Updating and improving of existing hydrologic and hydraulic models and configuring a Flood Early Warnings System (FEWS) in Sudan

Inception Report
Project No Customer's ref.: CTCN 23-001

23-11-2023

Prepared for General Administration of Nile Water Affairs, Ministry of Irrigation and Water Resources, Sudan

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Prepared for:	General Administration of Nile Water Affairs, Ministry of Irrigation and Water Resources, Sudan
Represented by	Eng. A Saghayroon

Approved by

27-11-2023

X

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1 Introduction

Climate change has exacerbated Sudan's social and economic challenges with the increasing occurrence of floods and droughts due to the growing inter-annual variability of precipitation in the Nile basin. These effects can already be seen today and have a massive impact on the water-food-energy-nexus. Extreme events have led to widespread property loss, damage to irrigation facilities and water services, and the spread of waterborne diseases.

Many major cities of Sudan (e.g., Khartoum, Wad Madeni, Singa, Rabak, and Ad Damar) are located along the mainstream or tributaries of the Nile, and the combined population of these cities alone amounts to more than 10 million, many of which suffered severely from the flood disasters in the last decades.

During the recent flood in 2020 the Nile reached its highest water level in 100 years, by more than 60 centimetres, and inflicted devastating damage to Sudan. The flood began in mid-July and marked the country's worst event in 30 years. According to the National Council for Civil Defence in Sudan, at least 121 people died, 54 were wounded, more than 98,000 houses collapsed, and more than 97,000 agricultural acres and numerous livestock were lost. Moreover, many buildings and facilities were adversely affected.

The present technical assistance is the result of the technical assistance request submitted by the Nile Water Department, Ministry of Irrigation and Water Resources of Sudan to the United Nations Climate Technology Centre and Network (CTCN). The requested technical assistance focused on strengthening the capacities for flood and drought preparedness and early warning system in Sudan using operational and innovative models. In mutual discussions with the CTCN, the General Administration of Nile Water Affairs, Ministry of Irrigation and Water Resources 'Project proponent' and the Higher Council for Environment and Natural Resources, Climate Change Directorate 'National Designated Entity (NDE)', it was agreed to focus the scope of the technical assistance on flood early warning and preparedness. The initially requested technical assistance was subjected to a scope reduction shifting from a broad range of interventions (flash floods, drought, installation of telemetric monitoring stations, amongst other aspects) to the enhancement of an existing flood early warning system and corresponding modelling framework.

The proposed technical assistance will enhance the existing Flood Early Warning System (FEWS) setup by the Nile River basin regional entity the Eastern Nile Technical Regional Office (ENTRO) – comprising Egypt, Ethiopia, South Sudan, and Sudan – so that it is appropriate for Sudanese authorities' flood management operations in Sudanese national sub-basins.

The key outcome of this technical assistance will be Sudan being enabled to operate an innovative adaptation technology such as a FEWS to increase the resilience of communities, infrastructure, and economic sector investments in flood affected areas. The enhancements to the existing technology will include an early warning component that will allow better preparation and increased response capacity by authorities and communities for upcoming floods, minimizing losses and damages.

2 Objectives and Scope

2.1 Objective

The objective of the technical assistance is to strengthen the capacity of the staff of the General Administration of Nile Water Affairs, Ministry of Irrigation and Water Resources, enhance flood preparedness and early warning systems, and link the systems with stakeholders concerned and communities' inhabitants in flood-prone areas.

The objective will be achieved by:

- Expanding and enhancing the components of the current FEWS in Sudan for increased coverage, efficiency, and lead time in the Blue Nile, Setit-Atbara, Dinder and Rahad national sub-basins.
- Assessing potential and opportunities of the Eastern Nile Flood Early Warning System EN-FEWS of ENTRO available to Sudan - as well as its current protocols/procedures and institutional framework - to supplement the FEWS in Sudan;
- Training system operators and enhancing the capacities of key stakeholders of the FEWS to improve and benefit the country's disaster management framework.

2.2 Scope of Work

The scope of work under this technical assistance comprises three expected outputs to be achieved through three activities.

- Output 1: Assessment of the existing FEWS system protocols and identifying existing data gaps and needs.
    - Activity 1: Stakeholder consultation, assessment of available data and existing FEWS
- Output 2. Enhanced FEWS
    - Activity 2 – Enhancement of the FEWS
- Output 3. Strengthened capacity and sustainability for uptake and effective use of the upgraded FEWS
    - Activity 3 – Capacity building for use of the enhanced FEWS

2.2.1 Activity 1 – Stakeholder consultation, assessment of available data and existing FEWS

This activity will help establish understanding of the current system capabilities and increase understanding as to what extent the FEWS is able respond to the current country needs and where are the most pressing gaps. The findings will also incorporate stakeholder feedback on what aspects of the current system need upgrading to be able to perform adequately and provide the best possible decision support to respond to climate hazards.

Activity 1 includes the following activities:

- Activity 1.1 – Project initiation and kick-off meeting
- Activity 1.2 – Data collection and stakeholder consultation

- Activity 1.3 – Inception workshop
- Activity 1.4 – Review of the collected data
- Activity 1.5 – Model and FEWS review
- Activity 1.6 – Capacity needs assessment

2.2.2 Activity 2 – Enhancement of the FEWS

This activity will enable the uptake of the latest technologies and data and will also support expansion of the system coverage to include additional sub-basins currently not covered by FEWS. In this way, the enhanced FEWS will improve the capability of the decision makers and relevant national institutions to effectively and timely use the system for better flood early warning and response.

Activity 2 includes the following activities:

- Activity 2.1– Expansion and improvement of the FEWS components
- Activity 2.2– Review and improvement of the overall performance of the system
- Activity 2.3– Technical manual update

2.2.3 Activity 3 – Capacity building for use of the enhanced FEWS

This activity will strengthen the capacity for system use and maintenance. The results of this activity will contribute to long-term sustainability of the system, enabling more effective long-term and strategic use of the relevant technologies.

Activity 3 includes the following activities:

- Activity 3.1 – Production of training materials
- Activity 3.2 – Training of government bodies and stakeholders for use of the system
- Activity 3.3 – Stakeholder workshop for FEWS product end users
- Activity 3.4 – Preparation of the closure report

2.3 Deliverables

The list of deliverables is presented in the table below.

Table 2.1 Deliverables (including those of the inception phase)

ID	Deliverable	Type	Explanation and Remarks
1.1	Kick-off meeting	Workshop	Remote kick-off meeting and formally initiate the Technical Assistance (TA), establish staff relations and communication lines at required levels. Mapping of stakeholders.
1.3	Inception Workshop	Workshop	A multi-stakeholder workshop to understand the expectations, identify the needs, gaps, guidelines, and results and lessons learned from completed and ongoing projects to collect/generate and provide similar data/systems
1.3	Inception Report	Report	Documentation of the kick-off meeting and inception workshop
1.5	Enhanced FEWS design report	Report	Concise documentation of the enhancements and improvements made to the EN-FEWS
1.6	In person meeting	Meeting	A meeting in person will take place to inform the capacity needs assessment
1.6	Capacity needs assessment note	Report	Concise documentation of the needs assessment including identification of System operators, and assessment of their capacity to inform the training sessions required to enable the identified staff to operate the enhanced FEWS
2.1	Model calibration and validation report	Report	Report on the model calibration and validation with the historical time series collected, and implementation of a data assimilation procedure depending on real time data available.
2.2	Enhanced FEWS operationalized	System	The system performance review will focus on the model evaluation by comparison of historical observations and forecasts with simulated data series at various locations. Improvement of the system performance will depend highly on the quality of the available time series
2.3	Updated technical manual	Report	The existing technical manual will be updated in accordance with system alterations carried out.
3.1	Training materials	Materials	Materials for the online and face-to-face training sessions of system operators as well as for the stakeholder workshop for FEWS product end users.
3.2	In person training session and remote support	Workshop	The planned format is a face-to-face 5-day training session for a maximum of 12 participants on use of the forecasting system. Online ad-hoc assistance via email will be available for the duration of Activity 3
3.3	FEWS product end user workshop	Workshop	1-day workshop for a maximum of 25 participants

ID	Deliverable	Type	Explanation and Remarks
3.3	Capacity enhancement report	Report	Concise note describing the outcomes of the technical training and the end user workshop as well as participants feedback and evaluation
3.4	Technical assistance management documentation	Documentation	Technical assistance closure report as required by CTCN TA implementation guidelines
3.4	2-years of maintenance of the final system using DHI's infrastructure and transfer of the system	Maintenance	keeping the system online at DHI's infrastructure then installation of the system at proponent's premises, once the country has purchased and installed their own hardware and supporting IT infrastructure during that period.

3 Implementation Arrangement

The project will be implemented by CTCN Consortium Partner UNEP-DHI, hosted by DHI (here from in text: ‘DHI’).

3.1 The Consultant’s Team

The team members are as detailed in Table 3.1 and the organisation chart is shown in Figure 3.1.

Table 3.1 Project Team members

	Role	Personnel	Citizenship	Number of years of Experience	Location
Expert 1 (E1)	Project Manager (PM)	Mekuria Beyene	German	35	Denmark
Additional Expert 1 (AE1)	Deputy PM	Okechukwu Amogu	Nigerian / French	18	France
Additional Expert 2 (AE2)	Project advisor / Quality Supervisor	Maija Bertule	Latvian / Danish	13	Denmark
Expert 2 (E2)	Hydrologist & Flood Modelling Expert	Hans Christian Ammentorp	Danish	41	Denmark
Additional Expert 3 (AE3)	National Flood Modeller	TBD			Sudan
Expert 3 (E3)	Flood forecasting and Operational systems Expert	Jakob Luchner	German	10	Denmark
Expert 4 (E4)	Gender Expert	Hawa Dahab	Sudanese	16	Sudan

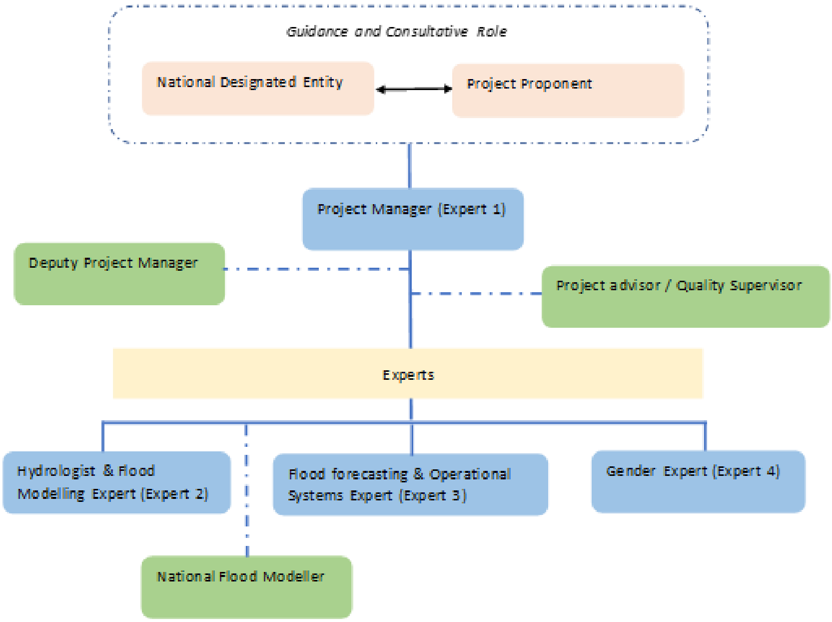


Figure 3.1 Proposed Organisational chart.
Note: boxes in blue mean experts are as per requirements in TA while the green boxes are additional experts considered required for the TA.

3.2 Inputs and Responsibilities

The distribution of technical roles and responsibilities among team members for each task is as follows (see Table 3.2).

Table 3.2: Inputs (i) and Responsibilities (R) of the consultant's project team members

Input and Responsibility per Output/Activity for Experts	Project Manager (PM)	Deputy PM	Project advisor / Quality Supervisor	Hydrologist & Flood Modelling Expert	National Flood Modeller	Flood forecasting and Operational systems	Gender Expert
Output / Activity & Expert ID	E1	AE1	AE2	E2	AE3	E3	E4
Output 1: Assessment of the existing FEWS system protocols and identifying existing data gaps and needs.							
Activity 1 Stakeholder consultation, assessment of available data and existing FEWS							
Activity 1.1 – Project initiation and kick-off meeting	R	i	i				
Activity 1.2 – Data collection and stakeholder consultation	R	i	i				
Activity 1.3 – Inception workshop	R	i	i				i
Activity 1.4 – Review of the collected data	R			i	i	i	
Activity 1.5 – Model and FEWS review	i			i		R	
Activity 1.6 – Capacity needs assessment	R			i		i	
Output 2. Enhanced FEWS							
Activity 2 – Enhancement of the FEWS							
Activity 2.1 – Expansion and improvement of the FEWS components	i			i		R	
Activity 2.2 – Review and improvement of the overall performance of the system	i			i		R	
Activity 2.3 – Technical manual update	R		i	i		i	
Output 3. Strengthened capacity and sustainability for uptake and effective use of the upgraded FEWS							
Activity 3 – Capacity building for use of the enhanced FEWS							
Activity 3.1 – Production of training materials	R	i	i				
Activity 3.2 – Training of government bodies and stakeholders for use of the system	R		i		i		i
Activity 3.3 – Stakeholder workshop for FEWS product end users	R	i					
Activity 3.4 – Preparation of the closure report	R	i	i				

R	Responsible
i	Input

4 Implementation Approach and Methodology

4.1 DSS Platform MIKE Workbench

DHI's DSS platform supports multiple-user interactions through tailor-made UIs for a variety of work duties by specialists, managers, and stakeholders.

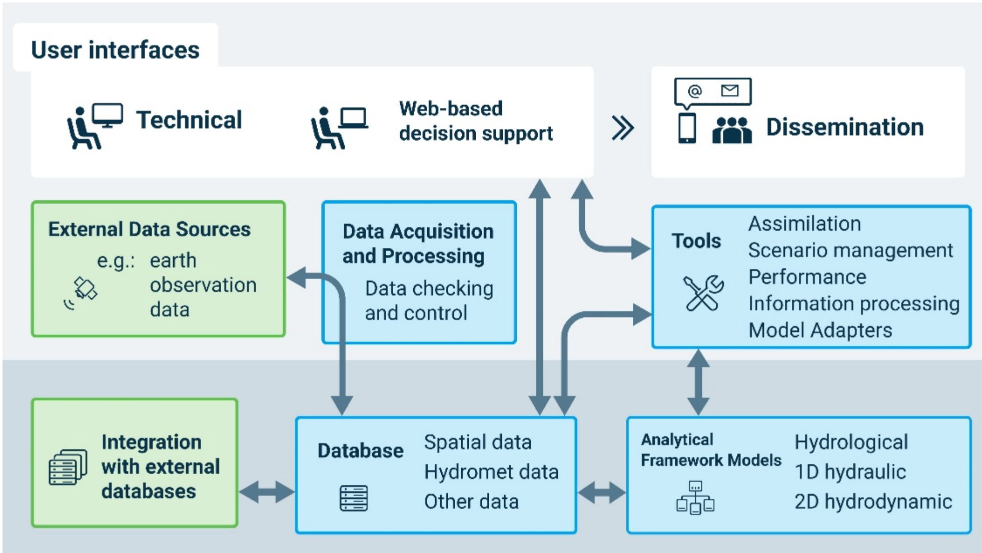


Figure 4.1 DHI's water resources oriented DSS architecture

This DSS platform has a modular web-based user interface including user management functionalities which can be customised to meet the needs of the client and stakeholders, and a workbench for advanced operational use and configuration. The web user interface is integrated with the underlying workbench that has a suite of tools and functionalities for data processing and technical analysis, which in turn are linked to an object-relational database management system (PostgreSQL). External data sources and other systems are linked through an integrated script manager (IronPython). The DSS platform can be customised to implement an all-in-one integrated system as shown in Figure 4.1.

DHI's MIKE Workbench software is the IT platform on which the EN-FEWS is built (see Figure 4.2).

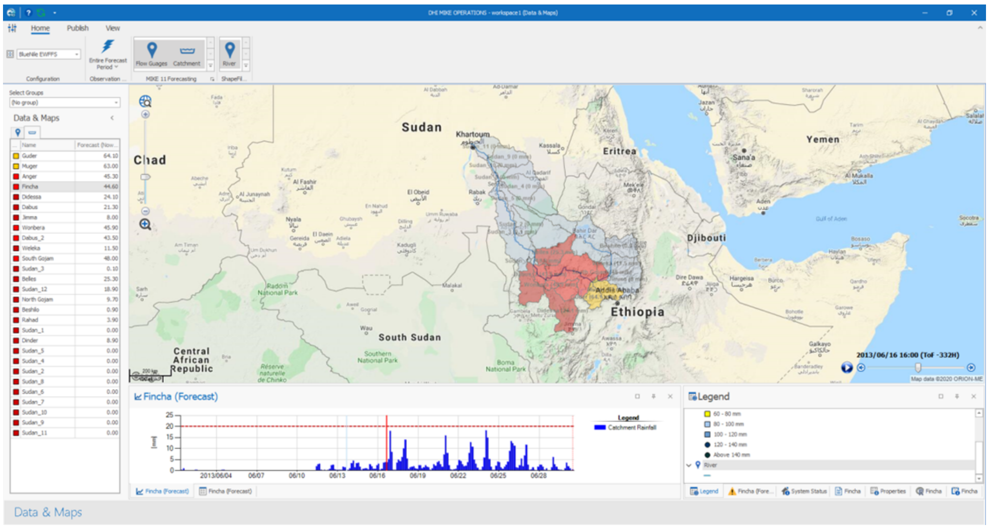


Figure 4.2 Screenshot of the current desktop user interface for the Blue Nile River basin FFEWS - built on MIKE Workbench.

Key Backend Features of the MIKE Workbench that are relevant for the EN-FEWS:

1. The following functionalities are built in this software framework - either as customisations or inherent tools that come along with the software products: (a) input data handler, (b) data import and extraction, (c) data correction and conversion, (d) handling uncertainties, (e) data archiving, (f) visualisation, (g) computation controller, (h) model linker, (i) dissemination and reporting, and (j) process log.

2. For forecasting purposes this software framework can be customised. Workflows can be defined and automated in a well-defined manner to trigger the following: (1) input data handler, (2) data input and extraction, (3) data correction, (4) model runs via model adapters, (5) data quality control, (6) generation and dissemination of logs, as well as (7) dissemination of forecasts.

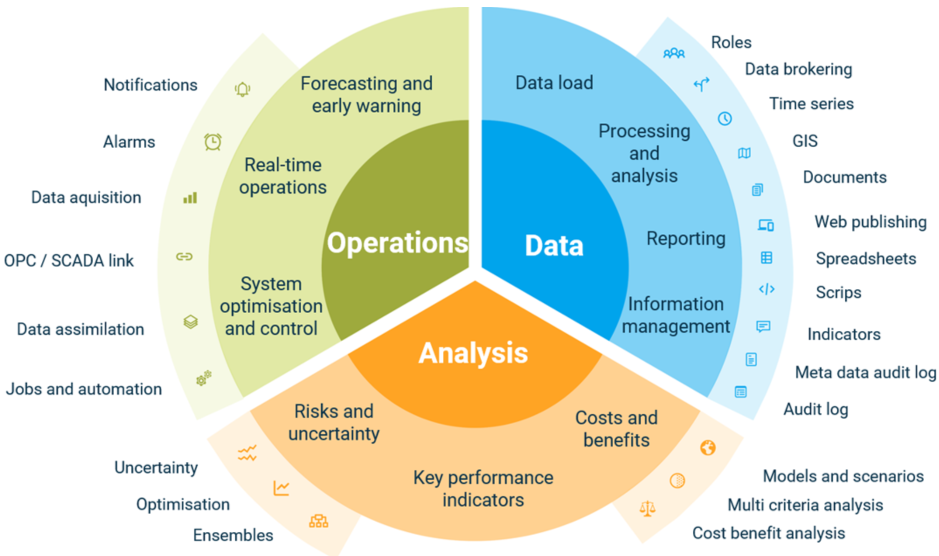


Figure 4.3 MIKE Workbench is an IT platform to establish client centric solutions for decision support.

4.2 Web-based Portal

A key feature of the EN-FEWS with its integrated components is the web user interface that is accessible online. The consultant recommends that the flood forecast and early warning system be embedded in DHI's Water Tools Portal. DHI's Water Tools Portal is a flexible, expandable, and modular web-based platform which provides a user interface for decision support systems and integrates the frontend components with backend functions and tools. The Water Tools Portal is a frontend platform for information dissemination, analysis, and visualisation. It also provides functionalities for integration with the EN-FEWS backend database and tools.

The Water Tools Portal structure is modular in that it is designed to embed and integrate "applications". Applications are developed as standalone entities hosted on a web server and have diverse functionalities based on user requirements. For example, applications (or 'apps') include MIKE Operations Web 2.0, the flow and flood forecasting and early warning system, that can also be customised for infrastructure operation support based on flow forecasts.

The Water Tools Portal includes a comprehensive user management system. Each user has a user profile associated with personalised login. Owners can manage user profiles and access permissions in a user management system interface in the Water Tools Portal.

4.3 Flood Forecasting with MIKE OPERATIONS

Flood Forecasting and Early Warning Systems (FFEWS), as part of a DSS, are attractive and cost-effective operational instruments to predict the spatial and temporal evolution of potential floods and help to take timely mitigation actions, e.g. through quick water management operations and quick emergency actions. The "generic" process is schematised in Figure 4.4.

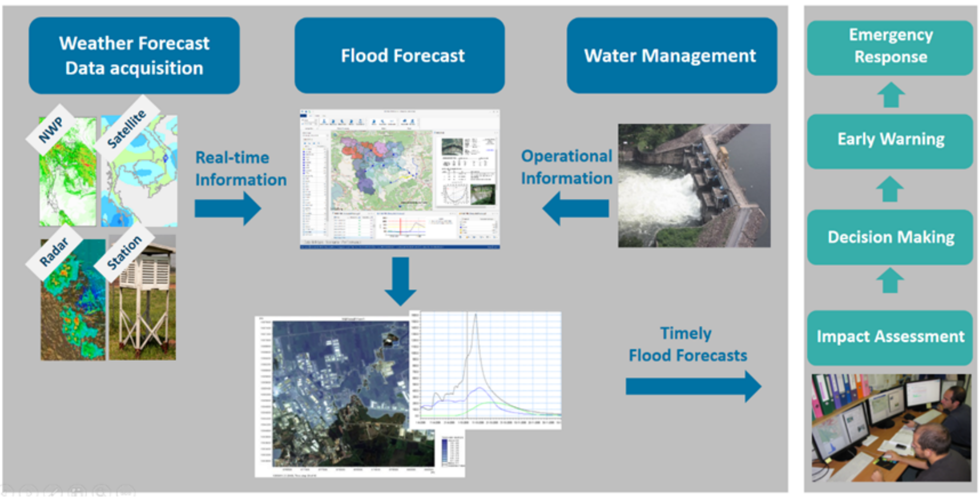


Figure 4.4 DHI's FFEWS Component Concept

The consultant recommends that DHI's Flood Forecasting and Early Warning app (MIKE Operations Web 2.0) be the central component of the enhanced flood forecast and early warning system. This application software has in the backend models running in an automated manner in a well-defined sequence with forecast data and observations, and it provides a web-based user interface for analysis and visualisation of flood forecasts, early warning dissemination, and forecast performance evaluation.

Figure 4.5 shows the Nile Basin River Flow Forecasting System that DHI implemented and developed with the NBI in 2020.

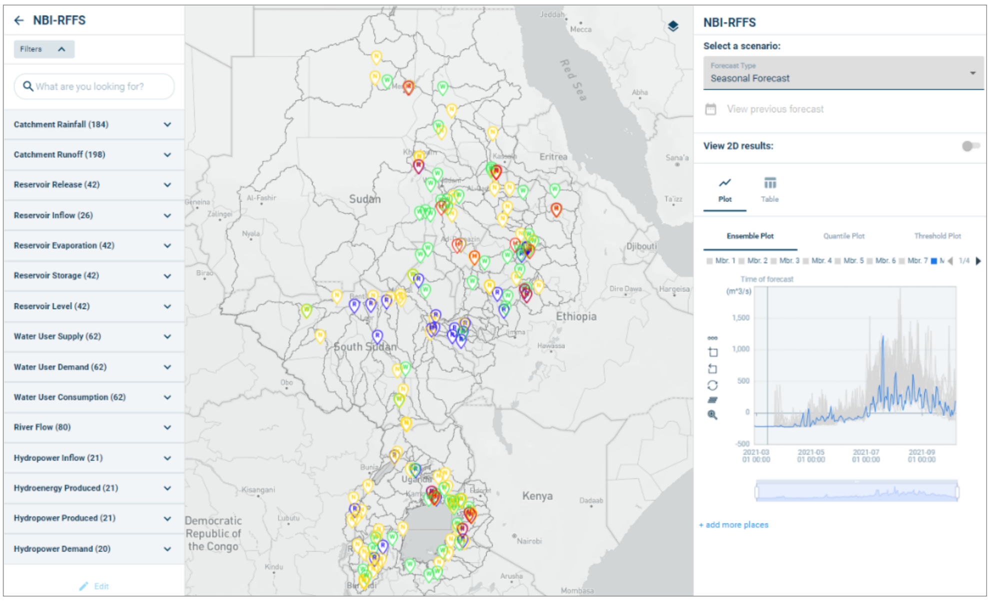


Figure 4.5 **Interactive map showing the status of stations and allows viewing forecasted flows and water levels as ensemble timeseries (based on MIKE Operations Web 2.0).**

Forecast scenarios set up in MIKE Workbench are visible in MIKE Operations Web 2.0. Different scenarios can be selected, and each scenario may have several simulations and their results saved in the database. Colours based on threshold exceedances, timeseries plots, table values and rainfall time varying rasters are dependent on the selected simulation. In the object-relational database, simulation input and output timeseries, observation timeseries, and thresholds values are associated to geospatial locations. These geospatial locations are referred to as “places” in MIKE Operations Web 2.0. Timeseries and associated thresholds can be added to the plot either by selecting the place from the map or from the panel (an example is shown in Figure 4.6).

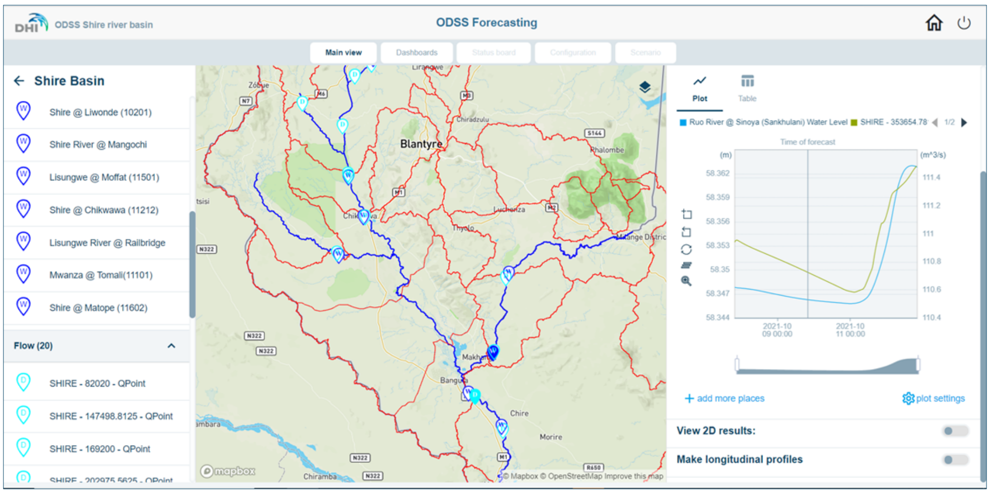


Figure 4.6 **Selecting a location, choosing plotting items in the pop-up window and exploring the plot component options (example from demo site for the Shire basin in Malawi)**

Operators can configure rules for disseminating flood alerts. For each place configured – this may be a point location or a catchment area – it is possible to associate thresholds to the place's indicator time series. These thresholds represent warning/danger levels: green, yellow, and red (see Figure 4.7).

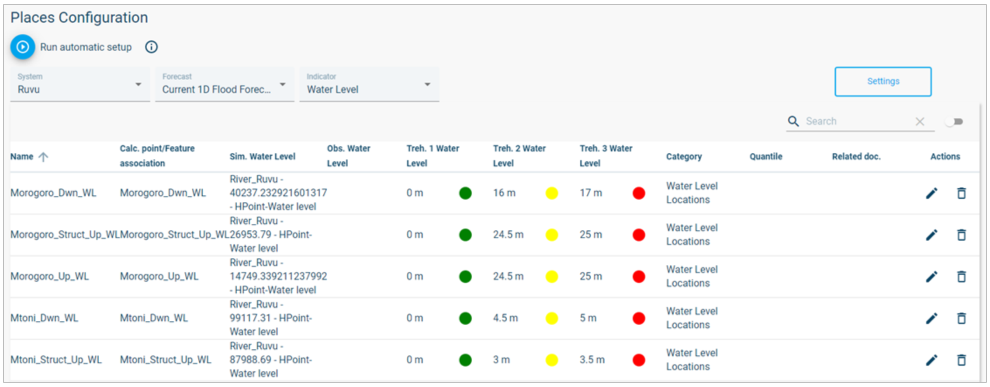


Figure 4.7 Example of the configuration page of places, indicators, and threshold values in MIKE Operations Web 2.0

Similarly, operators can interactively configure dashboards in MIKE Operations Web 2.0, so that users can see latest forecast results and analyses in a standardised manner for the most critical locations and parameters (see Figure 4.8).

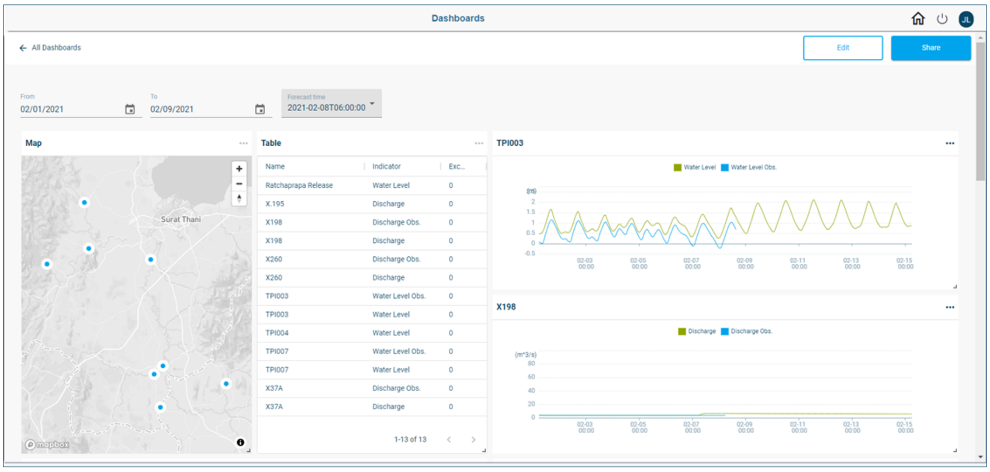


Figure 4.8 Dashboard view of forecasts in MIKE Operations Web 2.0

The dissemination component enables operators to define what type of alert is to be sent to which recipient under what circumstances. Recipients of alerts can get tailored warnings for selected locations through communication channels of their choice (e.g. e-mail, WhatsApp). The sending out of the alerts is triggered when thresholds are exceeded.

generated: 2023-01-27 08:01
simulation: Simulation of Scenario of WamiRuvu_FFEWS_HD at 2023-01-27 07:46:11
start of simulation: 2023-01-22 12:00
time of forecast: 2023-01-27 12:00
end of simulation: 2023-02-03 12:00

Flood Forecast - forecasted Water Level (max. 168 hours)

Status	Location	Alert	Water Level [m]	Warning Threshold [m]	Danger Threshold [m]
	Kinyasungwe - 37048	Danger	763.46	762	763
	Mkondoa - 35570	Danger	477.62	476	477
	Mkondoa - 98931	Danger	382.64	380	381
	Kinyasungwe - 17818	Warning	788.67	788	789
	Miyombo - 17103	Warning	491.47	491	492
	Miyombo - 27170	Warning	468.9	468	469
	Miyombo - 29430	Warning	464.72	464	465
	Miyombo - 32554	Warning	461.46	461	462
	Mkondoa - 26059	Warning	500.24	500	501
	Diwale - 34270	Ok	358.72	361	362
	Miyombo - 8537	Ok	509.19	515	516
	Mkundi - 10470	Ok	763.17	772	773
	Mkundi - 64476	Ok	407.92	408	409
	Msimbazi - 11450	Ok	58.05	60	61
	Msimbazi - 21150	Ok	22.15	25	26
	Msimbazi - 23725	Ok	18.74	21	22
	Msimbazi - 28346	Ok	3.8	6	7
	Msimbazi - 31774	Ok	3.81	5	6
	Msimbazi - 3944	Ok	100.06	103	104

Figure 4.9 Registered stakeholders can receive flood forecast alerts through different communication channels (e.g. e-mail) - example from ODSS-Tanzania

4.4 Enhancement of the Models

New datasets are expected under an ongoing consultancy by ENTRO to improve the EN-FEWS and will enable enhancement of the flood forecast and early warning system for this project.

The consultant shall update the hydrological models (NAM) and the hydrodynamic models of the sub-basins – Blue Nile (including Lake Tana, Dinder and Rahad), and Tekeze-Atbara-Setit:

1. The review will evaluate the models in terms of quality of the data used, and the quality of the calibration and validation (with historical rainfall data).
2. In addition, the review will assess the quality of forecasted floods in past rainy seasons (with the rainfall forecasts used).
3. Furthermore, the review will also investigate how the linkage between two sub-systems, (a) the meteorological model WRF, and (b) the flood forecasting system, can be optimised.

On this basis, and with datasets from ENTRO's ongoing consultancy to improve the EN-FEWS, as well as with global datasets where necessary, the consultant shall carry out the following:

1. Re-configure the hydrological models, re-calibrate them, and re-validate them. Where relevant the consultant shall use DHI's Global Hydrological Model (GHM) to verify/validate the hydrological models.
2. Re-configure the hydrodynamic models, re-calibrate them, and re-validate them. MIKE+ is the successor of MIKE Hydro River and backwards compatible. When re-configuring the hydrodynamic models, the consultant shall upgrade the models to MIKE+.
3. Register the models in MIKE Workbench and configure MIKE Workbench for flood forecasting purposes.
4. Link the MIKE Workbench platform to (a) global, (b) regional and (c) Sudan's national numerical weather prediction models (from SMA)
5. Re-configure the linkage between the two sub-systems – MIKE Workbench with numerical weather prediction model(s) – for optimal real-time automated data transfer.
6. Evaluate the performance of the flood forecasts as far as possible with national and regional real-time hydro-meteorological observations.

5 Outcomes of Activities during Inception Phase

5.1 Review of the Existing Systems

The consultant has reviewed the current EN-FEWS and investigated the following aspects:

1. What models are implemented and integrated in the forecast system for which areas and what are the modelling methodologies and tools?
2. What is the software framework that integrates models, forecasts, visualizations, and dissemination of alerts, and how is it configured/setup?
3. How is the system operationalized and deployed?
4. Based on the above 3 aspects, what needs to be done to upgrade and ameliorate the EN-FEWS?

5.1.1 Models of the Forecast System

Main Nile between Khartoum and Dongola

The current EN-FEWS does not include the river stretch of the Main Nile between Khartoum and Dongola. The flood forecasts for this river reach will have to be developed with datasets from the client (e.g. cross-sections) and global earth observations products (e.g. digital elevation models). Calibration and validation of the hydrodynamic model for this sub-system will be carried out with historical hydro-meteorological datasets of the client.

Tekeze-Setit-Atbara

The hydraulic model is developed with MIKE 11 and NAM model is used for rainfall runoff computation on sub-catchments (see map in Figure 5.1). The model includes the Tekeze-Setit-Atbara river system. Atbara dams and reservoirs are not included in the model.

Cross sections were generated from Airbus DEM20 with a horizontal resolution of 25m, which has a low vertical accuracy. Rainfall input data source is RFE for hindcast and WRF for forecast. If, WRF (Weather Research and Forecasting) is not available, it uses NOAA GFS (Global Forecasting System) model.

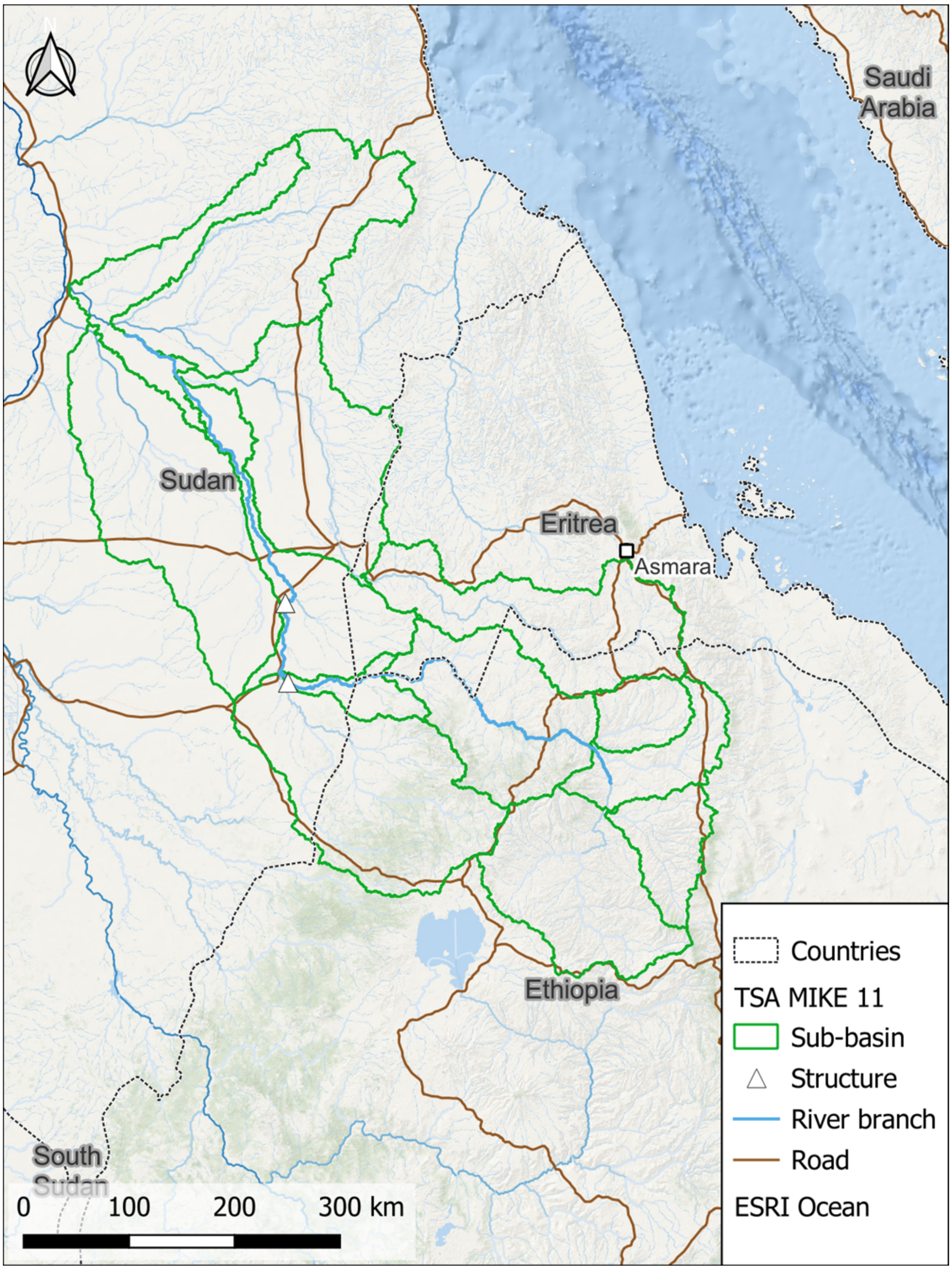


Figure 5.1 Extent of Tekeze Atbara Setit MIKE 11 model

The downstream boundary condition is a Q-H relation defined 90 km upstream the confluence with the Nile at Atbara. There is no lateral inflow defined as boundary condition. All inflows are calculated from the Rainfall-Runoff model.

The roughness coefficient is defined based on Manning's n formulation. On Tekeze and Atabara rivers, the coefficient is defined at 0.05 $s/m^{1/3}$. There is no difference of roughness between the river channel and the floodplain.

Atabara and Girba dams are defined as regulated structures. The overflow spill is calculated from a Q-H relation and the outflow is defined based on a time series of daily discharge. The same is used for both dams.

Cross sections are equally distributed with 4000 m between two cross sections. Several things would need to be corrected in cross sections:

- Most of the cross sections are more than 100 m high
- All cross sections are 1500 m wide
- There are low elevation points outside the river channel.
- Most of the cross sections are flat in the riverbed.

The Blue Nile

The hydraulic model is developed with MIKE 11 and NAM model is used for rainfall runoff computation on sub-catchments (see map in Figure 5.2). The model includes the Blue Nile from Eldiem to Khartoum including the White Nile confluence.

Cross sections were imported from the HEC-RAS model developed for flood mapping (see section 5.2.2). Rainfall input data source is RFE for hindcast and WRF for forecast. If, WRF (Weather Research and Forecasting) is not available, it uses NOAA GFS (Global Forecasting System) model.

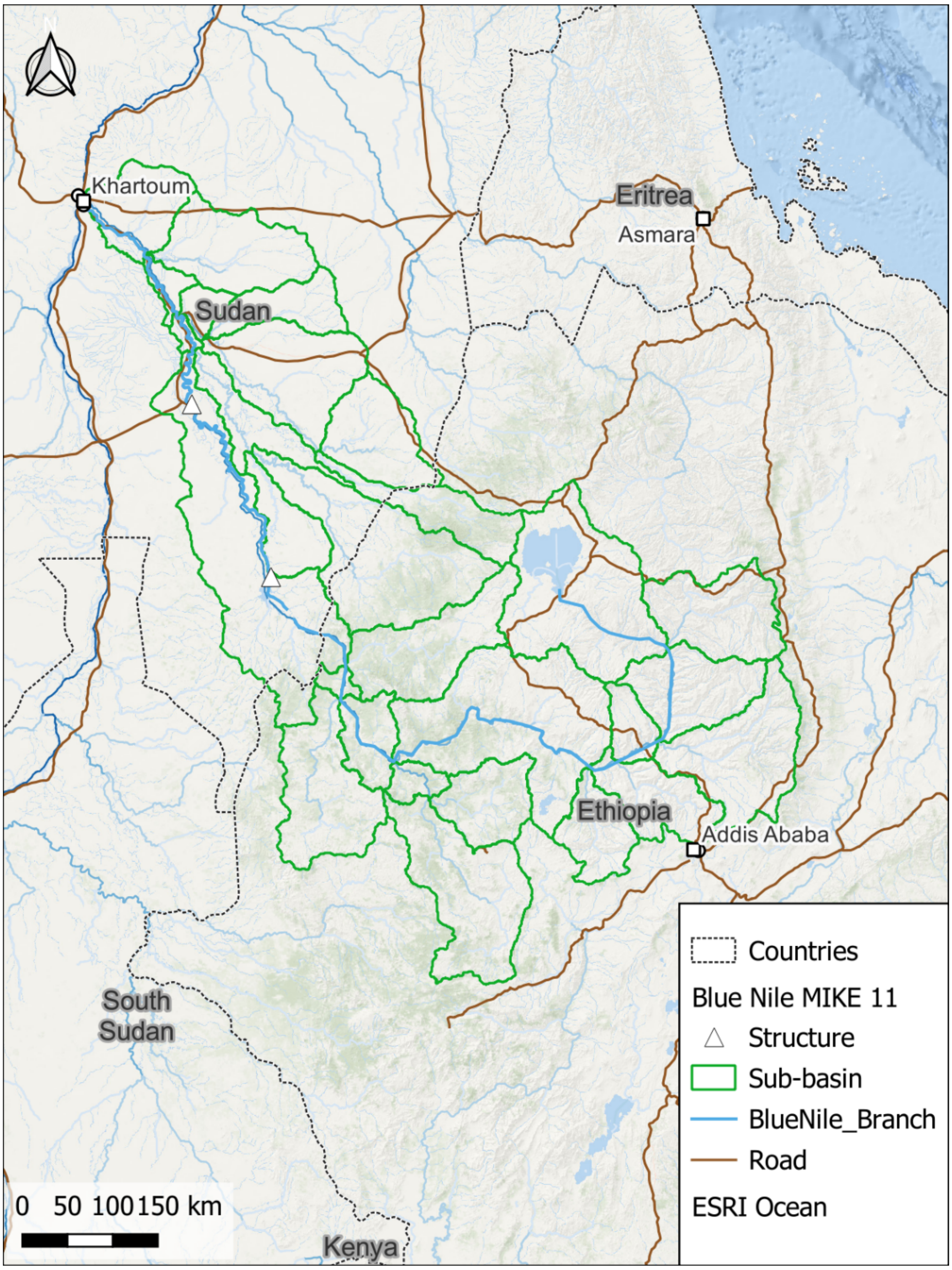


Figure 5.2 Extent of Blue Nile MIKE 11 model

The downstream boundary condition is a Q-H relation on the Blue Nile in Khartoum upstream the confluence with the White Nile. This rating curve zas defined based on the observed rating curve at the station. There is no lateral inflow defined as boundary condition. All inflows are calculated from the Rainfall-Runoff model.

The roughness coefficient is defined based on Manning's n formulation. Upstream Roseires dam, the coefficient in the riverbed is defined at 0.04 s/m$^{1/3}$, and downstream up to Khartoum, it is defined at 0.03 s/m$^{1/3}$ at the confluence with Baro river. In the upper Blue Nile from Lake Tana to upstream Roseires reservoir, there is no difference of roughness between the river channel and the floodplain. From Roseires reservoir to Khartoum, the riverbed is smoother than the floodplain. The roughness coefficients are described in Table 5.1.

Table 5.1 Roughness coefficients in the Blue Nile model

Reach	Manning n in the river bed	Manning n in the floodplain
From Lake Tana to Abu Shunaynah	0.04	0.04
From Abu Shunaynah to upstream Roseires Reservoir	0.04	0.045
First half of Roseires Reservoir	0.04	0.045
Second half of Roseires Reservoir	0.04	0.04
Downstream Roseires dam to El Roseires	0.04	0.045
From El Roseires to Sennar Reservoir	0.03	0.05
Inside Sennar Reservoir	0.03	0.034
From Sennar dam to Al-Hajj Abd Allah	0.03	0.05
From Al-Hajj Abd Allah to Alnoba	0.03	0.04
From Alnoba to Khartoum	0.03	0.055

Roseires and Sennar dams are defined as regulated structures. The overflow spill is calculated from a Q-H relation and the outflow is defined based on a time series (the daily outflow from 2017 is used for Roseires and from 2014 for Sennar).

The upper Blue Nile (from Lake Tana to Roseires) is defined in reverse order with decreasing chainage when moving downstream. The lower Blue Nile (From Roseires to Khartoum) is defined with increasing chainage when moving downstream.

In the Upper Blue Nile, cross sections are equally distributed with 4000 m between two cross sections. Several things would need to be corrected in cross sections:

- The right-most point of the cross section is often several meters lower or higher than the previous one
- Most of the cross sections are more than100 m high
- All cross sections are 1500 m wide
- There are low elevation points outside the river channel.
- The same cross section is sometimes repeated for several kilometres (up to 232 km) using a datum to take into account the river slope.
- Some cross sections are flat in the riverbed.

In the Lower Blue Nile, cross sections are not equally distributed, the average distance between two cross sections are available in Table 5.2. Jump in the riverbed up to 10 m high are visible.

Table 5.2 Average distance between cross section in the Blue Nile model

Reach	Average distance in m
From Lake Tana to Abu Shunaynah	4000
From Abu Shunaynah to downstream Roseires dam	2700
From Roseires dam to Sennar Reservoir	900
Inside Sennar Reservoir	4300
From Sennar Dam to Khartoum	900
In Khartoum	130

Dinder and Rahad

The current EN-FEWS does not forecast floods of the rivers Dinder and Rahad. In the current system the two rivers are rather modelled hydrologically as contributors of lateral inflows to the Blue Nile. The hydrological model of the two rivers will be discretized in more detail, and the hydrodynamic models will be developed with datasets from the client (e.g. cross-sections) and global earth observations products (e.g. digital elevation models). Calibration and validation of the hydrodynamic model for this sub-system will be carried out with historical hydro-meteorological datasets of the client.

5.1.2 The Software System

The software and configuration of the four present real-time flood forecasting systems have been investigated and reviewed.

For each river basin (Blue Nile, Lake Tana, Tekeze-Setit-Atbara (TSA), Baro Akobo-Sobat (BAS)), the real-time flood forecasting system is configured in a separate MIKE Workbench PostgreSQL database. Table 5.3 lists the software components used in the four real-time forecasting systems.

Table 5.3 Software of current real-time flood forecasting systems

Software	Version	Function	Basin
MIKE 11	2022 update 1	Model Engine	Blue Nile, Lake Tana, BAS, TSA
PostgreSQL	14.2	Database	Blue Nile, Lake Tana, BAS, TSA
MIKE Workbench	2022 update 1	Desktop Backend of real-time system	Blue Nile, Lake Tana, BAS, TSA
MIKE Operations	2022 update 1	Desktop Frontend of real-time system	Blue Nile, Lake Tana, BAS, TSA
MIKE Operations Web 2.0	2022 update 1	Web Frontend of real-time system	Blue Nile
Water DSS	Cloud Hosted (up-to-date)	Web Portal including user management to access web frontend	Blue Nile

MIKE Workbench

In the EN-FEWS the operational flood forecasting systems for the four basins are configured using MIKE Workbench. The forecasting systems are scheduled to produce a new forecast every day and occasionally forecasts seem to be executed manually during the day. Table 5.4, and Table 5.5 list observations made on the setups of the respective scheduled jobs for the Blue Nile and Tekeze-Setit-Atbara flood forecast systems.

Table 5.4 Job schedules of Blue Nile real-time flood forecasting system

Job	Scheduled	Frequency	Duration	Description
01_ImportData	3:00 AM	Daily	2 min	Download latest GFS forecasted rainfall from DHI FTP server
04_ProcessGFS	3:30 AM	Daily	8 min	Process GFS gridded rainfall to mean area rainfall for all sub-catchments
NOAA	4:00 AM	Daily	8 min	Download and process RFE observed rainfall for all sub-catchments
ImportWRF	6:00 AM	Daily	4 min	Download and process WRF forecasted rainfall for all sub-catchments. Currently not scheduled.
Run_scenario	6:10 AM	Daily	50 min	Run MIKE 11 model together with NAM runoff model to produce water level and flow forecasts along the defined river branch

Table 5.5 Job schedules of Tekez-Setit-Atbara real-time flood forecasting system

Job	Scheduled	Frequency	Duration	Description
04_ProcessGFS	5:00 AM	Daily	2 min	Process GFS gridded rainfall to mean area rainfall for all sub-catchments
NOAA	5:30 AM	Daily	6 min	Download and process RFE observed rainfall for all sub-catchments. Currently failing.
ImportWRF	6:30 AM	Daily	1 min	Download and process WRF forecasted rainfall for all sub-catchments. Currently not scheduled.
Run_scenario	6:40 AM	Daily	10 min	Run MIKE 11 model together with NAM runoff model to produce water level and flow forecasts along the defined river branch

The review of the MIKE Workbench configurations confirmed that all real-time flood forecasting systems of the EN-FEWS are operational and produce water level and flow forecasts in each basin. The simulation period of the real-time simulations is:

Start of Simulation: 10 days before time of forecast

Time of Forecast: at midnight of the day before the day of runtime

End of Simulation: 9 days after time of forecast

Additionally, the following was noted:

a. No database maintenance and archiving seem to be configured.

b. No real-time water level and/or flow observations seem to be available. Hence, no data assimilation seems to be applied.

c. No forecast performance seems to be collected.

d. Uncertainty of the deterministic flood forecasts does not seem to be estimated.

e. GFS rainfall forecasts are bias-corrected using linear scaling based on factors derived from CRU rainfall observation stations. WRF forecasted rainfall and RFE observed rainfall do not seem to be bias-corrected.

f. The observed rainfall RFE does not seem to be up to date in the operational databases. Consequently, the simulations use forecasted WRF or GFS rainfall as input in the hindcast period.

g. The job to import WRF forecasts does not seem to be scheduled in some of the forecasting systems.

h. There does not seem to be automatic messages of flood warnings and alerts to relevant stakeholders produced by the real-time systems.

i. There does not seem to be automatic messages on the status of the scheduled jobs of the real-time systems to the respective operators.

MIKE Operations Desktop

Operator views are configured for all real-time flood forecasting systems in MIKE Operations Desktop. The configurations include relevant flow forecast locations together with corresponding alert, critical and flooding thresholds.

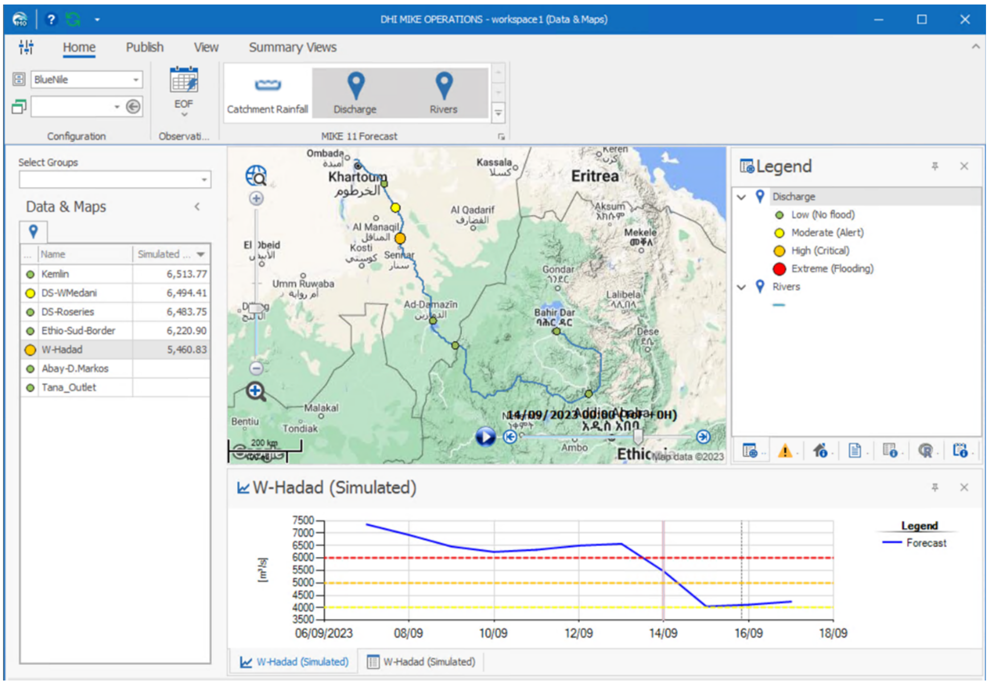


Figure 5.3 MIKE Operations Desktop configuration for the Blue Nile flood forecasting system. The forecast issued on 15th September 2023 is displayed.

The following was noted in the MIKE Operations Desktop configuration:

a. There are no water level forecasts configured in the MIKE Operations Desktop view.

b. Three warning thresholds categories are defined in the MIKE Operations Desktop view: alert, critical and flooding.

c. Two dynamic layers are configured: catchment rainfall and discharge.

d. One static layer is configured: rivers.

MIKE Operations Web 2.0

The newly released MIKE Operations Web 2.0 web user interface to real-time forecasting systems configured in MIKE Workbench has been deployed for the Blue Nile flood forecasting system.

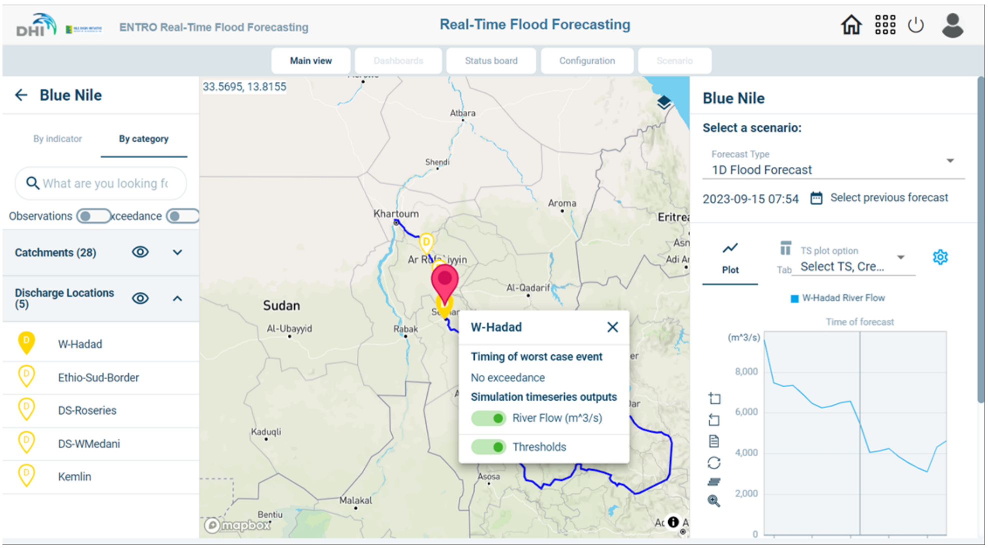


Figure 5.4 MIKE Operations Web 2.0 configuration of the Blue Nile flood forecasting system. The website can be reached via ENTRO's water DSS portal workspace[1]: https://entroeffs.waterdss.com/.

The following was noted in the MIKE Operations Web 2.0 configuration:

a. The configuration seems to be only available for the Blue Nile flood forecasting system.

b. No threshold values seem to be configured in the web user interface.

c. Similarly, to the MIKE Operations Desktop configuration, there are two dynamic layers (catchment rainfall and discharge) and once static layer (rivers).

Water DSS Portal

There is a workspace configured for ENTRO in the water DSS portal which currently hosts the MIKE Operations Web 2.0 application configured for the Blue Nile flood forecasting system.

ENTRO's workspace can be reached via the following url: https://entroeffs.waterdss.com/.

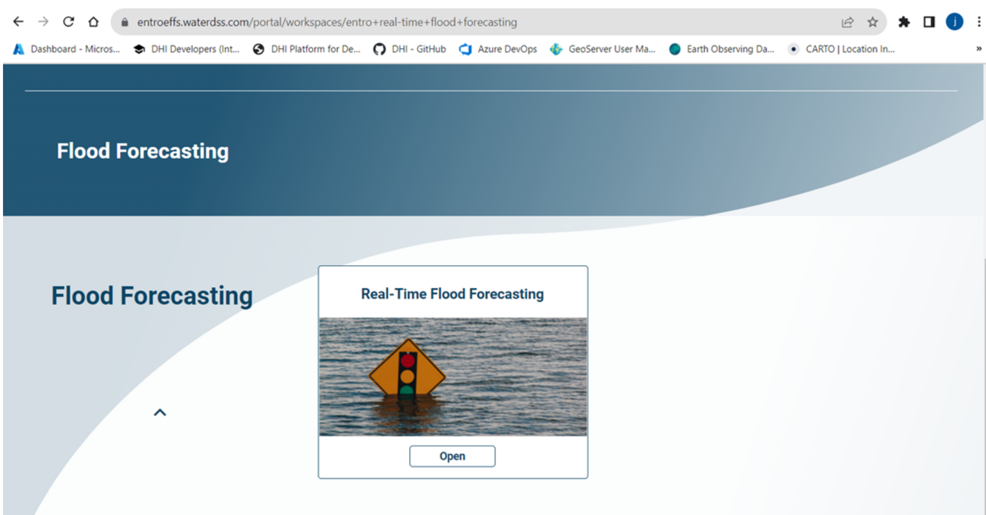


Figure 5.5 Landing page of ENTRO's workspace in the water dss portal.

[1] https://entroeffs.waterdss.com/

5.1.3 Deployment of the System

The MIKE Operations setups including the real-time flood models of the real-time flood forecasting systems are deployed on the windows virtual machine (IP: 172.24.16.5) within NBI's IT infrastructure.

The WRF rainfall forecasts are produced on an external server within NBI's IT infrastructure. The data is copied daily in netCDF file format to the windows virtual machine in the following location: *D:\ENTRO\Data\WRF\2021archive*. In this location, the WRF forecasts are also archived and stored in folders for each year, e. g. *D:\ENTRO\Data\WRF\2021archive\wrf_ppt_2023*.

Currently, MIKE Operations Web 2.0 and ENTRO's water DSS workspace are hosted in the Azure cloud under DHI's subscription. The main functionality of ENTRO's water DSS workspace is to manage the user access to the MIKE Operations Web 2.0 user interface to the real-time flood forecasting systems. Additionally, the water DSS portal has advanced functionality to design and automatically send messages to various internal and external users of ENTRO's water DSS workspace.

Recommendations for deployment options for the enhanced system require understanding the requirements in detail and scrutinizing implications and costs. The consultant shall prepare a concept note that discusses cloud deployment modalities and options for the EN-FFEWS. The concept note will address the following aspects for feasible deployment options:

1. Hardware and software requirements for the cloud deployment
2. Dedicated access for Sudan to the EN-FEWS
3. Technical and financial implications

5.2 Geographic Scope

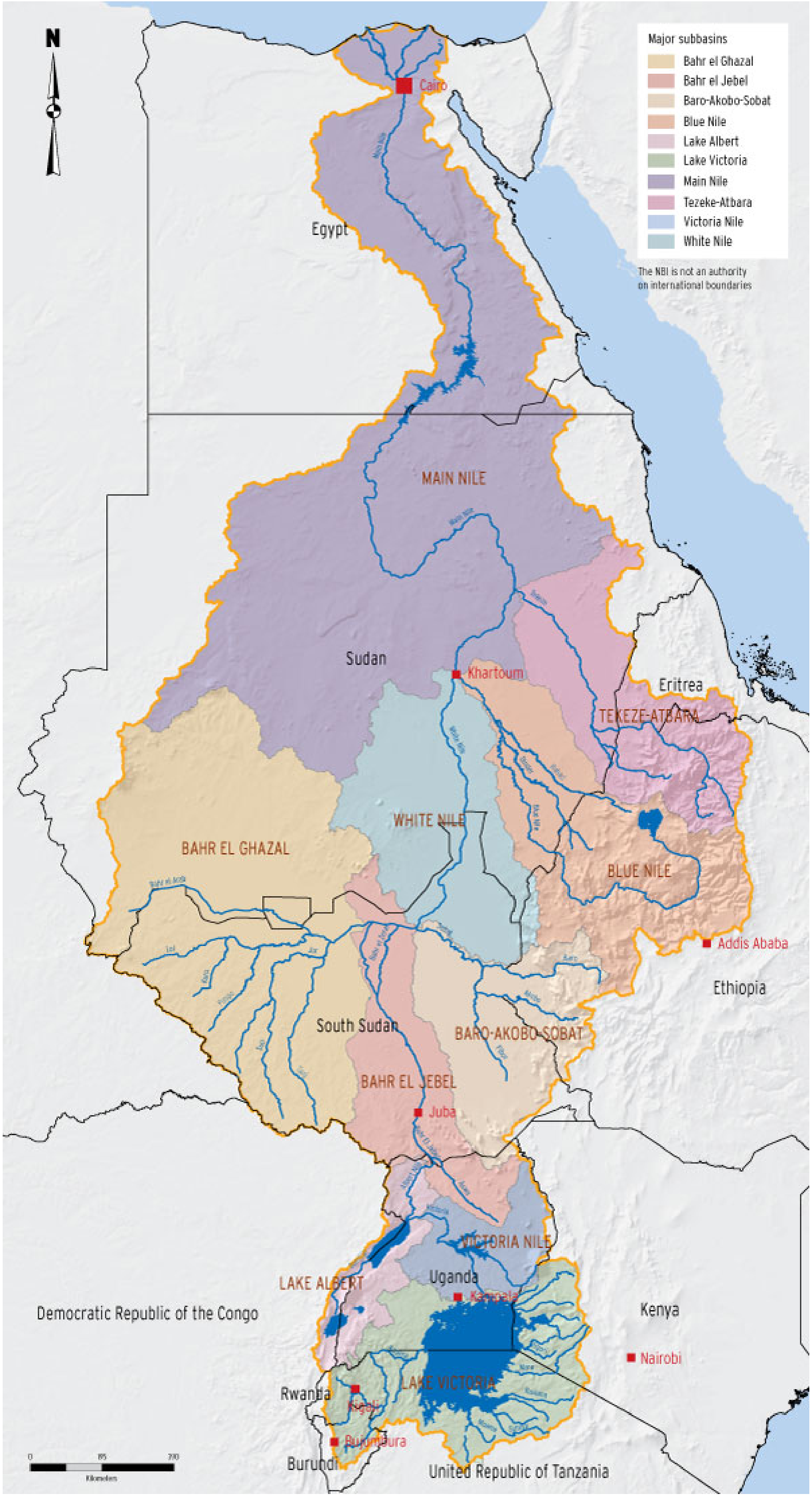


Figure 5.6 The Nile Basin - overview

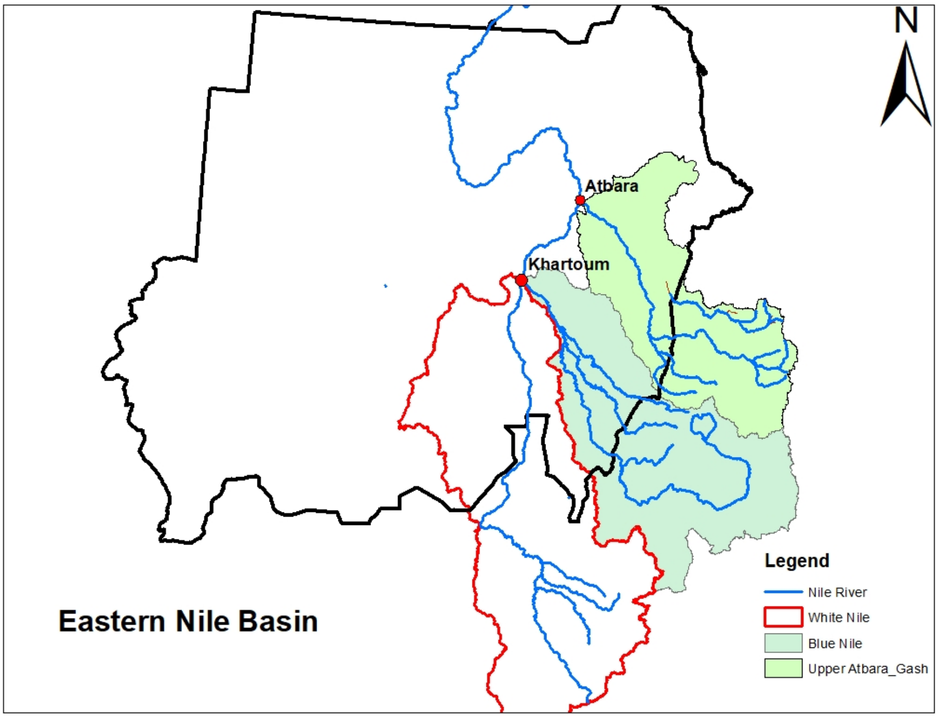


Figure 5.7 The Eastern Nile sub-basin – Tekeze-Setit-Atbara, Blue Nile and White Nile (including Baro-Akobo-Sobat) sub-basins

The enhanced FEWS for Sudan will cover the following extents:

- The Main Nile River between Khartoum and Dongola

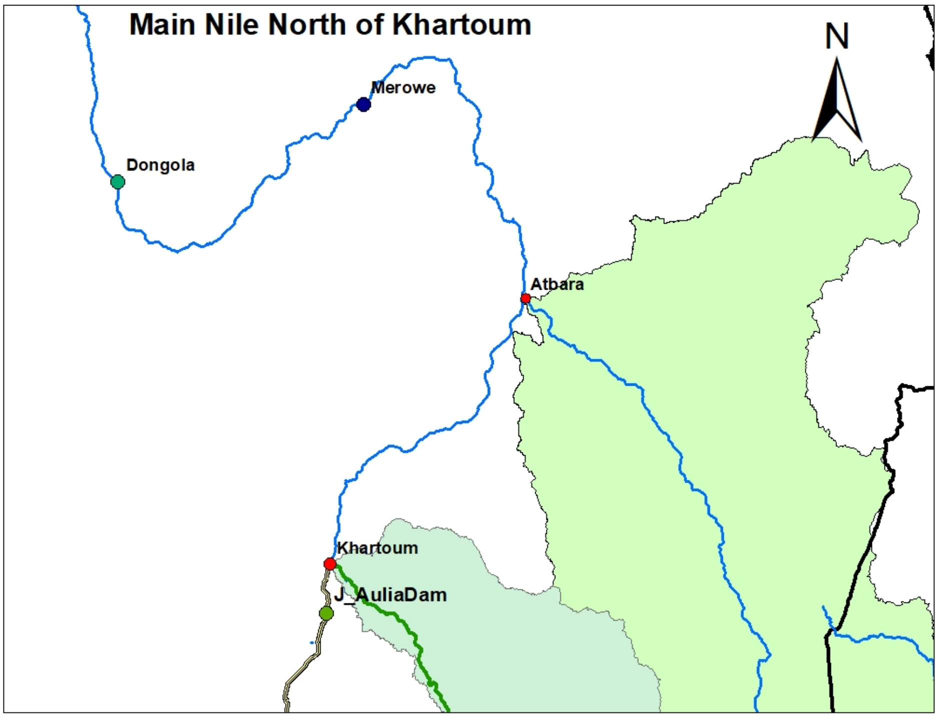


Figure 5.8 The Main Nile between Khartoum and Dongola

- The Tekeze-Setit-Atbara basin covers the catchment heading in the northern highlands of Ethiopia up to the confluence of the Atbara River.

The river of interest for the EN-FEWS are Atbara downstream of the Setit inflow, parts of Setit and Tekeze downstream of the Tekeze dam.

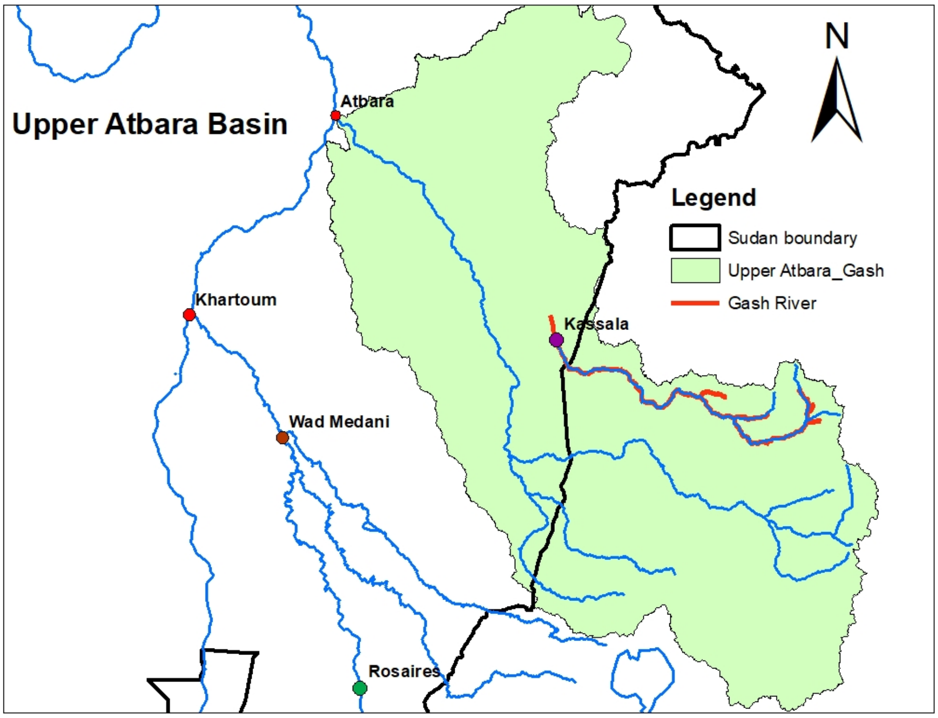


Figure 5.9 The Tekeze-Setit-Atbara sub-basin

- The Blue Nile basin encompasses the catchments that drain into the Blue Nile River between Lake Tana and Khartoum including those of the rivers Dinder and Rahad. The lower boundary condition may be influenced by conditions of the White Nile at the confluence. The river of interest for the EN-FFEWS is the Blue Nile downstream of the Grand Ethiopian Renaissance Dam (GERD).
- The Dinder River (as far as the available cross sections reach)
- The Rahad River (as far as the available cross sections reach)

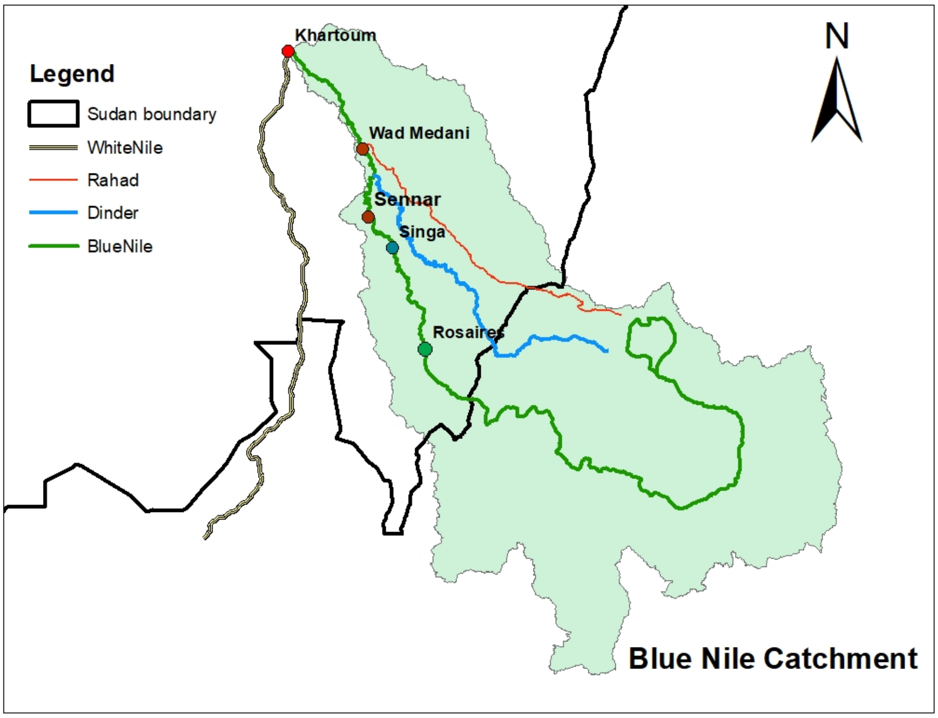


Figure 5.10 The Blue Nile, Dinder and Rahad rivers and the Blue Nile sub-basin

6 Implementation Plan

The following sections outline the details of the technical assistance implementation plan.

6.1 Activity 1 – Stakeholder Consultation, Assessment of Available Data and Existing FEWS

6.1.1 Activity 1.1 – Project initiation and kick-off meeting

In this activity the implementer will hold a remote kick-off meeting and formally initiate the Technical Assistance (TA), establish staff relations and communication lines at required levels. Map all relevant stakeholders that need to be involved. Evaluate risks and map these jointly with the Nile Water Department.

In addition, the technical assistance management documentation, namely, Detailed work plan, Monitoring & evaluation (M&E) plan and impact statement will be prepared as required by the TA implementation guidelines.

The result of this activity will be documented in Activity 1.3's written deliverable, the Inception Report.

Deliverables	Delivery date
Kick-off meeting	16 March 2023

6.1.2 Activity 1.2 – Data collection and stakeholder consultation

Consultative meetings with the Nile Water Department will be held to understand in depth the current processes/protocols for the generation, provision, management and sharing arrangements of data as well as current approach to FEWS. This is crucial so that only technology and operational practice is supplanted and does not impose restrictions on to the existing institutional framework.

It is assumed that the Sudan Nile Water Department can have access to ENTRO's forecast models and all required software licenses through the provisions of collaboration between Sudan and ENTRO.

Table 6.1 lists examples of data types required for the establishment of a FEWS. An assessment will be made on the availability of the data listed. An initial pre-assessment is also included in Table 6.1 and will be further elaborated and validated together with stakeholders.

Table 6.1 Required data for Technical Assistance

Data type	Accuracy	Specifications
TIME SERIES (Excel columns of date-time and value. Missing data as blanks)		
Rainfall at stations	Daily	
Satellite rainfall time series	Daily	CHIRPS and/or similar
Potential evaporation	Daily or monthly	
Water level	Hourly or daily	
Discharge	Hourly or daily	
Data at real-time reporting stations	Hourly or more frequent	All historical data available
Quantitative precipitation forecasts	As available	Historical QPFs of heavy rainfall events if available
Water use	Daily	Including information on abstraction points and return flow
Reservoir water level	Daily	
Reservoir releases and estimated evaporation	Daily	
Estimated reservoir inflow if available	Daily	
Hydropower production	Hourly or daily	
PHYSICAL DATA (Excel or text files)		
River cross sections	Every 5 km or closer	Covering all possible water levels along the river, where flood forecasting is planned
Rating curves and associated discharge measurements		Including background data on validity etc.
Structure dimensions		Reservoirs, weir, bridges etc.
Operational rules for reservoirs		
GIS (shapefiles, raster)		
Rainfall stations		point layer
River stations		point layer
Reservoirs		point layer
Digital elevation model	30m or better	Hydrologically corrected if available
Land use		

The list of FEWS product end users for flood alerts will be updated by collecting information on vulnerable communities in flood-prone areas in Sudan. Sources of such information are expected to be in addition to the Nile Water Department itself, the national and local authorities, international development and aid organizations and non-governmental organizations operating in those areas. This will ensure that continued preparedness and early warning measures communication and dissemination are easily accessible to rural communities.

Based on the stakeholder mapping, consultative meetings will be held with the different organizations to inform and understand expectations about the TA and for collection of data and information from those stakeholders.

The result of this activity will be documented in Activity 1.3's written deliverable, the Inception Report.

6.1.3 Activity 1.3 – Inception workshop

A multi-stakeholder inception workshop will be held to understand the expectations, identify the needs, gaps, guidelines, and results and lessons learned from completed and ongoing projects to collect/generate and provide similar data/systems. The workshop will be chaired and organized by the Nile Water Department with support by the TA implementer. It is envisioned that it will be up to 1-day virtual workshop a maximum of 25 participants.

Deliverables	**Delivery date**
Inception workshop	24 October 2023
Inception report	21 November 2023
Technical assistance management documentation	13 June 2023

The crisis in Sudan since April 2023 has created some disruption and therefore some delays in some of the deliverables above.

6.1.4 Activity 1.4 – Review of the collected data

The MoIWR is making a great effort to manage the floods by expanding and upgrading the ordinary hydrometric water level stations to automatic water level stations with fully real-time and remote transmission (telemetry system). It is assumed real-time data will be available to the TA implementer as it is not part of the TA the delivery of any monitoring equipment or new observed data.

Assuming the required data in Table 1 is available and shared with the TA team, the collected data will be reviewed for quality and gaps. Additional data collected during the stakeholder consultation activity will also be processed and reviewed.

It is recognised that these are transboundary basins and not all data is available at the national level. Depending on the agreements / data sharing protocols that are in place some of the required data may not be available. The TA Implementer will advise the Nile Water Department of the repercussions the missing data will have on the following activities and the FEWS and possible mitigation measures.

Repercussions would impact the design of the enhanced system itself (including modelling framework) and ultimately operations and performance. Hydrometry (real-time and historical) time series for calibration/validation and data assimilation will be used to carry out activities relative to Output 3.

Similarly, river cross-sections will be the basis for expanding the hydraulic model for the additional river reaches.

The result of this activity will be documented in Activity 1.4's written deliverable.

6.1.5 Activity 1.5 – Model and FEWS review

The hydrologic and hydraulic components of the existing FEWS modelling framework will be revised and the performance assessed. The forecasting and dissemination components will also be reviewed, and the technical improvements captured in an enhanced FEWS design report. The report will be presented to the client in Activity 1.6's meeting.

Deliverables	Delivery date
Enhanced FEWS design report	29 December 2023

6.1.6 Activity 1.6 – Capacity needs assessment

System operators will be identified, and their capacity assessed to inform the training sessions required to enable the identified staff to operate the enhanced FEWS. The results will be captured in a capacity needs assessment brief note containing the proposed training programme.

A meeting in person will take place to inform the capacity needs assessment as well as to present the deliverables of the previous activities 1.4 and 1.5, the Enhanced FEWS design report.

Deliverables	Delivery date
In person meeting	18 to 22 December 2023
Capacity needs assessment note	29 December 2023

6.2 Activity 2 – Enhancement of the FEWS

6.2.1 Activity 2.1 – Expansion and improvement of the FEWS components

Based on the needs assessment the technical team will develop the changes to each of the FEWS components, namely the weather, hydrological, hydraulic forecasting and dissemination components.

A weather forecasting system will be added to the FEWS. This translates into selecting the most suitable source for rainfall forecasts – provided access by ENTRO is given to Sudan Nile Water Department – WRF would be applied and carrying out the configuration of the system with the required automated processes.

The hydrological and hydraulic modelling framework will be improved as established in the design report. It is expected this may include for the hydrological component:

- Land use changes have occurred since the model was established and the model parameters will be dully altered to represent these changes.
- Improvement of the model to cover the Setit/Atbara basin and Dinder & Rahad basins

For the hydraulic component:

- Updates will be carried out based on recent topographic and structural information, where available
- Expansion of the model to cover the Setit/Atbara and the Dinder & Rahad rivers

This work will be followed by the calibration and validation with the historical time series collected, and implementation of a data assimilation procedure depending on real time data available and collected (Table 6.1).

The enhanced hydrologic and flood forecasting system will be integrated into the FEWS. This involves extensive reconfiguration efforts of the information flows in and out of the models. A dissemination system will be designed together with the Nile Water Department and relevant stakeholders, and its implementation and configuration carried out by the TA team.

The system will be hosted at DHI's servers for a period of 2 years to create a time window for the Ministry to purchase and install their own hardware, so that the system can be transferred to their premises, the transfer will be done with DHI's assistance. Therefore, the assumption that the Ministry has access to ENTRO software licenses is key as a new installation at DHI's servers will need to be made.

Deliverables	**Delivery date**
Model calibration and validation report	15 January 2024

6.2.2 Activity 2.2 – Review and improvement of the overall performance of the system

The forecast model must show that it is simulating the historical conditions (in terms of flow and water levels) with accepted accuracy and computational efficiency. This mainly focuses on the model evaluation by comparison of historical observations and forecasts with simulated data series at various locations. In assessing the forecasting performance, goodness-of-fit measures are presented as the average magnitude of the errors as a function of lead time over the evaluation period for select key locations. Improvement of the system performance will depend highly on the quality of the time series data in Table 6.1.

During a period of 7 months, the trained operators will run the FEWS system and report on any issues and difficulties observed. It is anticipated that a dedicated communication process during this period with the TA implementer may be established e.g., through the initiation of interactive emailing on a regular basis (twice a month).

The TA implementer will provide the Nile Water Department with recommendations of what actions should be prioritized targeting the future improvement of system performance specifically.

Deliverables	Delivery date
Enhanced FEWS operationalized	26 February 2024

6.2.3 Activity 2.3 – Technical manual update

The existing technical manual will be updated in accordance with system alterations carried out.

Deliverables	Delivery date
Updated technical manual	26 February 2024 (and 30 September 2024)

6.3 Activity 3 – Capacity Building for Use of the Enhanced FEWS

6.3.1 Activity 3.1 – Production of training materials

The CTCN TA implementer will produce materials for the online and face-to-face training sessions of system operators as well as for the stakeholder workshop for FEWS product end users.

Deliverables	Delivery date
Training materials	16 February 2024

6.3.2 Activity 3.2 – Training of government bodies and stakeholders for use of the system

The selected system operators will receive training in the usage and operation of the system. The proposed format is a face-to-face 5-day training session for a maximum of 12 participants, assuming active involvement of the designated staff on use of the forecasting system. Online ad-hoc assistance via email will be available for the duration of Activity 3.

Deliverables	Delivery date
In person training session and remote support	4 March to 8 March 2024, and during March 2024 to September 2024

6.3.3 Activity 3.3 – Stakeholder workshop for FEWS product end users

A broader range of selected relevant stakeholders, from those already identified during the activities 1 and 2, will be trained in the application of the FEWS products as determined by the Nile Water Department. This will be done via a 1-day workshop for a maximum of 25 participants, these may be the same as the inception workshop participants. Active involvement of the proponent is expected in the organization of the workshop in support of the project manager similarly to the Inception workshop (for example chairing, sending official invitations and contributing to the agenda).

At the end of Activity 3 an encompassing Capacity enhancement report will be produced, describing the outcomes of the technical training and the end user workshop as well as participants feedback and evaluation.

Deliverables	Delivery date
FEWS product end user workshop	20 September 2024
Capacity enhancement report	30 September 2024

6.3.4 Activity 3.4 – Preparation of the closure report

As required by the CTCN TA implementation guidelines, the technical assistance closure report will be prepared and submitted.

A period of 2-years maintenance is included to cover costs of keeping the system online at DHI's infrastructure, plus time up to a day for assistance by IT expert to install the system at Sudan's premises, once the country has purchased and installed their own hardware and supporting IT infrastructure during that period.

Deliverables	Delivery date
Technical assistance management documentation	23 October 2024
2-years of maintenance of the final system using DHI's infrastructure and transfer of the system	Post-project

7 Workplan

Table 7.1 illustrates the proposed workplan to carry out the tasks and activities during the project. In the workplan Month 1 is March 2023. The last deliverables are expected to be handed over by October 2024.

Table 7.1: Work schedule and planning for activities and deliverables

Work schedule and planning for Activities and Deliverables	Months																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Activity 1 Stakeholder consultation, assessment of available data and existing FEWS	■	←	—	—	—	→	■	■	■	■	■	■										
Activity 1.1 – Project initiation and kick-off meeting	□																					
Kick-off meeting	◆																					
Activity 1.2 – Data collection and stakeholder consultation							□	□	□	□												
Activity 1.3 – Inception workshop									□													
Inception Report									◆													
Activity 1.4 – Review of the collected data									□													
Activity 1.5 – Model and FEWS review										□	□											
Enhanced FEWS design report											◆											
Activity 1.6 – Capacity needs assessment											□	□										
In-person meeting											◆											
Capacity needs assessment note											◆											
Activity 2 – Enhancement of the FEWS										■	■	■	■	■	■	■	■	■	■	■	■	
Activity 2.1 – Expansion and improvement of the FEWS components										□	□	□	□									
Model calibration & validation report											◆											
Activity 2.2 – Review and improvement of the overall performance of the system													□	□	□	□	□	□	□	□	□	
Enhanced FEWS operationnalized													◆									
Activity 2.3 – Technical manual update												□										
Updated technical manual													◆									
Activity 3 – Capacity building for use of the enhanced FEWS												■	■	■	■	■	■	■	■	■	■	■
Activity 3.1 – Production of training materials												□										
Training materials													◆									
Activity 3.2 – Training of government bodies and stakeholders for use of the system													□									
In-person training session													◆									
Remote support														-·-	-·-	-·-	-·-	-·-	-·-	-·-	-·-	-·-
Activity 3.3 – Stakeholder workshop for FEWS product end users																				□	□	□
FEWS product end-user workshop																				◆		
Capacity enhancement report																					◆	
Activity 3.4 – Preparation of the closure report																					□	□
Technical assistance management documentation																						◆

■ Activity □ Sub-activity ◆ Deliverable ←→ Gap due to situation in Sudan -·- Remote support

Appendix A Kick-off meeting March 16, 2023 – summary and action points

Strengthening the community-based Flood and drought preparedness and early warning system in Sudan

CTCN Technical assistance on

Updating and improving existing hydrologic and hydraulic models and configuring a Flood Early Warning System (FEWS) in Sudan

Kick off meeting March 16th 2023: summary and action points

1. Meeting agenda

(Opening of kick-off meeting by CTCN)
1. Introduction of the implementation team
2. Appointment of focal points for day-to-day coordination from all parties
4. Overview of work plan in short and priorities for the next months
5. Planned travels if any at this point
6. Discuss next steps/ way forward

2. Meeting attendees list

Mr. Valentin Rudloff (CTCN)
Ms. Molly Sharone (CTCN)
Eng. Mohammed Adil Hassan (Ministry of Irrigation & Water Resources (MoIWR))
Eng. Abdelrahman Saghayroon Elzein (DG of Nile Water Affairs, MoIWR)
Ms. Aisha Ahmed (MoIWR)
Dr. Ahmed Hassan (General Directorate of Climate Change)
Ms. Huyam Ahmed Abdalla (General Directorate of Climate Change /CTCN Focal Point)
Mr. Mekuria Beyene (UNEP-DHI)
Mr. Okechukwu Amogu (UNEP-DHI)
Ms. Maija Bertule (UNEP-DHI)

3. Meeting summary

- CTCN provided opening remarks on the technical assistance project
- Introductions were made to CTCN representatives, the project proponent team (MoIWR), national focal point and NDE team, and the project implementation team (UNEP-DHI)
- UNEP-DHI presented an overview of project components, timeline and immediate next steps
- Operational focal points for all relevant parts were identified as follows:

Institution	Operational FP	Keep in CC
CTCN	Mr. Valentin Rudloff	Ms. Molly Sharone
MoIWR	Eng. Mohammed Adil Hassan* **Main FP for coordination of the technical work going forward*	Eng. Abdelrahman Saghayroon Elzein
NDE	Ms. Huyam Ahmed Abdalla	Dr. Ahmed Hassan
UNEP-DHI	Mr. Mekuria Beyene	Mr. Okechukwu Amogu Ms. Maija Bertule

The immediate priorities for the TA implementation were identified as following:

- Identify focal persons of stakeholders
- Identify users and stakeholders
  - Who will operate the FEWS?
  - How can the beneficiaries of the FEWS be reached?
  - How can one get latest quality-controlled data?
- Establish sharing of EN-FFEWS (get ENTRO's commitment)
- Identify national experts
  - Flood modeling expert (brainstorm on who)
  - Gender expert (we need support)
- Plan meetings for Activity 1

- NDE requested to know the timing of the inception workshop. Possible timing for the inception workshop was identified as second part of May 2023 – all in agreement.
- The need for operational FEWS for testing in time for the flood season was underlined by the MoIWR.
- UNEP-DHI confirmed that the expectation is to be able to test the currently operational FEWS during the flood season at least partly, with remaining elements being refined and deployed in the course of the project duration.

4. Action points and follow-up

Following actions were agreed up on as priority for next steps:

1. **Identification of relevant stakeholders within national FEWS operations**: MoIWR and NDE to discuss and share a list of relevant institutions and the respective contact persons for each institution
2. Identification and **contracting of national flood modelling expert**: UNEP-DHI to share options and MoIWR to provide additional recommendations, if any (no need to place a call for candidatures). Contracting of national flood modelling expert to be handled by UNEP-DHI.
3. Identification and **contracting of national gender expert**: UNEP-DHI to identify options via own network. MoIWR and NDE to provide additional recommendations, if any(no need to place a call for candidatures).. Contracting of national gender expert to be handled by UNEP-DHI.
4. Preparation of the **mandatory project start CTCN communication and reporting documents**, including detailed implementation plan within stipulated timelines: UNEP-DHI
5. Establish contact and **secure engagement of ENTRO FEWS**: UNEP-DHI with support from MoIWR to initiate contact and discussions

6. Discuss potential **in person and virtual meeting timings** with the MoIWR – bilaterally between PM and MoIWR.

Appendix B CTCN Sudan FEWS Inception workshop – meeting notes

Strengthening the community-based flood and drought preparedness and early warning system in Sudan

CTCN Technical assistance on
Updating and improving existing hydrologic and hydraulic models and configuring a Flood Early Warning System (FEWS) in Sudan

Inception Workshop
24 October 2023

Objectives of the project

The Nile Water Department, supported by UNEP-DHI, plans to Improve flood preparedness in Sudan through enhancing and updating its FEWS. It aims to achieve this by

A. Expanding and enhancing the components of the current FEWS in Sudan for increased coverage, efficiency, and lead time in the Blue Nile, Setit-Atbara, Dinder and Rahad national sub-basins.
B. Assessing potential and opportunities of the Eastern Nile Flood Early Warning System EN-FEWS of ENTRO available to Sudan - as well as its current protocols/procedures and institutional framework - to supplement the FEWS in Sudan;
C. Training system operators and enhancing the capacities of key stakeholders of the FEWS to improve and benefit the country's disaster management framework.

Purpose of the workshop

The workshop will be chaired and organized by the Nile Water Department with support by the Technical Assistance Implementer (UNEP-DHI). The purpose of the Inception Workshop is to

A. understand stakeholders' expectations;
B. analyze requirements of the enhanced FEWS;
C. identify synergies with ongoing developments of the EN-FEWS;
D. determine key actions to improve the FEWS accordingly;
E. outline the implementation and operationalization of the FEWS;
F. align stakeholders' expectations with the planned implementation of the FEWS.

Participants

- National Designated Entity (NDE): Higher Council for Environment and Natural Resources Climate Change Directorate, Khartoum, Sudan
- Project Proponent: Nile Water Department, Ministry of Irrigation and Water Resources, Sudan
- Technical Assistance Implementer: UNEP – DHI
- Stakeholders:
    - Sudan Meteorological Agency,
    - Remote Sensing Agency of Sudan,
    - High Council of Civil Defense of Sudan,
    - Ministry of Water and Irrigation of Sudan,
    - Eastern Nile Technical Regional Office (ENTRO),
    - IGAD Climate Prediction and Applications Centre (ICPAC),
    - Academia

Expected outcomes

The expected outcomes are the following:

- Datasets required to enhance the FEWS are identified, including the entities that shall provide the datasets, and the deadlines for receiving the datasets are agreed on.
- Geographic scope of FEWS is delineated.
- Synergies with ongoing developments of the EN-FEWS are clarified.
- Advantages and disadvantages of implementation and deployment options are identified.
- Stakeholders are aware of the project implementation plan.

Workshop agenda

The workshop will take the following form:

- The Nile Water department and the Technical Implementer (UNEP- DHI) will make presentations.
- These presentations will be followed by questions and moderated discussions on key issues.

The proposed agenda is detailed in the table below.

No.	Item	Responsible	Time
1.	Introduction / Opening remarks & introduction of participants	Nile Water Department	9:00 am to 9:15 am
2.	Project background & expectations	Nile Water Department	9:15 am to 9:30 am
3.	Project overview & implementation	UNEP – DHI	9:30 am to 9:45 am
4.	Coffee break		9:45 am to 10:00 am
5.	Moderated discussions		10:00 am to 11:30 am
5.1	*Questions/comments on the presentations*	Moderated by NDE	
5.2	*Geographic scope of extension: Precise delineation of project extents*	Moderated by NDE	
5.3	*Datasets required to enhance the FEWS: Data, providers, timelines*	Moderated by NWD	
5.4	*Enhancement of FEWS with real-time data: e.g. NWPs from Sudan Met Agency, hydro-met data from telemetry servers*	Moderated by NWD	
5.5	*Synergies with ongoing developments of the EN-FEWS: Data collection, analyses, sharing repositories*	Discussion between NDE, Nile Water Department, UNEP-DHI and ENTRO	
5.6	*Implementation & deployment options: Pros & cons of (a) one system Sudan & ENTRO, (b) separate systems, and (c) hybrid solutions*	Moderated by UNEP – DHI	
6.	Break		11:30 am to 11:45 am
7.	Summary of outcomes and conclusion	UNEP – DHI (moderated by NDE)	11:45 am to 12:15 pm
8.	Any other business / Closing remarks	Nile Water Department	12:15 am to 12:30 pm

Minutes of the workshop

1. Introduction / Opening remarks & introduction of participants

- Mohammed A Hassan opened meeting and invited Mr. Saghayroon to officially open the workshop.
- Mr. Saghayroon requested Mohammed Adil Hassan (WR management and planning and modeler, and the FP of the project in Sudan) to proceed with the opening due to connectivity issues.
- The workshop was opened with remarks from Mr. Mohammed Adil Hassan with thank you to the participants despite the challenges with connectivity caused by the ongoing political situation. The workshop will focus on very important flood early warning project in Sudan. He extended the thank you to the partners of the project, the higher council of the environment and natural resources, the academia and all other stakeholders.
- It was noted that the request of the TA originated after the significant floods in 2020, that caused devastating consequences to the people of Sudan. The goal of the project is to develop technology to provide timely and accurate flood warning information to the relevant authorities in Sudan, a technology that should be hosted in Sudan.

2. List of Participants of the Workshop

No.	Name	Institution	Email address
1.	Eng. A Saghayroon	General Director of the Nile Water Affairs, Ministry of Irrigation and Water Resources of Sudan	a.saghayroon@gmail.com
2.	Ms. Huyam Ahmed	Environmental Officer at the Higher Council for Environment and Natural Resources (NDE)	hoyamahmed66@gmail.com
3.	Dr. Ahmed Hassan	Ministry of Irrigation and Water Resources of Sudan	ahmed.10000@yahoo.com
4.	Mr. Mohammed Adil Hassan	Ministry of Irrigation and Water Resources of Sudan	mohammed.wre@gmail.com
5.	Ms. Sharone Molly	Climate Technology Center and Network (CTCN) Industry and Economy Division United Nations Environment Programme (UNEP)	sharone.molly@un.org
6.	Ms. Hawa Dahab	Gender Expert for the project	hawa.dahab@yahoo.com
7.	Ms. Azza Ahmed	Higher Council for Environment and Natural Resources	
8.	Prof. Yilma Seleshi (Flood and drought risk mitigation project coordinator)	Eastern Nile Technical Regional Office (ENTRO)	yseleshi@nilebasin.org

No.	Name	Institution	Email address
9.	Ms. Hanan Rabbah	General Director of the Sudan Meteorological Authority, SMA	hanan_rabbah@hotmail.com
10.	Dr. Igbal Salah	(Hydrologist at ICPAC)	Igbal.Salah@igad.int
11.	Dr. Surafel Mamo (Water resources modelling and knowledge management expert)	Eastern Nile Technical Regional Office (ENTRO)	smamo@nilebasin.org
12.	Mr. Taha Mohammed Dafalla	Hydraulic Research Centre (HRC), Ministry of Irrigation and Water Resources	tahamce2008@gmail.com
13.	Dr. Elhadi	(Assistant Professor of Civil Engineering, Faculty of Engineering, University of Kassala, working with the ENTRO project)	elhadi.adam@yahoo.com
14.	Mr. Ishag Babiker Osman	(Groundwater specialist, senior hydrologist at Kassala)	ishaggwwdi@hotmail.com
15.	Dr. Muna Musnad	Director, UNESCO Chair in Water Resources-OIU, Sudan.	munamusnad72@gmail.com
16.	Hazim Surag		hazimsu@hotmail.com
17.	Dr. Mekuria Beyene	UNEP-DHI	mebe@dhigroup.com
18.	Ms. Maija Bertule	UNEP-DHI	mabe@dhigroup.com
19.	Dr. Okechukwu Amogu	UNEP-DHI	okam@dhigroup.com

3. Project background & expectations

- Mr. Mohammed A Hassan started the presentation on the project background and expectations of the project. (PPT to be shared with the participants).
- Mr. Mohammed A Hassan noted that the project is to last 18 months, with the 250k USD funding granted from the CTCN, with technical assistance provided from UNEP-DHI
- The partners on the project are the NDE (Climate Change Directorate, Higher Council for Environment and Natural Resources)
- The project proponent is the General Administration of Nile Water Affairs at the Ministry of Water and Irrigation of Sudan
- Mr. Mohammed A Hassan walked the participants through the technical assistance submission history and the key questions that were asked during the TA assistance submission process (the problem, ongoing activities to address the problem and main barriers).
- Climate change problems faced by Sudan were briefly introduced to the meeting participants. The presentation noted that Sudan is very prone to flood disasters, and that climate change in Sudan is manifesting itself through the increased frequency of flood disasters. The frequency of floods has increased steadily. In the last decade, floods have occurred almost annually.
- The annual maximum water levels and flood level records show increase and also show that the floods generally also last longer than before – thus increase is seen not only in the frequency but also the intensity of the floods. The floods are being experienced for almost a month each year.

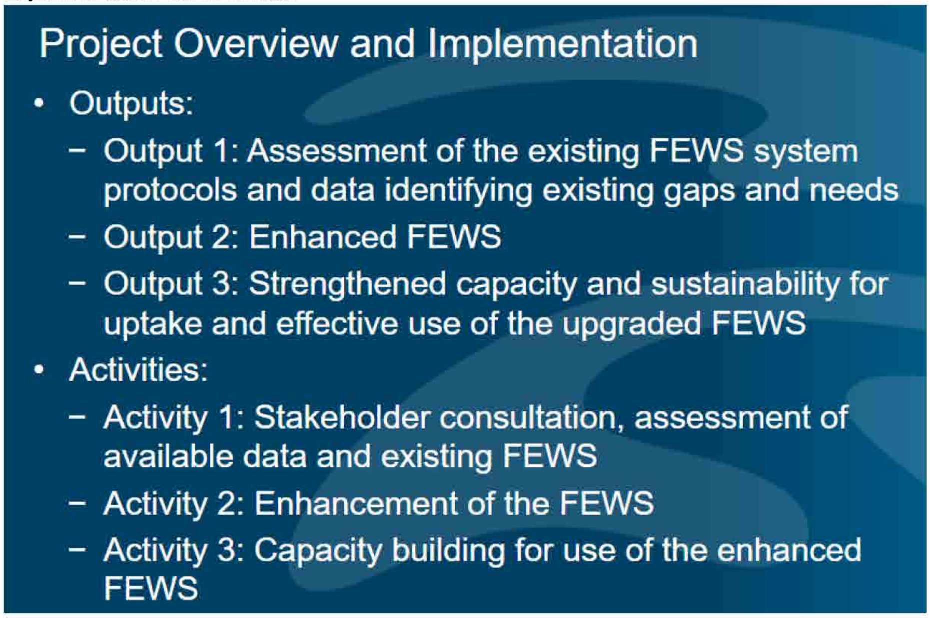
- The presentation noted that the year 2020 was a special year (the reason for submitting the request) when the Blue Nile reached the highest record in 100 years, with 1.16m above the flood levels. In Khartoum state, 500km2 of the area was inundated with extensive damage to homes and properties, affecting 100,000 people. The floods caused the government to declare a state of emergency for 3 months.
- This event was one of the main reasons for submitting the TA request to the CTCN.
- Historically the Blue Nile has been main cause of flooding, however recently, flooding has also been increasingly experienced in the White Nile. In 2020 and 2021 the flows in the White Nile also surpassed the records of the last 100 years. The waters were 2 m above the average.
- The presentation also outlined the past and on-going efforts to address these problems in Sudan. It noted the initial development of FEWS Sudan as part of the reconstruction program (1992). The system was operated successfully from 1992 to 1995, whereafter alternative models and rainfall sources were deployed.
- After discontinuation of the system, the FEWS was upgraded to another operating system, using open source as part of ENTROs activities. However, the issue was that the system was not fully operational and required some manual adjustments. The system required enhancements to include increased lead time for the forecast and also needed inclusion of several basins (it only included the Blue Nile).
- The system requires upgrading, both to include the missing basins, but also to inputs, formats and operationalisation. The model should also be fully operational from the gathering of the data to distribution of the data via report. The reliability of the 2010 FEWS system decreased due to the issues noted.
- Other models have also been developed by the Ministry for the daily forecasts during the flood season (e.g. mHM), with excellent performance. The key problem remains the lead time (15 days at borders).
- One of the key efforts from the Ministry has been to upgrade and expand the hydrometric water level station network from ordinary to automatic stations, particularly in the Blue Nile. This has improved flood routing and early warnings significantly as the automatic stations read the water level every 15 minutes with suitable lead time. Request for additional instruments was also made to CTCN, but unfortunately was not possible via CTCN funding. Thus, the focus of the TA is on the FEWS.
- The main barriers and challenges to the technologies to date have been that Sudan remains a developing country presenting some challenges in advancing the flood early warning technologies:
    - Economic challenges
    - History of conflict and tensions, including international sanctions
    - Institutional capacities both at national and subnational levels
    - Lack of data sharing agreements with the other countries of the Nile stream.
- The request specified that assistance should be hosted in Sudan, and the TA requested will help to address these barriers listed.
- The overall objective of the TA will be to support the flood forecasting capabilities of the technical staff and other stakeholders and fostering community engagement in the flood affected areas.

- Dr. Ahmed requested that before proceeding participants are introduced. Round of introductions to all participants was held.

- Hanan Rabbah from SMA inquired if any participants from civil defence are present. Mohammed A Hassan explained that efforts were made to reach out to the civil defence. The civil defence colleagues had notified that they are facing internet connection issues therefore were not able to attend. However, follow up with the colleagues will be made after the inception workshop as civil defence are very important stakeholders in this work.

4. Project overview & implementation

- Dr. Beyene presented the meeting agenda and then the project activities. Dr. Beyene presented project objectives which are as follows:



- Dr. Beyene then proceeded to present the workshop agenda in more detail and proceed to present the project and implementation plan overview.
- Dr. Ahmed Hassan opened the floor for questions and reflections before proceeding with the PPT. No immediate comments or questions were received at this time.
- The presentation outlined the project overview and implementation. Dr. Beyene walked participants through the main components and all activities planned under the project implementation plan. The presentation is to be shared with participants.

After the presentation, the floor was opened to participants for questions and clarifications. Dr. Ahmed Hassan suggested to collect the questions, then take break and return to discussion.

- Comments from Dr. Yilma Seleshi: Raising the issue of synergies with the enhancement of the FEWS but highlighting the time lag between the two projects. The model enhancements in most cases will be of similar nature, and the enhancements to the ENTRO models should be useful to the model enhancement activities in Sudan and vice versa, given the regional nature of the projects. Highlighting that this might be a very good opportunity for Sudan to review where the gaps are. The ENTRO project will focus primarily on the Blue Nile (not covering all tributaries). Thus, there may be very good synergies with the Sudan TA FEWS enhancement activities. ENTRO project are ready to contribute to the Sudan TA project in any way and engage with the stakeholders.

- Question from Hannan Rabbah (SMA): question relating to the first presentation, regarding the stations and the server (server for each station or a separate server referred to?). Mohammed A. Hassan responded, "the Server is the location to accommodate the measurements of all the stations, so that data can be stored in the same place, and later retrieved". Thus, the server mentioned in the initial presentation was primarily for the data storage from the automatic stations.

- Question from Dr. Muna Musnad: availability of the data in the current situation in Sudan. There are some damages in the main centre in Khartoum where data are likely stored – are data available or do we need to look for other ways to get the data and combine them with other sources? Mohammed A Hassan replied that some data are available, but most data are outside of Khartoum (server is located outside of Khartoum), therefore expect to be able to retrieve the data at any time. The details pertaining to data will be further discussed in the afternoon session. It is also proposed that it is discussed with the UNEP-DHI team on what to do if data are not available in some instances (to identify alternatives).

--Following initial questions, Dr. Beyene shared the discussion questions before continuing to the coffee break.

5. *Coffee break 15 minutes*

6. Moderated discussion

The discussion focused on questions as outlined below:

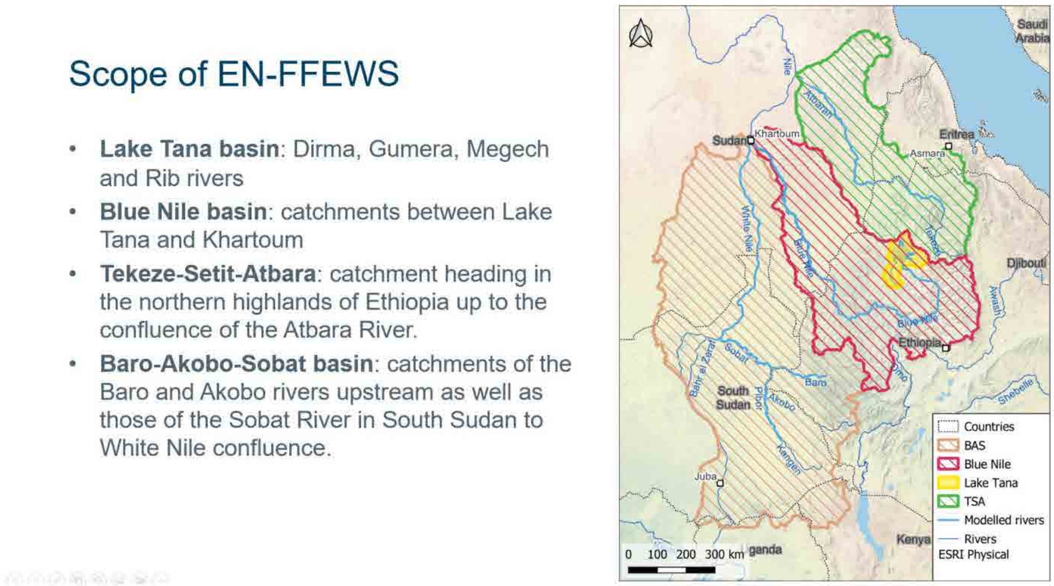
- Questions/comments on the presentations
- Geographic scope of extension: Precise delineation of project extents
- Datasets required to enhance the FEWS: Data, providers, timelines
- Enhancement of FEWS with real-time data: e.g. NWPs from Sudan Met Agency, hydro-met data from telemetry servers
- Synergies with ongoing developments of the EN-FEWS: Data collection, analyses, sharing repositories
- Implementation & deployment options: Pros & cons of (a) one system Sudan & ENTRO, (b) separate systems, and (c) hybrid solutions

7. Break

Participants reconvened after the break and proceeded with the moderated discussions.

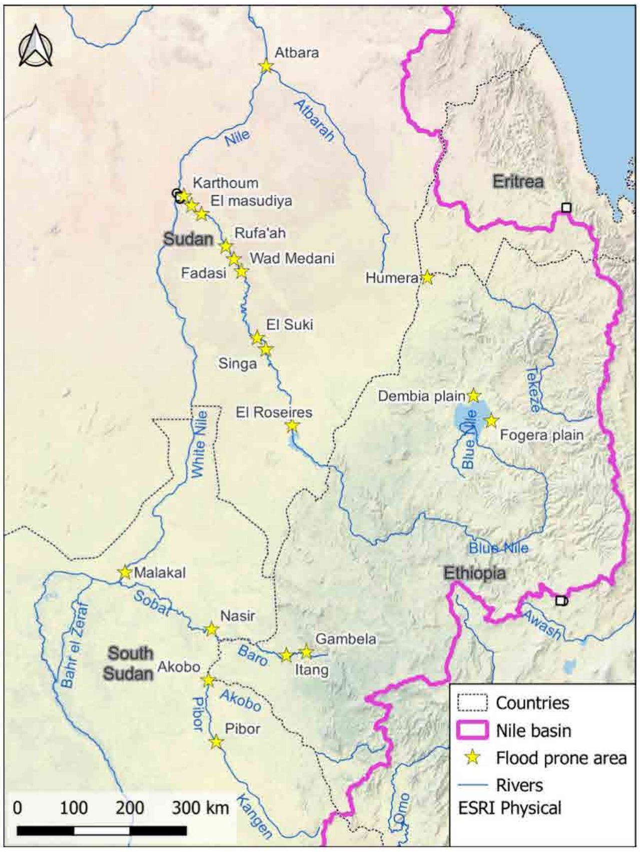
Geographic scope of extension: Precise delineation of project extents

To kick off the discussion session, Dr. Beyene shared a short presentation on the coverage of the ENTRO FEWS:

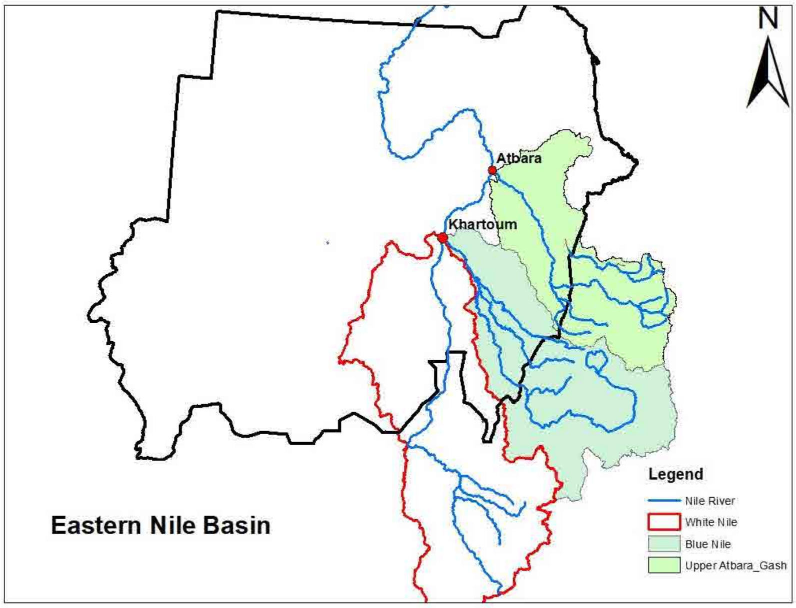


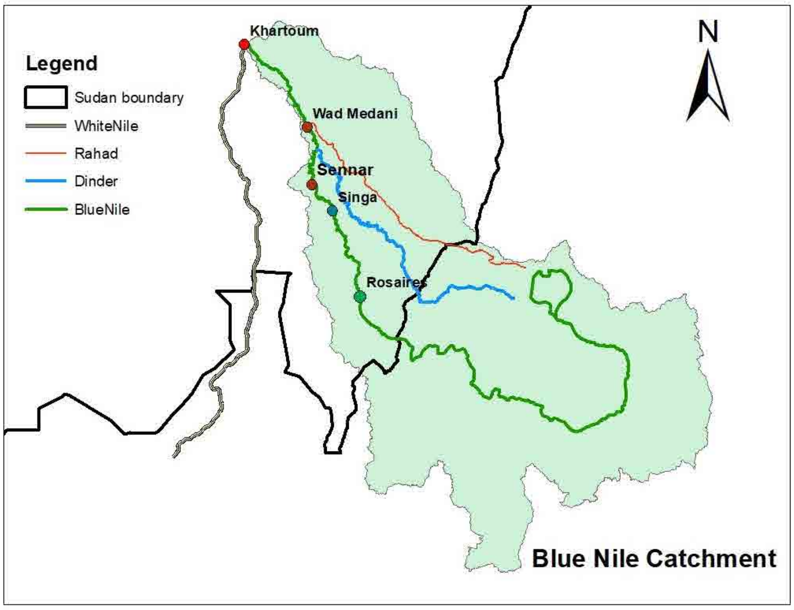
The potential hotspots were also identified (settlements most prone to flooding):

8

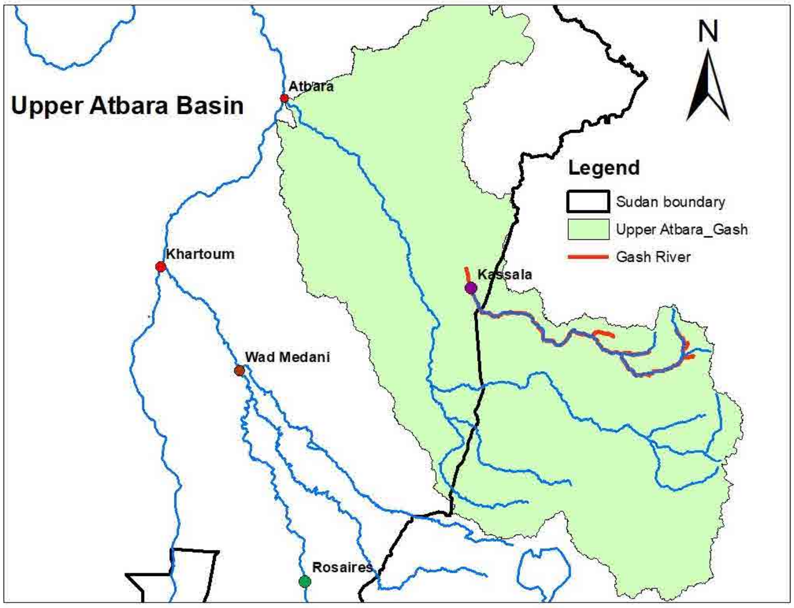


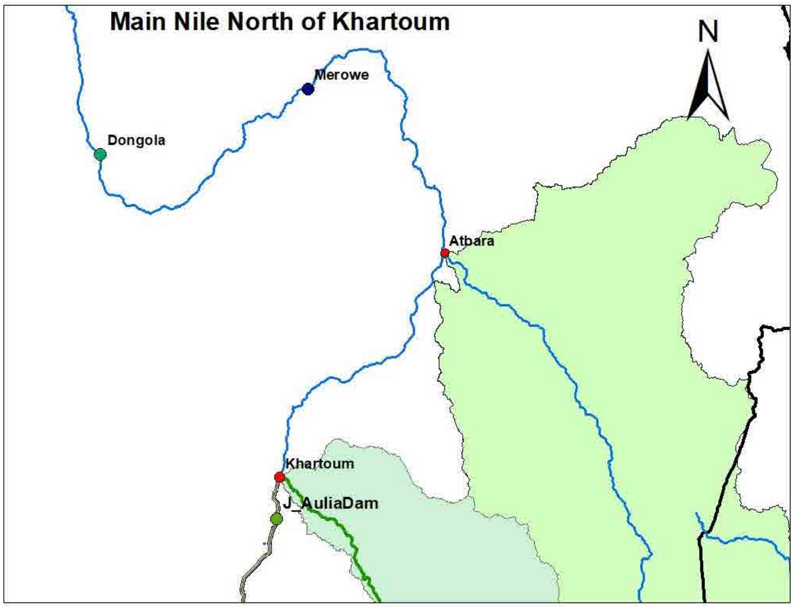
The presentation then proceeded to identify the rivers most relevant for the catchment modelling in Sudan (relevant for the flood FEWS in Sudan).


N
Atbara
Khartoum
Legend
Nile River
White Nile
Blue Nile
Upper Atbara_Gash
Eastern Nile Basin


Legend
Sudan boundary
WhiteNile
Rahad
Dinder
BlueNile
Khartoum
Wad Medani
Sennar
Singa
Rosaires
N
Blue Nile Catchment

10


Upper Atbara Basin
N
Legend
Sudan boundary
Upper Atbara_Gash
Gash River
Atbara
Khartoum
Kassala
Wad Medani
Rosaires


Main Nile North of Khartoum
N
Merowe
Dongola
Atbara
Khartoum
J_AuliaDam

11

The discussion started with discussion on the geographical limits of the existing FEWS and on which basins should be included in the FEWS geographic scope.

- Mohammed A Hassan: We cannot separate the Blue Nile from Dinder and Rahad (they are part of the Blue Nile). However when it comes to the early warning system, it may be decided later to include the reach between Khartoum and Dongola, because there is significant population residing in these areas that could greatly benefit from the FEWS. Suggestion is to include these basins in the FEWS but discuss later on how to best deal with these in terms of early warning.

- Dr. Muna Musnad: agree on the point above. The reach between Atbara and Dongola has to be included in the FEWS, as we will need to include this in the future systems, also in relation to the Merowe dam operation.

- Dr. Igbal Salah: It is better to represent the system based on the hydrological subbasins and basins and hydrometric stations, to reflect the natural flows. This would be better for the system representation.

- Dr. Beyene provided clarification on the way that FEWS systems work. The nodes (e.g. sub-basins' flow outlets) will be defined based on where the critical flood prone reaches in the rivers are. The nodes will have to be selected and once the critical location nodes have been selected, the model will be enhanced with the relevant infrastructure that influences the flows (e.g. reservoirs and significant diversions/abstractions). The resulting flows are then modelled into water levels with hydrodynamic models.

- Ishag Babiker: Very important to include the area of Khartoum to Dongola, as there are many people living in these areas. There are data available for the dam and Merowe which can feed into the model. Regarding the Dinder and Rahad, these are already included in the Blue Nile basin, so may not be needed to make separate models for these.

- Mohammed A Hassan summarized the outcomes of comments: most comments confirm that the reaches from Khartoum to Dongola should be included in the modelling activities. But also, to include them in all other early warning activities, including dissemination.

- Dr. Ahmed: is it possible to include these areas already now, or is this for the next stages? Mekuria clarified that we should include these already in this project. We may need to make assumptions on how the infrastructure is operated to be verified by the national stakeholders.

Clarification: the question is not about the possibility of modelling these basins, it is about how important it would be to include these in the FEWS. Based on previous comments, it is confirmed that it IS important to include these areas in the FEWS due to the populations living along the respective flood prone river reaches.

Dr. Beyene confirmed that the following river reaches should be included in the flood forecast system:

- Atbara River: from Atbara Town to the Upper Atbara and Setit Dam Complex (twin dam complex Rumela Dam & Burdana Dam)
- Main Nile River: from Dongola to Khartoum
- Blue Nile River: from Khartoum to Roseires
- Dinder River: from the river mouth as far upstream as necessary and possible
- Rahad River: from the river mouth as far upstream as necessary and possible

- Comment from Huyam (NDE): suggests that the areas selected for the modelling should be selected based on accessibility (e.g. Dongola to Khartoum is very long).

- Clarification from Mohammed A Hassan: clarifying that selection of areas does not include any physical travel, this is purely numerical/desktop activity. So would suggest that these areas are included (as no travel is required).

No further comments on the geographic reach of the FEWS were received.

Datasets required to enhance the FEWS: Data, providers, timelines.

Datasets required to enhance the FEWS: Data, providers, timelines

Expected outcome : Clear vision of required data, available data, providers and timelines for data to be provided, alternative data

Guiding questions

- Required data for the model?
- Available data?
  - Data / Providers?
  - Timelines?
- Alternative datasets?

The key data required include:

Data type	Accuracy	Specifications	Source
PHYSICAL DATA			
River cross sections	Every 5 km or closer	Covering all possible water levels along the river, where flood forecasting is planned	MoIWR
Rating curves and associated discharge measurements		Including background data on validity etc.	MoIWR
Structure dimensions		Reservoirs, weir, bridges etc.	MoIWR
Operational rules for reservoirs			MoIWR
Geospatial (vector, raster)			
Rainfall stations		point layer	SMA, MoIWR
River stations		point layer	MoIWR
Reservoirs		point layer	MoIWR
Digital elevation model	30m or better	Hydrologically corrected if available	global – UNEP/DHI local – through MoIWR
Land use			global – UNEP/DHI local – through MoIWR

- Mohammed A Hassan: invited colleagues from ICPAC to comment on what data may be available from their activities and extended this invitation to ENTRO as well and how can these be best included in the model to enhance the system and/or increase the lead time of the forecast. Suggestion to discuss this and then deep-dive on the local data (especially the local data for calibration and validation).

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- Dr. Igbal Salah (ICPAC): ICPAC currently produce weekly forecasts, in the coming months the forecasts will be daily. The lead time of the forecast is 1 week. The forecast runs every week for the next week (hourly rainfall). In the coming months, the plan is to run it daily (for the Horn of Africa). ICPAC also have a forecasting system (also a model using Mike Hydro software), including more than 6000 subbasins, including forecasts for the next 15 days. The outputs are made for about 300 selected locations that are key locations in the countries.

- Mohammed A Hassan: clarification question on the reliability of the results, calibration and validation of the system (are the results promising and reliable for the next 15 days).

- Dr. Igbal Salah: For the Mike model, it is already calibrated for 6 zones. This includes historic data. They do miss information from dams and other structures. So far, the outputs are good, even though they are in the testing mode.[1]

- Dr. Ahmed Hassan: What would be the procedure to retrieve the data?

- Dr. Igbal Salah: The portal is open, and the link has already been shared with the ministry (the forecast system portal is eahydrowatch.icpac.net).

- Dr. Beyene: this is great opportunity not only for this project but also for the enhancement of the ENTRO model (which also uses WRF model like ICPAC). The characterizations of the catchments could be very useful, including using the models developed (provided that institutional arrangements are in place).

- Surafel Mamo (ENTRO): ENTRO has some key resources which may support enhancement of the Sudan FEWS. This includes WRF. Time resolution is hourly data, including whole Eastern Nile system, covering 3 countries. Resolution is 18 km for the entire system, especially for the flood prone areas, where the resolution is 6 km. Regarding the river cross sectional profiles, ENTRO project's Work package 1 which relies on data collection on the ground, including survey of the river cross section profiles in different flood prone areas which may be useful complement to the existing data they already have. Clarification: the measured data are already available on hand (cross sectional profile measurements have been produced by a consultant – may miss some areas due to security issues, which is expected to be finalizedby the end of December 2023). Most are already collected and on-hand. It would be good to exchange some of these data not only for the national system enhancement but also for the enhancement of the regional system done by ENTRO. Highlighting very strong synergies for the region as well, including sharing with ICPAC. Happy to connect for more information exchange later as needed. All data can be made available via mutual collaboration, as Sudan is also part of the ENTRO.

- Hannan Rabbah (SMA): SMA have WRF forecast for rainfall and numerical weather predictions. For WRF have difficulties to reach the servers in the headquarters and hope to be able to reactivate the servers soon. SMA will do its best to make these data available for the project. For the historical rainfall data, there should be no difficulties to reach the data within the next days or whenever the system needs the data. SMA will be ready to

[1] Clarification by Dr. Igbal Salah by email 1/11/2023: The Model that is operation in ICPAC is GeoSFM forced with IMERG/GEFS and it does not consider water regulation infrastructure. The Mike model for the Nile basin is still under development/calibration. The total sub basins for the whole of Greater Horn of Africa is 4300 while the Nile basin has 1619 sub catchments.

share the data. SMA also collaborates with ICPAC, where the subregional forecast comes from. SMA is ready to share all available data to them when needed.

- Dr. Beyene – summarizing previous discussions:

    - WRF is the numerical weather prediction model used by most, and the necessary intra-institutional arrangements are there to make exchange

    - The ICPAC subregional models - weather forecast, hydrological and hydraulic - can be used, where there also seems to be institutional arrangements in place for sharing the model

    - Historical rainfall data can be retrieved to calibrate and validate the system.

- Mohammed A Hassan: question about interfacing to third-party products in the system. There may be some risks with accessibility issues – they may be accessible now, but the access may be cease later. E.g. server down, technical issues, etc. Is this a concern and how will these risks be addressed in the FEWS?

- Dr. Beyene: In ICPAC the added value could be the hydrological models which would be used once to validate and ameliorate the hydrological models. On the ENTRO FEWS, to be discussed in the last session - how to make arrangements how both systems can run in parallel (independently) in a synergized way. When it comes to WRF (the numerical weather prediction model) – there are ways to develop hierarchical accesses to create access to alternatives (e.g. if ENTRO should fail or not be operational, then access the Sudanese WRF or vice versa).

- Mohammed A Hassan: clarifying that more people from the ministry were scheduled to attend, but many have been affected by connectivity issues. All essential data for calibration and validation, especially the data from the borders, will be provided. On flows and water levels in the rivers, data for calibration and validation (e.g. inflow, water level etc) will be provided. Regarding the cross-sections, the ministry is missing some cross section data so the gaps will need to be filled. The ministry does not have cross section data for some of the new areas. From Khartoum to Dongola, to investigate if the cross-section data are there (even if older data). But he would welcome data to fill the gaps from ENTRO. The incorporation of the dam operations, most data on rule curves should be available. ENTRO may even have copies of this. Suggest to first incorporate the rule curves available on the outset. Then suggest to deeper dive at looking at these during the enhancement process.

- Dr. Beyene: Satellite products could be used to fill some gaps of cross-sections. Some challenges may exist in the Dinder and Rahad catchments, due to resolutions. Here potentially we can investigate some high-resolution satellite products to produce these cross-sections.

- Mohammed A Hassan: concern about model openness. Need to make sure that the model is not a black box and is open to further improvements and adjustments. E.g. if new data on cross sections should become available in time, then these data can be included in the system in time by the Sudanese (also beyond the lifetime of the projects).

- Dr. Beyene: confirmed that system will be accessible for any users with the access rights, so technically this will be possible. Clarifying that the institutional questions need to be addressed – in the capacity development stage – need to ensure that the staff to work with these systems are trained to be able to use and enhance the system. E.g. some modelers will need to be trained on the use of the system. Technically it will not be an issue, rather the concern may be the capacity of the staff to fully adjust the model system when necessary.

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- Hannan Rabbah (SMA): what will be the output form of the warning produced (SMS, bulletin, other?)

- Dr. Beyene: when certain thresholds are exceeded, there will be an automatic dissemination of alerts (3 channels: emails, whatsapp, sms). This will be done to each forecast location, where there is critical infrastructure. Thresholds will usually be defined by statistics. The system moderator/operator will get an alert. The moderator will review and approve the alert. Languages can be adapted. The alerts will NOT recommend actions, they will only provide information on the forecasted situation. The thresholds will be determined together with the relevant national institutions, as will the key locations.

- Ishag Babiker: Do we have risk assessment maps, and if not, is there a plan to make a risk assessment within the project.

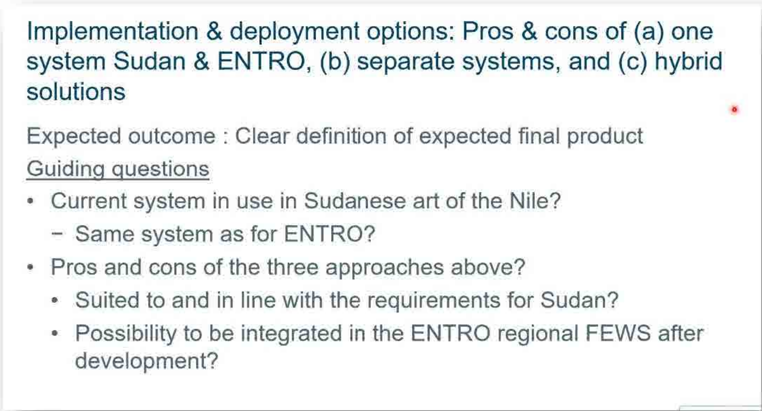
Mekuria: Flood risk maps are not in the scope of this project.

- Eng. Saghayroon: Concerning the data availability for calibration, the ministry is ready to share the data (except the data on water consumption/abstraction). Wanted to raise a point on the historical data from SMA – some of the catchments are outside of Sudan, so need to take note of the calculation of the runoff data from the upper catchments outside of Sudan. Regarding the cross-sections – will do best to provide the data they have. Currently the head office is not accessible, so some data may be inaccessible. However, there is another server outside of Khartoum and some backup.

After concluding the discussion on the data availability, discussion was open on the synergies with the ENTRO FEWS enhancement project, and implementation and deployment options.

Synergies with ongoing developments of the EN-FEWS: Data collection, analyses, sharing repositories / Implementation & deployment options: Pros & cons of (a) one system Sudan & ENTRO, (b) separate systems, and (c) hybrid solutions

- Dr. Beyene explained the different deployment options of the system.



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- Mohammed A Hassan: The intention of collaboration between the systems is there. Willingness to exchange the data with ENTRO and ICPAC is also there. If possible, would suggest having this discussion as a separate session. Suggest developing the framework for the system and then take the further discussion later on how it should be hosted/operated. In the next stages, the further cooperation and communication on the exact setup of the platforms should come later in the course of the project.

- Surafel Mamo (ENTRO): Agrees with the comment made. The key point at this stage would be to ensure collaboration between the institutions, which has been done. For the future, suggests that both systems should be technically stand alone, but set up in a way that they can exchange information. This would mean sharing of the data for enhancement of the forecasting products for both systems. Whether the forecasting products and services should be merged or not, this requires more detailed discussion which would be better to be had later on. This would require more detailed understanding of both of the systems before deciding this.

The floor was opened for any questions or comments from the participants on the matter.

- Dr. Ahmed Hassan: Suggest having a dedicated discussion and decision making on this (decisions need to be made at higher level both in ENTRO and the Ministries) in the future.

- Dr. Igbal Salah: no further comments, happy to be part of further collaboration.

- Dr. Muna Musnad: Concern is about the funding and sustainability of the system. For the success of the FEWS, there will need to be coordination at a regional level (strong coordination between national stakeholders and also international stakeholders).

- Mohammed A Hassan: clarifying that one of the goals of the TA is to engage and coordinate with the stakeholders, so will try to ensure engagement of all national stakeholders in the project, but also upgrade this engagement regionally with the relevant institutions.

No further comments received and agreed to continue on this discussion via dedicated meetings.

8. Summary of outcomes and conclusion

Dr. Beyene summarized outcomes of the moderated discussions:

- It will be important to reach out to the real stakeholders. Dissemination will be to representatives of selected communities. The process of dissemination of the system outputs will have to be moderated by the moderator in the ministry.

- Geographic scope agreed will be:

- Atbara River: from Atbara Town to the Upper Atbara and Setit Dam Complex (twin dam complex Rumela Dam & Burdana Dam)
- Main Nile River: from Dongola to Khartoum
- Blue Nile River: from Khartoum to Roseires
- Dinder River: from the river mouth as far upstream as necessary and possible
- Rahad River: from the river mouth as far upstream as necessary and possible

- Datasets required: commitments to provide data received from SMA, ENTRO and ICPAC. Data on the ground (including historical): will be provided by the Ministry. Cross section data will be provided by the Ministry, ENTRO and gaps will be filled using earth observation data processing. ICPAC will provide hydrological model for the region, institutional arrangements are in place to provide insights on those models.

- Separate technical session to be arranged to discuss and make decisions on the technical deployment of the system.

9. Agreed Data Sharing Plan for the Project

All datasets required for the project should be available to the TA by end of December 2023.

#	Datasets / Data Type	Data Provider	Remarks & Notes
1	List of hydrometeorological stations – rainfall, river flow, water level	MoIWR	This activity is to be carried out as soon as possible because this is key for setting up, configuring and calibrating the models.
2	Historical rainfall timeseries at selected weather stations	SMA	The selection of the relevant stations will be driven by the outcome of #1
3	SMA's rainfall forecasts (NWP)	SMA	Procedures need to be established that SMA can upload daily rainfall forecasts to the FEWS that is to be developed – this should be in place before May 2024
4	Historical timeseries of flows and water levels at selected river gauging stations – including rating curves	MoIWR	The selection of the relevant stations will be driven by the outcome of #1
5	All datasets and models used in the upgraded EN-FEWS	ENTRO	
6	ENTRO's rainfall forecast WRF	ENTRO	Procedures need to be established that WRF used in the EN-FEWS can be accessed from the FEWS of this project - this should be in place before May 2024
7	Models used in ICPAC's forecast system – rainfall runoff & hydraulic (where available)	ICPAC	ICPAC's models will be used to validate the FEWS models. Therefore, this activity should be given high priority.

10. Closing remarks

Mohammed A Hassan closed the workshop.

Appendix C Gender-based participation report

Gender Based Participation Report

Inception Workshop

Introduction:

The Nile Water Department with support from the Technical Assistance Implementer (UNEP-DHI) organized an inception workshop for the Strengthening the community-based flood and drought preparedness and early warning system in Sudan, Updating and improving existing hydrologic and hydraulic models and configuring a Flood Early Warning System (FEWS) in Sudan on the 24 October 2023 virtually.

A total of 19 participants, 8 females and 11 male (of which 42% were females and 58% Males) attended the workshop virtually, including people from Higher Council for Environment and Natural Resources Climate Change Directorate, Nile Water Department, Ministry of Irrigation and Water Resources, Technical Assistance Implementer UNEP – DHI in addition to stakeholders including Sudan Meteorological Agency, Remote Sensing Agency of Sudan, High Council of Civil Defense of Sudan, Ministry of Water and Irrigation of Sudan, Eastern Nile Technical Regional Office (ENTRO).IGAD Climate Prediction and Applications Centre and Academia. The workshop was facilitated by the Nile Water Department and (UNEP-DHI).

The inception workshop was a great opportunity for stakeholders to deepen their understanding of the overall project and share information about the project, exchange feedback despite the challenge of network connectivity due to the political instability and war in the Sudan.

Objectives of the inception workshop:

- Understand stakeholders' expectations.
- Analyze requirements of the enhanced FEWS.
- Identify synergies with ongoing developments of the EN-FEWS.
- Determine key actions to improve the FEWS accordingly.
- Outline the implementation and operationalization of the FEWS.
- Align stakeholders' expectations with the planned implementation of the FEWS.

Expected outcomes:

- Datasets required to enhance the FEWS are identified, including the entities that shall provide the datasets, and the deadlines for receiving the datasets are agreed on.
- Geographic scope of FEWS is delineated.
- Synergies with ongoing developments of the EN-FEWS are clarified.
- Advantages and disadvantages of implementation and deployment options are identified.
- Stakeholders are aware of the project implementation plan.

Project background and expectation:

Sudan during the recent flood in 2020 the Nile reached its highest water level in 100 years, by more than 60 centimeters, and inflicted devastating damage and marked the country's worst event in 30 years. According to the National Council for Civil Defense in Sudan, at least 121 people died, 54 were wounded, more than 98,000 houses collapsed, and more than 97,000 agricultural acres and numerous livestock were lost, Moreover, many buildings and facilities were adversely affected.

Of the various natural hazards in terms of economic and social consequences, flood disasters are perhaps the most prevalent cause of death and destruction in society Floods are responsible for more than 30% of all-natural hazards in the last century,

Flood Early Warning System must reach end users as well as meet the different needs of women and men equally in order to be effective. It is imperative to consider the unique barriers women and marginalized groups face in disasters and to build community resilience to disasters, which can save lives and livelihoods.

The floods can be devastating to a large percentage of households living along the Nile mainstream or tributaries of Sudan's major cities, the population in the Nile River system is estimated at 31 million. Although the population at risk of flood is unknown, many of major cities of Sudan (e.g., Khartoum, Wad Madeni, Singa, Rabak, and Ad Damar) are located along the mainstream or tributaries of the Nile, and the combined population of these cities alone amounts to more than 10 million, many of which suffered severely from the flood disasters in the last decades.

CTCN assistance aims to enhance the knowledge on flood disaster management for vulnerable communities by engaging with FEWS in flood-affected areas. Additionally, it seeks to formulate inclusive policies that promote equal participation and awareness among both men and women due to the integration of gender issues into FEWS is crucial, as it fosters the active involvement and understanding of both genders.

The Nile Water Department under the Ministry of Irrigation and Water Resources will ensure that women and men participate equitably in decision-making related to climate technology implementation as well as benefit equitably from technical assistance and project-related training to ensure that flood EWS are gender sensitive, responsive, and effective.

Gender analysis:

A gender sensitive FEWS ensures disaster preparedness, response and contingency planning, and proactively considers gender, making some adaptations to respond to the specific needs concerns, and capabilities of marginalized gender groups. Involve women in all aspects of FEWS in addition to ensuring gender balance in the staffing of agencies implementing disaster management and FEWS to improve the gender sensitivity and responsiveness and Strengthen the capacity of communities for FEWS.

To ensure the sustainability of the FEWS, it is crucial to consistently enhance the capacity of communities, with a specific focus on engaging women in risk knowledge, monitoring and warning, dissemination and communication, and response capacity.

For an effective natural hazards early warning system (EWS), it is crucial to have a strong technical and scientific foundation, as well as a focus on those who are at risk. A people-centered flood EWS has demonstrated greater success in conveying risk messages and safeguarding lives during times of crisis.

the key Gender aspect of the inception workshop:

- An efficient EWS system depends on precise predictions, prompt dissemination, and responsive measures in flood-prone regions, to enhance the effectiveness of early warning systems, it is imperative to develop gender-inclusive techniques and approaches for disseminating and receiving alerts, and enhancing the response capacity of both genders

- It is crucial to guarantee that the materials utilized in capacity building programmes and technology for FEWS are tailored to meet the requirements of every community member and promote the involvement of both genders in the decision-making process.
- To enhance the gender sensitivity and responsiveness of FEWS, it is crucial to ensure a gender balance in the staffing of Partners involved in implementing disaster management and FEWS.
- It is important to train the stakeholders to acquire the relevant skills to enable them to advocate for gender inclusion in the use of FEWS to broaden participants' knowledge on flood risk management and associated issues to gender
- To ensure the sustainability of the FEWS, it is crucial to enhance the capacity of the targeted communities, with a specific focus on involving women in risk knowledge, monitoring and warning, dissemination and communication, and response capacity.
- It is crucial to gather both quantitative and qualitative data on women and girls in the target communities. The data collection can be utilized to improve the equitable participation, access, understanding, and response between men and women for effective early warnings.
- It is crucial to acknowledge the significance of taking into account the gendered effects on vulnerability, participation, dissemination, response, power, and decision making, the significance of these factors may differ depending on the specific context and are influenced by pre-existing gender norms, gendered systems, and gendered power dynamics.
- It will be important to reach out to traditional authorities and local community leaders to know the power relation, land use and gender disparities in the target communities so that the entire community benefits equally from the FEWS technology.

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List of Participant

#	Name	Institution	Gender
1.	Eng. A Saghayroon	General Director of the Nile Water Affairs, Ministry of Irrigation and Water Resources of Sudan	Male
2.	Ms. Huyam Ahmed	Environmental Officer at the Higher Council for Environment and Natural Resources (NDE)	Female
3.	Dr. Ahmed Hassan	NDE	Male
4.	Mr. Mohammed Adil Hassan	Ministry of Irrigation and Water Resources of Sudan	Male
5.	Ms. Sharone Molly	Climate Technology Center and Network (CTCN) Industry and Economy Division United Nations Environment Programme (UNEP)	Female
6.	Ms. Hawa Dahab	Gender Expert for the project	Female
7.	Ms. Azza Ahmed	Higher Council for Environment and Natural Resources	Female
8.	Prof. Yilma Seleshi (Flood and drought risk mitigation project coordinator)	Eastern Nile Technical Regional Office (ENTRO	Male
9.	Ms. Hanan Rabbah	General Director of the Sudan Meteorological Authority, SMA	Female
10.	Dr. Igbal Salah	(Hydrologist at ICPAC)	Female
11.	Dr. Surafel Mamo	(Water resources modelling and knowledge management expert) Eastern Nile Technical Regional Office (ENTRO	Male
12.	Mr. Taha Mohammed Dafalla	Hydraulic Research Centre (HRC), Ministry of Irrigation and Water Resources	Male

13.	Dr. Elhadi Adam	(Assistant Professor of Civil Engineering, Faculty of Engineering, University of Kassala, working with the ENTRO project)	Male
14.	Mr. Ishag Babiker Osman	(Groundwater specialist, senior hydrologist at Kassala)	Male
15.	Dr. Muna Musnad	Director, UNESCO Chair in Water Resources-OIU, Sudan	Female
16.	Hazim Surag		Male
17.	Dr. Mekuria Beyene	UNEP-DHI	Male
18.	Ms. Maija Bertule	UNEP-DHI	Female
19.	Dr. Okechukwu Amogu	UNEP-DHI	Male