop scenarios of sustainable water resources management and development in the Nile Basin.

In this regard, it seems appropriate to include a preparatory phase in two steps:

Step 1:
Preliminary development and analysis of scenarios and presentation of results in June 2017.

Step 2:
More detailed analysis with approximately 9 – 12 month duration in which options of coordinated operation of dams in the Eastern Nile sub-basins will be defined, explored, their performance quantified and prioritized.

Results can then be used to feed into the second phase of the strategic analysis and to prepare the benefit sharing option assessment.

In conclusion, the preparatory phase will bundle together analytic (modelling) work with appropriately designed stakeholder process for the identification, specification, modelling, evaluation and prioritization of the options. As the Nile-Sec is planning to organize a visioning and scenarios construction workshop around June 2017, results of the preparatory phase Step 1 could be presented to the riparian countries.

Apart from the advantage to make use of already compiled data during phase I of the Nile Strategic Analysis, a preparatory phase also meets the request of the riparian countries expressed during the consultation workshop in Khartoum in November 2016.

8.3.1 Background

This introduction stems from personal communication with Nile-SEC and ENTRO and is included below.

Exploring coordinated operation of dam cascades in the Eastern Nile [Seid, A (2016)].

The Nile-Sec concluded the first phase of the Strategic Water Resources Analysis in July 2016. This work stream established the current (baseline) water demands and water use in the Nile Basin, developed projections of future water demands and supply based on national water resources plans of the riparian countries. The baseline water supply (availability), demand and use have been endorsed by the National Expert Group as the basis for future analytic work. The analysis demonstrated that there are risks that the growing water demands in the Nile Basin can surpass the available water. Based on the analysis, the National Experts Group identified a number of options for ensuring that growth in water demand can be addressed sustainably thereby reducing the risks of conflict due to shortage of water. One of the options identified was coordinated operation of storage reservoirs.

In phase II of the strategic analysis (see power point slides for high level process chart), these options will be explored and the extent to which each option will contribute towards addressing the estimated water deficit quantified.

With respect to coordinated operation of dams, the Eastern Nile Technical Regional Office (ENTRO) is in the process of finalizing a roadmap for coordinated operation of dams in the Eastern Nile. The Nile-Sec would like to use this on-going process initiated by ENTRO to generate plausible options of coordinated operation of dams (existing and planned), assess their performance in terms of agreed upon metrics and prioritize a set of options as most promising. These options will then be used in the second phase of the strategic water resources analysis by Nile-Sec together with other options to develop scenarios of sustainable water resources management and development in the Nile Basin.

In this regard, there is a need to further elaborate a preparatory phase (approximately 9 – 12 month duration) of the roadmap in which options of coordinated operation of dams in the Eastern Nile sub-basins will be defined, explored, their performance quantified and prioritized; based on this a set of strategic options will be identified that will feed into the second phase of the strategic analysis by Nile-Sec. The preparatory phase will bundle together analytic (modelling) work with appropriately designed stakeholder process for the identification, specification, modelling, evaluation and prioritization of the options.

The Nile-Sec is planning to organize a visioning and scenarios construction workshop around June 2017 where some of the preliminary results from the preparatory phase of the dam cascade operation process will be used to support the scenario construction efforts. In this regard, the preparatory phase will have to be designed to deliver some results for the scenario construction workshop. More detailed analysis of the options will follow after the deliberations on the options in the scenario construction workshop.

8.3.2 Scope of Work and Timeline for the preparatory phase

The timeline is determined by two constraints.

1. Visioning and scenario construction workshop in June 2017
2. Inclusion of results representing scenarios of cascade operation of dams in phase II of the Strategic Water Resources Analysis

Constraint 1 limits the number of weeks which are available to prepare results for the workshop in June 2017. The workshop is supposed to identify, specify, determine and select scenarios to further include in the strategic analysis. In preparation for the workshop and to facilitate decision-making, cascade dam operation scenarios should be selected and results presented which do have the potential to demonstrate options, benefits and risks with and without coordinated cascade dam operation. Furthermore, riparian countries obtain more knowledge and become more certain about coordinated cascade dam operation if first scenarios are modelled and results demonstrated.

Constraint 2 is determined by the process of phase II of the Strategic Water Resources Analysis. Scenarios for coordinated cascade dam operation should feed into the strategic analysis encompassing the whole Nile Basin. As such, cascade dam operations scenarios combined with baseline/water demand projections should be at hand, evaluated and finally included in the Nile Basin assessment.

Given aforementioned considerations, there are two work packages:

Work package 1:
Cascade dam operation modelling in preparation for the visioning and scenario generation workshop, June 2017

Timeline: March to June 2017

Work package 2:
Detailed analysis of options concluded after the deliberations on the options in the scenario construction workshop

Timeline: from July 2017 onwards to 2018

8.3.3 Work Package 1

8.3.3.1 Prioritisation of Scenarios

Work package 1 should take place from March to June 2017. A set of scenarios is explained in Section 8.4.4 from which a preliminary ranking favours three scenarios to be assessed for the Workshop in June 2017:

1. B) Assessment of benefits from drought early warning without forecasts
2. E) Assessment of benefits from balancing storage volumes to minimise evaporation losses
3. C) Assessment of benefits from upstream dams to adjust filling and emptying phases for downstream dams

Scenario 2 can be modified to assess the capabilities of coordinated operation during dry spells.

8.3.3.2 Study Area

The study area can be limited in work package 1 to the Eastern Nile Region. This simplifies the model setup and suffices the goal of identifying cascade reservoir operation. A suitable boundary of the model is the observation point Malakal. The discharge time-series of Malakal can be used as input into the model. Data requirements are limited to the study area accordingly.

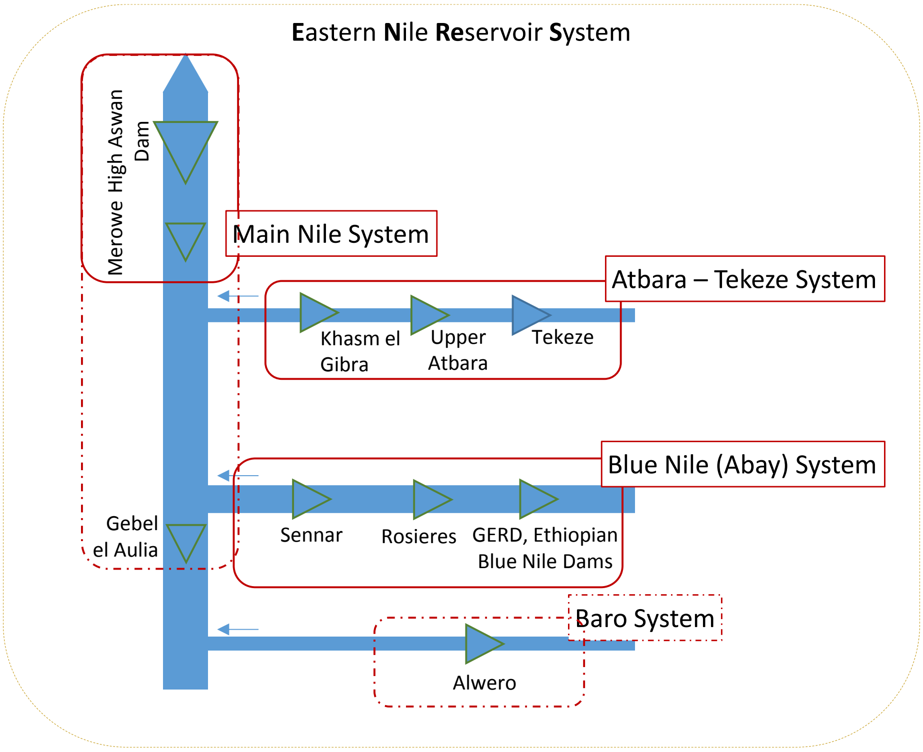


Figure 40: Reservoir systems for work package 1

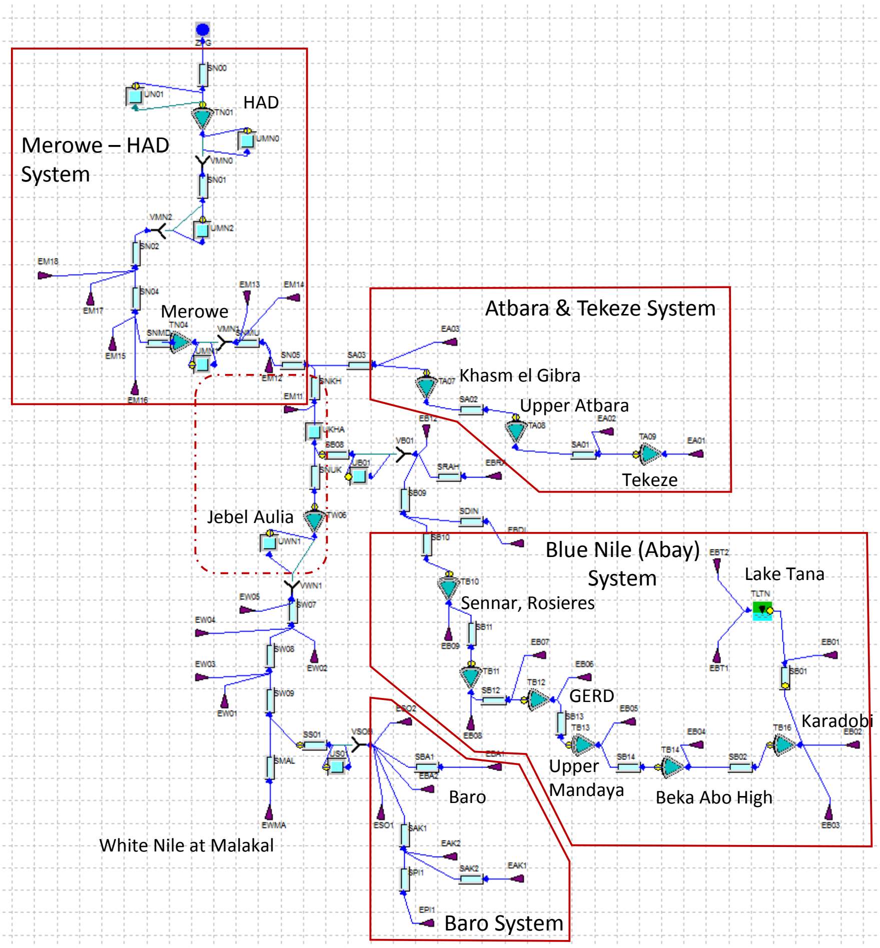


Figure 41: Schematic view of the reservoir systems for work package 1 with sub-systems

8.3.3.3 Data Requirements

Only data and information are needed which are located within the study area.

The data requirements for the work package 1 could be as follows:

Table 8: Data requirements for work package 1 of the preparatory phase

ID	Description
1	Water demand acquisition
1.1	Water demand baseline data from phase 1 affecting reservoir operation
	Water supply (monthly distribution)
	Irrigation (monthly distribution)
	Demand for Irrigation as time series for different years
2	Hydraulic infrastructure
2.1	Update the characteristics of hydraulic infrastructure like
	Current Storage-Elevation-Area relationship (sedimentation!)
	Spillway capacity as Elevation-Discharge relationship
	Capacities of outlet structures as Elevation-Discharge relationship
	Capacity of turbines,
	Type of turbine and efficiency curve
	Elevation of turbines
2.2	Operation and Water Management
	Current operation rules for existing structures (see Figure 40)
	Planned structures (see Figure 41)
2.3	Hydropower generation of previous years as a benchmark
3	Observations
3.1	Discharge measurement stations
	Stage-discharge curves
3.2	Time Series
	Precipitation
	Temperature
	Humidity
	Wind
	Potential Evaporation
	Discharge at measurement stations
4	River Network
4.1	Representative cross-sections
	Tekeze and Atbara
	Blue Nile (Abay)
	White Nile

8.3.3.4 Prerequisites and Capabilities of the Model

The model used may by no means impose any restrictions on the use of operating rules. The risk cannot be accepted that due to limited capabilities of a model cascade operation of dams cannot be scrutinised to the level of detail needed. Hence, the following prerequisites are required to obtain reliable and transparent results for the visioning and scenario generation workshop. The list below specifies the requirements in terms of a suitable river basin and water management model:

- Ability to perform long-term simulations with different time-steps from monthly up to daily time steps.
- Capability to incorporate time series as input.
- Ability to model a river network with representative cross-sections and/or discharge-elevation curves.
- The model must be scalable, that is, the schematisation, river network and hydrological features must be editable and extendable when new and more detailed data emerge.

- Ability to consider gains and losses from open water surface areas in the form of precipitation and evaporation as dynamic process depending on elevation dependent surface areas.
- Ability to incorporate generic water management and operating rules like the following, but not limited to:
  - Rule-based control of fluxes.
  - Building of virtual reservoirs by combining existing or planned reservoirs in any combination.
  - Reservoir zoning.
  - Unlimited use of purposes and releases.
  - Sequence and ranking of purposes and/or releases must be possible within one reservoir
  - Control of downstream river reaches by upstream dams. This entails the ability to perform iterations within one time-step.

It must be possible to define all aforementioned types of rules as time dependent either as varying rules within a year or with a limited validity for a certain period of time within a year.

8.3.3.5 Tasks and Deliverables

The main tasks to perform cascade operation of dams in preparation for the work shop in June 2017 are:

Table 9: Tasks and deliverables work package 1 of the preparatory phase

ID	Description
1	Data acquisition
2	Model set up
3	Definition of performance indicators
4	Scenario modelling
4.1	Baseline as benchmark
4.2	Assessment of benefits during drought conditions with phasing in and out
4.3	Assessment of benefits from upstream dams to adjust filling and emptying phases for downstream dams
5	Evaluation of performance with the performance indicators
6	Documentation
6.1	Model set up and scenarios
6.2	Implementation and testing of rules
6.3	Results
6.4	Recommendations how the Decision-Support System must be enhanced with respect to operating rules
7	Presentation on results during the work shop

8.3.4 Work Package 2

The work package 2 should extent the study area so that the whole Nile Basin is included and is meant to incorporate all relevant hydrological features linking the Eastern Nile Region with the Equatorial Nile Region. Cascade dam scenarios could be combined with other scenarios determined during and after the work shop in June 2017. Thus, the range of scenarios can be fixed not until results of the workshop are clear.

8.3.4.1 Study Area

Figure 42: Study area for work package 2

8.3.4.2 Data Requirements

The data requirements are generally identical to work package 1 but must be extended according to the size of the study area.

8.3.4.3 Prerequisites and Capabilities of the Model

The prerequisites of the model remain as mentioned in 8.3.3.4.

Depending on the Decision-Support Tool of Nile-Sec, it could be considered to run the model within the framework of the DSS. This entails the development of an adapter for the model according to the specifications of the DSS. This should be considered, discussed and determined at the beginning of the work.

8.3.4.4 Tasks and Deliverables

The main tasks to perform the work package 2 are:

Table 10: Tasks and deliverables work package 2 of the preparatory phase

ID	Description
1	Data acquisition
2	Model extension
3	Compilation of relevant scenarios
4	Scenario modelling
4.1	Baseline as benchmark
4.1	Long-term simulation of scenarios
5	Evaluation of performance with the performance indicators
6	Documentation
6.1	Model set up and scenarios
6.2	Implementation and testing of rules
6.3	Results
6.4	Recommendations how the Decision-Support System must be enhanced with respect to operating rules
7	Presentation on results

8.4 Process for developing coordinated operation of reservoirs

There is evidence that institutional aspects and governance progress slower than technical issues and thus can impede technical development, especially in regard to coordinated cascade reservoir management with a long tradition of controversial discussions. Hence, a technical framework should be developed first with a minimal institutional setup.

It is recommended to establish an Interim Coordination Unit (ICU) hosted by ENTRO. This unit should consist of members from all four countries and oversees and coordinates the development of the Roadmap. It is the voice of Coordinated Operation of Dams and accompanies the activities regarding the technical framework.

The concept of the Roadmap is based on four pillars:

- Procedures and mechanisms for harmonising reservoir operation
- Assessment of benefit sharing options which pave the way for coordinated operation of dams

(as an accompanying process)

- Basin wide forecast as continuation of the Hydromet system
- Continuation of the Dam Safety programme to establish harmonised Dam Safety Management Regulations

From the viewpoint of aligning the Roadmap with already existing tools and programmes, the following components were integrated:

- The Hydromet system
- Flood Early Warning application at ENTRO
- The Regional Dam Safety Framework developed by ENTRO
- The Decision-Support System developed by Nile-Sec.

These existing elements were considered during the development of the Roadmap. The continuation of the Regional Dam Safety Framework and the Hydromet systems should run parallel to the coordinated operation of reservoirs but can be seen as independent. Coordinated operation of reservoir would profit from both.

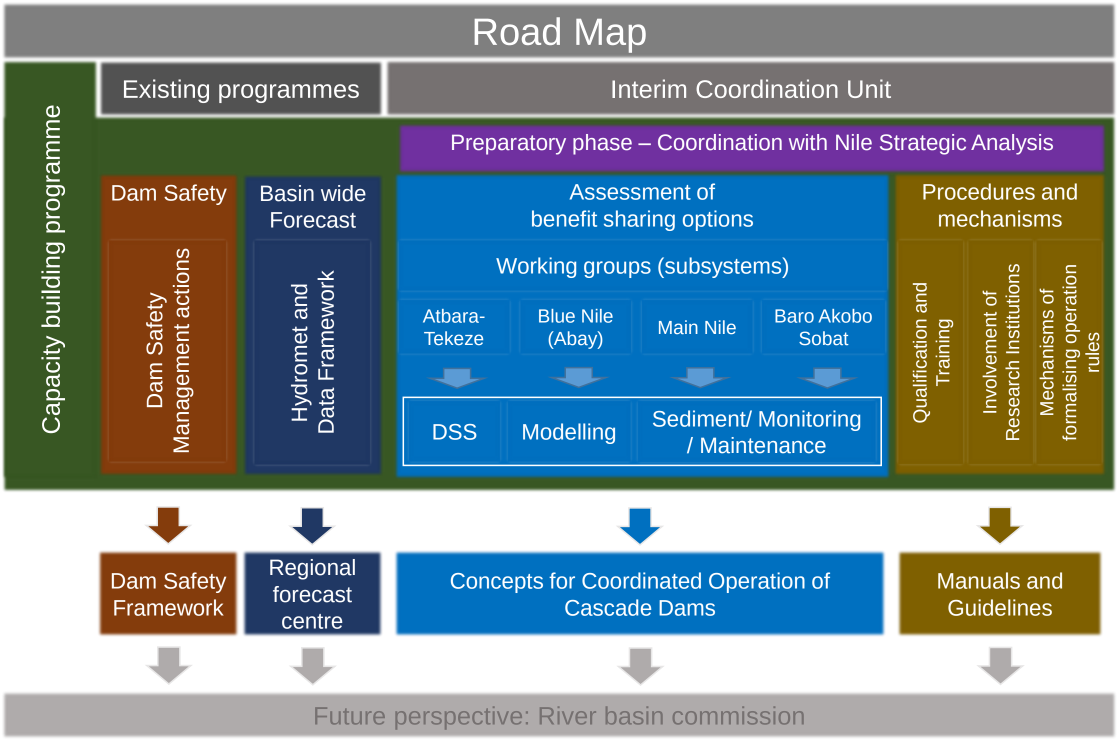


Figure 43: Structure of the Roadmap

8.4.1 Interim Coordination Unit

The establishment of an Interim Coordination Unit (ICU) hosted by ENTRO constitutes the beginning of the process towards coordinated operation of reservoirs. The ICU should oversee and accompany the whole Roadmap development and parallel should try to prepare procedures in terms of

- Qualification and training of staff
- Involvement of research institutions
- Mechanisms of formalising operation rules

Ideally, the ICU creates documents and manuals in preparation for an agreement between the countries to embark on coordinated operation of reservoirs. The unit works at transnational level and liaises with national boards.

8.4.2 Procedures and mechanisms for harmonising reservoir operation

In the long run, the development of common procedures and mechanisms for qualification, training and operation rules are seen as essential with the following topics:

- Harmonisation of procedures for qualification and training measures
- Harmonisation of mechanisms concerning operation rules including
  - validation of rules and level of validation
  - involvement of public authorities
  - public consultation mechanisms

This can be best achieved by the Interim Coordination Unit.

Procedures for qualification and training of staff

To facilitate measures for qualification and training, two aspects should be considered:

- Development of a manual on training courses for coordinated reservoir operation

A harmonised manual on training courses for coordinated reservoir operation seems mandatory with the rapid development of dams in mind. A manual should serve as a reference for all countries with aligned contents and the needs of all members considered.

- Development of regulations defining the course of action for training

  At the same time, regulations are needed to establish training as part of the professional conduct of staff. Thus, regulations should be established which define the course of action for training and the financing mechanism.

  This activity should go hand in hand with the actions suggested in Section 8.4.3.

Mechanisms of formalising operation rules

A step-by-step approach is recommended to develop regulations for formalising and approving operation rules.

International good practice is to separate responsibilities of approval and operation. Hence, approving authorities and operators should be separated and independent from each other. Ideally, the course of action can be depicted as given in Figure 31.

The Interim Coordination Unit should prepare the process of formalising operation rules. Steps are needed when operation of reservoirs is concerned as the following:

- What kinds of assessments are required

  In order to identify the performance of operation rules, assessments are required. These assessments can be long-term continuous simulation, evaluation of supply safety for all purposes, evaluation of safety against overtopping, etc. The performance indicators (see 8.4.4) should be integrated here.

- What a level of validation is needed depending on the expected impact of operation rules

  It is not necessary to conduct all assessments (see above) every time when operation rules are changed. In fact, it depends on the expected impact a change of the rules might have. As a consequence, rules should be classified according to expected implications and associated with a level of validation. The level of validation decides on the extent of the evaluation and approving process as given in Figure 31.

- Determine who needs to be consulted

  The involvement of stakeholders depends on the level of validation. The group of stakeholders must be identified for each country.

- Determine and harmonise review periods for operation rules

  Operation of reservoirs must be reviewed even without any change in the rules. This needs to be discussed and coordinated between the countries.

The findings should be adopted at national level ensuring that different operators obtain equal treatment. Finally a guideline and template for operation manuals should be prepared to establish a common standard.

National boards for reservoir operation

National boards dealing with operation of reservoirs should be established. They act as regulator to facilitate and monitor the implementation and ongoing development of the coordinated operation of reservoirs and liaise with the Interim Coordination Unit. Their tasks should be to adopt the mechanisms of formalising operation rules and adjust them according to local conditions.

8.4.3 Capacity building

An overarching element of the Roadmap is capacity building.

Capacity building programme

It is recommended to establish a capacity building programme which accompanies all four pillars by means of training courses

- Eastern Nile Dam Operation Capacity Building Centre

  The Roadmap suggests setting up an Eastern Nile Dam Operation Capacity Building Centre. This is regarded as a milestone for future dam operation in the Eastern Nile Region because of the massive impact dams will have in the future.

  The vision of an Eastern Nile Dam Operation Capacity Building Centre (ENDOC) is to set up a centre with the assistance of international partners. Training courses held by practitioners from international dam owners and consultants need to be organised. This should be accompanied by site visits to dams in Europe, USA or elsewhere where upstream/downstream coordination plays an important role. A period of four years seems to be sufficient to establish powerful training courses and to educate trainers from each country who are able to continue the training courses on their own. In other words, trainees become trainers after a while so that a kind of a snowball principle can be established. After four years, the Training Operation Centre with international support could smoothly fade out and organisations in the countries take over. This is in line with the consideration of involving research organisations from each country in the Roadmap.

- Involvement of research institutions

  The riparian countries own research institutions with good reputations either as universities or integrated into governmental organisations. The have the mandates for doing research in the field of water resources.

  It is suggested involving these research institutions from each country at national level as facilitators in terms of supporting modelling and for capacity building (see 8.4.3). Research institutions are supposed to act as pioneers, impartial supporters and to bring on exchange on scientific level. Data collection, verification, data management and modelling are typically domains of research institutions. Feeding back of results and streamlining various data sources help enhance the NBI Information System and provide each member country with sufficient and above all coherent information.

- The Interim Coordination Unit should be the organ who organises the involvement.

8.4.4 Assessment of benefit sharing options

Benefit sharing options must be identified to create incentives why coordinated reservoir operation is needed. It is also important to demonstrate consequences and risks if no coordination takes place.

Subsystems for coordinated operation of reservoirs

Considering the Eastern Nile Reservoir System, it seems advisable to start with coordinated operation by using subsystems. The Eastern Nile Reservoir System offers opportunities to use subsystems at national level and subsystems which combine two riparian countries. This is considered as an advantage to proceed from “small” to “large” as less institutional arrangements are involved.

This has the distinct advantage that less effort is needed to establish working groups if only two countries are involved. In addition, mutual interactions are easier to coordinate and comprehend. Collaboration, data and information sharing can be launched with less institutional effort. The disadvantage that subsystems do not represent the complete reservoir system can be eliminated later on. After a successful phase of working at subsystem level, the approach should be extended to cover the whole reservoir system. This is definitely easier since knowledge already gathered can be utilised.

Suitable subsystems are illustrated in Figure 44. The approach of building subsystems serves as a recommendation to the countries in their effort to cope with more and more complex reservoir systems.

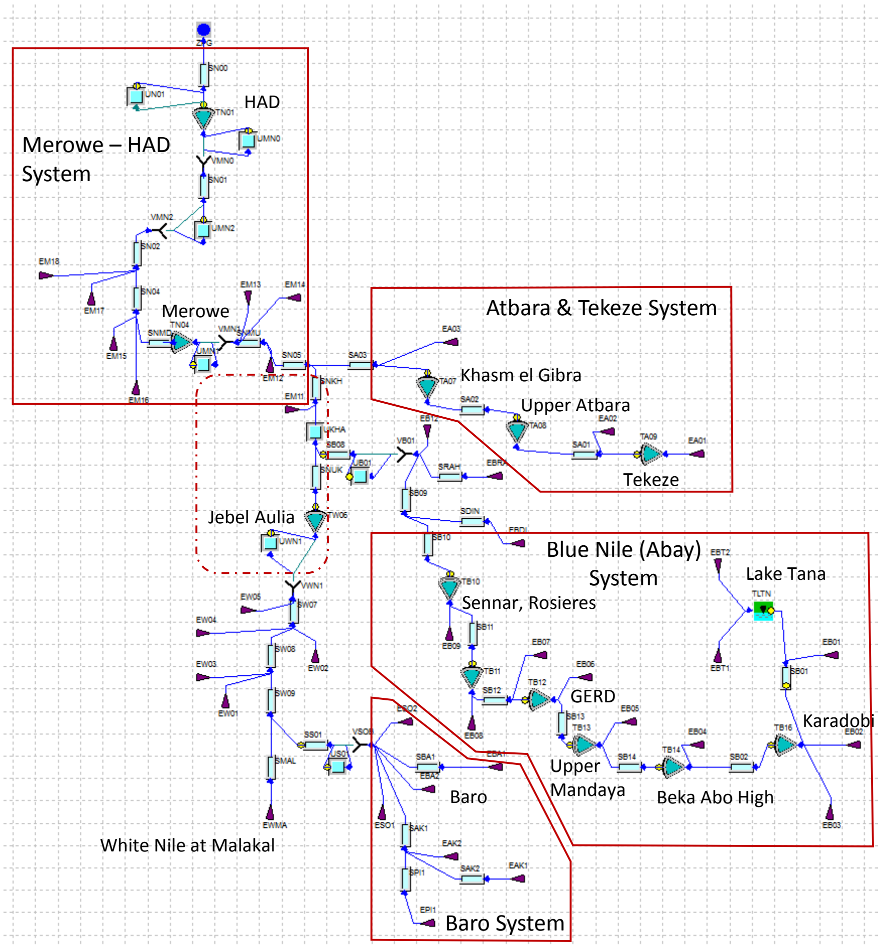


Figure 44: Subsystems for coordinated reservoir operation

Each subsystem should be analysed step-by step, beginning with the Tekeze-Atbara system, followed by the Blue Nile (Abay), Main Nile and Baro-Akobo-Sobat subsystems. The Tekeze-Atbara subsystem is less complex than the Blue Nile (Abay) system but is complex enough to offer solutions for coordinated reservoir operation. The other subsystems should follow to make full use of experiences emerging from the Tekeze-Atbara system.

Constitution of working groups

Working groups should be constituted for each subsystem. It is recommended to start with the Tekeze-Atbara river basin, followed by the Blue Nile (Abay), Main Nile and Baro-Akobo-Sobat subsystems. Each working group assesses a subsystem with regard to benefit sharing options. Subsequently, the subsystems should be combined to one system which covers the whole Eastern Nile Reservoir System.

Working groups undertake detailed benefit sharing analysis and work out various coordinated reservoir operation policies. At the final stage, findings from each subsystem are transferred to the combined reservoir system in order to assess overall benefit sharing options with all reservoirs.

The main task of each working group is to assess benefit sharing options by means of modelling. Each working group should be tasked with the following topics:

- Data collection and streamlining data management (see 8.5.1)
- Development of basic cause-effect relationships of the respective subsystem
- Development of a baseline scenario
- Agreement on performance indicators and sharing them with other working groups
- River basin modelling
- Presentation of results

Each country nominates practitioners and researchers to join the working groups. The developed of the Regional Dam Safety Guideline provides an example showing the benefits of working groups.

The establishment of small working groups is more efficient and should be preferred. The working groups should ideally include authorities, practitioners and researchers from each country. A maximum number of 10 to 12 members are considered to be efficient. Based on experience, larger groups often tend to become less effective while very small groups may work efficiently but do not generate enough momentum.

External consultants with experience in coordinated reservoir operation could be included in order to provide support and guidance and, if need be, to act as mediator.

River basin modelling and detailed assessments

In order to understand benefits of coordinated reservoir operation, a sound knowledge of the interaction of operation within a multi-reservoir system is essential. A course of action for water management and reservoir operation should comprise (see also Section 6.1.3):

- Geographical scaling

  Geographical scaling seems clear when subsystems are considered. However, the river basin is not necessarily the border at which water management stops and implications can go beyond the watershed. For example, subsidies in the agriculture sector promoting certain crops are often drivers impacting on water management. Such issues must be considered during the geographical scaling.

- Scoping and causal-chain analysis

  Apart from hydro-meteorological stress, watershed management policies, energy demand, urban planning and land use/agricultural practices are mostly major drivers for conflicts and water resources related problems. In other words, the water, energy, food security and ecology nexus, comprising sectors like domestic and industrial water supply, agriculture, mining, forestry, ecology, fisheries, energy, rangelands and livestock, must be taken into account.

It is important to note that all these components cannot be addressed in detail as it exceeds the goal of the Roadmap but the topic comes into play, requires attention and should be tackled parallel. To include them with an appropriate level of detail, proxies are needed representing the nexus in a simplified manner.

Cause-effect relationships constitute such simplified forms, if they are described with functions incorporating uncertainties. Not all relationships can easily be described with functions. A way around is to apply regressions, classes of impacts.

- Operation policy options analysis

  Combining these functions with a generic cause-effect relationship builder and integrate them as part of a river basin and water management model provides comprehensive insight of interactions. This sheds light on reservoir operation and their impacts. Following such a methodology, environmental and social aspects are included and impacts become transparent.

  The Nile Basin Decision-Support System (DSS) is the ideal platform for this task [Seid, A. (2016)].

- Detailed assessments

  Modelling should start with hydrological features and needs to be extended into other sectors to cover cross-sectoral causal-chains. Energy demand, population growth, subsidies and maintenance to mention some, should be incorporated into the model step by step. This calls for a software package which is capable of modelling river basins with water management and offers extensions to cover cause-effect modelling. In other words, hydrological modelling and generic cause-effect modelling must go hand in hand.

  A flow network with all hydrologic and hydraulic elements like sub-basins, point-sources of discharge, rivers, canals, reservoirs, dams pertaining to the basin specific requirements must be composed. In addition to the flow network, a logical network representing the structure for operational aspects and cause-effects from different sectors must be added and linked with hydrological features in the model.

As described earlier, the Nile Basin Decision-Support System (DSS) is already in existence and constitutes the software environment needed. An appropriate tool which covers the requirements for reservoir operation needs to be included in the DSS as integrated model adapter.

The tools used at ENTRO comprise:

- SWAT (The Soil and Water Assessment Tool),
  a complex rainfall-runoff model with limited features for water management. Capable of modelling land use changes but no capability to assess cause-effect relationships. Open-source product. Not suitable for this purpose.
- HEC-HMS (Hydrologic Modelling System),
  a rainfall-runoff model with less parameters than SWAT. No operation features and no capability to assess cause-effect relationships. Free software product. Not suitable for this purpose as it does not offer sufficient options for water management.

- RIBASIM (River Basin Simulation Model),
  able to cope with operation. Time series driven model. Limited capability to integrate cause-effect relationships. Obtaining licences must be arranged with Deltares.
- MikeBasin and NB DSS
  Advanced tool for river basin and water management analysis. Offers enhanced possibilities to integrate different sectors. Licence required. This counters an application as the distribution of the model for a number of modellers is required in the future. The licence issue discourages its application.

Existing tools but not yet in use at ENTRO are:

- RiverWare
  flexible modelling package with rule-based operation policies which could be used to incorporate cause-effect relationships. Apart from rainfall-runoff modelling, it covers all features needed to model a river basin with water management. Licence required. The licence issue discourages its application.
- HEC-ResSim (Reservoir simulation model),
  offers only reservoir simulation capabilities. Could be used in combination with HEC-HMS. Application of HEC-ResSim is not very intuitive. Rules for operation are limited. Application of the tool is not recommended.
- Talsim-NG (Water management software package),
  combines river basin modelling, water management including reservoir operation with generic causal-chain modelling. The interplay between different sectors and their relationships to the water sector are an integrative part of water resources modelling. It can be used as rainfall-runoff model, as time series driven model or a combination of both. No licence required. Can be used also in real-time operation. Could be provided to ENTRO.

It is recommended to use a single modelling package within a working group. This ensures that same features can be utilised and that only one set of input data is created.

It is crucial to make sure that all time series of discharge, abstractions etc. must be identical before different working group members start modelling and comparing results. Time steps should be larger or equal one day and less than one month. Continuous long-term simulation is strongly recommended using the longest time horizon possible which is covered by reliable discharge time series.

Performance indicators

Comparing results and examining goal attainment requires performance indicators.

- The working groups should agree on indicators prior to analysing results.
- Indicators should be shared with other working groups to enhance the experience in using them.
- Performance indicators should be endorsed and adopted by the member countries for coordinated course of action.

Baseline scenario

The baseline scenario represents the current situation. It constitutes the basis against which all further scenarios must be compared to. It portrays the river basin with all relevant features and demonstrates the current goal attainment by applying the performance indicators.

Using the history as a baseline scenario and comparing it against scenarios with coordinated operation is one sure way of gaining insight. A common modelling tool which is available for all without licensing issues and ideally with a client-server architecture, which enables all users to employ one set of time series and to exchange their scenarios, is regarded to be a prerequisite. The baseline multi-reservoir system must be made available for all modellers in the working group and serves as a benchmark. It is paramount to concentrate on coordinated operating rules and not to struggle with time series issues and other side functions.

The working group and the member countries should agree on the baseline scenario.

8.4.4.1 Coordinated reservoir operation scenarios

Scenarios with coordinated reservoir operation need to be carried out. There are different options to incorporate coordinated water management with reservoirs. Some are suggested which are good starting points:

Assessment of flood protection benefits downstream with forecasts from upstream

- Scenarios with coordinated upstream/downstream releases
- Scenarios with coordinated upstream/downstream releases and short-range forecasts

The accuracy of short-range forecasts should be varied to see how much benefit a forecast would bring. It should be started with a perfect forecast and then gradually reduce the skill of the forecast. For long-range forecast see Section 0.

Assessment of benefits from drought early warning with long-range forecasts

- Scenarios with coordinated upstream/downstream releases
- Scenarios with coordinated upstream/downstream releases and long-range forecasts

The length and accuracy of long-range forecasts should be varied to see how much benefit a forecast would bring. It should be started with a perfect forecast for six month and then gradually reduce the skill and length of the forecast. For long-range forecast see Section 0.

Assessment of benefits from upstream dams to adjust filling and emptying phases for downstream dams

The dams in Sudan apply rule curves defining filling and emptying. The rule curves can be made more flexible to adopt current situations with upstream dams in place.

Assessment of a prolonged life time of reservoirs due to reduced sediments trapped by dams upstream

This requires sediment modelling. Continuous long-term simulation is required to assess the impact of sediments. This is a very important aspect and has direct links to Section 8.4.4.2. The results produced in the modelling working group feed into the work of the maintenance working group.

Assessment of benefits from balancing storage volumes to minimise evaporation losses

There is evidence that taking different storage-elevation-area relationships into account brings about overall advantages [Blackmore, D, Whittington, D. (2008)]

By analysing the storage-elevation-area functions of the Blue Nile and Main Nile reservoirs, it becomes clear that increasing storage volume or elevation increases the water surface area disproportionately at different reservoir locations

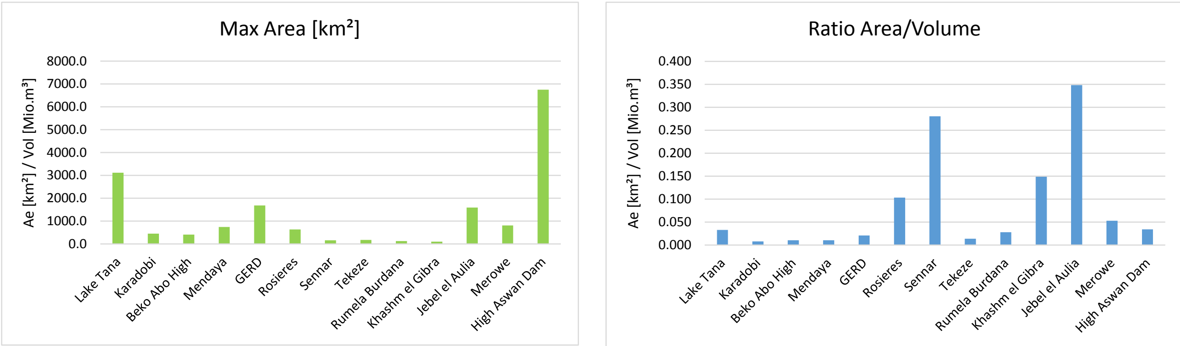


Figure 45: Increase of water surface area per MCM storage and maximum water surface area

The storage in the reservoirs must be balanced such that evaporation losses are minimised. Water can be saved by increasing the storage volume at one dam location with favourable area/volume ratio and less evaporation and reducing the storage volume at a location with unfavourable area/volume ratio and high potential evaporation. Furthermore, not only overall evaporation losses can be reduced, but also head for hydro power generation will increases overproportionally so that more hydropower generation upstream is possible. This principle of taking advantage of different climate and topography should be intensively scrutinised for the different cascade systems in the Eastern Nile Region.

8.4.4.2 Sediment, monitoring and maintenance

The example of the Chu-Talas transnational reservoir system (see Section 7.2) shows how monitoring and maintenance can serve as a basis for coordination.

Kazakh Republic and the Government of the Kyrgyz Republic have agreed on a financial reimbursement scheme based on maintenance and utilisation of water management facilities. The parties share expenses connected with the operation and maintenance of these water management facilities.

Such an approach could be used by

- assessing sedimentation and impacts on storage
- evaluating costs for monitoring at each dam site
- evaluating costs for maintenance at each dam site
- suggesting an allocation formula for reimbursing monitoring/maintenance and upstream sediment traps

8.5 Accompanying processes

8.5.1 Basin-wide forecast

Basin wide streamflow forecasts are considered as a crucial element for reservoir operation. The usefulness of streamflow forecasts can be derived from examples given in Section 7. The development of an operational forecast system is regarded as a direct follow-up of the Hydromet system which has already been launched as the design for a basin-wide hydromet systems has been prepared and first phase implementation is planned to start in 2017 [NBI (2015)], so that the suggestions given here would supplement the process.

Short-range and long-range forecasts are clear benefits for dam operation but also for other stakeholders and sectors, for example the agriculture sector. Hence, an operational basin-wide forecast system should be an ultimate goal

Establishment of a forecast unit should be worked out parallel to the development of coordinated operation of reservoirs. It consists of four milestones:

- Establishment of a unified data framework for reservoir monitoring
- Continuation of the Hydromet system
- Development of basin wide forecast (short- and seasonal)
- Establishment of a forecast unit

Unified data framework

The need to streamline data access for an extended group of users was derived in the gap analysis. This will become more important for each member country if new dams come into operation, operation will become more complex and sophistication of data analysis will increase to derive foresighted operation rules. This is usually obstructed by observed raw data with errors, gaps and outliers. Raw data must be interpreted, checked and converted into production time series before they can be disseminated to end users like operation engineers, water resources managers in order to make analyses, etc. Instead of expending effort in each country to install software and process time series, a coordinated approach is recommended.

Routines and procedures to check time series and to convert them from raw to production time series can be developed in a coordinated approach to save time, money and to benefit from the experience of a larger group of experts. Steps required are:

- Provide homogeneous data formats for ease of use
- Identify typical error and gaps in the time series specific for different locations and states (water level, discharge, rainfall, etc.)
- Devise and code methods to eliminate them or alternatively by software if this is generic enough and affordable
- Deployment of software to all member countries
- Testing, bug fixing and improvement

A technical working group should be established which deals with data management and tries to organise homogeneous methods and formats. Members should have expertise in data management, mass data and software development.

Advantages of a coordinated approach are coherent data checks, streamlined procedures and a working group which can advocate for homogeneous data management approaches and can support the countries. Disadvantages are the fact that initial effort is needed to make time series available.

The approach should be automated at a later stage which requires a few technical prerequisite. Raw data, observed at various locations, are transferred to the central data storage in each country. The central data storage uploads raw data to an ENTRO hosted platform where data checks are performed, errors, gaps, outliers are eliminated etc. All data checks which can be carried out in an automated way could be implemented. The software saves production time series and sends them back to the sender where further processing and/or data dissemination can take place if required.

Even without considering data checks, the requirement to make time series accessible by means of intuitive software solutions, like web-based data managers, is mandatory for coordinated reservoir operation. The NBI already has a data platform. It could be used to provide a data framework which is kept updated by periodically uploading records.

Forecast of streamflow

It is obvious that reservoir management benefits from short and long-range forecasts of streamflow enabling operators to execute foresighted release patterns. Prerequisites are

- Forecast of streamflow comprises all major tributaries
- Forecasts are coherently generated throughout the river basin
- Lead time of forecast is long enough to cover travel time through the river basin
- Forecasts are long and reliable enough to support the timing of filling and emptying
- Results are made available for all
- Streamflow calculation incorporates release patterns of major reservoirs

With all points in place, short-range forecasts are best suited in the headwater areas of Ethiopia while long-range forecasts can improve coordinated reservoir management as a whole and is a strong possibility to concentrate resources from all member countries on one overarching forecast unit. Such a unit should be split into two groups:

- forecasters
- reservoir managers

The forecasters focus on achieving reliable forecasts and provide streamflow predictions for the reservoir managers who make suggestions in terms of filling, release strategies and probabilities of supply safety.

This topic is closely linked to the National Meteorological Agencies. Each NMA would profit as well as resources are concentrated and procedures are developed to use satellite data based predictions based on numeric weather models, for example from NOAA.

8.5.2 Dam Safety

In the long run dam safety should arrive at a harmonised dam safety framework. This pillar is a direct follow-up of the draft Regional Dam Safety Framework. It extents the Regional Dam Safety Framework as it recommends also dam break studies, notification procedures, transnational inundation maps and joint preventive actions in case of emergencies. Especially clear communication is a crucial element of coordination.

Dam break studies

Dam break studies analyse different failure modes from which flood hydrographs will be derived to develop inundation maps. Failures modes can arise from

- Internal erosion / sheer stress / abutment failure
- Earthquakes
- Floods
- Landslides
- Driftwood jam and spillway blockage
- Operation failure

The list of failure modes shows that the dam safety working group requires additional expertise with regard to geotechnics and structural engineering.

Inundation maps

Inundation mapping includes flood routing of a dam break flood, estimation of water levels and mapping the levels to the area. It should be continued to a point downstream where the dam break flood no longer poses a risk to life and there is limited potential for further damage of property. In a cascade of reservoirs, the downstream point is the next dam. In any case, the impact of a dam break must be assessed to see if the dam downstream is able to resist the incoming flood wave.

Several software tools are possible for flood routing. It is recommended to apply a 2D hydraulic model which can be shared among the working group members. HEC-RAS version 5.0 is free and performs well. Any other appropriate 2D model which might be in use in the countries could be used as well.

Notification chain

A notification flowchart shows who is to be notified, by whom and in what priority. The working group should set out to compile the information needed to launch a call-down tree. This could be accompanied by awareness raising measures for stakeholders who are not directly involved in the dam safety business.

Preventive measures

Early warning makes or breaks preventive measures in case of an emergency. Part of preventive measures is regular drills. The countries could embark to design common drill procedures to train staff on-site and dam managers in dam safety and emergency preparedness activities.

Emergency Preparedness Plans

Reservoirs are perfect structures to enhance emergency preparedness if they are monitored, well-staffed and procedures for identifying hazards, notification and preventive measures are unambiguously organised.

In particular, cascade dams are beneficial in disseminating information of upcoming emergency situations from upstream to downstream. The Eastern Nile Reservoir System is large enough to provide sufficient lead time on the condition that notification works across country borders.

The coordinated development of Emergency Preparedness Plans should comprise aforementioned topics:

- Dam break studies
- Triggers for warning levels
- Notification chains
- Preventive measures

8.5.3 Establishment of an Eastern Nile Modelling Centre

Each country has similar problems to be tackled when it comes to complex reservoir operation. Debris flow and sediment management are two of them. It is worth scrutinising the problem in a coordinated 2D/3D hydraulic modelling approach. Such modelling approaches require good software, and even more, experienced modellers. The most time consuming and thus costly part of 2D/3D modelling is to set up the Digital Elevation Model (3D DEM terrain) including the dam and to calibrate it. While good and free software is available, modellers with expertise and good terrain data are usually not. A modelling centre which sophisticated modelling software, high resolution DEMs, calibrated 3D models of the dam sites and experienced modellers at hand can serve as a focal point to devise methods for diverse tasks. One task could be to work out solutions in order to prevent debris from reaching susceptible structures like turbines, flexible gates, etc. 2D/3D models can be utilised to optimise position and shape of structural elements such that currents are created which cause debris to be located in areas which are easy to maintain.

The mutual benefit is to establish models and keep them updated for all dams in a joint effort so that costly hydraulic planning and design can be streamlined, which saves resources for all countries.

8.6 River basin commission as long-term perspective

A long-term perspective for close cooperation between the countries is to establish a River Basin Commission.

According to [GWP (2012)], a transboundary River Basin Organization can be defined as a permanent institutional arrangement dedicated to all or part of the management of shared waters between at least two countries. This covers a wide range of organizational types performing various functions. The legal framework and the statute of these institutions are often determined by the basin's context and history as well as by the mandate given to the body established by the member states. The functions of a transboundary basin organizations are varied and may contain coordination and advice function, executive function or the body owns control function on implementation of the agreement between the countries.

The possible level of mandates range from

- informational, focusing on the exchange of data and tasks mainly technical and execution
- consultative, where the body represents an institution complementary to the States but has no decisional power
- decisional, where the organization possesses the right to implement regulation in the field of shared waters implying indeed a partial loss of the States' sovereignty

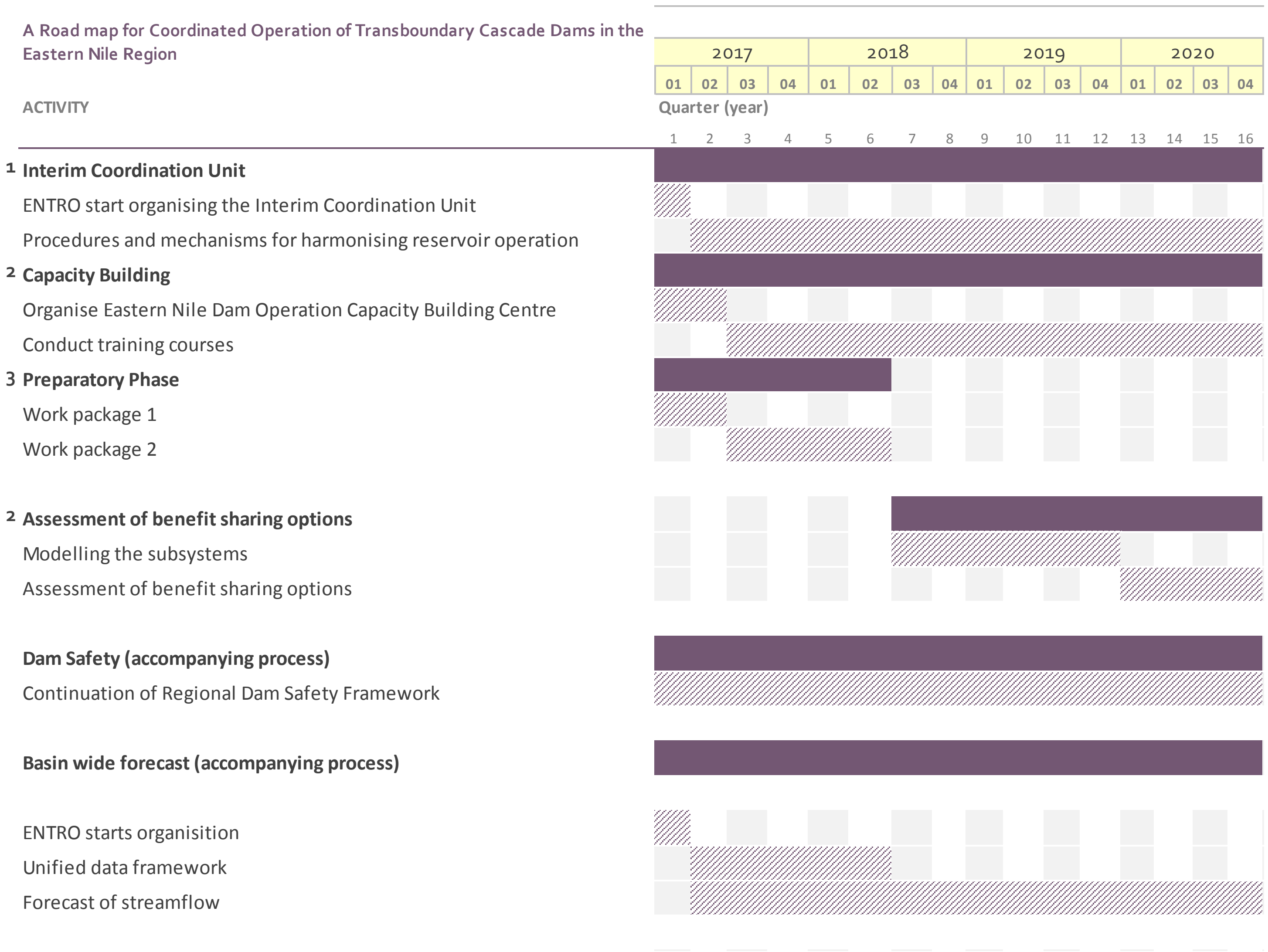
Disregarding the level of mandate, the general idea of establishing a River Basin Commission would promote collaboration not only in the field of coordinated reservoir operation, but also basin water resources management planning processes suitable for the context of the Nile Basin would be fostered.

In all cases, the institutional arrangements established should eventually lead to the creation of a joint basin management body. The semantics chosen to name the institution is much less important than its actual mandate.

Functions assigned and tools for implementation must be aligned. As stated above, this especially implies:

- water monitoring, observation and information systems
- warning systems for floods, droughts and pollution, prevention and intervention
- mechanisms to face disasters caused by water and protect lives and properties
- methods and means for dialogue

8.7 Work plan and schedule



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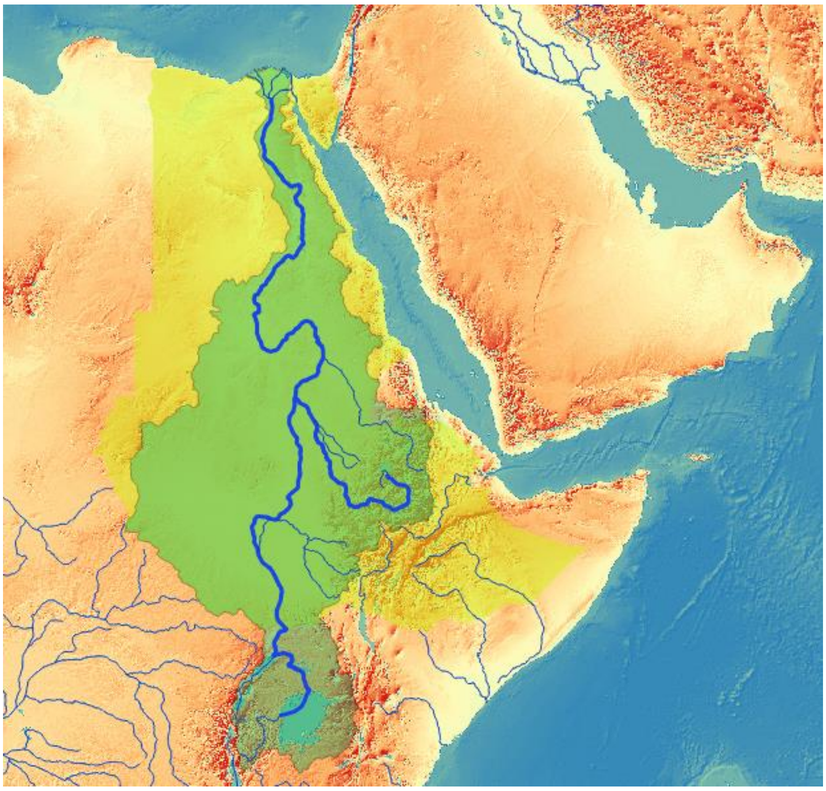
9.2 GIS

GIS data used in this report are as following.

Table 11: GIS data used

Subject	Parameters	Remarks	Source
Dams	Existing hydropower project sites		ENTRO
	Planned hydropower project sites		ENTRO
Monitoring	Hydromet Station		ENTRO
Geography	Country borders		FAO
	Elevation Model World		USGS
	SRTM90 Elevation		USGS
	Land cover		ESA
Hydrology	River network	derived from SRTM90	
	Subbasins	derived from SRTM90	

Gap Analysis – Annex 1



Nile Basin Initiative (NBI)
Eastern Nile Technical Regional Office (ENTRO)
Nile Cooperation for Results Project (NCORE)

Project Number	-
Project Name	Road map for Coordinated Operation of Transboundary Cascade Dams in Eastern Nile
Project Country	Egypt, Ethiopia, South-Sudan, Sudan
Date	19.11.2016

Contents

Gap Analysis – Annex 1

Document Information

Project	Road map for Coordinated Operation of Transboundary Cascade Dams in Eastern Nile
Project Countries	Egypt, Ethiopia, South-Sudan, Sudan
Document	Gap Analysis – Annex 1
Date	19.11.2016
Version	vs. 00
Consultant	Dr.-Ing. Hubert Lohr, Water Resources Planner, SYDRO Consult
Client	Nile Basin Initiative (NBI) Eastern Nile Technical Regional Office (ENTRO)
Client Representative	Michael Abebe, ENTRO
Financing Organisation	CIWA/World Bank

1 GAP ANALYSIS

1.1 Gap analysis for Ethiopia

1.1.1 Institutional settings

1.1.1.1 Separation between operation and supervision

Are separated roles for operation and supervision clear?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	Roles are specified but not in the sense of separation.	
Roles and responsibilities are overlapping	A.2	One authority has the mandate for both.	
Roles and responsibilities unclear	A.3		
Roles and responsibilities are clear	A.4		

Is separation established by law?

Legislation domain gaps	B	Remarks	
Regulations are not in place	B.1	No regulation addresses or stipulates separation.	
Regulations unspecified	B.2	-	
Regulations too limited in scope	B.3	-	
Regulations in place but not applied	B.4	-	
Regulations are in place and applied	B.5	-	

1.1.1.2 IWRM principles

Are IWRM principles anchored in structures and mandates?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	Roles are specified but without focusing on IWRM	
Roles and responsibilities are overlapping	A.2	Water, mining and environmental affairs bear overlaps to some extent	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	-	

Are IWRM principles established by law?

Legislation domain gaps	B	Remarks	
Regulations are not in place	B.1	There are fragments pointing at IWRM, Basin wide approach is addressed with the River Basin Councils. But these are not in charge of transnational river basins and not for reservoirs.	
Regulations unspecified	B.2	-	
Regulations too limited in scope	B.3	The fragments are not sufficient and seem to have no practical implications.	
Regulations in place but not applied	B.4	Interaction and consultation mechanisms are not fully established	

Regulations are in place and applied	B.5	-	

Are IWRM principles known and training established?

People domain gaps	C	Remarks	
Understaffed	C.1	If all IWRM components were introduced, authorities and operators would need more staff.	
Training gaps	C.2	New tasks coming along with IWRM will require training.	
Staff will be overwhelmed in the near future	C.3	New dams will noticeably increase the scope and extent of work. Moreover, IWRM will add more tasks.	
Enough staff available	C.4	-	

Financial resources for IWRM are clear?

Financial domain gaps	F	Remarks	
Resources seem insufficient	F.1	More tasks and training needs funding which is at present not allocated.	
Origin of resources is unclear or not established	F.2	Funding mechanisms for IWRM are most likely not established.	
Relationship between beneficiaries and source of funding seems unclear or	F.3	The framework of IWRM cuts across different sectors and apparently beneficiaries, water tariffs, ecosystem services payments are not introduced.	
Lack of financial resources is likely to occur in the near future	F.4	Lack of financial resources is likely to happen with fully established IWRM.	
Financial resources are sufficient	F.5	-	

1.1.1.3 Dam operator's qualification

Required qualification is specified by law?

Legislation domain gaps	B	Remarks	
Regulations are not in place	B.1	Qualifications for dam operators are not defined by regulations.	
Regulations unspecified	B.2	-	
Regulations too limited in scope	B.3	-	
Regulations in place but not applied	B.4	-	
Regulations are in place and applied	B.5	-	

Enhancement of qualification required?

People domain gaps	C	Remarks	
Understaffed	C.1	From the viewpoint of integrating dam operation in IWRM encompassing dam safety, operation, monitoring and maintenance, more staff is needed.	
Training gaps	C.2	The value of monitoring and data are not fully recognized. Operation embedded in river	

		basin management requires training.	
Staff will be overwhelmed in the near future	C.3	River basin management will very likely lead to gaps with current personnel.	
Enough staff available	C.4	-	

Process for training is established?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	Training is not institutionalised and formalised.	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.5	-	

Financial resources are allocated?

Financial domain gaps	F	Remarks	
Resources seem insufficient	F.1	Financial gaps will be expected as regular training courses are not yet developed.	
Origin of resources is unclear or not established	F.2	-	
Relationship between beneficiaries and source of funding seems unclear or	F.3	-	
Lack of financial resources is likely to occur in the near future	F.4	-	
Financial resources are sufficient	F.5	-	

1.1.1.4 Capacity building

Who carries responsibility for training, curricula? Are capacity in the country available to qualify people?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	-	
Roles and responsibilities are overlapping	A.2	-	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	Qualified research organisations are available.	

Are enough trainers available? Is training for trainers required?

People domain gaps	C	Remarks	
Understaffed	C.1	-	
Training gaps	C.2	On the subject of coordinated reservoir operation, training for trainers will be required. This is due to the fact that the subject of coordinated reservoir operation is theoretically known but not practically applied.	
Staff will be overwhelmed in the near future	C.3	If training for trainers is organised and	

		conducted, capacity building organisations will be able to cope with training.	
Enough staff available	C.4	Research organisations have staff to conduct training.	

Process for performing capacity building is established?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	Capacity building is not institutionalised, that is, no measures for regular capacity building for operators and authorities are established.	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.5	-	

Model, licenses, working places are at hand and sufficient?

Tools domain gaps	E	Remarks	
Tools are missing	E.1	Diverse model packages are available most of which are free and/or open source. But, for instance, tools for cause-effect relationships and real-time reservoir operation are not yet used as it was not deemed necessary.	
Tools are duplicate and yield diverse results	E.2	The reason why a specific tool was chosen is often driven by particular needs and preferences of the respective researcher. This resulted in applying diverse tools yielding diverse results, especially in terms of operation rules, as most of the tools offer only limited options in that regard.	
Tools are inefficient	E.3	Tools are inefficient as long as reservoir operation is concerned.	
Tools lack functionality	E.4	Software used offer only limited options so it remains unclear if solutions really cover all requirements and possibilities.	
Tools are likely to be insufficient in the near future	E.5	Yes, as long as reservoir operation is concerned, in particular, with more dams to be considered.	
Tools are in place with sufficient functions	E.6	-	

Financial resources are allocated?

Financial domain gaps	F	Remarks	
Resources seem insufficient	F.1	If training is institutionalised and made mandatory, universities will need more support to conduct regular courses and to keep themselves abreast of latest developments.	
Origin of resources is unclear or not established	F.2	-	
Relationship between beneficiaries and	F.3	-	

source of funding seems unclear			
Lack of financial resources is likely to occur in the near future	F.4	Research organisation will need support to fulfil their role for regular capacity building if it goes beyond their present scope of work.	
Financial resources are sufficient	F.5	-	

Institutions are in place with sufficient technical equipment?

Facility domain gaps	G	Remarks	
Lack of buildings	G.1	-	
Lack of office space	G.2	-	
Lack of computer and IT equipment	G.3	Possibly yes, if data management and data quality assurance will be entrusted to research organisations.	
Gap in technical communication facility like Internet, transmission lines	G.4	Time to load a homepage of a research organisation takes long or even fails completely indicating less upload rates or the server is down.	
No gaps of buildings, office space, equipment	G.5	No lack of buildings and office space	

Data are available and accessible to conduct qualified and practically oriented training?

Information domain gaps	I	Remarks	
Data not sufficient	I.1	Yes. Reservoir operation needs long and quality-assured time-series.	
Data not located where needed	I.2	Data available at research organisations are not the data which are used in practice.	
Not the data that is needed	I.3	Hydro-meteorological data might be available but reliable information about demands, withdrawals etc. not to the extent needed.	
Data not available when needed	I.4	The effort to acquire latest data obstructs smooth and fast work progress.	
Data not created	I.5	Data which are needed to conduct capacity building are most likely not ready to use.	
Data not consumed	I.6	Data compiled from reservoir operation are maybe stored and theoretically available but not consumed to its full extent.	
Data relationship gaps	I.7	Different sources of data exist. Derivations of the same data sources with different interpretations might exist as well, causing redundant and inhomogeneous data.	
No data gaps	I.8	-	

1.1.2 Monitoring

1.1.2.1 Readings

Performing readings is anchored in structures and mandates?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	-	
Roles and responsibilities are overlapping	A.2	-	

Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	The Beles Scheme shows that readings are a clear mandate of the operator. Monitoring at and in the vicinity of reservoir sites is tasked to the operator as well.	

Performing readings is established by law?

Legislation domain gaps	B	Remarks	
Regulations are not in place	B.1	The general mandate to monitor water resources is set out. There are no regulations stipulating what a reservoir operator must monitor and how. There are only project specific arrangements to serve the needs of the respective site.	
Regulations unspecified	B.2	-	
Regulations too limited in scope	B.3	-	
Regulations in place but not applied	B.4	-	
Regulations in place and applied	B.5	-	

Staff is available to perform readings sufficiently?

People domain gaps	C	Remarks	
Understaffed	C.1	Monitoring is confined to the sole purpose of the respective dam site. More attention should be paid to river basin management, for instance, to monitor downstream impacts of dams.	
Training gaps	C.2	More training is required to raise awareness about wider implications of dams.	
Staff will be overwhelmed in the near future	C.3	Yes, if and when tasks will be extended with the same number of personnel.	
Enough staff available	C.4	-	

Process for performing readings is established?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1		
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.5	The procedures for readings are clear.	

Software, licenses are at hand and sufficient? Validation tools are in place?

Tools domain gaps	E	Remarks	
Tools are missing	E.1	-	
Tools are duplicate and yield diverse results	E.2	-	
Tools are inefficient	E.3	-	

Tools lack functionality	E.4	-	
Tools are likely to be insufficient in the near future	E.5	With water quality and sediment in mind, gaps will occur.	
Tools are in place with sufficient functions	E.6	The tools to perform readings are established.	

Financial resources are allocated?

Financial domain gaps	F	Remarks	
Resources seem insufficient	F.1	High quality monitoring requires considerable financial resources. Gaps are expected.	
Origin of resources is unclear or not established	F.2	-	
Relationship between beneficiaries and source of funding seems unclear or	F.3	-	
Lack of financial resources is likely to occur in the near future	F.4	Yes, if monitoring will be extended to meet IWRM principles. Otherwise see F.1	
Financial resources are sufficient	F.5	-	

Devices and measurement equipment are at hand?

Facility domain gaps	G	Remarks	
Lack of buildings	G.1	-	
Lack of office space	G.2	-	
Lack of computer and IT equipment	G.3	-	
Gap in technical communication facility like Internet, transmission lines	G.4	If and when time, effort and money is spent the same way as it is performed at the Beles scheme, no gaps can be identified.	
No gaps of buildings, office space, equipment	G.5	No lack of buildings, office space and equipment.	

Locations are sufficient? Observed values are sufficient?

Monitoring and measurement domain gaps	H	Remarks	
Measurements not sufficient	H.1	Measurements of discharge downstream is one of the minimum requirements but not installed at all locations downstream of dams. A fully-equipped meteorological station covering rainfall, temperature, sunshine duration etc. should be obligatory at each dam site. Monitoring of major diversions is not integrated.	
Measurements not located where needed	H.2	Discharge downstream also as cross-check for operation are regarded as mandatory.	
Not the measurements that is needed	H.3	From the viewpoint of river basin management and environment, more observations are regarded as necessary.	
Measurements not available when needed	H.4	Generally, records are available. Attention must be paid to make data access as efficient as possible, especially when monitoring is enhanced.	
Measurements available, spatially and temporally	H.5	-	

1.1.2.2 Data storage

Who is in charge of data storage?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	-	
Roles and responsibilities are overlapping	A.2	-	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	EEP is responsible.	

Data storage is made obligatory by law?

Legislation domain gaps	B	Remarks	
Regulations are not in place	B.1	Based on the information at hand, it is assumed that this is not stipulated.	
Regulations unspecified	B.2	-	
Regulations too limited in scope	B.3	-	
Regulations in place but not applied	B.4	-	
Regulations in place and applied	B.5	-	

Staff is available to conduct data storage sufficiently?

People domain gaps	C	Remarks	
Understaffed	C.1	On the condition that monitoring will be extended to cover reservoir operation's needs in the context of IWRM, more staff is needed.	
Training gaps	C.2	Training about managing hydro-meteorological mass data is most likely required to enable multi-user access and sophisticated evaluations by different parties.	
Staff will be overwhelmed in the near future	C.3	Yes, with more new reservoirs come into being.	
Enough staff available	C.4	-	

Process from observation to data storage is clear?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	Course of action is clear and specified	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.4	-	

Software, licenses are at hand and sufficient? Validation tools are in place?

Tools domain gaps	E	Remarks	
Tools are missing	E.1	Using the Beles scheme as example, a SCADA system does not cover the hydromet	

		functionality needed. Data recorded in the SCADA must be backed by hydro-meteorological tools.	
Tools are duplicate and yield diverse results	E.2	-	
Tools are inefficient	E.3	-	
Tools lack functionality	E.4	A SCADA system must ensure operation and thus is understandably isolated for safety reasons. It does not allow for hydro-meteorological evaluations, import and export.	
Tools are likely to be insufficient in the near future	E.5	This concerns both each dam site and the central data storage as more functionality and distributed access will be needed.	
Tools are in place with sufficient functions	E.6	-	

Financial resources are allocated?

Financial domain gaps	F	Remarks	
Resources seem insufficient	F.1	unknown	
Origin of resources is unclear or not established	F.2	unknown	
Relationship between beneficiaries and source of funding seems unclear or	F.3	Data monitored at dam sites are not only useful for operating a dam. They should be integrated in the IWRM monitoring concept and thus obtain more beneficiaries.	
Lack of financial resources is likely to occur in the near future	F.4	New dams will require more financial resources.	
Financial resources are sufficient	F.5	-	

Computer equipment, internet connections, etc. established?

Facility domain gaps	G	Remarks	
Lack of buildings	G.1	-	
Lack of office space	G.2	-	
Lack of computer and IT equipment	G.3	-	
Gap in technical communication facility like Internet, transmission lines,	G.4	Upload and download rates as well as response times need to be enhanced so as to cope with mass data.	
No gaps of buildings, office space, equipment	G.5	No lack of buildings, office space and equipment.	

1.1.2.3 Data access

Process of retrieving data is established and easy?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	Currently, EPP is in charge of enabling data access. The problem is that data access and retrieval is seemingly an exception. As requesting data is restricted to provide information for decision-making prior to each hydrological season, specifications for data	

		dissemination for a wider range of clients are not yet developed.	
Roles and responsibilities are overlapping	A.2	-	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	-	

Staff is available to maintain data access and keep data updated?

People domain gaps	C	Remarks	
Understaffed	C.1	Once the process of retrieving data is settled, it becomes clear if more personnel is required	
Training gaps	C.2	Training is required if new technologies like GIS servers with web-based GUI are applied.	
Staff will be overwhelmed in the near future	C.3	Very likely as more data need to be processed.	
Enough staff available	C.4	-	

Process to retrieve data is established and publicised?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	-	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	Process of data dissemination is not yet fully developed. Homepages which offer data access are empty or result in problem loading page messages (see Hydromanager or data portals at http://www.mowr.gov.et)	
Course of action is clear	D.5		

Are data retrieval technically feasible? Large data volumes are retrievable?

Tools domain gaps	E	Remarks	
Tools are missing	E.1	Ideally, data are accessible by, e.g. GIS web-based solutions offering clear, intuitive and effective solutions. Using such technology assumes sufficient up- and download rates.	
Tools are duplicate and yield diverse results	E.2	-	
Tools are inefficient	E.3	-	
Tools lack functionality	E.4	-	
Tools are likely to be insufficient in the near future	E.5	-	
Tools are in place with sufficient functions	E.6	-	

Financial resources are allocated?

Financial domain gaps	F	Remarks	
Resources seem insufficient	F.1	-	
Origin of resources is unclear or not established	F.2	-	

Relationship between beneficiaries and source of funding seems unclear or	F.3	-	
Lack of financial resources is likely to occur in the near future	F.4	Maintaining large time series, cross-checking values for outliers and data gaps requires a constant support. This will become more and more important while more dams come into being.	
Financial resources are sufficient	F.5	-	

Computer equipment, internet connections, etc. established? Upload and download rates sufficient?

Facility domain gaps	G	Remarks	
Lack of buildings	G.1	-	
Lack of office space	G.2	-	
Lack of computer and IT equipment	G.3	-	
Gap in technical communication facility like Internet, transmission lines,	G.4	The most important gap is expected concerning fast and stable internet connections.	
No gaps of buildings, office space, equipment	G.5	No lack of buildings, office space and equipment.	

Range of data is sufficient?

Information domain gaps	I	Remarks	
Data not sufficient	I.1	Hydro-meteorological data, water levels and discharge is considered as most important. Reservoirs should be regarded as focal points of monitoring contributing to the national data monitoring programme. Restricting monitoring to purely control the main priority of a dam is too narrow. Apart from that, water quality will become an issue.	
Data not located where needed	I.2	See I.1	
Not the data that is needed	I.3	In view of river basin management, a wider scope of monitoring should be incorporated at dam sites.	
Data not available when needed	I.4	-	
Data not created	I.5	-	
Data not consumed	I.6	Data from reservoir monitoring are stored but dissemination and re-evaluation seems not be fully developed.	
Data relationship gaps	I.7	Operation and control of operation can only be facilitated if cross-checks are possible with the data observed.	
No data gaps	I.8	-	

1.1.3 Approval of operation rules

1.1.3.1 Scoping

Scoping is established by law?

Legislation domain gaps	B	Remarks	

Regulations are not in place	B.1	Scoping is carried out as integrative part of EIA but not in preparation for reservoir operation.	
Regulations unspecified	B.2	-	
Regulations too limited in scope	B.3	-	
Regulations in place but not applied	B.4	-	
Regulations in place and applied	B.5	-	

Is the way how to conduct scoping established?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	Approval of operation is not considered as an independent process. It is closely linked with the approval of commissioning a dam.	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.5	-	

Content of scoping is clear, templates and manuals are at hand?

Tools domain gaps	E	Remarks	
Tools are missing	E.1	International standards for EIA are applied if international development banks are involved. This is, however, independent from operation rules. No special scoping tools are considered for reservoir operation.	
Tools are duplicate and yield diverse results	E.2	-	
Tools are inefficient	E.3	-	
Tools lack functionality	E.4	-	
Tools are likely to be insufficient in the near future	E.5	The performance of a multi-reservoir system, which will be in place in the near future, will strongly depend on a clear and comprehensive understanding of all impacts and their mutual dependencies.	3
Tools are in place with sufficient functions	E.6	-	

Are information needed for scoping available?

Information domain gaps	I	Remarks	
Data not sufficient	I.1	By judging the Water Resources Atlas issued by NBI, important data are available.	
Data not located where needed	I.2	-	
Not the data that is needed	I.3	See I.5	
Data not available when needed	I.4	See I.5	
Data not created	I.5	By judging the Water Resources Atlas issued by NBI, data are available but not readily at hand. Effort is needed to create concise and homogeneous formats. Data should undergo a post-processing to make it easily available for further evaluation.	

Data not consumed	I.6	At present, there is no demand expressed to use them.	
Data relationship gaps	I.7	The importance of cross-sectoral information for reservoir operation is not fully recognised.	
No data gaps	I.8	-	

1.1.3.2 Regulatory documents and rules

Who is in charge of preparing and ratifying normative documents?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	Regulatory documents with regard to operation rules are not in place. The MoWIE would be in the best position to assume responsibility.	
Roles and responsibilities are overlapping	A.2	-	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	-	

Are regulations established by law?

Legislation domain gaps	B	Remarks	
Regulations are not in place	B.1	It is not stipulated to have regulatory documents concerning reservoir operation in place.	
Regulations unspecified	B.2	-	
Regulations too limited in scope	B.3	-	
Regulations in place but not applied	B.4	-	
Regulations in place and applied	B.5	-	

Process of preparing regulations is in place?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	Unspecified. MoWIE is in the best position to organise actions accordingly.	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.5	-	

1.1.3.3 Separation between operation and supervision

Are the roles for operator and supervisor clear?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	-	
Roles and responsibilities are overlapping	A.2	Operation is determined, supervision is vacant.	
Roles and responsibilities unclear	A.3	No separation is established. The role of a supervisor is open.	

Roles and responsibilities are clear	A.4	-	

Is the separation established by law?

Legislation domain gaps	B	Remarks	
Regulations are not in place	B.1	No regulations are in place.	
Regulations unspecified	B.2	-	
Regulations too limited in scope	B.3	-	
Regulations in place but not applied	B.4	-	
Regulations in place and applied	B.5	-	

1.1.3.4 Level of validation

Who does what?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	Unspecified	
Roles and responsibilities are overlapping	A.2	-	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	-	

Are different levels of validation established by law?

Legislation domain gaps	B	Remarks	
Regulations are not in place	B.1	No regulations are in place.	
Regulations unspecified	B.2	-	
Regulations too limited in scope	B.3	-	
Regulations in place but not applied	B.4	-	
Regulations in place and applied	B.5	-	

Process for validation is clear?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	Unspecified	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.5	-	

1.1.3.5 Cross-sectoral involvement

Are different sectors involved?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	Not institutionalised. Only EIA employs cross-sectoral involvement. Reservoir operation is specified by demands expressed by beneficiaries. There is possibly no official way	

		for indirectly affected sectors to formally express their concerns.	
Roles and responsibilities are overlapping	A.2	Different ministries (mining, health, livestock & fishery, agriculture) have overlaps in their responsibility addressing water affairs.	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	-	

Cross-sectoral involvement established by law (apart from initial EIA)?

Legislation domain gaps	B	Remarks	
Regulations are not in place	B.1	No regulations are in place.	
Regulations unspecified	B.2	-	
Regulations too limited in scope	B.3	-	
Regulations in place but not applied	B.4	-	
Regulations in place and applied	B.5	-	

Is the involvement of different authorities institutionalised?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	Unspecified	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.5	-	

1.1.3.6 Public consultation

Organisation of public involvement is tasked?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	Unspecified	
Roles and responsibilities are overlapping	A.2	-	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	-	

Is involvement of the public determined by law?

Legislation domain gaps	B	Remarks	
Regulations are not in place	B.1	Not in the sense of reservoir operation, only during the planning stage.	
Regulations unspecified	B.2	-	
Regulations too limited in scope	B.3	-	
Regulations in place but not applied	B.4	-	
Regulations in place and applied	B.5	-	

Is the public involvement institutionalised?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	Unspecified	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.5	-	

1.1.4 Review of operation rules

1.1.4.1 Periodical review

Who supervises and triggers the process?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	Seasonal reviews are specified to cope with current conditions. But periodical reviews of reservoir operation are not set out.	
Roles and responsibilities are overlapping	A.2	-	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	-	

Is the review process clear?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	Unspecified. Only in terms of seasonal adaptions.	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.5	-	

Is sufficient information available to conduct a review?

Information domain gaps	I	Remarks	
Data not sufficient	I.1	-	
Data not located where needed	I.2	-	
Not the data that is needed	I.3	-	
Data not available when needed	I.4	-	
Data not created	I.5	-	
Data not consumed	I.6	Reservoir performance is not periodically documented.	
Data relationship gaps	I.7	-	
No data gaps	I.8	-	

1.1.5 Evaluation of operation rules

1.1.5.1 Development of causal-chains

Who carries out and is involved?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	Unspecified	
Roles and responsibilities are overlapping	A.2	-	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	-	

Is there an adequate number of staff available? Is the knowledge about causal-chains given?

People domain gaps	C	Remarks	
Understaffed	C.1	No	
Training gaps	C.2	Training is necessary as causal-chains development needs special attention.	
Staff will be overwhelmed in the near future	C.3	The more dams are in operation the more cause-effects relationships exist which can easily cause staff to be overwhelmed.	
Enough staff available	C.4	-	

Are causal-chains clear and who needs to be involved?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	Unspecified. Causal-chains are not yet developed, neither qualitatively nor quantitatively.	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.5	-	

Financial resources are allocated?

Financial domain gaps	F	Remarks	
Resources seem insufficient	F.1	-	
Origin of resources is unclear or not established	F.2	-	
Relationship between beneficiaries and source of funding seems unclear	F.3	As it should be in the interest of reservoir operators to quantify all impacts of dams and to know direct and indirect effects, clear links need to be established.	
Lack of financial resources is likely to occur in the near future	F.4	-	
Financial resources are sufficient	F.5	-	

Is sufficient information available to qualify and quantify causal-chains?

Information domain gaps	I	Remarks	
Data not sufficient	I.1	Not all information will be readily at hand. The Water Resources Atlas from NBI will serve as a very good starting point.	
Data not located where needed	I.2	-	

Not the data that is needed	I.3	It is to be expected that not all cause-effect relationships can be backed with observed records.	
Data not available when needed	I.4	-	
Data not created	I.5	Data might be observed but not transferred into relationships or correlations.	
Data not consumed	I.6	-	
Data relationship gaps	I.7	Data might be observed but the need to relate it to other data was not yet recognised.	
No data gaps	I.8	-	

1.1.5.2 *Detailed assessment*

Who carries out and is involved?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	No roles are specified which fully address detailed assessments. A first evaluation of operation rules is carried out during then planning stage of dams.	
Roles and responsibilities are overlapping	A.2	-	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	-	

Is there an adequate number of staff available? Is the knowledge about detailed assessments given?

People domain gaps	C	Remarks	
Understaffed	C.1	Detailed assessment is not fully covered and staff is not assigned.	
Training gaps	C.2	Training will be required as it is a new task.	
Staff will be overwhelmed in the near future	C.3	Assuming detailed assessment will be introduced, staff will be overwhelmed.	
Enough staff available	C.4	-	

Is the scope of detailed assessment clear and who needs to be involved?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	Unspecified	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.5	-	

Models for detailed assessment are at hand?

Tools domain gaps	E	Remarks	
Tools are missing	E.1	Causal-chains and detailed assessment are closely linked. Tools combining both are not at hand.	
Tools are duplicate and yield diverse results	E.2	There is the potential that existing tools yield	

		contradicting results depending on the spatial and temporal resolution of the assessment.	
Tools are inefficient	E.3	The necessity to apply more sophisticated tools with increasing number of dam sites becomes more and more evident.	
Tools lack functionality	E.4	See E.1	
Tools are likely to be insufficient in the near future	E.5	See E.3	
Tools are in place with sufficient functions	E.6	-	

Is sufficient information available to qualify and quantify detailed assessments?

Information domain gaps	I	Remarks	
Data not sufficient	I.1	Not all information will be readily at hand. The Water Resources Atlas from NBI will serve as a very good starting point.	
Data not located where needed	I.2	-	
Not the data that is needed	I.3	Most of the hydrological data required are available even though they are not instantly ready to use.	
Data not available when needed	I.4	-	
Data not created	I.5	-	
Data not consumed	I.6	-	
Data relationship gaps	I.7	No gaps in terms of hydrology but with regard to causal-chains.	
No data gaps	I.8	-	

1.1.5.3 Operation rules and operation manual

Guidelines and templates for operation manuals are in existence?

Tools domain gaps	E	Remarks	
Tools are missing	E.1	No manual is at hand	
Tools are duplicate and yield diverse results	E.2	-	
Tools are inefficient	E.3	-	
Tools lack functionality	E.4	-	
Tools are likely to be insufficient in the near future	E.5	-	
Tools are in place with sufficient functions	E.6	-	

1.2 Gap analysis Sudan

1.2.1 Institutional settings

1.2.1.1 Separation between operation and supervision

Are separated roles for operation and supervision clear?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	Roles are specified but not in the sense of separation.	
Roles and responsibilities are overlapping	A.2	Two authorities have the mandate for both.	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	-	

Is separation established by law?

Legislation domain gaps	B	Remarks	
Regulations are not in place	B.1	No regulation addresses or stipulates separation.	
Regulations unspecified	B.2	-	
Regulations too limited in scope	B.3	-	
Regulations in place but not applied	B.4	-	
Regulations in place and applied	B.5	-	

1.2.1.2 IWRM principles

Are IWRM principles anchored in structures and mandates?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	Roles are specified and some structures show signs of IWRM principles.	
Roles and responsibilities are overlapping	A.2	Overlaps might exist between different ministries.	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	-	

Are IWRM principles established by law?

Legislation domain gaps	B	Remarks	
Regulations are not in place	B.1	Fragments of IWRM are established but not with the clear goal of implementing IWRM.	
Regulations unspecified	B.2	-	
Regulations too limited in scope	B.3	The parallelism of Dam Implementation Unit (hydropower) and the Dam Directorate (multi-purpose) gives way to create overlaps and is not conform to IWRM and basin approaches.	
Regulations in place but not applied	B.4	Interaction and consultation mechanisms are not fully established	
Regulations in place and applied	B.5	-	

Are IWRM principles known and training established?

People domain gaps	C	Remarks	
Understaffed	C.1	-	
Training gaps	C.2	The concept of IWRM is not yet anchored and would require training.	
Staff will be overwhelmed in the near future	C.3	In general, the current structure seems appropriate to tackle IWRM even with the need to streamline the existing parallelism.	
Enough staff available	C.4	At present, staff could cope with IWRM components if IWRM was implemented.	

Financial resources for IWRM are clear?

Financial domain gaps	F	Remarks	
Resources seem insufficient	F.1	The importance of a water resources management is recognised and rooted within the ministry. Resources could be allocated but require close collaboration with other sectors.	
Origin of resources is unclear or not established	F.2	Funding mechanisms for IWRM need to widen the view into other sectors.	
Relationship between beneficiaries and source of funding seems unclear or	F.3	The framework of IWRM cuts across different sectors with the whole range of beneficiaries, water tariffs, ecosystem services payments are not yet introduced.	
Lack of financial resources is likely to occur in the near future	F.4	See F.1	
Financial resources are sufficient	F.5	-	

1.2.1.3 Dam operator's qualification

Required qualification is specified by law?

Legislation domain gaps	B	Remarks	
Regulations are not in place	B.1	Qualifications for dam operators are not defined by regulations.	
Regulations unspecified	B.2	-	
Regulations too limited in scope	B.3	-	
Regulations in place but not applied	B.4	-	
Regulations in place and applied	B.5	-	

Enhancement of qualification required?

People domain gaps	C	Remarks	
Understaffed	C.1	From the viewpoint of integrating dam operation in IWRM encompassing dam safety, operation, monitoring and maintenance, more staff is needed.	
Training gaps	C.2	Awareness of monitoring and data exists but needs to be widened towards river basin management. This requires training.	
Staff will be overwhelmed in the near future	C.3	River basin management will very likely lead to gaps with current personnel.	
Enough staff available	C.4	-	

Process for training is established?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	Training is not institutionalised and formalised.	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.5	-	

Financial resources are allocated?

Financial domain gaps	F	Remarks	
Resources seem insufficient	F.1	Regular training courses are not yet developed. Financial resources must be allocated to ensure dam operator's qualification.	
Origin of resources is unclear or not established	F.2	-	
Relationship between beneficiaries and source of funding seems unclear or	F.3	-	
Lack of financial resources is likely to occur in the near future	F.4	-	
Financial resources are sufficient	F.5	-	

1.2.1.4 Capacity building

Who carries responsibility for training, curricula? Are capacity in the country available to qualify people?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	-	
Roles and responsibilities are overlapping	A.2	-	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	Qualified research organisations are available.	

Are enough trainers available? Is training for trainers required?

People domain gaps	C	Remarks	
Understaffed	C.1	-	
Training gaps	C.2	On the subject of coordinated reservoir operation, it seems as if existing knowledge is not fully utilised by operators.	
Staff will be overwhelmed in the near future	C.3	-	
Enough staff available	C.4	Research organisations have staff to conduct training. Existing experience should be adequate to encompass training needed for coordinated reservoir operation.	

Process for performing capacity building is established?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	Capacity building is not institutionalised, that is, no measures for regular capacity building for operators and authorities are established.	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.5	-	

Model, licenses, working places are at hand and sufficient?

Tools domain gaps	E	Remarks	
Tools are missing	E.1	Diverse model packages are available most of which are free and/or open source. But, for instance, tools for cause-effect relationships and real-time reservoir operation are not yet available.	
Tools are duplicate and yield diverse results	E.2	Awareness of problems related to the application of diverse tools exists	
Tools are inefficient	E.3	Tools are inefficient as long as the whole range of sectors affected by reservoir operation is concerned.	
Tools lack functionality	E.4	There is a lack of functionality, as long as reservoir operation in an integrative sense of cross-sector involvement is concerned.	
Tools are likely to be insufficient in the near future	E.5	Gaps are more likely in the future when demands increase requesting higher performance of reservoir, in particular, with regard to upstream-, downstream relationships.	
Tools are in place with sufficient functions	E.6	-	

Financial resources are allocated?

Financial domain gaps	F	Remarks	
Resources seem insufficient	F.1	If training is institutionalised and made mandatory, organisations will need more support to conduct regular courses and to keep themselves abreast of latest developments.	
Origin of resources is unclear or not established	F.2	-	
Relationship between beneficiaries and source of funding seems unclear	F.3	-	
Lack of financial resources is likely to occur in the near future	F.4	Gaps are likely to occur if periodical training for reservoir operators will be stipulated.	
Financial resources are sufficient	F.5	-	

Institutions are in place with sufficient technical equipment?

Facility domain gaps	G	Remarks	
Lack of buildings	G.1	-	
Lack of office space	G.2	-	
Lack of computer and IT equipment	G.3	Gaps are in place, if data management and data quality assurance in operational mode will be entrusted to research organisations.	
Gap in technical communication facility like Internet, transmission lines,	G.4	Mass data require IT assessments.	
No gaps of buildings, office space, equipment	G.5	No lack of buildings and office space.	

Data are available and accessible to conduct qualified and practically oriented training?

Information domain gaps	I	Remarks	
Data not sufficient	I.1	-	
Data not located where needed	I.2	Data access must be open to those in charge of capacity building. Given the technology used, this is not considered as a major gap.	
Not the data that is needed	I.3	Hydro-meteorological data are available but information about demands, withdrawals etc., if any, are kept in diverse technical environments difficult to compile.	
Data not available when needed	I.4	The effort to acquire latest and homogeneous data obstructs must be streamlined.	
Data not created	I.5	-	
Data not consumed	I.6	-	
Data relationship gaps	I.7	-	
No data gaps	I.8	If all existing data are available, no gaps are indicated.	

1.2.2 Monitoring

1.2.2.1 Readings

Performing readings is anchored in structures and mandates?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	-	
Roles and responsibilities are overlapping	A.2	Observation carried out by Egypt's hydromet units overlap measurements performed by hydromet units from The Sudan.	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	Roles at each dam site are clear.	

Performing readings is established by law?

Legislation domain gaps	B	Remarks	
Regulations are not in place	B.1	It is unclear if concise regulations are in existence describing the scope of monitoring at dam sites. Taking dam safety as an example, it is likely that no regulations define monitoring are existent.	

Regulations unspecified	B.2	-	
Regulations too limited in scope	B.3	-	
Regulations in place but not applied	B.4	-	
Regulations in place and applied	B.5	-	

Staff is available to perform readings sufficiently?

People domain gaps	C	Remarks	
Understaffed	C.1	-	
Training gaps	C.2	-	
Staff will be overwhelmed in the near future	C.3	-	
Enough staff available	C.4	Monitoring is conducted and observation units work on the ground and report to dam operators. The importance of monitoring is well known and practised. This indicates no gaps.	

Process for performing readings is established?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	-	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.5	The procedures for readings are clear.	

Software, licenses are at hand and sufficient? Validation tools are in place?

Tools domain gaps	E	Remarks	
Tools are missing	E.1	-	
Tools are duplicate and yield diverse results	E.2	-	
Tools are inefficient	E.3	-	
Tools lack functionality	E.4	-	
Tools are likely to be insufficient in the near future	E.5	With water quality and sediment in mind, gaps will occur.	
Tools are in place with sufficient functions	E.6	Tools to perform readings are established.	

Financial resources are allocated?

Financial domain gaps	F	Remarks	
Resources seem insufficient	F.1	High quality monitoring requires considerable financial resources. Gaps are expected with water quality and sediment monitoring.	
Origin of resources is unclear or not established	F.2	-	
Relationship between beneficiaries and source of funding seems unclear or	F.3	-	
Lack of financial resources is likely to occur	F.4	A gap will occur if monitoring will be extended	

in the near future		to fully meet IWRM principles. See F.1	
Financial resources are sufficient	F.5	-	

Devices and measurement equipment are at hand?

Facility domain gaps	G	Remarks	
Lack of buildings	G.1	-	
Lack of office space	G.2	-	
Lack of computer and IT equipment	G.3	-	
Gap in technical communication facility like Internet, transmission lines,	G.4	-	
No gaps of buildings, office space, equipment	G.5	All technical prerequisites seem to be in place. No gaps identified.	

Locations are sufficient? Observed values are sufficient?

Monitoring and measurement domain gaps	H	Remarks	
Measurements not sufficient	H.1	-	
Measurements not located where needed	H.2	Abstractions, taking place along a river outside reservoirs, should be integrated into the monitoring network of the MWIE to improve reservoir operation assessments.	
Not the measurements that is needed	H.3	-	
Measurements not available when needed	H.4	Apparently, data access is efficiently organised within MWIE. A gap exists concerning data services for other sectors.	
Measurements available, spatially and temporally	H.5	Scope of monitoring is apparently sufficient.	

1.2.2.2 Data storage

Who is in charge of data storage?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	-	
Roles and responsibilities are overlapping	A.2	-	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	MWIE takes care with three units (Nile Waters Directorate, Dam Directorate, Dam Implementation Unit), although three units may lead to redundant and inhomogeneous data.	

Data storage is made obligatory by law?

Legislation domain gaps	B	Remarks	
Regulations are not in place	B.1	It is assumed that this is not stipulated.	
Regulations unspecified	B.2	-	
Regulations too limited in scope	B.3	-	
Regulations in place but not applied	B.4	-	

Regulations in place and applied	B.5	-	

Staff is available to conduct data storage sufficiently?

People domain gaps	C	Remarks	
Understaffed	C.1	-	
Training gaps	C.2	Training about managing hydro-meteorological mass data would enhance the service already in place, in particular with multi-user access and sophisticated evaluations by different parties.	
Staff will be overwhelmed in the near future	C.3	-	
Enough staff available	C.4	-	

Process from observation to data storage is clear?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	-	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.5	The procedures for data storage are clear.	

Software, licenses are at hand and sufficient? Validation tools are in place?

Tools domain gaps	E	Remarks	
Tools are missing	E.1	Data storage at dam sites could be improved to enable operation engineers and dam manager to conduct quick and efficient assessments. Internet access and data platforms are already in place.	
Tools are duplicate and yield diverse results	E.2	-	
Tools are inefficient	E.3	-	
Tools lack functionality	E.4	-	
Tools are likely to be insufficient in the near future	E.5	New dam sites and new gauging stations can be integrated in the existing data management structure.	
Tools are in place with sufficient functions	E.6	-	

Financial resources are allocated?

Financial domain gaps	F	Remarks	
Resources seem insufficient	F.1	unknown	
Origin of resources is unclear or not established	F.2	unknown	
Relationship between beneficiaries and source of funding seems unclear or	F.3	Hydropower generation is relatively new compared to dams for irrigation. The direct money-generating mechanism of hydropower apparently outstrips benefits from irrigation.	

		To avoid misinterpretation, beneficiaries, direct and indirect, should be taken into account to evaluate funding mechanisms.	
Lack of financial resources is likely to occur in the near future	F.4	See F.3	
Financial resources are sufficient	F.5	-	

Computer equipment, internet connections, etc. established?

Facility domain gaps	G	Remarks	
Lack of buildings	G.1	-	
Lack of office space	G.2	-	
Lack of computer and IT equipment	G.3	-	
Gap in technical communication facility like Internet, transmission lines,	G.4	-	
No gaps of buildings, office space, equipment	G.5	All technical prerequisites seem to be in place. No gaps identified.	

1.2.2.3 Data access

Process of retrieving data is established and easy?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	-	
Roles and responsibilities are overlapping	A.2	-	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	The responsibility of disseminating data rests on the head office of MWIE in Khartoum.	

Staff is available to maintain data access and keep data updated?

People domain gaps	C	Remarks	
Understaffed	C.1	unknown	
Training gaps	C.2	Internet technology is already in use for data access, e.g. websites for gauging station and dam sites. Further development can be covered without training.	
Staff will be overwhelmed in the near future	C.3	-	
Enough staff available	C.4	-	

Process to retrieve data is established and publicised?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	-	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.5	Data access via internet can be made open to a wider range of clients with login procedures and user accounts. As this builds on existing	

		applications, it is not considered as a gap.	

Are data retrieval technically feasible? Large data volumes are retrievable?

Tools domain gaps	E	Remarks	
Tools are missing	E.1	-	
Tools are duplicate and yield diverse results	E.2	-	
Tools are inefficient	E.3	-	
Tools lack functionality	E.4	-	
Tools are likely to be insufficient in the near future	E.5	-	
Tools are in place with sufficient functions	E.6	No gap identified	

Financial resources are allocated?

Financial domain gaps	F	Remarks	
Resources seem insufficient	F.1	In view of maintenance of monitoring equipment, funding should be enhanced to embark on water quality and sediment observation. Data processing, however, applies appropriate technology and has reached a sophisticated level.	
Origin of resources is unclear or not established	F.2	-	
Relationship between beneficiaries and source of funding seems unclear or	F.3	-	
Lack of financial resources is likely to occur in the near future	F.4	See F.1	
Financial resources are sufficient	F.5	-	

Computer equipment, internet connections, etc. established? Upload and download rates sufficient?

Facility domain gaps	G	Remarks	
Lack of buildings	G.1	-	
Lack of office space	G.2	-	
Lack of computer and IT equipment	G.3	-	
Gap in technical communication facility like Internet, transmission lines,	G.4	-	
No gaps of buildings, office space, equipment	G.5	All technical prerequisites seem to be in place. No gaps identified.	

Range of data is sufficient?

Information domain gaps	I	Remarks	
Data not sufficient	I.1	Observations of water quantity related parameter is established while water quality will become a challenge in the future.	
Data not located where needed	I.2	See I.1	
Not the data that is needed	I.3	See I.1	

Data not available when needed	I.4	-	
Data not created	I.5	-	
Data not consumed	I.6	Data from reservoir monitoring are stored but dissemination and re-evaluation seems not be fully developed.	
Data relationship gaps	I.7	Gaps exist regarding water quality and possibly sediment observations.	
No data gaps	I.8	-	

1.2.3 Approval of operation rules

1.2.3.1 Scoping

Scoping is established by law?

Legislation domain gaps	B	Remarks	
Regulations are not in place	B.1	Scoping is carried out as integrative part of EIA but not in preparation for reservoir operation.	
Regulations unspecified	B.2	-	
Regulations too limited in scope	B.3	-	
Regulations in place but not applied	B.4	-	
Regulations in place and applied	B.5	-	

Is the way how to conduct scoping established?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	Approval of operation is not considered as an independent process. It is closely linked with the approval of commissioning a dam.	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.5	-	

Content of scoping is clear, templates and manuals are at hand?

Tools domain gaps	E	Remarks	
Tools are missing	E.1	Yes. International standards for EIA are applied if international development banks are involved. This is, however, independent from operation rules. No special scoping tools are considered for reservoir operation. Impacts on various sector are not formalised or supported by manuals, tools, guidelines.	
Tools are duplicate and yield diverse results	E.2	-	
Tools are inefficient	E.3	-	
Tools lack functionality	E.4	-	
Tools are likely to be insufficient in the near future	E.5	See E.1	
Tools are in place with sufficient functions	E.6	-	

Are information needed for scoping available?

Information domain gaps	I	Remarks	
Data not sufficient	I.1	See I.5	
Data not located where needed	I.2	-	
Not the data that is needed	I.3	See I.5	
Data not available when needed	I.4	See I.5	
Data not created	I.5	By judging the Water Resources Atlas issued by NBI, data are available in principle but not readily at hand. Effort is needed to create concise and homogeneous formats. Data should undergo a post-processing to make it easily available for further evaluation.	
Data not consumed	I.6	At present, there is no demand expressed to use them.	
Data relationship gaps	I.7	The importance of cross-sectoral information for reservoir operation is recognised but without adequate follow-up actions.	
No data gaps	I.8	-	

1.2.3.2 Regulatory documents and rules

Who is in charge of preparing and ratifying normative documents?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	Regulatory documents with regard to operation rules are not in place.	
Roles and responsibilities are overlapping	A.2	-	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	-	

Are regulations established by law?

Legislation domain gaps	B	Remarks	
Regulations are not in place	B.1	Regulatory documents concerning reservoir operation are not stipulated.	
Regulations unspecified	B.2	-	
Regulations too limited in scope	B.3	-	
Regulations in place but not applied	B.4	-	
Regulations in place and applied	B.5	-	

Process of preparing regulations is in place?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	Unspecified. MWIE would be in the best position to organise and launch actions accordingly.	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	

Course of action is clear	D.5	-	

1.2.3.3 Separation between operation and supervision

Are the roles for operator and supervisor clear?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	-	
Roles and responsibilities are overlapping	A.2	Operation is determined, supervision is vacant.	
Roles and responsibilities unclear	A.3	No separation is established. The role of a supervisor is open.	
Roles and responsibilities are clear	A.4	-	

Is the separation established by law?

Legislation domain gaps	B	Remarks	
Regulations are not in place	B.1	No regulations addresses separating operation and supervision.	
Regulations unspecified	B.2	-	
Regulations too limited in scope	B.3	-	
Regulations in place but not applied	B.4	-	
Regulations in place and applied	B.5	-	

1.2.3.4 Level of validation

Who does what?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	Unspecified	
Roles and responsibilities are overlapping	A.2	-	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	-	

Are different levels of validation established by law?

Legislation domain gaps	B	Remarks	
Regulations are not in place	B.1	Unspecified	
Regulations unspecified	B.2	-	
Regulations too limited in scope	B.3	-	
Regulations in place but not applied	B.4	-	
Regulations in place and applied	B.5	-	

Process for validation is clear?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	Unspecified	
Course of action is inhomogeneous	D.2	-	

Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.5	-	

1.2.3.5 Cross-sectoral involvement

Are different sectors involved?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	The Blue Nile Committee and the High Committee are organs allowing for involvement of different sectors. However, the range of involvement is restricted and does not comprise all sectors affected.	
Roles and responsibilities are overlapping	A.2	unknown	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	-	

Cross-sectoral involvement established by law (apart from initial EIA)?

Legislation domain gaps	B	Remarks	
Regulations are not in place	B.1	The constitution of the Committees are backed by regulations, but not the whole range of affected sectors contribute.	
Regulations unspecified	B.2	-	
Regulations too limited in scope	B.3	-	
Regulations in place but not applied	B.4	-	
Regulations in place and applied	B.5	-	

Is the involvement of different authorities institutionalised?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	A seat in the Committees assures involvement in the operation of dams. As stated above, not all who should be involved have a voice.	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.5	-	

1.2.3.6 Public consultation

Organisation of public involvement is tasked?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	Unspecified	
Roles and responsibilities are overlapping	A.2	-	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	-	

Is involvement of the public determined by law?

Legislation domain gaps	B	Remarks	
Regulations are not in place	B.1	Not in the sense of reservoir operation, only during the planning stage.	
Regulations unspecified	B.2	-	
Regulations too limited in scope	B.3	-	
Regulations in place but not applied	B.4	-	
Regulations in place and applied	B.5	-	

Is public involvement institutionalised?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	Unspecified	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.5	-	

1.2.4 Review of operation rules

1.2.4.1 Periodical review

Who supervises and triggers the process?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	Seasonal reviews are specified to cope with current conditions. But periodical reviews of reservoir operation are not implemented.	
Roles and responsibilities are overlapping	A.2	-	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	-	

Is the review process clear?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	Only in terms of seasonal adaptations. A review of operation rules is not foreseen. The operation manual at Roseires and Sennar, for example, dates back to the late 60's.	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.5	-	

Is sufficient information available to conduct a review?

Information domain gaps	I	Remarks	

Data not sufficient	I.1	-	
Data not located where needed	I.2	-	
Not the data that is needed	I.3	-	
Data not available when needed	I.4	-	
Data not created	I.5	-	
Data not consumed	I.6	Reservoir performance is not periodically documented.	
Data relationship gaps	I.7	-	
No data gaps	I.8	-	

1.2.5 Evaluation of operation rules

1.2.5.1 Development of causal-chains

Who carries out and is involved?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	Unspecified	
Roles and responsibilities are overlapping	A.2	-	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	-	

Is there an adequate number of staff available? Is the knowledge about causal-chains given?

People domain gaps	C	Remarks	
Understaffed	C.1	-	
Training gaps	C.2	Training is necessary as causal-chains development needs special attention.	
Staff will be overwhelmed in the near future	C.3	The more upstream/downstream relationships are in place the more cause-effects relationships exist. This will exceed the current capacity.	
Enough staff available	C.4	-	

Are causal-chains clear and who needs to be involved?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	Causal-chains are not yet at hand, neither qualitatively nor quantitatively.	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.5	-	

Financial resources are allocated?

Financial domain gaps	F	Remarks	
Resources seem insufficient	F.1	-	
Origin of resources is unclear or not	F.2	-	

established			
Relationship between beneficiaries and source of funding seems unclear	F.3	As it should be in the interest of reservoir operators to quantify all impacts of dams and to know direct and indirect effects, clear links need to be established.	
Lack of financial resources is likely to occur in the near future	F.4	-	
Financial resources are sufficient	F.5	-	

Is sufficient information available to qualify and quantify causal-chains?

Information domain gaps	I	Remarks	
Data not sufficient	I.1	Not all information will be readily at hand. The Water Resources Atlas from NBI will serve as a very good starting point.	
Data not located where needed	I.2	-	
Not the data that is needed	I.3	It is to be expected that not all cause-effect relationships can be backed with observed records.	
Data not available when needed	I.4	-	
Data not created	I.5	Data might be observed but not transferred into relationships or correlations.	
Data not consumed	I.6	-	
Data relationship gaps	I.7	Data might be observed but the need to relate it to other data was not yet recognised.	
No data gaps	I.8	-	

1.2.5.2 Detailed assessment

Who carries out and is involved?

Structural and mandate domain gaps	A	Remarks	
Roles and responsibilities unspecified	A.1	No roles are specified which fully address detailed assessments. A first evaluation of operation rules is carried out during then planning stage of dams.	
Roles and responsibilities are overlapping	A.2	-	
Roles and responsibilities unclear	A.3	-	
Roles and responsibilities are clear	A.4	-	

Is there an adequate number of staff available? Is the knowledge about detailed assessments given?

People domain gaps	C	Remarks	
Understaffed	C.1	Detailed assessment is not covered and staff is not assigned.	
Training gaps	C.2	Training will be required as it is a new task.	
Staff will be overwhelmed in the near future	C.3	Assuming detailed assessment will be introduced, the current capacity is not sufficient.	
Enough staff available	C.4	-	

Is the scope of detailed assessment clear and who needs to be involved?

Process domain gaps	D	Remarks	
Course of action is unspecified	D.1	Unspecified	
Course of action is inhomogeneous	D.2	-	
Course of action is overlapping	D.3	-	
Course of action is unclear	D.4	-	
Course of action is clear	D.5	-	

Models for detailed assessment are at hand?

Tools domain gaps	E	Remarks	
Tools are missing	E.1	Causal-chains and detailed assessment are closely linked. Tools combining both are not at hand.	
Tools are duplicate and yield diverse results	E.2	There is the potential that existing tools yield contradicting results depending on the spatial and temporal resolution of the assessment.	
Tools are inefficient	E.3	The necessity to apply more sophisticated tools with increasing number of dam sites becomes more and more evident.	
Tools lack functionality	E.4	See E.1	
Tools are likely to be insufficient in the near future	E.5	See E.3	
Tools are in place with sufficient functions	E.6	-	

Is sufficient information available to qualify and quantify detailed assessments?

Information domain gaps	I	Remarks	
Data not sufficient	I.1	Not all information will be readily at hand. The Water Resources Atlas from NBI will serve as a very good starting point.	
Data not located where needed	I.2	-	
Not the data that is needed	I.3	The hydrological data required are available. Whether quality assurance was carried out or not is unknown.	
Data not available when needed	I.4	-	
Data not created	I.5	-	
Data not consumed	I.6	-	
Data relationship gaps	I.7	No gaps in terms of hydrology but with regard to causal-chains.	
No data gaps	I.8	-	

1.2.5.3 Operation rules and operation manual

Guidelines and templates for operation manuals are in existence?

Tools domain gaps	E	Remarks	
Tools are missing	E.1	No manual is at hand	
Tools are duplicate and yield diverse results	E.2	-	

Tools are inefficient	E.3	-	
Tools lack functionality	E.4	-	
Tools are likely to be insufficient in the near future	E.5	-	
Tools are in place with sufficient functions	E.6	-	

1.3 Gap analysis for Egypt and South-Sudan

A gap analysis for Egypt and South-Sudan was conducted based on literature and thus not performed with the same depth given for Ethiopia and Sudan.