ANNEXES

PROCEEDINGS OF THE 3RD EASTERN NILE FLOOD FORUM

"ENHANCING FLOOD FORECAST AND EARLY WARNING IN EASTERN NILE BASIN"

August 16th -17th, 2018, Addis Ababa, Ethiopia

Eastern Nile Technical Regional Office

3rd AnnualEastern NileFloodForum

Enhancing Flood Forecast and Early Warning in Eastern Nile Basin

Proceedings

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By
TheEastern Nile Technical Regional Office

The opinions and interpretations expressed within are those of the authors and presenters and donot necessarily reflect the views of the Nile Basin Initiative

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LIST OF ABBREVIATIONS

BAS	Baro Akobo Sobat
BCM	Billion Cubic Meters
BN	Blue Nile
CBOs	Community Based Organizations
CDRTs	Community Disaster Response Teams
CIWA	Cooperation in International Waters in Africa
DA	Data assimilation
DEM	Digital Elevation Model
DRM	Disaster Risk Management
EN	Eastern Nile
ENCOM	Eastern Nile Council of Ministers
ENPM	Eastern Nile Planning Model
ENSAP	Eastern Nile Subsidiary Action Programme
ENTRO	Eastern Nile Technical Regional Office
EWS	Early Warning Systems
FAO	Food and Agriculture Organization of the UN
FEWS	Flood Early Warning System
FFEW	Flood Forecasting and Early Warning
FPEW	Flood Preparedness and Early Warning
HEC HMS	Hydrological Engineering Center, Hydrologic Modelling System
HEC RAS	Hydrological Engineering Center, River Analysis System
ICPAC	IGAD Climate Prediction and Application Center
IDA	International Development Assistance
MOL	Minimum Operating Level
MoU	Memorandum of Understanding
MWIE	Ministry of Water, Irrigation and Electricity- Ethiopia
MWRI	Ministry of Water Resources and Irrigation - South Sudan
MWRIE	Ministry of Water Resources, Irrigation and Electricity - Sudan
NBI	Nile Basin Initiative
NGOs	Non-Governmental Organizations
O&M	Operation and Maintenance
ODSS	Operational Decision Support System
PDUS	Primary data user station
SST	Sea Surface Temperature
TAF	Terminal Aerodromes Forecast
TaSBO	Tana Sub Basin organization
WMO	World Meteorological Organization of the UN
WN	White Nile

Forum Opening Session

WELCOMEADDRESS

Mr. Fekahmed Negash

Executive Director, ENTRO

Excellencies, Distinguished Guests, Ladies and Gentlemen: Good Morning

On behalf of the ENTRO, it is my pleasure and honour to welcome you to the 3rd Eastern Nile Flood Forum whose theme is 'Enhancing Flood forecast and Early warning in Eastern Nile Basin'. Floods, as you all well know, do not recognize national boundaries, and management and mitigation of floods can only be accomplished with a strong basin-wide cooperation.

Flood is a blessing due to abundance of water it brings although it causes loss of life and damage to infrastructure. Poor Catchment management in the Eastern Nile has led to increase in flood hazard and impact. There has been significant progress since the last Eastern Nile flood forum. We need to further improve our knowledge in flood management. Flood in the Eastern Nile is a transboundary issue, which is why ENTRO's flood early warning is ENSAP priority project.

We look forward to your collaboration with ENTRO in reducing vulnerability to floods in the region. I wish you a successful deliberation in the forum.

Thank you

OPENINGADDRESS

H.E.

Minister of State, Ministry of Water Resources, Irrigation and Electricity, Ethiopia

Distinguished Guests Ladies and Gentlemen: Good Morning.

I am honoured to deliver an opening statement to the 3rd Eastern Nile Flood Forum on behalf of the honorable Minister of Water Resources, Irrigation and Electricity of the Federal Republic of Ethiopia.It is encouraging to see such a large number of participants from such a variety of countries, regions and backgrounds.

The Forum's declared aims are to raise knowledge in enhancing flood forecast and early warning in Eastern Nile Basin. It is important, as measure to reduce the impact of floods, the Eastern Nile countries need to develop more water storage infrastructure.

I urge the flood forecasting and early warning operators to consider the end users and those affected by flood when designing communication means to issue warning. It is also important to periodically assess the effectiveness flood early warning system. Flash floods are increasing in frequency and need to be considered in the FFEW

Finally, I wish organizers and participants a fruitful and successful 3rd Annual Eastern Nile Flood Forum. Thank you very much

Introducing forum objectives

Mrs Azeb Mersha, ENTRO

Enhancing Flood Forecasting and Early Warning in Eastern Nile

EN Flood Preparedness and Early Warning Project (FPEW)

- 2001, ENCOM requested funding to advance work in the EN flood management;
- 2004, ENCOM decided to fast-track the FPEW project;
- 2006 , ENSAPT decided to phase the implementation of FPEW as Phase I and Phase II;
- The FPEW I grant agreement was signed in 2007and concluded during the period 2007-2010;
- The FPEW II project document finalized in Jan 2007 and distributed to different stakeholders and donors for funding;

FPEW Phase I

- **Component 1**: Regional coordination → Putting in place an institutional mechanism for establishing inter-country coordination
- **Component 2**: Flood forecasting warning & communication system → Aimed at improving flood forecasting institutions and developing a detailed design for EN flood forecasting, warning and communication system
- **Component 3**: Pilot flood preparedness & emergency response → Strengthened flood preparedness and flood mitigation planning at different levels

Phase I focused on non-structural intervention measures and strengthening the capacity of the national forecasting units in flood mitigation planning, flood forecasting and early warning

Phase I focuses on non-structural intervention measures and strengthening the capacity of the national forecasting units in flood mitigation planning, flood forecasting and early warning

- Establishment of the regional flood coordination unit at ENTRO and the National flood forecasting centers in the three EN countries;
- Development of real-time flood forecasting systems for Lake Tana floodplains in Ethiopia and the Blue/Main Nile River System in Sudan;
- Strengthen the Capability of the Nile Forecast Center in Egypt;
- Development of emergency response and preparedness plan for selected pilot communities
- Flood forum
    - 1st Flood Forum, Cairo, Egypt
    - 2nd Flood Forum, Khartoum, Sudan,

Bridging the Gap

Under ENPM:

- Assessment of the Impact of Regulation on the Floodplains of the Blue Nile River Systems in Sudan
- Flood Season Monitoring Activities
- FPEW phase I - Knowledge Base Development
- Web-Based Communication Platform for Flood

Under NCORE: CIWA and CIWA AF1

- EN Seasonal Flood Forecast and Early Warning Activity

Easter Nile FFEW & Seasonal Forecast

Objective

- To Enhance the current FFEW system
    - Flood forum

- Upgrading the existing
- Replicate flood forecast system
- Address Flash flood
- Web base early warning system
- Stakeholder mapping

- To expand the FFEW system other flood prone areas in EN basin
- To support the EN countries by issuing seasonal river flow forecast and its application in reservoir operation and irrigation water use
  - Seasonal river flow Forecast
  - Tools developed using river flow forecast for
  - Operation of dams
  - Irrigation water use
- Capacity Building
  - Capacity building training Workshops
  - Infrastructure

Forum Objective

- To create awareness on issues of Flooding
- To create a platform for information exchange and discuss both national and regional issues of flooding and share successful experience
- To assess the status of flood forecasting activity and the on-going concerns in the basin
- To learn from scientist community on innovative approach for doing more accurate forecasting and effective warning
- To provide networking opportunities to facilitate further collaboration

Participants

- Decision makers
- Representative from
  - Meteorology agencies
  - Water Ministries
  - Disaster managements
  - NGO
  - Sub-basin Authorities
- Donors
- EN universities Professors
- Regional experts
- International experts
- Officials
- Researchers
- Young professionals
- Interns

KEYNOTE SPEECH

Dr.AbdulkarimH. Seid

Deputy Executive Director and Head of Water Resources Department, Nile Basin Initiative, Nile Sec, Entebbe Uganda

Guest of Honor,
ENSAPT members
ENTRO Executive Director
Dear participants of the Eastern Nile flood forum
Ladies and Gentlemen
It is an honor as well as a privilege to me to stand in front of you this morning and share with you my perspectives on the topic of flood forecasting and early warning.
When I was asked to give a keynote on this forum, my memory went back 15 years – to 2004, when I joined ENTRO as the regional coordinator for the then Flood Preparedness and Early Warning (FPEW) project. Looking through the documents from those times, I could find the objectives of the project expected outcomes, which are relevant still today. I recalled, the field visits we made to flood prone communities around lake Tana, such as 'na-bega' locality, where we talked to a farmer family who told us how they cope with floods, such as by building high beds of some 1.5 m high on which they store their belongings for the flood water that enters their huts doesn't reach that level. I still remember the setting in the hut of this farmer family, the pictures I took of this high standing bed, how the family head talked about the floods – the challenges of evacuating his family, his belongings, including his livestock.
Another flood community we visited was in Sudan around sinja if I remember well. Interestingly those interviewed by our team didn't talk much about floods as threats – this is an arid area and floods bring the much needed water to replenish the soil. In contrast, when we visited the department of civil defense in Khartoum, the picture is was what we expected – floods are threats – this is an urban area where floodplains are inhabited and, hence, the river has lost it 'natural' living space and, hence has to exert its pressure on those who have taken away its temporary 'refuge' from the heavily congested river course.
Each community we visited, views floods from different angles – a threat to human lives and livelihood, to largely annual water replenishment process whose side effects must be coped with – in an agricultural community in arid region to seasonal, natural, phenomena to which the human race has to live with.
I brought the above examples to highlight the different settings of each flood prone area and perspectives/viewpoints of the flood prone communities
Furthermore, the causes of floods and, hence the types of forecasts and preparedness measures needed for each geographic area differ and this needs to be taken into account. The real question is how best to tailor the flood forecast and early warning services to the needs of those communities we serve.
As the former flood coordinator, it is gratifying to me to see how regularly ENTRO issues its flood bulletins. This is highly commendable work by ENTRO and I say keep it up. I occasionally open and go through the bulletins – not only the summaries in the emails, which I found informative. However, at times I also wonder how the farmer family I visited in June 2005 in Na-bega wereda would have used this important information or those who interpret the information for him so that he can make life saving decisions whether to evacuate his family, himself and his livestock. I understand the risks of flood early warning business – one false alarm would mean trusts on your forecasts are severely eroded. In spite of this – life is never perfect- I recommend to periodically assess how effective is the early warning information to the end users – if not done already. Such assessments would provide you with critical information needed to make your forecasts useful to the end users.
When I read the concept note for the forum, I was attracted by how the objective of the forum is set, i.e. to provide the forum for water resources experts, managers and decision makers… I very much wished if those who have to cope with flood disasters on daily basis during the high flow

seasons were also included in the objective – not only to share their experiences, but also to understand how water resources experts, managers and decision makers view floods and flood disaster. I hope ENTRO will consider to organize a forum for end users.

According to UN Water, water security also includes 'ensuring protection against water related disasters', such as floods and droughts. In fact, the SDGs have a number of targets that focus on protection/resilience against water/climate related extremes. These include Target 1.5, which is about reducing exposure and vulnerability of the poor to, among others, climate related extreme events; target 11.5, which focuses on reducing, among others, the number of deaths and number of people affected to water related disasters; to name just two.

With increasing population and more and more habitation of floodplains and other low-lying areas, damages due to floods are expected to rise. In all Nile Basin countries, the proportion of the total population that lives in urban areas is projected to increase in the coming decades, which could lead to increased habitation of floodplains and low lying urban areas.

Climate change and associated frequency and severity of extremes is likely to exacerbate the problem. On the other hand, the rapid improvement in computing infrastructure, data acquisition and mapping systems open new opportunities to more precisely forecast flood peaks and their likely areal extents – two vital components of any flood preparedness arrangements. I recently read how mapping drones are used in Dar es Salaam, Tanzania, to map flooded areas in an African urban environment. I hope the EN flood forecasting and early warning endeavors shall integrate more and more advanced technologies to improve its early warning information in quality, areal coverage and usefulness to its end users, i.e. the millions of inhabitants of flood prone areas.

Floods are caused, often, by the flows coming from the mountains. Therefore, to cope with floods, we need to work together with those people in the mountains to reduce flood peaks, such as through catchment treatment, get advance information on rainfall and, hence, impending floods, etc. The need and importance of cross-border cooperation, among others, in flood disaster mitigation and preparedness is demonstrated by what ENTRO has been doing in the Eastern Nile.

Before I conclude, I would like to stress, once again, to make the end users , i.e. the millions of people who live in flood prone areas, and their needs at the center of all the advanced flood forecasting, early warning and communication endeavors.

I thank you for your attention

Session 1: Current FFEWS

Chair: Mr. Thomas Jang Kan Doup

Mr. Surafel Mamo, Mr. Chuol Biel Thoan and Eng. Asma Mohamed-ENTRO

Eastern Nile Flood Preparedness and Early Warning (FPEW)

The Overall Objective of the EN-FPEW is to enhance regional collaboration and improves national capacity in the mitigation, forecasting, early warning, emergency preparedness, and response to floods in the EN basin countries.

The current EN-FPEW has the following main components

- Rainfall Forecast- Eastern Nile Basin
- Lake Tana flood forecasting system (Ethiopia)
- Blue and Main Nile flood forecasting (Ethiopia and Sudan)
- Baro-Akobo-Sobat (BAS) flood forecasting (Ethiopia and South Sudan)
- Flash Flood Inundation Mapping for Wadi Al Arish

Challenges and Commendations

- ❑ Limited Data sharing and collaboration between institutions, ministries and ENTRO is the main challenge in the flood forecast and developing hydrologic models
- ❑ Forecast model results needs to be re-validated, verified using ground data (rainfall, runoff and inundation maps) in order to improve the forecasts
- ❑ In addition, to produce good and more reliable forecast results, model enhancement is required together with the use of real-time data, telemetric systems or remotely sensing images
- ❑ The need of addressing flash flood issues should be as part of configured forecasting models
- ❑ It is highly recommended to address the environmental benefit of flooding in the EN region
- ❑ Upgrading of key flow monitoring stations, topographic surveying
- ❑ Limited assessment on the ground whether the forecast met its ultimate goal or not
- ❑ Lack of Data for Calibration of the Hydrologic Model developed for BAS
- ❑ Lack of detail details Topographic Data for BAS
- ❑ Detail Topographic Survey to be conducted in BAS
- ❑ Upgrading of key stations running now and new stations to be erected near locations where some structures are planned and specially in BAS Rivers Systems
- ❑ Capacity building in Flood Forecasting and Early Warning
- ❑ Extend the catchment modelling to include Tekezi/Atbara basin and Dinder & Rahad basins.

Key points of the Plenary

The WRF model for the existing FFEW system takes about three hours to run and generate results. The ultimate resolution is 6km

Issues to consider in improving the performance is computer specification and internet connection

There is generally 80% agreement between GFT and other hydrodynamic models. The differences observed between HEC-RAS and GFT in Khartoum is due to the difference in the resolution of DEM used.

Take-away messages

- It would be good to have more transboundary collaborative work between the countries particularly in the Blue Nile

- It is important to install and use automatic water level recorders rather than depending on one or two manual readings per day

Session 2: Gaps on the Current Eastern Nile Flood Forecasting and Early Warning System

Chair: Mr. Teshome Atnafe

Dr. Mohammed A Hassan-Consultant

The assessment of the EN-FFEW is given under the following themes

Coverage

- Current FFEW activities does not cover the entire Eastern Nile.
- Models have been developed for upstream of Lake Tana basin, Lower blue Nile & part of Main Nile and Baro-Akobo-Sobat (BAS).

Type of hazard forecasted

- The EN FFEW addresses riverine floods in the stated sub basins but does not address flash floods

Flood Forecasting System

- There is no unified operational flood forecasting system(FFS) for the Eastern Nile Flood Forecast and Early Warning System.
    - Only the Upper Blue Nile (u/s of El diem) has the Delft FEWs as the FFS. The other two sub basins (upstream of Lake Tana and BAS) do not have a FFS.
    - The flood forecasting activities are usually carried out during the rainy season.
- The FFEW system need to be tightly coupled and or automated from data transmission/collection to output/dissemination of results/warnings

Rainfall forecasting

- Currently a WRF model is run for the Eastern Nile with 3 days forecasts.
- Depending on one forecast system alone without any back up or fall back system can mean no forecast is issued when that system fails.

Rainfall Runoff modelling

- Model re-calibration is necessary since calibration was done long ago and in view of recent extreme rainfall events
- Model run on event mode
- Need to use data assimilation where possible

Hydraulic/hydrodynamic modelling

- Different system are currently in use and need to be unified for operational use
    - HEC RAS mainly used for Blue Nile and U/S Lake Tana and USGS GFT used for BAS.
    - Lower Blue Nile uses station to station correlation.
- Post flood event/season verification assessment is not undertaken

Dissemination System

- Currently dissemination is done through reports sent via email and available in the ENTRO website.
- It is thus not interactive and users cannot query and download information for further analysis and possible action.

Capacity Building on O&M of the FFEWS

- Staff (particularly those working on the Delft Fews) were trained on operating the system but not on development.
    - It is thus necessary to build capacity on both system development and operation so that future upgrades and modification can be done by the staff.
    - Training needs to be targeted to the staff who will operate and maintain the system
- There is lack of opportunities for continuous training particularly for the EN countries and ENTRO flood management team

Challenges for an effective Flood Forecasting and Early Warning System

IT and Internet infrastructure

- FFEW operation require downloading and processing of large datasets and the requisite computing facilities and internet which is currently a challenge in the region.
- It is thus necessary to explore other avenues such as cloud computing resources so as to overcome these challenges

Real time data transmission and sharing

- An effective FFEW activity require real time observed rainfall and river water level in order for the forecasters to give accurate information.
- This is still a challenge in the transboundary sub basins of the Eastern Nile and therefore it is important to have better institutional arrangements to share data in real time for key stations.

Stakeholder linkages

- Currently the major stakeholders are;

  Ethiopia
    - Ministry of Water, Irrigation and Electricity including relevant directorates and basin authorities under it.
    - National Disaster Risk Management Commission
    - Water Bureau of Amhara Regional State
    - Universities: Bahir Dar, Addis Ababa and Gambela

  South Sudan
    - Ministry of Water Resources and Irrigation

  Sudan
    - Ministry of Water Resources and Electricity
    - Ministry of Environment
    - Ministry of Defense

  Others: NGOs (Red cross/red crescent, World Bank..
- It is thus import to map out all the stakeholders and get their feedback particularly on the usefulness of the information provided and required improvements
- A questionnaire was distributed and the information targeted was:
    - Category of stakeholder and name
    - Location and area of operation
    - Roles/involvement in flood disaster management if any
    - Ideas on critical stakeholders and institutional arrangement for effective flood early warning in the Eastern Nile

Key points of the Plenary

- Cloud storage and data sharing – needs to be well evaluated and be addressed very early with the data sharing issue of NBI
- To first step FFEW is to have a real data sharing of key data with the member states.
- It is necessary to analyze freely available rainfall forecasts products to see which is more reliable.
- The data provision initiative of the Canadian space agency for Lake Tana flood plain should be revived and expanded to cover the whole of EN
- To improve the forecast it's better to work with national services providers under an agreement.
- Improvement of model skill is important and this needs real time river level data from automatic station which can be integrated into the FFEW system.

Take-away messages

- Data sharing protocols should be taken care of and with cloud computing
- Issues of WRF – we need to tap in other rainfall forecast sources available globally
- If Satellite rainfall data is available it important to carry out bias correction

Session 3: National Experience– Meteorology

Chair: Mr. Teshome Atnafe

Metekia Menza- Ethiopia National Meteorological Agency (NMA)

Met-stations for weather and flood forecasting

- NMA has been installing different class meteorological stations through the country.
- Currently, about 1153 functional meteorological stations are evenly distributed and their data are collected to the head quarter data base system through its 11 meteorological service centers.
    - Synoptic/GTS-17 stations
    - Principal-172 stations
    - Ordinary-546 stations
    - Precipitation (manual)-418 stations
- Currently NMA has more than 200 AWSs.
    - Collect all meteorological elements every 15 minutes

Drawbacks of AWS

- higher cost of the instruments and operation;
- It is not possible to observe all parameters automatically as are done by manual and AWOS for example visibility and cloud coverage and cloud types.
- It depend on network coverage.

Gridded data

- This is a data set obtained by blending surface based meteorological parameters with satellite estimation.
- Reconstructed rainfall and temperature data over land areas on a 0.0375˚ x 0.0375˚ lat/lon grid (about 4 km of resolution).
- The rainfall time series (1981 to 2016) and Temperature (1961 to 2014) were created by combining quality-controlled station observations with satellite rainfall estimates.
- The quality of gridded data with respect to ground data is more than 94%.
- This data set is very important for different research purposes.
- Available at any point in the country.
- Solves the problem of missing/discontinuity of data.

Weather Radar

- NMA has identified five Weather/ meteorological radars to cover the whole country.
- Currently, NMA and Ministry of Water, Irrigation and Energy of Ethiopia purchased a Weather radar (WRM200 Magnetron Weather Radar) from Visalia radar company (Finland) has successfully installed at North Gonder, Shawera, which is C band weather radar.
- It has been functional till the mid of Kiremt season (June-July).
- The first has been installed successfully
- The other two are expected to be installed in the near future

NWP/WRF

- The resolution of WRF output is at 17km grid.
- NMA produces 4 days lead time simulated weather forecast.
- WRF outputs are used for flood and extreme weather conditions.
- NMA has a high processing computer whereby NWP/WRF and other models are used to simulate a large data set.
- It is used for short range weather forecasting
- Its product has been used for flood early warning. Eg. *Awash Basin Authority*

Emmanuel Qurino- South Sudan Meteorological Department

Meteorological Observation Network

- The current monitoring network of SSMD is currently made of five Synoptic station at Juba International Airport, Renk, Malakal, Wau and Raga.
- The SSMD monitoring network was complemented by nine (9) Automatic Weather Stations (AWS) installed by United Nation Food and Agriculture Organization (UNFAO) in 2008 and 2009 in some states

Real time Data collection

- Meteorological Observation are recorded in Monthly Log books at the five (5) synoptic stations and are mainly for day time hours. The synoptic are transmitted by mobile phones .
- South Sudan Meteorological Department is not running any Satellite for Weather Observation therefor we using
- Eumetsat (real-time image).
- Sat24 (real –time image).

Rainfall Forecast

We have three type of forecast

1- Daily Three days Forecast for Radio and TV

2- Seasonal Forecast done through capacity building base on ICPAC (Nairobi, Kenya)

3- 24 hrs forecast (Terminal Aerodrome Forecast (TAF)) for Aviation Service

Global and Regional Models

- South Sudan Meteorological Department , Using regional and global Models for weather forecast verification and they are:
- NWP Models: Regional products (COSMO_00, COSMO_12, WRF_00, WRF_12, UK MET LAM).
- NWP Models: Global Products (Washington (NOAA/NCEP) Products, ECMWF Products and WMO EPS. and TIGGE_GIFS East Africa Products).

Communication for flood early warning

- Communication / dissemination is by :-
- quarterly early warning bulletins
- Press conferences
- Radio & TV
- Email
- Hard copies

Key points of the Plenary

- There is flexibility to share data with other institutions is an issue, it is better for the data to be shared to be online
- Currently there are no real-time meteorological data sharing between countries. This would benefit flood forecasting particularly for downstream stream

Take-away message

- Sharing of WRF and real time data can be initiated with MoU signed between ENTRO and Ethiopian NMA

Session 4: National Experience– Hydrology

Chair: Prof. Seifeldin Hamad Abdalla

Semunesh Golla- Ministry of Water, Irrigation and Electricity, Ethiopia

Experience on Flood management

- Provision of data and information using daily and real time data
  - Collection, Manual , Internet , mobile and direct lines
  - Automatic methods Data transmission telemetry using GPRS, LAN-WAN communication systems (office)

Reservoir water level prediction for water management and flood management

Reservoir water level prediction

- Monitor reservoirs water levels, inflow and releases
- Data used:
  - Historical and seasonal climate data, historical and real time hydrological data, reservoir levels and storage capacities, etc
  - A general water balance equation:$P = Q + E + \triangle S$
- Based on seasons of a year (Kiremt,), prediction reservoirs levels are produced
- Once, the prediction is done, water release and storage determined
- Flood control + hydropower - rainy seasons

Forecasting on upstream of Awash

1. Rain fall runoff forecast and inundation map
2. Real time forecast by using lead time
3. Inflow forecast to the dam

Initiation of IBF System

- IBF is a impact based hazard information to extreme weather events for warnings
- Science
  - compilation of required data sets: Hydro-met, socio-economic, GIS, etc (RBs, NMA, NDRMC)
  - Modelling (simple-excel to complex models) and interpret results
  - Analyze impacts (e.g., flooding)
- Communication:
  - Disseminate the forecast information (users: decision makers, end users)
  - Receive backups information (from the users)
- Local (vulnerability) information
- Partnerships (Govt, Users, NGOs, Met Services)

Relevant stakeholders

- NMA – sources of meteorological data (rainfall, temperature)
- DRMSFF – (During and after floods)
- Basin Authorities – data| information exchanges
- Regional water Buearo – as means of data| information dissemination and feedbacks
- Universities| Research Institutes – capacity building in flood forecasting and monitoring infrastructure (university - industry linkage), etc
- Communities – main data| information users

Flood preparedness

- Community training and awareness - usefulness of flood early warning systems, flood impacts and its consequences and mitigation measures

Structure of Communication

- Federal level – MOWIE, NMA and DRMSFF – (During and after floods)
- Basin Authorities
- Regional DRMSFF up to kebele level structure
- Relevant users, Community kebele level

Means of communication

- Internet
- Mobile,
- high frequency radio
- Sirens

Office equipment

- 7 Photo copier , 5 Fax machine , 8 Scanner , 7 Color printer
- 1 vehicle for region to follow up and support
- 8 motor cycle to project weredas for follow up and support
- 4 motor boats for supervisions, monitoring of flood hazard and vulnerable
- 104 Mobil phones with sim-card distributed to the local community in 4 weredas to facilitate communication among the the community and weredas during flooding
- 1 Dump trucker
- 1 Excavator, Dike construction
- 1 Dredger machine, removal of sediments from lake Tana

Remarks

- Integration of Resources, Knowledge and Skills, Technology and Models| Software are used to address challenges and problems
- Improve the hydro-meteorological data collection and monitoring system – improved decision support system
- Create a linkage between different actors| stakeholders and information users
- Capacity Building

Pagan John Ok - Ministry of Water Resources and Irrigation, South Sudan

Background

- Climate: South Sudan climate is similar to an equatorial or tropical climate , with a rainy and dry season alternating throughout the year. Most rainfall is recorded between the months of April to October.
- The rainfall ranges from more or less than 500 mm in the northern and south eastern parts to about 1,500 mm in the south western and limited eastern parts.

River System

- South Sudan has four (4) main river basins namely: Bahr el-Jebel, Bahr el-Ghazal, River Sobat and White Nile Basin including the Sudd wetland.

Monitoring System

- Hydrological Monitoring:

There are 22 functional stations in South Sudan seven(7) hydrometric stations and fifteen (15) manual stations distributed across the country

- Water level monitoring : Manual and automatic monitoring water level data collection
- Flow measurement: mainly includes monitoring of river flow, monitoring of inflow, outflow and overflow of river.
- Rainfall Monitoring: water level and flow are immediate parameters for measuring the size of flood. Rainfall the major factor that cased flood, measuring rainfall is an important of monitoring flood disasters

Data Management System : In South Sudan MWRI is responsible for the development and management of all water resources, data related to flood monitoring are usually given to government institutions, NGOs, international organization, universities and private sectors, in addition to being used to support internal work of the department

Type of Floods: Different types of flooding can be recognized as listed

- Flash flood: occurs when the amount of rainfall exceeds the infiltration capacity of the ground to absorb it.
- Rivers flood: occurs when the capacity of a watercourse is exceeded
  - The most areas affected by flood are in greater Bahr el-Ghazal Awiel and Lakes, Upper Nile especially Ulong and Bor along the Sobat and River Nile

Coordination and flood forecasting

South Sudan has formed early warning thematic technical working group from different institution led by the ministry of humanitarian affair and disaster management department of early warning and South Sudan Meteorological department, Ministry of Water Resources and Irrigation, Ministry of Agriculture and Food Security the propose is to plan for disasters affected populations such as flood mitigation and drought management, the group published every three months national hazard bulletin and dissemination.

Conclusion

- Improve the capability for flood disaster monitoring that reduce the threat and EWS need to be established
- Poor flood control facilities, and settlement in the flood plains is not accompanied by land use policies, or studies of flood hazard potential.
- Lack of preparedness, maintenance of flood control facilities, and weak hydrological networks.

Mr. Abdalrhman Saghayroon- Ministry of Water Resources, Irrigation and Electricity - DIU, Sudan

Flood Forecast and Management in Sudan

- Vulnerability of Sudan to EN Floods
- Source of the flood hazards
  - Nile Floods (BN, TSA)
  - Flash Floods (Gash-Baraka, local Rainfall)
  - Man-made Floods (development, drainage eff.)
- Flood management
  - Structural methods (Flood Control Struc., Dykes,.)
  - Non-structural methods (FEWS)
  - Combination of Structural and Non-structural

Vulnerability of Sudan to EN Floods

- Altitude difference
- Sudan is a flat lowland draining NB
- High Seasonality of Rainfall and rivers of EN (70% of BN flow occurs during flood period Jul-Sep)
- Low capacity of Sudan Reservoirs
- High sediment concentration (Reservoir kept ah MOL during Flood)
- Most of Sudan Large scale-project are in BN

Nile Flood Forecast

- Sudan FEWS initiated after the 1988 flood disaster, by WB as a component of an emergency flood reconstruction program “to enable more timely warning of the future floods and to provide an operational tool for flood management using modern forecasting techniques and improved data collection.”
- It covers BN, ATB, WN DS Malakal, MN up to Dongola.
- The system relies primly on the satellite imagery to estimate rainfall on daily basis, and a set of mathematical models for runoff estimation and flow routing
- Developed by Delft Hydraulics and finance by the IDA.
- FEWS first become operational in Aug. 1992.

FEWS Components

- Primary data user station (PDUS) receiving and processing of METEOSAT (TIR) on half hourly basis,
- Communication system for water levels real-time transmission
- Computerised flood forecasting system (Models), RFE, R_R, Routing Models

Flood Management-MWRIE

- Status and readiness of HMN and Telemtry System
- Reservoir Emptying programs (Flood Level)
- FEWS (in collaboration with SMA)
- Daily Flood Issue (30 stations)
- Flood Committees
  - NWD Flood committee (NW Director)
- BN at Deim at Alert Level (492m-350 Mm3)
- Daily Flood Issue (Levels and Discharges)
  - MWRIE Flood committee (Undersecretary)
- BN at Deim at critical Level (493.5m-600 Mm3)

- Daily flood issue (Reaches/Sectors water levels)

Recommendation to Enhance FEWS

- Enhance model inputs
    - Upgrade of HMN and Telemetry
    - Upgrade of and Enhance model inputs
- Enhance model Outputs
    - Interactive outputs
    - Windows (RFE, R-R, Routing)
    - Timing of receiving disseminated information
- Forecaster Role
    - Model Verification

Mr. Debebe Defersa- Awash Basin Authority, Ethiopia

Overview

- Awash is one of the 12 river basins in Ethiopia; 18.7 BCM of total potential;
- 1,280 kms long river, and the basin touch 5 regional states, 2 admin. Cities;
- Agriculture is the leading economic sector (25% of national production);
- Irrigation consumes 83% of surface water;
- Population growth , Industrialization, urbanization and mechanized farming have pressures on water;
- Strategic issues: Water Quality, Water scarcity, Degradation, *Flood and Drought;
- *Flood and drought strategic basin* plan;
- *Water monitoring and early warning* is a strategic action.

Flooding

- *71% annual rainfall and 72.5 % of annual flow occurs during only June to October*
- *33 % of the basin is highly to very highly exposed to flood;*
- *Flooding in Awash are: River flooding, Lake water flooding, and Catchment flooding;*

Flow forecasting

The model:

- *A hydrologic model to simulate precipitation-runoff process of dendrite watershed system;*
- *Event based and/or continuous flow simulation or forecasting;*
- *Can be applied for flow forecasting, reservoir operations, spillway design..*

***Inputs*:**

- *Catchment parameters – surface condition, loss, storage – with HecGeoHMS;*
- *Atmospheric – daily precipitation, and monthly evaporation (NOAA);*
- *Paired data – cross-sections, rating curves storage curves;*
- *Flow data – for calibration*

Recommendations

- *Verification of the different forecast data sources;*
- *Improve the spatial discretization of the modeling;*
- *Develop reservoir operation plans according to forecasts;*
- *Integrate the flow forecasting with the national weather forecasts;*
- *Improve instrumentation and automation;*

Key points of the Plenary

- Data sharing follows Ministry agreement (Ethiopia)
- Sudan most downstream is a problem and use satelites due to lack of data (Sudan)
- No clear policies guidelines on sharing data but a request will be recognised (S Sudan)
- Data are available for research mainly discharge but NMA data cannot be shared

Take-away message

- Data sharing between upstream and downstream countries is key to flood early warning and needs to discussed as a priority issue

Session 5: National Experience – Disaster Management

Chair: Prof. Seifeldin Hamad Abdalla

Almaz Demessie -National Disaster Risk Management Commission, Ethiopia

Ethiopian DRM Framework

- Pro-active early warning system with reliable baseline and trigger points
- Contingency planning for appropriate and timely response
- Contingency finance for timely financing
- Capacity building and institutional arrangement for effective implementation

Early Warning Advisory Products
Baseline information /Required document

- Woreda Disaster Risk Profiles (for the analysis of underlining causes of disaster)
- Contingency Plan (for timely response)
- Early Warning Systems

Contents of Flood Alert

- Background information
- Map for Flood Prone Areas
- Seasonal weather/Climate Outlook
- Details of Flood Risk Areas by Region
- Landslide Risk areas
- Recommended intervention
- Immediate like distribution of Food and N/Food Item
- Short & Long-term

Components of Flood Contingency Plan

- NMA Seasonal Forecast
- Map for Flood Risk Areas
- Assumption for Contingency Plan
- Proposed Intervention for the most likely Scenario
  - Mitigation and preparedness (EW&EA, Flood Protection ditches and evacuation plan.
  - Flood Contingency plan from sector offices (Agriculture, Health, Nutrition, Flood, Water and Education)
- Implementation Modalities
  - Federal level
  - Regional level
  - Zonal level
  - Woreda/comunity level

Users of EW Products

- Decision Makers at different level
- Technical Working Groups
- Donors,NGOs CBOs...etc

Betty Scopas- Ministry of Humanitarian Affairs & Disaster Management, South Sudan

National Institutional Arrangement for Disaster Management & Early Warning Systems

- South Sudan has a dedicated ministry for Humanitarian Affairs & Disaster Management (2010)
- National Early Warning System Technical Working Group official launched in Dec.2014
- Advisory role for EW & EA
- Early preparedness & response
- Collect, analyze data, and disseminate EW information for all types of hazards, (flood risk, drought, crop pest etc.)
- Publish EW monthly bulletin/quarterly (National Multi-hazard EW Bulletin
- Launch and establishment of State EWS Networks

Flood Impact

- Communities in flood prone areas experience disruption of livelihood activities, access to basic services, markets, collapse and damage of their tukuls/homes & water points.
- Crops submerged under water, displacement/relocation to high grounds, and outbreak of water borne diseases

Flood affected Community Coping Mechanisms

- Opening of water-way/channel
- Construction of local dykes
- Relocation to higher ground
- Use of local boats/moto-boat
- Storage of food supplies
- Maintenance of water pumps/points
- Community participation in awareness on flood risks

Risk Mitigation Plans

- Strengthen the capacity of DRM line institutions at all levels
- Continuous vulnerability & risk assessment in hazard prone areas
- Training of DRM technicians at all levels(SETWG/Networks, and communities in disaster preparedness & response, involving them in all stages from assessment-response)
- Prepare & continuous update of contingency plans
- Promotion of community based resilience program through climate smart livelihood adaptation program in major risk-prone areas
- Strengthen coordination and involvement of private sector in area of disaster preparedness & response

SSRC FloodsPreparedness Activities

- Training of Emergency Action Team (EAT) volunteers in the Branches and Units of South Sudan Red Cross across the country
- At the moment there are 49 EAT Units (each unit consists of 20-25 members) across the country

- Conduct Vulnerability Capacity Assessment (VCA) exercise (already done in SSRC Bor

Branch) in one of the floods-prone areas

- Formation of Community Disaster Response Teams (CDRTs) who will be First Responders not only in Floods Response but other emergencies as well
- Community members sensitization on floods and other related emergencies
- Community members urged to come up with Mitigation Measures based on their local resources

KEY CHALLENGES

- Complex emergency (diseases outbreak: cholera etc) associated with flooding
- Accessibility problem in reaching the affected areas
- Limited resources to support the flood-affected persons
- Lack of contingency planning in flood-prone areas to address unforeseen circumstances

Mr. Yasser Mohamed- Humanitarian Aid Commission

Sudan Hazard Profile

- The Sudan is a disaster prone country. Reoccurrence of disasters resulted in increasing levels of socio-economic vulnerability, and poverty.
- Floods, Drought, and desertification are the most common environmental hazards together with other hazards and disasters either man-made or natural such as civil conflicts, pest infestation and epidemics, these have had immense devastating impacts on the social structure and the economies of the country

Types of Floods

- Sudan has experienced many devastating Floods during the past several decades. These events have led to a widespread loss of property, public utilities /services and the spread of waterborne diseases.
- There are two main types of flooding in Sudan and it is important to take account of their characteristics in developing mitigation and alleviation measures. Flooding may be:
- Flash floods generated by torrential rainfall affects areas located on the slopes of the highlands , hilly and mountainous areasThis types of flooding considered one of the most disastrous types of floods because it allows very short lead time,endangering all states of Sudan
- River floods which takes place along the River Nile and its tributaries Riverine flood
- The main River Nile continues to rise until it peaks in mid-August to mid of September. Then levels starts to fall sharply during October.

Vulnerable Areas

- Vulnerability is the degree to which life, property and/or environment is open to being affected by, or unable to cope with, adverse effects of hazard impacts
- Vulnerability analysis considers the population and structures at risk within the flood-prone area.
- The analysis evaluates the potential costs of flooding in terms of damages to buildings, crops, roads, bridges and critical infrastructure, such as utilities.

Flood Disaster Management

- Preparedness: Measures taken in anticipation of a hazard to reduce the level of damage
  - Contingency planning
  - Coordination
  - Early warning
- Mitigation measures
- Response

Contingency Planning

- Contingency plan: An agreed set of arrangements that is developed and acted upon by the community to reduce the impact on to life, property and/or environment, when a hazard strikes
- Detailed contingency plans has been prepared for 3 state in Sudan so far three years ago and need to be updated regularly.
- The plans prepared and reviewed by sectors with the participation with all of the key stakeholders and partners. (There is no one "common" response plan as the linkages will be different in each sector).
- Mechanisms for coordination has been integrated in the plan, the plans include raising awareness of the local communities about what is expected.

Inventory of Resource

- In the case of flooding this include items such as emergency vehicles, buses and trucks, earthmoving equipment, pumps, plastic sheets, emergency generators, supplies of gravel and sand, sandbags, and mobile communications equipment.
- Emergency shelters should be designated in advance, their individual capacity defined and

plans made for obtaining sufficient supplies of water, food, medicine and medical/social assistance.

- If local resources are not sufficient, then the availability circle must be expanded to include adjacent communities, the state and national government levels.

Flood task Force (FTF) Inter-agency Collaboration

Mandate

- Liaise with relevant government authorities and humanitarian actors in regards to flood humanitarian preparedness and response.
- Recommend policy actions to address bottlenecks and incorporate lessons learned into humanitarian actions.
- Enhance coordinated efforts between central flood task force and relevant State levels' emergency preparedness and response structures, to help address any overarching issues that could not be addressed at State levels.
- Ensure existence of harmonized mechanisms for information sharing and early warning massages.
- Ensure regular inflow of information and updates on flood situations between States level flood emergency structures and central flood task force, to help the timely and effective response
- In case of flood events, it coordinates the emergency relief in support of the authorities on state level. The FTF recommends policy actions to address bottlenecks. It also incorporates lessons learned into the planning process and revises the lessons learned after the flood season accordingly

Key Sectors

- o Food security and livelihood;
- o Health
- o nutrition;
- o Basic Infrastructure and Settlement
- o Non-food items (NFI) and emergency shelter;
- o Water and sanitation.
- o Education
- o Infrastructure
- o Protection

Challenges

- Improve coordination, cooperation and planning for disaster preparedness and disaster risk reduction.
- Enhancing applications of new technologies, including GIS, ICT and remote sensing.
- Disasters are viewed in isolation from the processes of mainstream development and poverty alleviation planning.
- Sharing of good practices and transfer of knowledge and experience through workshops and training;
- Strengthening of comprehensive approach that meet the needs of DRM agencies and other stakeholders (in terms of lead time, national constraints).

Background: location of Tana Sub Basin organization

- TaSBO/ABA is established for the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable and participatory manner without compromising the sustainability of ecosystems

Background of flood in Tana Sub Basin

- Ethiopia is frequently threatened by different disaster such as g Drought, Flood, landslides and other multiple events. Flood is the second next to drought.
- Floods in TaSB occur as a result overflow of river, local rainfall and backflow of lake tana.
- Among the major rivers that cause flood surrounding Lake Tana are Gumara, Rib and Megech rivers .

Major Roles of TaSBO with respect to FFEWS

- Installation of hydro met stations
- Operation and maintenance of hydro met stations(both telemetric &others)
- Data collection, analysis, dissemination
- Development ,Operation and maintenance of database system
- Construction of database center(new building)
- Basin Planning
- Installation of hydromel monitoring network such as
    - Water level monitoring network
    - Flood monitoring network
    - Meteorological monitoring network
    - Ethiopia's only operational weather radar
- Telemetric-water level monitoring network stations
    - Installation of 26 water level stations automated
    - Operation and maintenance for water level
    - Data collection from the none telemetric stations

Micro-watershed Based Monitoring Programme – Status in December 2012

- Data collection on the central parameters since August 2009
- 17 stations established at the outlets of 15 microwaterhseds
- 12 stations within the TBIWRDP area, while 5 stations are in "control" waterhseds (no project activities taking place)
- >9000 samples collected August 2009 – August 2012

Facilitation for Weather Radar Prediction System installation

- One weather radar
    - Land acquisition from local Government
    - Stakeholder workshop
    - Facilitation for the operation such fuel supply

Final Remark

- Full operationalization of the whole basin information system needs further enhancement

Key points of the Plenary

Tana Beles includes real time stations can ENTRO benefit from it when the System is operational but this needs protocol and signed MoA between the two institutions for ENTRO to use the web portal

Every sector has three scenarios (Best middle worst) every sector develops its threshold and triggers. They seek government support to carry out their activities

Take away messages

- **It is important for ENTRO to follow up and discuss with MoA and Protocol for real data sharing with Tana Sub Basin organization**
- **Use of social media can improve the work of flood early warning dissemination**

Session 6: Regional and International Experience

Chair: Prof. Seifeldin Hamad Abdalla

Mekuria Beyene - Danish Hydraulic Institute

Shire Basin Operational Decision Support System through Enhanced Hydro-Meteorological Services

Project Objectives

- An implemented Shire Basin Operational Decision Support System to support forecasts and decisions to enhance productivity and reduce climate risks through timely warnings and access to information for various agencies and stakeholders
- Improved analysis and use of the hydro-meteorological information collected from ground monitoring and earth observations for climate, hydrological, flood & sector support forecasting with short-term and seasonal outlooks

Integrated Multi-Functional Forecasting and Early Warning System

- Short-term flood and rainfall warnings
- Seasonal forecasts for agricultural support
- Water Infrastructure Operations
- Drought Seasonal Indices
- Lake and Wetlands management support

Project Tasks - Overview

- Analysis of decisions to be supported by the ODSS
- Develop an Integrated Visualization & Analysis Platform
- Implement improved hydro-meteorological forecasting
- Design and deploy the ODSS
- Develop dissemination systems
- Performance assessment of the system
- Capacity building and facilitation

Summary of Project Implementation

- ODSS is operational, operated by designated operators (DCCMS- and DWR-staff).
- Key externalities that posed a challenge are:
    - Availability of real-time hydro-met data in due time
    - Infrastructure: reliable electric power supply and internet
- Solutions to overcome challenges have been implemented: e.g. deployment of the ODSS in the cloud
- Some compromises had to be made:
    - Capacity building and enhancement
    - Performance evaluation of the system

Limitations of Forecast Performance Evaluation

- No major rain events recorded in rainy season 2017/2018
- Evaluation period – 02-FEB-2018 to 14-MAR-2018
    - Only 80 TOF were evaluated
    - evaluated at 4 hourly intervals from the time of forecast to the end of simulation

The ODSS Sustainability Plan

Essential permanent requirements:

- Allocation of sufficient number of staff trained in the operation of the ODSS, and having appropriate working conditions (office facilities, power supply, internet, IT-hardware) for carrying out this work, by DWR and DCCMS respectively.
- Agreement between the involved institutions on how to collaborate for the optimal operation of the ODSS.
- Sufficient budget for operation and maintenance of all physical installations such as monitoring network, IT hardware and office facilities. This also includes the regular updating of rating curves for the river gauging stations.
- Maintenance of the contract with the Cloud Service Provider (for hosting the ODSS and related data).
- Payments of text message services when used for notifications and warnings.
- Continuous access to external data and information sources (e.g GFS, GPM and CFS).

Scope of Training

- Flood and Flow forecasting , Water Infrastructure, Flash Flood forecasting
    - Model development (incl. data)
    - Daily operations (MIKE Workbench/OPEARTIONS)
    - Scenario investigations
    - Real-time data acquisition (challenges)
    - Evaluation of logs
    - How to add contacts and their subscriptions
    - Using the manuals
    - Improvement to manuals
    - Dissemination
- Drought Monitoring
    - Different indexes (e.g. NDVI, SPI, VCI, VHI, etc)
- Crop Calendar
    - Planting times
- Others
    - System architecture
    - Azure file structure
    - System maintenance (disk, database)
    - Monitoring and evaluation report
    - System backup

What requires attention?

- Hydro-met data needs to be corrected and revised:
    - Real-time measurements
    - Cross sections and rating curves
- COSMO forecasts need to be available reliably.
- ODSS operators need to focus on operationalizing ODSS – amend job descriptions.
- Equip DCCMS control room with sustainable UPS!
- Sign MoU between DWR, DCCMS and DoDMA!
- Make contract with agent for cloud service provision!
- Arrange service and maintenance agreement for ODSS (3 to 5 years)!

Hari Prasad Vajja - **UNOSAT / ICPAC**

UNOSAT Flood Finder - Flood Forecast and Early Warning System

UNOSAT Rapid Mapping

- Provides satellite image analysis during humanitarian emergencies – disasters and conflict-situations
- Maps, GIS-ready data, statistics and reports
- On call 24/7

Mapping Activities

- Floods
- Earthquakes
- Cyclones
- Landslides
- Refugee and Internally Displaced Persons Mapping
- Cultural Heritage Sites
- Conflict Damage Assessment

Flood Forecasting and Early Warning System: Flood Finder

- Flood-FINDER is a modelling tool that has been created by effectively linking meteorological, hydrological and inundation models to produce global early warnings and simulated flood scenarios
- Flood-FINDER is a tool for decision makers within UN agencies, international humanitarian organizations, civil protection and first responders in national and regional water authorities.
- The Flood-FINDER project brings together skills, tools and data from different complementary experiences of high profile entities from academia, governmental and UN agencies.

Flood Preparedness, Response, Impact Assessment and Mitigation and Planning

Flood-FINDER's objectives 1:

- Improving disaster response planning with timely identification of potential affected areas, in particular for critical areas of the world that lack of data
- Supporting humanitarian actors during flood emergency with timely data and analysis

Flood-FINDER's objectives 2:

- Overcoming delays due to the triggering process of satellite imagery
- Guiding the acquisition of satellite imagery needed for high resolution impact assessments

To Operationalise Flood Forecast and Early Warning System in any country

- o What is required?
- o A dedicated department or institute responsible for this activity
- o Water Level / Discharge measurements in flood prone rivers
- o Calibrate and validate hydrologic-hydrodynamic model
- o Use forecast rainfall and hydrologic-hydrodynamic model to predict water levels at strategically selected important locations
- o Using forecasted water levels issue warnings, if necessary
- o Using forecasted water levels develop possible flood inundation area
- o Using the possible flood inundation area, assess the exposure of population, infrastructure etc.
- o If budget allows, depend a live map on a web-portal and share with all stakeholders

Andrew Njogu – Kenya Meteorological Department

NZOIA FLOOD EARLY WARNING SYSTEM

Dissemination Via Community radio network

BENEFITS TO COMMUNITY IN FLOOD MITIGATION

- INSTANT COMMUNICATION LINK
  - Makes community aware of escape and evacuation routes
- EARLY WARNING
  - Information officers collect timely information from the community while communication officers get the same through call-ins and meteorological alerts are communicated in all stages of disaster management
- ALERTING AUTHORITIES
  - Receives information from the community on how government services are being delivered
- ASSESSING DAMAGES AND MOBILIZING SUPPORT FOR RECONSTRUCTION
  - Monitor water level and dyke weak points through listener call-ins and information officers alert authorities in case there is need for action
- INCREASE CAPACITY TO COPE WITH DISASTER
  - Creates platform for government departmental heads to use to inform the community on precautionary measures to reduce flood effects such as cholera outbreaks and spread
- COORDINATING RELIEF OPERASTIONS AND SAVING LIVES
  - alarming water levels

Genesis of RANET

- The RANET program began in Africa in 1998/9, following the experience of Seasonal Outlook Forums. It was recognized that benefits from advances in science and applications could only be realized if populations outside central cities could be reached.
- ACMAD developed a cost effective mechanism that exploits internet, the world space multimedia system, solar powered radio transmitters & windup radios with potential of reaching people ,in Africa
- RAdio InterNET (RANET), was the answer to the question of getting vital Weather &Climate predictions to people in rural areas

RANET Objectives

RANET seeks to change the status quo in terms of delivering weather and climate information to the needy rural community affected by weather disasters through the following:

- Awareness creation on weather & climate issues
- Providing weather forecasts, alerts and advisory
- Providing synergies and partnerships between NMHS & Community
- Promoting development in rural areas through the radio programmes

RANET- MISSION

- To improve agriculture and livestock production, mitigate impacts of disasters, promote health and conserve the environment of the vulnerable rural communities using weather and climate prediction for sustainable development

Success stories

- Niger
  - Over 150 community FM radio stations and 50 community information centers
- Uganda
  - Uganda has established cooperation with private FM radios
  - Kenya
  - 6 Community FM radio stations

Key points of the Plenary

- **Reliability and sustainability of the tool.**
- **Differences between Nile DSS and Malawi DSS**
- **Prone and cones of cloud computing**
- **Whether RANET is effective in addressing flood warning and existence of collaborations between KMD and WRA.**
- **The applied methodology, threshold method, whether it is reliable or not**

Take-away messages:

- **Extending the method by applying other tools.**
- **Possible accessibility of final FEW outputs with institution that share necessary data with them.**
- **Assessing and implementing flood forecasting should take institutional and infrastructural setting into account.**

Bio Data of Selected Paper Presenters

1. Ahmed Ali Nasr, Egypt

Ahmed holds a BSc degree with honors in Civil Engineering and MSc degree in Irrigation and Hydraulics Engineering both from Cairo University in Egypt. In addition, he holds an Erasmus Mundus MSc degree in Flood Risk Management from UNESCO-IHE Delft in he Netherlands jointly with TU Dresden in Germany, Barcelona Tech in Spain, and University of Ljubljana in Slovenia. Ahmed has over 6 years of academic, research, and technical consultancy work experience within the water sector where he worked on various projects related to flood risk management in the Eastern Nile Basin (Egypt, Ethiopia, South Sudan and Sudan), the Middle East (KSA and Oman), Asia (Afghanistan, Bangladesh, and Vietnam), Europe (Germany, the Netherlands, Spain, and Slovenia), North America (USA), and Latin America (Colombia). Currently, Ahmed is Assistant Lecturer at Department of Irrigation and Hydraulics Engineering at Cairo University and a Hydrology & Storm Drainage Design Engineer at a multinational engineering consultancy firm. Previously, Ahmed participated in the young water professional program (AKA internship program) at the Nile Basin Initiative – Eastern Nile Technical Regional Office.

2. Hailay Zeray, Ethiopia

Hailay is a PHD student at African Center of Excellence in Water Management (ACEWM), Addis Ababa University.
Hailay has more than seven years Practical experience in Hydrological modeling for the application of flood forecasting, Climate change, hydro-power, irrigation and drought analysis, this include 7-month experience working in one of world's leading consulting firm at Deltares, The Netherlands.

3. Ehadi Eisa Adam, Sudan

Eng. Ehadi was graduated from Sennar University Faculty of Engineering, Sudan (Civil). He did his M-Tech degree in IIT Roorkee, India (Hydrology). Now he is doing PhD at the Water Research Center, University of Khartoum in the field of Flood Early Warning System (FEWS). He has a long experience in the field of water. He worked for the Ministry of Irrigation and Water Resources, Nile water directorate (Sudan) for more than 15 years. Recently, he joined the faculty of Engineering, University of Kassala, Sudan as a lecturer and tell now.

4. Hisham I. M. Abdel-Magid, Sudan

Hisham is a Civil & Infrastructures Engineer by profession,

with nearly fifteen years of experience in various aspects of civil infrastructure engineering & hydroinformatics, including hydrological drainage, water resources assessment, processing and analysis of satellite imageries through state-of-the-art GIS/RS packages or bespoke development of on-job scripts and computational modules.
Currently, he works as Assistant Professor in-charge of Geomatics & GIS research group at Environmental Engineering Department, College of Engineering, Imam Abdulrahman Bin Faisal University (IAU), Saudi Arabia; as well as visiting Associate Researcher with WaterResearch Centre (WRC), University of Khartoum, Sudan. He previously worked as Civil Engineering Consultant & International Expert with Enginormatics Engineering Ltd., United Kingdom; Hydrology & Hydroinformatics Expert with SES Consultancy, Sudan & Nigeria; Regional GIS & Hydroinformatics Consultant for Eastern Nile Technical Regional Office (ENTRO), Nile Basin Initiative (NBI), Ethiopia; Lecturer at Environmental Engineering Dept., College of Water and Environmental Engineering, Sudan University for Science and Technology (SUST), Sudan; Civil & Infrastructures Engineer for Dar Al-Handasah Shair and Partners, Qatar; and Research Engineer at Institute of Research in Engineering Research and Materials Technology of The National Center for Research (NCR), Sudan.
Hisham holds a Ph.D. in Environmental Engineering from SUST, Sudan, an M.Sc. Hydrogeology from University of Strathclyde, UK, an M.Sc. in Civil Engineering from SUST, Sudan, and a Post Graduate Diploma in Information Technology (PGDIT) from Amity University, India.

5. Goitom Kelem, Ethiopia

Goitom has bachelor degree in Meteorology sciences from Arba minch University and currently he is MSc student in Mekelle university in a field of Meteorology and climate risk management specialization in Hydrology. He has seven years' experience in Meteorology as meteorological forecaster and numerical weather prediction expert especially (WRF, COSMO and RegCM) models in National Meteorological Agency of Ethiopia.

6. Khalid E. A. Hassaballah, Sudan

Khalid is a civil engineer with nearly fifteen years of experience covering different aspects of water science and engineering includes: Hydroinformatics, catchment hydrology and modelling, hydraulics and river engineering, river morphology, reservoir simulation and optimization, reservoirs bathymetric survey, water resources planning & management and GIS & Remote Sensing

Applications. He has been working as a researcher at HRC-Sudan since November 2003. In 2010, Eng. Khalid graduated from the MSc Programme in Water Science and Engineering, Hydroinformatics specialization, from UNESCO-IHE Institute for Water Education, Delft, The Netherlands. Since November 2012 he is working on his PhD at the same institute. Between 2010 and 2012, he worked for the Eastern Nile Watershed Management Project (ENWMP) as a water resource specialist for the Sudan component. Beside his PhD work, Khalid has also been involved in many projects at national, regional and international levels. In 2013 he was involved in the sedimentation and operation study for upper Atbara dam complex (SOSADC) national project as a hydrological modeller. In 2015 he was involved in the Tekezi Atbara project for IGAD as a catchment modelling advisor and supervisor. Later in 2018, Khalid has participated as ateam member of the Eastern Nile flood preparedness and early warning system at ENTRO. Eng. Khalid is a full member of the Sudan Engineering Society (SES), Sudan Engineering Council (SEC), National Member of Nile Basin Initiative Decision Support System Network (NBI/DSSN) and representative of the IHE-Delft Alumni Sudan.

7. Maha Algaffar, Sudan

Maha holds PhD degree in Water Resources Management from the University of Khartoum and is Head Department Environmental Studies, UMST University. She was assigned integrated water resources consultant by the Centres of Natural Resources Development (CNRD) hosted by ITT Cologne and DAD. Also served UNESCO and Eastern Nile Technical Regional Office (ENTRO) as a Lead Expert in program management, coordination and research on Integrated Water Resources Management, water quality and climate change. Maha has a wide experience in water resources management research and capacity development. She has trained community membbers and civil society workers on emergency measures and contingence planning regarding WASH practices during flood seasons. She has carried out many consultancies, research and development assignements at national and international levels with partners including among many,ACTION_AID, CNRD, FAO, Sudan Federal Ministry of Health, UNICEF, ISLAMIC RELIEF and UNESCO.

8. Kiflom Degef, Ethiopia

Kiflom has a bachelor degree in Soil and Water Engineering from Haramaya University, Ethiopia and Master Degree on Water Resources and Irrigation Engineering, Arba Minch University Institute of water technology, Ethiopia. He has over 8 years' experience in water sector. Currently he is working in Tigray Agricultural research institute, Ethiopia as a Researcher in Irrigation Engineering and Water resource Management.

9. Mohamed Mustafa, Sudan

Mohamed Mustafa Abbas, is a Sudanese working for the UNESCO Regional Centre for Capacity Development and Research in Water Harvesting, Ministry of Water Resources and Electricity, Sudan. As a background of his academic qualifications, he get his PhD in Civil Engineering from Khartoum University in 2017, M.Sc in Water Resources Engineering from Khartoum University in 2004, another M.Sc in Strategic Studies from Karari

University 2016, B.Sc in Civil Engineering from Sudan University of Science and Technology.
He has a membership with the National Capacity Building Network for the Nile Basin countries, and Member of the Sudan Council of Engineering, member of the Arab Water Council. He has more than 20 published scientific papers in the area of water resources engineering.

10. Mohamed Tarig, Sudan

Mohammed is a lecturer of Hydrology at Civil Engineering Department - University of Khartoum. He holds MS degree in Civil Engineering with more focus on Water Resources and Engineering from King Fahd University of Petroleum and Minerals (KFUPM), Dhahran, Saudi Arabia, BSc in Civil Engineering from University of Khartoum. He has a wide research experience on water and environmental aspects. His research interest includes but not limited to Modeling and applications in hydrometeorology, Effect of climate change on hydrology, Flood modeling and risk management, Environmental Applications of Remote Sensing, Data Analytics, Water quality monitoring, and modeling.

11. Mahmoud Fouad, Egypt

Mahmoud is one of the qualified water and wastewater treatment Experts in Egypt, he holds a Master Degree on Environmental Sciences, Ain Shams University in Cairo, Egypt. He has over 15 years' experience in the water and wastewater sectors, and freelance consultancy services include working in many national and international organizations such as: Holding company for water and wastewater, Egypt, North and South Exchange consultants, He is currently working in as the General Manager for quality and environmental affairs in the holding company for water and wastewater.

12. Zelalem Mekonnen, Ethiopia

Zelalem Mekonnen is currently an engineer and researcher in the Water Resources Management Division at Research Triangle Institute (RTI International). Mr. Mekonnen's nine years of experience and research interest includes climate change and its impact on water resources management, the application of remote sensing in water resources, hydrology and climate modeling and forecasting, water allocation and optimization, and drought and flood modeling.
Mr. Mekonnen got his BS in Civil Engineering from Addis Ababa Institute of Technology, Ethiopia in 2009 and his MS in Civil and Environmental Engineering from University of California, Los Angeles, in 2015. He is pursuing his PhD at University of California Los Angeles since 2015 focusing on water resources and climate change.
Past experiences include water resources engineer at Eastern Nile Technical and Regional office (ENTRO), Assistant lecturer at Addis Ababa Institute of Technology and National

Network Member for the Nile Basin Decision Support System.

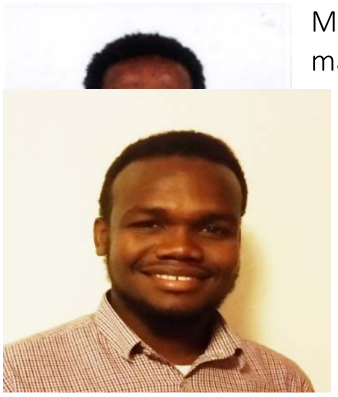
13. Ammar Abdalla, Sudan

Ammar has Bachelor degree in Water Resources Engineering from Sudan University of Science and Technology, Master degree in Transboundary Water Management in the Eastern Nile Basin, from Khartoum University and he is currently a PhD Candidate student, in Sustainable Water Resources Management, UNESCO Chair in Water Resources, Khartoum, Sudan.
Ammar has 11 years' experience working in the Ministry of Water Resources, Irrigation and Electricity, Sudan.

14. Tesfay Gebretsadkan, Ethiopia

Tesfay is an agricultural engineer by training and specialized in hydrology and water resources modelling. Currently, he is a PhD researcher in IHE Delft Institute for Water Education and Delft University of Technology, the Netherlands. He has wide experience in hydrological and water resources modelling, water resources systems, irrigation systems, remote sensing applications for water resources management. In the last six years, he has been conducting research activities in the Upper Blue Nile basin and Tekeze-Atbara basin and published a number of articles in peer reviewed international journals and conferences.

15. Mohammed Basheer, Sudan



Mohammed is a Sudanese researcher in the field of water resources management with a Bachelor of Science in Civil Engineering from the University of Khartoum, Sudan and a Master of Science in Integrated Water Resources Management from Cologne University of Applied Sciences, Germany. Mohammed worked as a research assistant at the University of Khartoum, as a Hydrology Engineer at Kenana Engineering and Technical Services, and as a research associate at the Institute for Technology and Resources Management in the Tropics and Subtropics at Cologne University of Applied Sciences.

16. Shamseddin Musa Ahmed, Sudan

Shamseddin is a water management specialist, associate professor working for Water Management and Irrigation Institute (WMII), University of Gezira, the head of postgraduate studies and scientific research at WMII. He is also a guest lecturer at the United Nation University-PAUWES Algeria. His teaching and researching activities span a range of integrated water resources management issues, e.g. irrigation systems, groundwater hydrology, soil-water conservation & relations and remote sensing & GIS, climate change, etc. The University of Gezira has awarded him the Best Publication List Prize in 2014. He is endowed with proactive relations with local, regional and international institutes working on water-related issues. Currently, he is the president of the African Professionals' Initiative for Water, Environment, Energy and climate (APIWEC).

17. Redwan Abdelrhman Mohammed, Sudan

Redwan he has a bachelor degree in Civil Engineering from Sudan University and Master degree on Water Resources Development & Management UNESCO, Chair in Water Resources, Omdurman Islamic University, Sudan. he has over 22 years' experience in the water sector, include working in many national and international organizations such as: IGAD-Hycos project, hydrologist in Ministry of Irrigation and Water Resources.

Session 7: Selected Paper Presentations

Session 7A: Tools and methodologies for flood analysis
Chair: Dr. Maha Algaffar; Rapporteur: Milly Mbuliro

Abstract Paper 7A-1

Bayesian Networks and Data Driven Models for Estimating Extreme River Discharges Case Study: Magdalena-Cauca Basin, Colombia

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Flood hazard quantification (water level and extent) requires adequate estimation of extreme discharges (obtained from discharge observations or hydrological models). The MagdalenaCauca river basin in Colombia, as in many basins in the developing world, has insufficient amount of available records of discharge observations in several locations. Consequently, the quantification of hazards becomes challenging, particularly in completely ungagged areas.

To overcome this problem, we used and proposed different methods that are computationally inexpensive to indirectly estimate extreme discharges from different and easy to obtain data sources. One of them, a stochastic model based on Bayesian Networks (BNs) previously applied in Europe and the contiguous USA is used in this study. A Bayesian Network is a direct acyclic graph that consists of nodes that represent random variables and arcs that represent the dependence structure between these variables. To validate the performance of the Bayesian Network (BN) model in the Magdalena-Cauca basin, it is compared to two novel deterministic data driven models based on lazy learning (k-nearest neighbours) and eager learning (M5 Model Trees). In addition, the BN model performance is evaluated with regional frequency analysis. The inputs of all the models, seven in total at the catchment level, are: 1) the steepness; 2) the area; 3) the annual maximum of daily precipitation and snowmelt; 4) the maximum runoff coefficient; 5) the percentage of the catchment area covered by marshes, 6) lakes and 7) built-up areas. All the models establish relations among them and the annual maximum of daily river discharges, in such a way that it can be predicted for different inputs.

Results show that all the models perform well when used in big sub-catchments and underperform in small ones. Frequency analysis applied on the peak discharges obtained by all the models show that the output of the BN model outperforms other models. The methods can be replicated and applied to other river basins (e.g. Nile Basin). Moreover, the results discharges from the models can be used to run hydrodynamic models and obtain resulting flood hazard (water level and extent) which is very useful for preparedness, early warning, and flood risk management.

Abstract Paper 7A-2

Effect of State noise and model parameterization in data assimilation for flood forecasting with distributed hydrological model: application of Meuse river basin.

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An accurate, timely and improved flood forecasting is vital in order to make key decisions in flood risk management mainly, in river floods. Minimizing uncertainties related to input, structure, parameter, initial conditions and post processing improves flood forecasting. Integrated reliable hydrological model and data assimilation (DA), updating techniques are important to reduce the uncertainties in the initial conditions and parameters. In the last two decades, most hydrological forecasting system uses lumped hydrological model to conduct state updating deterministically. However, there is a shift from lumped to distributed hydrological model for state updating with ensemble forecasting. Recently, Ensemble Kalman filter (EnKF) becomes the most commonly used sequential data assimilation approach in most hydrological updating processes. Data assimilation with EnKF is mainly synchronous or 3D, observation is assumed to be taken at the assimilation time, whereas Asynchronous Ensemble Kalman Filer (AEnKF) or 4D-EnKF considers observations at different time than the update time.

This study describes the data assimilation procedure using AEnKF to update model states for the case of Meuse river basin. The aim of the study is to investigate the effect of state noise and parameterization on the state updating using AEnKF and hence, for flood forecasting. One spatially lumped HBV-96 and two grid based distributed hydrological models (OpenStreams, 2014) are used for this purpose. The grid based hydrological models are linked to a generic data assimilation package (OpenDA, 2014) within an open shell system Delft- Flood Early Warning System (Delft-FEWS) using PCRaster application. Hourly hindcasting run is carried out for seven years in three stages; one with HBV-96 and two with OpenStreams models (Model 1 and Model 2). Here, Model 1 has the same calibration parameter as to operationally used HBV-96 whereas Model 2 has different kinematic routing parameter. The data assimilation experiment is carried by introducing noise to the soil moisture, upper zone storage and precipitation on two different models. Spatially distributed grid based models outperform the spatially lumped hydrological model (HBV-96). Of the two grid based models, Model 2 performs and captures the time to peak and the recession limb of the hydrograph better than Model 1. From data assimilation experiment, the introduced noise on upper zone storage and soil moisture states yields improved update than noise on precipitation tested on seven sub basins. Moreover, noise on upper zone storage yields the improved performance followed by noise on the soil moisture and noise on precipitation. The effect of parameterization is significant as Model 2 overcomes problems related to time to peak, magnitude of peak flow, rising and recession limbs more accurately than model 1 and control simulation of model 2. The data assimilation procedure is validated for independent sub basin and a reduction of 40 % in RMSE is found compared to control simulation. Therefore, the implemented data assimilation procedure has improved the model states and can be used for improved flood forecasting purpose.

Keywords: **Data assimilation, lumped and distributed hydrological modeling, flood forecasting, uncertainty, asynchronous ensemble kalman filter, Delft-FEWS**

Abstract Paper 7A-3

Maximizing the use of satellite data and hydrological modelling for streamflow prediction: Case study of Dinder and Rahad rivers (tributaries of the Blue Nile, Ethiopia-Sudan)

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Thedemand for accurate satellite rainfall products is increasing mainly in areas where ground measurement data are unavailable, inaccessible or unreliable. This paper aims to predict streamflow of the Dinder and Rahad rivers using satellite data and hydrological modelling.

In this study, three widely used, satellite-based rainfall estimates (SBRE) products (Rainfall Estimates (RFE 2.0), Tropical Rainfall Measuring Mission (TRMM 3B42 v7), and Climate Hazards Group InfraRed Precipitation with Stations (CHIRPS 2.0)), were used to run the Wflow hydrological model. The performance of the model was assessed using the coefficient of determination (R^2) and the Nash-Sutcliffe efficiency (NSE). The results of predicted streamflow are satisfactory and indicate that the best products over the Dinder and Rahad basins is CHIRPS v2.0 with 0.8 for both R^2 and NSE. This approach shows the capability of SBRE to predict streamflow at sub-basin levels, which can be used for enhancing the flood forecast and early warning decision making actions. This approach can be extended to improve river flow prediction in sparsely gauged or ungauged basins in the region.

Keywords:Dinder and Rahad, streamflow prediction, satellite data, hydrological modelling, PCRaster

Abstract Paper 7A-4

Recent Advances in Flood Forecasting and Early Warning Systems.

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Floods top the list of most frequent natural disasters on planet earth. Millions of people will be affected by them and billions of dollars will be lost in property damage every year. Several billions of dollars have also been spent to better forecast floods and warn communities early to reduce loss of life and damage. In this paper we will review some of the recent advances in flood forecasting science and technologies that allow for more accurate and reliable predictions.

A major source of uncertainty in flood forecasting is the input precipitation. In addition to the uncertainty in precipitation forecast from a single model, the discrepancy between different models has been a challenge. We will introduce a method to improve multi-model precipitation ensembles by using performance-based weighing. Another critical component of flood forecasting is the topographic information. Recent advances in satellite and flight-based stereography allow the development of high resolution and often hydraulically corrected DEMs across the globe. This allows for the schematization of more accurate 1D and 2D hydraulic models, we will present one example here.

Advances in atmospheric and land surface modeling have allowed for major improvements in short term weather forecasting but that doesn't translate into seasonal or long-term forecasts. We will try to answer the question:" how much skill sophisticated models do have compared to simpler statistical models for seasonal forecasting?". Likewise, the application of artificial intelligence might revolutionize flood forecasting in the mid-term. We demonstrate a research idea in this field that aims at approximating hydrologic model outputs in a novel way.

Ensemble forecasting, and advanced pre-and post-processing can further enhance the accuracy of flow forecasts while retaining the inherent uncertainties of the process. We will introduce a particle filters approach as one such application. The wide-scale availability of high-scale computer resources also is enabling the use of reforecasting as a way to improve forecast through the assessment of historical *forecast* performance rather than historical *simulation* performance. Finally, Recent advances in remote sensing also allowed for real-time monitoring of floods and better verification of flood forecasting models. We will review the application of SAR and altimetry for flood mapping and forecast verification.

KEY WORDS: Flood, Forecasting, AI, Particle Filters, DEM, Precipitation, Ensembles, Postprocessing, Reforecast

Key points of the Plenary

- **Each flood modelling method has advantages and disadvantages**
- **Use of Radar together with other techniques is recommended**
- **Model performance in small verses large catchments in addition to catchment characteristics**
- **Are statistical models better than physical complex models? Are Semi distributed models are preferred**
- **Landcover and landuse projections incorporated in flood forecasting**
- **Computation capacities should to be considered in addition to challenges in data download capacity**
- **Possibility of these models be applied in the Nile Basin region?**

Take-away messages

- **Use of satellite data in hydrological modelling for stream flow prediction is encouraged especially in data scarce regions like the Nile Basin**
- **Land use changes need to be taken into consideration during flood analysis**
- **Simple regression models may at times perform better than complex models and therefore there is need to investigate different models before work is undertaken**

Session 7B: Flood Forecast under Climate Change impact

Chair: Dr. Seifu A. Tilahun; Rapporteur: Amna Omer

Abstract Paper 7B-1

Verification of precipitation forecasted by the SOO/STRC Workstation Eta and five points over Blue Nile catchment

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The operational version cat of the workstation Eta model at Ministry of water Resources in Sudan, it uses the hydrostatic approximation and is setup with 45 vertical levels in a step mountain vertical coordinate system also called eta co-ordinates the model top is 25mb. The horizontal grid is defined as rotated latitude/longitude staggered Arakawa E grid. A grid dimension 80X105 this domain covering most area of Blue Nile catchment in Sudan and Ethiopia. The forecast information, the input data for the model are derived from the NCEP-GFS 1-degree resolution, 3-hourly forecast data is used to create the necessary initial and boundary conditions for the model runs. Surface input data include 4-minute land/sea mask, high resolution of sea surface temperature (SST) of 0.5^{o} hires and other time – dependent fields such as vegetation, albedo and snow cover. The forecast output is up to the forecast length of 120 hours. A sample of quantitative precipitation forecasts have been extracted from cumulative of 24 hrs and compared with daily measured point rainfall over catchment. A series of statistical scores are compute based on a categorical contingency table; whereby an event ("yes") is defined by rainfall greater than or equal to the specified threshold (0.1 mm/day) occasionally on this paper, but usually (0.5cm/day); otherwise, it is a nonevent ("no"). The validation of WS Eta over the Blue Nile area is based on comparisons of model results from WS Eta configured to cover the part of basin area and daily mean precipitation measurements from five point stations. The result of the rainfall recorded in stations are comply with the extreme precipitation events were predicated by the model, moreover the model in most cases is clearly indicated a tendency of overestimate. However, investigation single events of heavy rainfall reveal that there is underestimation.

Abstract Paper 7B-2

Aridity trends amidst climate change in the Eastern Nile region

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Developing a rainfall-runoff relationship is a daunting hydrological task. However, it is largely governed by aridity, i.e. to what extent potential climatic water demand is being met in a given region (energy/water). Climate changes impacts on water resources on the other hand has yet remained largely uncertain especially at a regional scale. The reviewed results of 18 recently published papers reported on the Nile basin for example have stated the overwhelmingly increasing trend in surface air temperature (SAT), mixture trends in rainfall and dominant decreased runoff amounts. This presentation made use of SAT, rainfall (P) and reference evapotranspiration (ET_o) for indexing the future trend in aridity in the eastern Nile basin by the year 2080 using the ensemble average of 16 GCMs provided by the Coupled Model Inter comparison Project Phase 5 (CMIP5). Datasets were analyzed via ArcMap 10.3 environment. Future Climatic datasets were downscaled using the delta approach. The observed Penman-Monteith based ET_o datasets (1960-1960) of 39 regional meteorological stations were extracted from the ClIMWAT, which then being used to project the future values via developed empirical relationships between observed SAT and observed ET_o. The results showed the regional increase of 4.3 ^{0}C in SAT coupled with a regional increase in ET_o of 1-59%. These changes lead to substantial increase in the aridity index (ET_o/P), ranging in 70-100% despite the projected increase of 40% in regional rainfall. Synoptically, the runoff amount (supply) is projected to decrease due to increase in aridity which in turns increases water demands, irrigation water in particular. Thus, climate change would have detrimental impacts on water resources of the eastern Nile region, which call for regional cooperation and building early warning systems for operating regional dams.

Keywords: Climate change; aridity; water resources; eastern Nile basin

Abstract Paper 7B-3

Effect of climate change on Long term trend of Climate variability's in the sub-catchment of Tekeze basin, Ethiopia

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The effects of climate change are significant on both weather and long term climate variability. The present study is concerned with the effect of climate change on long term climate variability's for rainfall, temperature and potential evapotranspiration in Tekeze sub-catchment, Tekeze basin in Ethiopia. The future climate variables were obtained from Coordinated Regional Climate Downscaling Experiment (CORDEX) Africa program for Representative Concentration Pathways (RCPs) of RCP 2.6 and RCP 4.5scenarios. The Mann-Kendall test and Sen.'s slope estimator were used for trend detection using XLSTAT software package. The results indicated a decreasing trend in annual rainfall and an increasing trend in average temperature and evapotranspiration for selected scenarios. At the catchment level, precipitation decreases by 20% for both RCP 2.6 and RCP 4.5 scenarios, and actual evapotranspiration show 0.4% and 8.1%increment for RCP 2.6 and RCP 4.5, respectively. This study results would help policy makers, scientists, government officials and local stakeholders in planning and management of water resources and for early warning of drought and flooding in the study area in particular and in Ethiopia in general.

Keywords Tekeze catchment, Climate change, Trend analysis, Ethiopia

Abstract Paper 7B-4

Title: Transboundary management of day-to-day variations in discharge and water levels in the Blue Nile downstream the GERD

Author: Mohammed Adam Abbaker Basheer

Day-to-day variations in river discharge and water levels are quintessential components that influence the livelihoods of the populations that reside along river banks. Though the construction of mega dams on rivers creates a variety of benefits (e.g., hydropower, irrigation), they alter the natural day-to-day variation patterns of river discharge and water levels based on the dam function/s, the hydrologic condition, and/or the water volume available in the reservoir.

The Grand Ethiopian Renaissance Dam (GERD), an under-construction hydropower storage dam on the Blue Nile River in Ethiopia, triggered several studies and debates on its possible impacts on the downstream countries. While the construction of the GERD is approaching its final stages, questions about the operation of the dam and the consequent downstream impacts are still arising. This study sets out to demonstrate the long-term implications of the GERD for the day-to-day change in the Blue Nile discharge and water levels. To this end, a daily 30-year hydro-policy model is developed for the Eastern Nile Basin using RiverWare, a river and reservoir simulation tool, to include major water fluxes, storage dams, significant water users, and stage and discharge river gauges. Point-to-pixel evaluation is carried out for four daily satellitebased rainfall products, and the best performing one is utilized as a boundary condition to estimate the inflow of ungauged river streams using HEC-HMS. The implications of the GERD for discharge and water levels are analysed at two locations (namely Eldiem and Khartoum gauges) in two cooperation scenarios: unilateral action in which the GERD is operated to maximize energy generation; collaboration in which a higher priority is given to keeping the absolute day-to-day change in the dam outflow below 100 MCM/day whenever possible. The two scenarios in addition to the baseline are tested across 30 hydrologic sequences developed using the index-sequential method. The results show a decrease in the probability of exceedance of the annual energy generation from the GERD when shifting from unilateral action to collaboration. However, the extreme day-to-day variations in river discharge and water levels decrease with raising the cooperation level. Moreover, with increasing the cooperation level, the results show a decrease in the probability of exceedance of the number of events with an absolute day-to-day change in river discharge of above 100 MCM/day.

The present analysis is imperative to improve transboundary management of floods in the context of dam operation in the quest for maximizing the benefits from the Nile water resources.

Keywords: Day-to-day variation, satellite-based rainfall products, RiverWare, HECHMS, cooperation

Key points of the Plenary

- Weakness and strength of Eta Model
- How to decide whether the forecast is good or not
- Number of Climate change models used in predicting the aridity
- Precipitation indicates a decreasing trend for the observation and future projected for both the climate change scenarios RCP 2.6 and RCP 4.5.

Take away messages

- Mixt Aridity trends will exist by the year 2070
- 36- 58% of the region's area suffers decreased runoff amounts
- The results show a decrease in the probability of exceedance of the annual energy generation from the GERD when shifting from unilateral action to collaboration.
- The extreme day-to-day variations in river discharge and water levels decrease with raising the cooperation level.

Session 8A: Improving Precipitation and Flood Forecasting
Chair: Mr. Thomas Jang Kan Doup; Rapporteur: Dr. Modathir

Abstract Paper 8A-1

Validation of multiple satellite rainfall products over the complex topography of Tekeze-Atbara tributary of the Nile basin

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Satellite rainfall products are considered an important source of rainfall data in the absence of ground measurements. However, estimates from these products need to be validated as their accuracy can be affected by geographical position, topography, climate and embedded algorithms. Five satellite rainfall products (TRMM, CHIRPS, RFEv2, PERSIANN and CMORPH) were evaluated against ground observations over the complex topography of the Tekeze-Atbara basin in Ethiopia. The performance was evaluated at various temporal and spatial scales over the period 2002-2015. Results show that CHIRPS, TRMM, and RFEv2 give estimates that are closest to rainfall measured from rain gauges at all spatiotemporal scales. The percentage bias (PBIAS) and correlation coefficient (r) of these products were within ±25% and >0.5 for all time and space domains. The remaining products performed poorly at daily time step with PBIAS up to ±100% and lower r (<0.5) at all spatial scales. However, the performance of all products improved at monthly and seasonal scale in both point and aerial comparisons. Compared to the lowland, the PBIAS at highland sub-basin increased by 35% whilst r dropped by 28%. CHIRPS and TRMM products showed best agreement in the mountainous area. CMORPH and TRMM overestimated while the remaining products underestimated rainfall in all conditions. The performance of the products did not show a uniform pattern with respect to space. Their performance improved from point to aerial comparisons in the lowlands whereas it slightly reduced in highland areas. Unlike all other products, CHIRPS and TRMM estimates improved at basin level compared to point data. Our results show that rainfall estimates by CHIRPS and TRMM have a consistently good agreement with ground rainfall at all spatio-temporal scales. Though, interpolation of ground measurements of sparse gauge network over the rugged terrains of the Upper Tekeze-Atbara basin may introduce unknown uncertainties. Considering the complex topography and limited gauges, the performance of CHIRPS and TRMM indicates that both products can be applied for any hydrological and overall water management applications in the region.

Keywords: Rainfall estimation**,** Satellite products, validation, Tekeze-Atbara Basin, Nile River Basin, Ethiopia

Abstract Paper 8A-2

The Potential of the GPM satellite rainfall products towards the enhancement of the precipitation measurement and flood forecasting

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The measurement of rainfall intensity is always challenging due to high spatial and temporal variation of the precipitation. Accurate and continuous monitoring of rainfall is crucial for many hydrometeorological applications such as flood forecasting, flood warning systems, design of hydraulic structures, water resources management and other numerous applications. Recently, many techniques and instruments that have been developed for estimating precipitation that eliminate the shortcomings of the traditional methods. Multi-satellite sensors have been globally utilized over the past three decades to measure the precipitation. At the present, many satellites continue to prove their efficiency in estimating the precipitation accurately. The Global Precipitation Measurement (GPM) satellite has the capability to detect and measure all types of precipitation using a combination of advanced instruments; a GPM Microwave Imager (GMI), and a Dual frequency Precipitation Radar (DPR) ta unprecedented spatial and temporal resolutions. The Integrated Multi satellite Retrievals for GPM (IMERG) algorithm has been developed to produce the precipitation estimates. This study validates the accuracy of the GPM IMERG early, late and final rainfall products over arid and semi-arid regions, against ground rainfall observations using multiple spatial and temporal assessments. The evaluation was conducted to evaluate three satellite capabilities, namely: the contingency of satellite estimates, bias and error of satellite precipitation products, and consistency of rain-gauge data and satellite estimates.

The results showed that the GPM IMERG near-real-time products (early-run-product and late-run-product) could play a significant role in enhancing the output of the flood early warning systems. While using the GPM IMERG gauge-calibrated product (final-run product precipitation product) could provides not only a better understanding of the rainfall variability and pattern over the arid and semi arid regions, but also could serve as a reliable product to complementing and/or substituting ground precipitation measurements for ungauged or poorly gauged regions. To the best of the author's knowledge, this research represents one of the earliest assessments of the GPM IMERG products in the Middle East. Furthermore, it could be used as a valuable reference for future improvement of the IMERG algorithms.

Abstract Paper 8A-3

Improving Satellite Rainfall Data to Predict
Blue Nile River Flow

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Obtaining representative meteorological data for Blue Nile River Basin hydrological modeling can be difficult and time consuming. The main objective of this study is to develop methodology for obtaining hydrological data for the Blue Nile sub-basins. As well to establish different types of data bank for the Blue Nile River Basin by using the Climate Forecast System Reanalysis. Data scarcity has been regarded as a huge problem in modeling the water resources of the Blue Nile River Basin. Satellite rainfall data together with the evapotranspiration have been used to calculate the runoff data. However, in data-scarce regions such as in a transboundary basin, remote sensing data could be a valuable option for hydrological predictions when ground rainfall stations are not available. As well as the remote sensing data can be used to fill gaps in the ground rainfall stations. The satellite rainfall data for all Blue Nile sub-basins were downloaded in a monthly basis for the period 1980-2010 from the Global Weather Data for the National Centres for Environmental Prediction (NCEP) from its website (www.globalweather.tamu.edu). This data was modified with the actual measured rainfall from near gauge stations for the period 1993-1999 by using a weighting factor depending on the distance between satellite data, by using inverse equation and the distances between the middle of sub-basins and the first and second nearest measured rainfall stations respectively, the modified satellite rainfall data have been derived. The selection of the boundary coordinates are used for each sub-basin to set the nearest rainfall satellite station in the middle of each sub-basin and, this is done by using the global weather and Google earth capability. The relation between modified rainfall data and the satellite rainfall data have been found. Different types of input data are used in the WEAP model after being modified and calibrated, such as satellite rainfall data, ET_{ref}, effective precipitation, and crop coefficient K_c in the upper Blue Nile basin. The observed stream flows, using rainfall-runoff relationship, have been simulated with the measured flows by using WEAP model at the four river gauging stations (El-deim, Giwiasi, Hawata and Khartoum) in a monthly time step yielded reasonable values. By evaluating the Blue Nile River Basin at the calibration period (1980-1995) in a monthly time step, the NSE, r^2, and d results for the Blue Nile River at the gauging stations showed a very good model performance.

Abstract Paper 8A-4

Importance of Calibrated Satellite Data for Weather and Climate Monitoring and Forecasting.

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The RFE (satellite rainfall estimation) has significant role in weather and climate forecast and Monitoring. Calibration and gridding using thermal infrared satellite data from (METEOSAT) EUMETSAT at high resolution (10x10km) based on CCD (cold cloud duration) of cloud top temperature and rainfall homogeneity, for each months the CCD value is differ from place to place and from month to month, then the satellite RF is correlate with climatologically observed data, the high correlated is selected for calibration. After calibration two data type is producing merged (satellite and gauge) and TAMETHRFE (calibrated rainfall estimation only), then the gridded process is done using climate aided interpolation and kriging for interpolating, the Merged and TAMETH data is evaluated using, bias error method regenerating nwp model, LEAP software, DRMFSS (disaster risk management and food security sector assessments), FAO field report and central statistic yield report. According the evolution there's not much difference between calibrated (TAMETH) grid satellite data and merged data then using more gauge data haven't significant role over the calibrated TAMETHRFE, the satellite gridded data is the most important more than 95% for NWP, 97% for flood monitoring, 72%, for crop monitoring 93% for moisture index, 67% yield assessment and yield reduction estimation, according the evolution. Finally using satellite has significant role due to availability resolution in time and space.

Key points of the Plenary

- **The correlation coffcient is not enough without calculating the significance.**
- **Other error assessment methods should be used.**
- **Is the high correlation between CHIRPS and gauge due CHIRPS high resolution?**

Take away messages

- **Satellite precipitation data are not very good in capturing peaks but t depicts the climate very well.**
- **The IMERG final run products could replace the ground observational data**
- **Calibrated satellite data has better skill than RFE only**

Session 8B: Flood Management and Preparedness Plan

Chair: Dr Amare Haileslassie; Rapporteur: Ms. Mwasiti A. Rashid

Abstract Paper 8B-1

Community awareness for Managing Natural Disaster Risks of Flash in Sudan: Case of River Gash, Kassala State, Sudan

Maha A. Algaffar & Gamal Abdo; Water Research Centre, University of Khartoum

According to the Sudan Meteorological Authority, the rainfall in July 2016 was two and a half times higher than in July 2015. The Sudanese Red Crescent Society reported that 25 people died in eastern Sudan's Kassala, and around 8,000 houses have been destroyed since heavy rains lashed the state.Under such circumstances, access to affected communities remains challenging due to the poor capacities regarding risk management among rural communities. The prime objective of this paper is to reduce the socioeconomic devastating impacts caused by floods through building capacities for early communal response in the study area. The economy depends primarily on agriculture. Pastoral is the second activity for inhabitants, the pastoral form of production includes nomadic, semi nomadic and sedentary livestock raising.The Gash River, is a major water supply source in the state providing around 560 million cubic meters of water per year during its months of heightened flow. It is the source that had created the Gash Delta (300 thousand fedans) that has the most fertile land on which most of the Kassala's socio economic activities depend. Serious damages were caused by the River Gash when it floods. The recent incidents of 2007, 2010, 2013 and 2016 caused devastating effects to the city of Kassala and other parts in the state.

Twelve designed posters were prepared for various target groups using simple drawings and pictures to attract the public attention on the negative impacts of the flash floods, protection and safety of humans and properties beside community preparedness and response. All posters were put to test in two primary schools in Khartoum and Kassala States. One pocket booklet was produced using simple ideas and illustrative drawings to inform primary school pupils on the impacts of the disasters caused by flash floods. Another Manual booklet for teachers was produced including the impacts and consequences of flash floods. Two documentary films (7 minutes each) were produced including different messages regarding floods positive and negative impacts. The documentary also reflects on the health related problems during flood events. One documentary was presented at the Blue Zone arena at the Marrakech Cop 22 meeting and was well received.

Two basic schools and two high schools were selected in the areas of high risks for raising the awareness of school children and teachers on the impacts of flood and the need for community awareness and involvement in the pre and post flood consequences. The selection criteria for the school was to include among other factors representation of urban and rural schools covering the flood prone areas of River Gash.The issues discussed with students and teachers included how to get prepared for before, during and after flood happens, how to do flood safety and contingency planning, how to empower community to become more resilient, availability of resources, flow of information through Community Radio. Four awareness workshops were organized in the three above mentioned risk areas in the state. One in Aroma Locality Hall.Two workshops were conducted in Wagar locality at the girl's school buildings and the last one was conducted at the Oleib primary school. The agenda of the workshops included, flash floods definition, causes, impacts and consequences, introduction of a list of action and recommendations for protection and

safety procedures before, during and after Flash Flood Event, how to make contingency plans and follow-up plansusing social media and mobile phones and to formulate active and communication groups. It was recommended that a simple monitoring system should be developed to be implemented by the active and communication groups formed earlier at the awareness workshops. The monitoring results are to be circulated among other communities using mobile phones and Community Radio channels.It is extremely important to develop future plans for sustainable flood related awareness actions to reduce losses of lives and belongings.

Abstract Paper 8B-2

Improved early warning communication and preparation for better flooding management.

Mahmoud Mohamed Fouad Hussein.
Director of drinking water quality department, Holding Company for water and wastewater, Egypt.

The world's climate is changing and will continue to change into the coming century at rates projected to be unprecedented in recent human history. The risks associated with these changes are real but highly uncertain. Societal vulnerability to the risks associated with climate change may exacerbate the present social and economic challenges, particularly for those parts of societies dependent on resources that are sensitive to changes in climate.
Many of the urban poor in Africa face growing problems of severe flooding. Increased storm frequency and intensity related to climate change are intensified by such local factors as the growing occupation of floodplains, increased runoff from hard surfaces, inadequate waste management and silted up drainage.
The communication of an early warning is the crucial step between the forecasting itself and the acting upon a warning. To be used to trigger response actions, warnings need to be trusted, understood, and usable.
This paper aims at studying the efficient early warning communications and preparations in extreme climate events like heavy rains and flooding. As a case study, Egypt has experienced several extreme heavy rains that were not as usual in some areas. This affected in the past the community in these areas very badly.
Mainly, there were three regions that affected very with the heavy rains upper Egypt, red sea and west-northern coasts. During the forecasted periods for heavy rains, some adaptation measures are set and proceeded to ensure minimum loses. These measures include but not limited to **<u>Prevention:</u>** preventing damage caused by floods and heavy rains by avoiding construction of houses and industries in the present and future flood-prone areas; by adapting future developments to the risk of flooding; by promoting appropriate land-use, agricultural and forestry practices; **<u>Protection:</u>** taking measures, both structural and nonstructural, to reduce the likelihood of floods and/or the impact of floods in a specific location; **<u>Preparedness:</u>** informing the population about flood risks and what to do in the event of a flood; Emergency response: developing emergency response plans in the case of a flood; **<u>Recovery and lessons learned:</u>** returning to normal conditions as soon as possible and mitigating both the social and economic impacts on the affected population.
Finally, the previously mentioned measures and precautions have rescued the life of many people and ensured a high percentage of rainwater saving. Especially Egypt suffers nowadays from limited water resources.

Abstract Paper 8B-3

Adaptive Flood Management Approach for the Eastern Nile

Dr. Yosif Ibrahim[1]& Eng. Ammar Abdalla[2]

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The high seasonal and interannual variability in the Eastern Nile accompanied by the uncertainties associated with recent trends of climate extremes poses a great threats and challenges in coping with floods and drought in the EN region. On the other hand, the Grand Ethiopian Renaissance Dam (GERD) and the heightening of Rosaries Dam, among other storage infrastructures, offer an opportunity for integrated adaptive management approach in dealing with climate extremes (floods and drought), with the overall goals of enhancing the resilience and adaptive capacities of communities along the EN. We argue on the need for a resilient framework for floodplain management that integrate smart technologies and effective communication between upstream and downstream storage infrastructure.

This paper highlight a blue-print of a framework for flood management approach that integrate smart technology and automated communication among storage infrastructures to cope with climate extremes.

The proposed framework would require a real flood forecasting system that consider the connectivity and feedback loop among flood management infrastructures. Building on the theory of Complex Adaptive System (CAS), Network theory, Agent based Modelling and the existing Flood forecasting capability in the EN, the proposed framework will integrate the entire system as a network that consists of nodes that effectively communicate with each other with a flow of information from and to these nodes.

The paper highlight the proposed methodology, the analytical framework and means of integrating and operationalizing the system as part of the EN Flood forecasting system and means of transitioning such a system as part of joint operation of the Eastern Nile storage infrastructures.

Abstract Paper 8B-4

FLASHY RIVERS FLOOD FORECASTING USING OPEN SOURCE DATA: GASH RIVER AS CASE STUDY, SUDAN.

El-Hadi Adam.[1], Barsi, B.I.[2], Mohamed, Y.A.[3] Salih A.MA[4]

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The Gash River, in Kassala State - Eastern Sudan- is a flashy seasonal river originates from the Eritrean and Ethiopia highland, and flows only during the period from July to September. The Gash river crosses Kassala city, and causes large damage during high floods when frequently breaches into the city. Despite the continuous intensive protection work, yet the city is still under a high risk of flooding. This paper presents a Flood forecast system developed for the Gash river. The US Army Corps of Engineering, Hydrologic Engineering Center's - Hydrologic Modeling System (HEC-HMS) software was used for rainfall-runoff modeling. The study used near-real-time Satellite Rainfall Estimate (SRE) data from Tropical Rainfall Measuring Mission (TRMM-3B42RT) to generate the areal-average daily and/or hourly rainfall over the catchment. Absence of ground rainfall data in the upper catchment inside Eritrea makes it very difficult to validate the SRE. New reliable discharge measurements at Gera station (outlet) for the years 2015 and 2016 were obtained for validation of the model. The (HEC-HMS) software was run for hourly intervals.HEC-HMS simulate the rainfall-runoff process very well. A reasonable lead time was obtained. The main function of the proposed flood forecasting system is to issue warning message when water levels exceed threshold values to prevent disastrous flooding.

Key words: Gash Basin, Rainfall-runoff modeling, HEC-HMS, TRMM-3B42RT.

Key points of the Plenary

- **The benefits of translating community awarenes materials to four languages to impove reach**
- **awareness campaign in Sudan involved on female teachers. This is due to the fact that majority of those affected disasters are women are affected with disasters.**
- **How to find an exceptional/unique way from gender professionals on how to involve women in Sudan**

Take-away messages

- **Flood management response should come from the communities themselves and they should not depend only on the government and relief organizations, so there is a need to increase awareness for individuals to protect their families and properties against flash flood impacts**
- **Flood risk awareness documentary should be prepared and circulated to different stakeholders including the communities**
- **Find good ways to link different organization working in flood management for improving early warning communication**
- **Improve data and information management before and after the flood events**
- **EN agreed need to have a regional approach for CC adaptation dealing with climate extremes flood and drought**

Session 9: Enhancing FFEW system (Plenary Sessions)

Chair: Dr. Abdulkarim H. Seid

Dr. Mohammed A Hassan - Consultant-ENTRO
Proposed EN Flood Forecasting and Early Warning System

Effective flood early warning needs to;

- Have continuous input-data availability in real/near real time,
- Be end to end; from data acquisition and ingestion, hydrologic and hydraulic modeling to issuing of warnings
- Be operational around the clock

Background

- The objective of the proposed enhancements is to have 'an operational, unified and enhanced flood forecast and early warning system for the entire EN that include Lake Tana, TAS and BAS sub basins'
- The system will Includes a suits of models that deals with
  - rainfall forecasting,
  - hydrologic modelling,
  - hydraulic modelling and
  - A Web based system for accessing model outputs and other relevant information

Type of hazard forecasted

- Though the current focus is riverine floods, it is necessary to start work on flash flood early warning for catchments which are prone.
  - Rank Catchment based on impact of flash flood and existing hydromet network
  - Scope for potential data sources for setting up a flash flood early warning system

Coverage

- Develop the Riverine Flood forecasting system for Tekeze-Setit-Atbara (TSA) sub basin
- Improve existing Riverine Flood forecasting system for Lake Tana, Blue Nile and Baro-Akobo-Sobat (BAS)

Flood Forecasting System

- An operational common flood forecasting system for all the models will be developed.
- (Options: Delft Fews, Mike Operation and HEC RTS)

FFS	HEC-HMS model compatibility	HEC-RAS model compatibility	Web Dissemination	Free for operational use?
Delft FEWS	Yes	Yes	?	No
HEC RTS	Yes	Yes	No	Yes
Mike Operation	No	Yes	Yes	No

- HEC Real Time Simulation (HEC RTS) is proposed as the most suitable FFS as it has most of the important FFS features and is compatible with existing models.

The HEC RTS analysis software includes

- HEC Met Vue: Processes meteorological data for HEC HMS
- MFP: Meteorological Forecast Processor for processing meteorological forecasts for input to the HEC HMS
- HEC-HMS: Simulates watershed Response to precipitation
- HEC-ResSim: Reservoir simulations Software
- HEC-RAS: River Analysis System for hydrodynamic modelling
- HEC-FIA: Flood Impact analysis software
- Scripting, Scheduling and reporting modules

Rainfall forecasting

- The proposed system will take advantage of global forecast data that is freely available and continuously improved. This can also be used to validate the locally produced WRF outputs
- Options on data to supplement and validate the existing ENTRO WRF Model are;
    - Global Forecasting System (GFS) by NOAA, free download from the internet (upto 7 days forecast, daily, 0.25deg spatial resolution
    - Regional WRF Forecasts by local regional climate agency (ICPAC). Up to 10 days forecast, 13.5 km spatial resolution, daily. (At the end of 2019 new system with a resolution of 4km, hourly will hopefully be available)
- Member states WRF systems

Rainfall Runoff modelling

- Include existing reservoirs in the Blue hydrological model
- Re- assess developed models on its accuracy and especially under the proposed changes (forecast rainfall, reservoirs ..),
- Develop and calibrate R-R model for Tekeze-Setit-Atbara system
- Run the models in a continuous mode
- Option for Input/forcing data (PET: USGS Global PET, Precipitation: IMERG, Rfe, CMORPH)
- Model Selection options depend on FFS: HEC-RTS
    - Three existing sub basin (LT, BN, BAS) use HEC-HMS it is advantageous to use these models and build the TSA system using HEC-HMS

Hydraulic/hydrodynamic modelling

- Migrate to one hydraulic/hydrodynamic model
- Since two of the already developed models are HEC-RAS and HEC –RAS can be run by both potential system it is proposed to use HEC-RAS in the unified system
- Assess model performance after flood event/season
    - Post flood event/season flood extent with Remote sensing data will be carried out to assess the model performance

Dissemination System

- Carry out stakeholder mapping and survey for flood prone areas to identify actors and information needs and means of communication
- It is necessary to have a web based interactive FFEW system where users can interact with historical and forecast data (time series, maps and reports)
- Design and develop and interface which integrate all forecast tools and help with the early Warning dissemination and linkage with the portal

Capacity Building and validation of FFEWS

Staff will be trained on the theory as well as practical on the development and operation of

- Data processing
- Meteorological forecast model
- Hydrologic and hydrodynamic model
- Dissemination portal
- Testing and validation of the FFEWS will be undertaken in collaboration with the operation and maintenance staff and other potential users

Dr. Modathir Zaroug-Nile Secretariat
Short Term to Seasonal River Flow Forecast over the Nile Basin

Introduction

- Operational decisions on water allocation for various uses can be improved if information is available on expected volume of water at a particular point in the river network.
- The Eastern Nile is prone to regular droughts and floods, which result in devastations to life and property.
- No basin-wide river flow forecasting system exists that would provide river flow (runoff volume) forecasts for operational use.
- To fill this gap, NBI intends to develop a short –range to seasonal operational river flow forecast system for the Nile Basin to support water resources management basin-wide.
- The flow forecast system may have a web-interface so that the forecast information is easily disseminated through the NBI Integrated Knowledge Portal.
- Improved river flows information helps to prevent unnecessary releases; improve planning decisions on cropping; improve safety of water infrastructure (due to unusually high flows).
- The success of the dams coordination depends on the degree of confidence on expected volume of water at the dams which lead to retain or release stored water.
- The development is planned to be done with two consultants.

Objective

- The ultimate objective of the proposed short-range to long-range seasonal forecast system is to provide river flow forecasts across selected pointed over the Nile Basin.
- Short-range forecasts will benefit from the data that will be collected through the planned Nile Basin Regional Hydromet System to provide more precise forecasts.

Preparatory phase

- Review of available forecast systems:
    - Review worldwide available and uses of short – range to seasonal range river flow forecast systems.
    - Classify river flow forecast systems taking in to account key factors, such as technologies used, data needs, flexibility, forecast information they generate, lead time.
    - Selection of approaches, methods and components for the NB river flow forecast system.
    - Comparative analyses on the advantages and disadvantages of the available river flow forecast systems, and data needs and availability.
    - Consider the challenges and gaps, and what need to take into account.

User Needs assessment:

- The river flow forecast system shall be developed to meet user expectations and needs.
- Designing appropriate process (questionnaire, user engagement format, etc) for gathering user needs and development of the user requirement specs to be used to drive the design of the forecast system.

Conceptual design:

- Detailed description of the types of uses for which the forecast system that shall employed for.
- Overall architecture of the forecast system: the user needs and the specific characteristics of the various identified uses of the system. The NB may have different forecast systems (e.g. multi-functionality system) depending on the sub-basins need (best system design that meets the wide range of requirements).

- Description of the components of forecast system; with sufficient technical details.
- Design specifications for the river flow forecasting system based on international standard.
- Description of specification of data inputs and sources of data

Working group

The Regional Working Groups will support the detailed development of the flow forecast system by:

- Take part in and contribute to the development of the flow forecast of the Nile River Basin development.
- Support sourcing the latest data (flow, rainfall, and any relevant information) for usage by NBI-Sec during and after the development of the river flow forecast system.
- Provide expert opinions in identifying gaps and needs/requirements for developing the forecast system.
- Contribute in the review and validation of data used during the river flow forecast development.
- Review the prepared outputs such as; technical background document and conceptual design.
- Share and solicit feedback from relevant country stakeholders and report back to NBI Task Team.
- Participation in Workshops to develop the users' needs/requirements and the survey questionnaire which gather information on current practices in the Nile Basin countries in the use of river flow forecast systems.
- Regularly report to the Nile-TAC members of his/her respective country at milestones in the preparation of the river flow forecast and findings.
- Support the dissemination of the final river flow forecast product.

Development of the river flow forecast system.

- Identify available tools, methodologies and datasets that for the Nile Basin water supply forecast systems and prepare a design document of the forecast system (use NBI analytic tools to the extent possible).
- Develop and operationalize the forecast system which, will make use of available global datasets (such as climate/weather forecasts; climate indices (such as ENSO index and forecast); precipitation. The number of predictors will be determined based on availability of the data, and the contribution of each predictor to the accuracy of the forecast.
- Develop operational forecasts of water availability at a number of points in the Nile Basin and post forecasts on NBI's data portals publicly;
- Test and validate forecast information; expert group meetings/roundtables to verify forecasts and their usefulness.
- Refine and finalize forecast system.
- Develop and operationalize a monitoring/reporting mechanism for periodic assessment of status of use of the operational forecasts, new requirements and user support needs
- Launch and issue the Nile Basin water supply forecast bulletin

Ms. Bessie Schwarz -Cloud to Street
Dynamic Flood Mapping Across the Eastern Nile for Risk Reduction

Introduction

- Traditional Flood Modeling and Mapping
    - Requires significant accurate local data
    - Precise but manual and goes out of date
    - Assumption based
- Advantage of Satellites
    - Seamless monitoring in the cloud
    - Rapid and remote installment & updating
    - Leverage observed existing data

Uses and Users

- Insurers & Development Agencies
    - Risk mapping
    - Affordable catastrophe insurance
- Emergency Managers
    - Predict the size and damage of a flood (future)
    - Emergency evacuation
- **Governments**
    - Map of communities hit hardest
    - Target recovery programs
- **Humanitarians & Climate Insurers**
    - Near-real time flood map
    - Release aid within 48 hours

Eastern Nile Basin Flood Maps Dashboard

- 17 Historic flood event maps
- Flood frequency across the watershed over 30 years
- Annual, seasonal, monthly comparisons
- Precipitation history
- Immediate Uses
    - Validate and calibrate current models
    - Identify hotspots of exposure across Eastern Nile
    - Identify wetlands
    - Design dykes
    - Assess changes from dykes, land use change, canals etc.
    - Public awareness

Potential Future Steps

- Accuracy assessment of current models and model calibration
- Near real-time flood alerts and monitoring
- Layer with more data (e.g. assets, road network)and integrate into new ENTRO portal and bulletins with text and email alerts
- Add more flood event to the library yourself
- Community engagement and remote sensing capacity building
- Additional statistical analyses to determine return time/probabilities of flood magnitudes based on gauges or precipitation

Key points of the Plenary

- WRFHydro which is a potential model since it combines both the meteorological as well as hydrological in one plaltform
- For Tekeze-Setit-Atbara sub basin, it is necessary to assess the rainfall products so as to understand which one is the best. Work done by UNESCO-IHE should be reviewed.
- On the comparison of the forecast system it is necessary to also consider the availability of the helpdesk support system.
- It is important to consider the of format of information dissemination to the end user for an effective EWS.

Session 10: Way forward (Plenary Sessions)

Chair: Mr. Fekahmed Negash

Dr. Mohammed A Hassan - Consultant-ENTRO

Key Message

The 3rd ENFlood forum has facilitated engagement of key flood related stakeholders in the region and exchange of knowledge between the experts in flood related research fields. The other key message emanating from this forum is that floods are trans-boundary and as such there is need for countries to collaborate in flood forecasting and early warning activities. Development of more water storage infrastructure and improved catchment management will lead to reduction of flood impact.

The participants agreed that flash floods are increasing and need to be considered in the FFEW. In addition, the WRF model need to be improved and its outputs included in the Blue Nile FFEW. The FFEW system should be extended to cover other flood prone areas and Stakeholder/end user communication needs to be improved by the countries

In future, ENTRO needs to initiate discussions on real-time data sharing agreement that is harmonized with the current NBI data sharing policy and take advantage of the hydromet project. Thus ENTRO is encouraged to engage the countries on data sharing particularly the WRF models outputs to be used in the enhanced FFEWs

Opportunities for testing the FFEWs reliability are few (rainy/flood seasons) and right institutional framework/agreements are needed between various Government agencies for an effective FFEWS. Cloud computing seems to be an option in cases of weak institutional and infrastructural setting.

Conclusion

The forum met its expectations, the papers and other presentations were of high quality. Special thanks was accorded ENTRO and the World Bank CIWA.

The forum organizers were urged to consider inviting directly affected stakeholders in the next forum. The participants also suggested that proposed Flood forecasting and Early warning as well as short term to seasonal forecasting work needs to continue as planned but will consider all the comments from the forum.

ANNEXES

ANNEXI.Forumprogramme

Flood Forum "Enhancing Flood Forecast and Early Warning in Eastern Nile Basin"		
Time	**Presentation/Activity**	**Presenter**
DAY 1: August 16th , 2018 (Plenary Sessions)		
08:30 - 09:00	Registration	All
	Forum Opening	**Master of Ceremony**
09:00 - 09:05	Official Opening Speech by Guest of Owner	
09:05 - 09:15	Opening	ENSAPT Chair ENSAPT Leaders
09:15 - 09:20	Welcome remark	Mr. Fekahmed Negash
09:20 - 09:30	Introducing forum objectives and program	Mrs. Azeb Mersha
09:30 - 09:40	Keynote	Dr. Abdulkarim H. Seid
Session 1: Current FFEWS *(ENTRO current FFEW practice and experience)*		**Chair: Mr. Thomas Jang Kan Doup**
09:40 - 09:55	Lake Tana Flood Forecasting	Mr. Surafel Mamo
09:55- 10:10	BAS Flood Forecasting	Mr. Chuol Biel Thoan
10:10– 10:25	Blue Nile Sudan Flood Forecasting	Ms. Asma Hussein
10:25 - 10:40	Discussion	All
10:40 - 11:10	**Exhibition over coffee break**	
Session 2: Gaps and proposed enhancement		**Chair: Mr. Teshome Atnafe**
11:10– 11:30	Gaps on current system	Dr. Mohammed Hassan
11:30 - 11:50	Discussion	All
Session 3: National Experience– Meteorology *(Real time data collection and communication through telemetric system for flood early warning and rainfall forecast)*		**Chair: Mr. Teshome Atnafe**
11:50- 12:00	Ethiopia	Mr. Asamenew
12:00- 12:10	South Sudan	Mr. Emmanuel Qurino
12:10– 12:20	Sudan	Mr. Nouralbalad Mahmoud
12:20- 12:40	Discussion	All
12:40 - 13:40	**Lunch Break**	
Session 4: National Experience– Hydrology *(National report on flood forecast and management)*		**Chair: Prof. Seifeldin Hamad Abdalla**
13:40 - 13:55	Ethiopia	Mrs. Semunish Golia
13:55 - 14:10	South Sudan	Mr. Gai Simon
14:10 – 14:25	Sudan	Mr. Abdalrhman Saghayroon
14:25 – 14:40	Awash Basin Authority	Mr. Debebe
14:40- 15:00	Discussion	All
Session 5: National Experience – Disaster Management *(Flood damage assessment and coping mechanisms & Community managed flood preparedness plan)*		**Chair: Prof. Seifeldin Hamad Abdalla**
15:00- 15:10	Ethiopia	Ms. Almaz Demessie
15:10- 15:20	South Sudan	Ms. Betty Kitta Scopas
15:20– 15:30	Sudan	Mr. Yasser Mohamed
15:30- 15:40	Tana Sub-basin Organization	Mr. Birlew Aebeb

Flood Forum "Enhancing Flood Forecast and Early Warning in Eastern Nile Basin"		
Time	**Presentation/Activity**	**Presenter**
16:40- 16:00	Discussion	
16:00 - 16:30	**Coffee Break**	
Session 6: Regional and International Experience		**Chair: Prof. Seifeldin Hamad Abdalla**
16:30 - 17:00	Flood Forecast and Early Warning system of Malawi	Dr. Mekuria Beyene
17:00- 17:20	UNOSAT and its operations globally including, Flood Finder System and Flood Forecasting and Mapping in Lake Chad Basin	Dr. Hari Prasad
17:20– 17:40	Nzoia Flood Early Warning including inundation mapping and community Flood radio station (RANET)	Dr. Andrew Karoki
17:40- 18:00	Discussion	All
18:00- 18:10	Planning for Second day	Dr. Mohammed Hassan
END of Day One		
Day Two: August 17th , 2018 (Parallel Sessions)		
Day Two Opening		**Chair: Eng. Michael Abebe**
09:00 - 09:20	Re-Cap from 1st day and planning for 2nd day	Dr. Mohammed Hassan
Session 7: Selected Paper Presentations – Parallel session		
Session 7A: Tools and methodologies for flood analysis		
Chair: Dr. Maha Algaffar **Rapporteur : Milly Mbuliro**		
09:20 - 09:25	Session Introduction	Dr. Maha Algaffar
09:25 - 09:40	Bayesian Networks and Data Driven Models for Estimating Extreme River Discharges Case Study: Magdalena-Cauca Basin, Colombia	Mr. Ahmed Nasr
09:40 - 09:55	Effect of State noise and model parameterization in data assimilation for flood forecasting with distributed hydrological model: application of Meuse river basi	Mr. Hailay Zeray
09:55 – 10:10	Maximizing the use of satellite data and hydrological modelling for streamflow prediction: Case study of Dinder and Rahad rivers (tributaries of the Blue Nile, Ethiopia-Sudan)	Mr. Khalid Hassaballah
10:10 – 10:25	Recent Advances in Flood Forecasting and Early Warning Systems	Mr. Zelalem Tesfay
10:25- 10:40	Discussion	All Participants
10:40 - 11:00	**Coffee Break**	
Session 7B: Flood Forecast under Climate Change impact		
Chair: Dr. Seifu A. Tilahun **Rapporteur : Amna Omer**		
09:20 - 09:25	Session Introduction	Dr. Seifu A. Tilahun
09:25 - 09:40	Verification of precipitation forecasted by the SOO/STRC Workstation Eta and five points over Blue Nile catchment	Mr. Redwan Abdelrhman
09:40 - 09:55	Aridity trends amidst climate change in the eastern Nile region	Dr. Shamseddin Musa

Flood Forum "Enhancing Flood Forecast and Early Warning in Eastern Nile Basin"		
Time	**Presentation/Activity**	**Presenter**
09:55 – 10:10	Effect of climate change on Long term trend of Climate variability's in the sub-catchment of Tekeze basin, Ethiopia	Mr. Kiflom Degef
10:10 – 10:25	Transboundary management of day-to-day variations in discharge and water levels in the Blue Nile downstream the GERD	Mr. Mohammed Basheer
10:25- 10:40	Discussion	All Participants
10:40 - 11:10	**Coffee Break**	
Session 8: Selected Paper presentations – parallel session		
Session 8A: Improving Precipitation and Flood Forecasting		
Chair: Mr. Thomas Oromo Henry **Rapporteur: Dr. Modathir**		
11:10 - 11:15	Session Introduction	Mr. Thomas Oromo Henry
11:15 - 11:30	Validation of multiple satellite rainfall products over the complex topography of Tekeze-Atbara tributary of the Nile basin	Mr. Tesfay Gebretsadkan
11:30 - 11:45	The Potential of the GPM satellite rainfall products towards the enhancement of the precipitation measurement and flood forecasting	Mr. Mohammed Mahmoud
11:45 – 12:00	Improving Satellite Rainfall Data to Predict Blue Nile River Flow	Mr. Mohamed Abbas
12:00– 12:15	Importance of Calibrated Satellite Data for Weather and Climate Monitoring and Forecasting	Mr. Goitom Kelem
12:15- 12:45	Discussion	All Participants
12:45 - 14:00	**Lunch Break**	
Session 8B: Flood Management and Preparedness Plan		
Chair: Dr Amare Haileslassie **Rapporteur: Ms. Mwasiti A. Rashid**		
11:10 - 11:15	Session Introduction	Dr. Amare Haileslassie
11:15 - 11:30	Community awareness for Managing Natural Disaster Risks of Flash in Sudan: Case of River Gash, Kassala State, Sudan	Dr. Maha Algaffar
11:30 - 11:45	Improved early warning communication and preparation for better flooding management	Mr. Mahmoud Fouad
11:45 – 12:00	Adaptive Flood Management Approach for the Eastern Nile	Mr. Ammar Abdalla
12:00– 12:15	Flashy Rivers Flood Forecasting using Open Source data: Gash River as Case Study, Sudan	Mr. Elhadi Adam
12:15- 12:45	Discussion	All Participants
12:45 - 14:00	**Lunch Break**	
Session 9: Enhance FFEW system(Plenary Sessions)		**Chair: Dr. Abdulkarim H. Seid**
14:00 - 14:30	Proposed FFEW System	Dr. Mohamed Hassan
14:30 - 15:30	Flood Dashboard	Ms. Bessie Schwarz
15:30 - 16:00	NBI – Seasonal River flow Forecast	Dr. Modathir Zaroug
16:00 – 16:30	Discussion	All
16:30 - 17:00	**Coffee Break**	
Session 10: Way forward (Plenary Sessions)		**Chair: Mr. Fekahmed Negash**
17:00 - 17:30	Key messages and conclusion	Dr. Mohamed Hassan

Flood Forum "Enhancing Flood Forecast and Early Warning in Eastern Nile Basin"		
Time	**Presentation/Activity**	**Presenter**
17:30 - 18:00	Closing Remarks	Prof. Seifeldin Hamad Abdalla Mr. Thomas Jang Kan Doup Mr. Teshome Atnafe
	END of Forum	

ANNEXII.Listofparticipants

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Evaluation Report of ENTRO Flood Forum
16th -17th August 2018, Addis Ababa, Ethiopia

Compiled by: Awoke Kassa, ENTRO M&E Officer

1. **Background Information:**

The Eastern Nile region is characterized by highly variable climate and river flows, making it prone to consequences of extremes of droughts and floods. A significant proportion of the annual runoff volume occurs during a few high rainfall months in the year, thus, requiring adequate regulation to maintain required flow during dry periods. During high rainfall periods major rivers in the region often give rise to large scale river flooding, particularly in floodplain areas in Sudan and Ethiopia.

The EN Flood Protection and Early Warning Project (FPEW) has been one of the earliest successful IDEN Projects. The Project aims to reduce human suffering caused by frequent flooding, while preserving the environmental benefits of floods. The project emphasis on enhancing regional collaboration and national capacity in flood risk management, including flood mitigation, forecasting, early warning systems, emergency preparedness, and response. The FPEW project that ran until 2010 operated in Egypt, Ethiopia, and Sudan.

After the completion of FPEW project ENTRO initiated with Eastern Nile countries and created a regional **Flood Forecast and Early Warning (FFEW)** system under the Eastern Nile Planning Model project (ENPM) and the FFEW activity continued under the current Nile Cooperation for Result project (NCORE). The FFEW, since its establishment, has been an important part of ENTRO's activity that continuously been conducted for the last seven years flood season (June – September). The FFEW has helped the Eastern Nile countries in reducing the loss of life and money by preparing flood forecast bulletins for the Lake Tana (Blue Nile -Ethiopia), the Blue Nile-Main Nile (Sudan) and Baro-Akobo-Sobat(BAS) sub-basins flood prone areas. The FFEW activity have strengthened national offices in terms of capacity and overall reduced the risk of flood devastation for 2.2 million people in the region.
Even though ENTRO have been supporting the Eastern Nile Country with the current FFEWS which has some gaps on coverage of all flood prone areas in the basin, robustness of the system and model, limited capacity in enhancing the system to up-to-date forecast standard. It is with this objective ENTRO apply and secured a funding from the World Bank by the Cooperation in International Waters in Africa (CIWA) trust fund, and intends to apply to various projects and "**Enhancing Flood Forecast and Early Warning**" is one of these projects. This project aims at ensuring a robust forecasting, issuing and warning system that effectively minimize loss of life and damage by enhancing, expanding and developing a unified Flood Forecast and Early Warning (FFEW) system for EN basin.

This project will also ensure continued relevance of this vital program; forecast communication and dissemination need to be more easily accessible to wider and important stakeholders. Thus, there is the need for further in-depth understanding of most vulnerable communities, their socio-economic characteristics in order to design fit-for-purpose stakeholder mapping.

2. Objectives of the Flood Forum:

The main objectives of the Forum include the following:

1. To create awareness on issues of Flooding
2. To create a platform for information exchange and discuss both national and regional issues of flooding and share successful experience
3. To assess the status of flood forecasting activity and the on-going concerns in the basin
4. To learn from scientist community on innovative approach for doing more accurate forecasting and effective warning
5. To provide networking opportunities to facilitate further collaboration

3. Key Topics/themes covered:

Among others, the following are the key topics covered during the 2 days Flood Forum.

Session 1: Current FFEWS (*ENTRO current FFEW practice and experience)*

- Lake Tana Flood Forecasting
- BAS Flood Forecasting
- Blue Nile Sudan Flood Forecasting

Session 2: Gaps and proposed enhancement

- Gaps on current system

Session 3: National Experience– Meteorology(Real time data collection and communication through telemetric system for flood early warning and rainfall forecast)

- National Experience of Ethiopia
- National Experience of South Sudan
- National Experience of Sudan

Session 4: National Experience– Hydrology(*National report on flood forecast and management*)

- National Experience of Ethiopia
- National Experience of South Sudan
- National Experience of Sudan
- National Experience of Awash Basin Authority

Session 5: National Experience – Disaster Management (Flood damage assessment and coping mechanisms &Community managed flood preparedness plan)

- National Experience of Ethiopia
- National Experience of South Sudan
- National Experience of Sudan
- Tana Sub-basin Organization

Session 6: Regional and International Experience

- Flood Forecast and Early Warning system of Malawi
- UNOSAT and its operations globally including, Flood Finder System and Flood Forecasting and Mapping in Lake Chad Basin
- Nzoia Flood Early Warning including inundation mapping and community Flood radio station (RANET)

Session 7:Selected Paper Presentations – Parallel session

Session 7A:Tools and methodologies for flood analysis

- Bayesian Networks and Data Driven Models for Estimating Extreme River Discharges Case Study: Magdalena-Cauca Basin, Colombia
- Effect of State noise and model parameterization in data assimilation for flood forecasting with distributed hydrological model: application of Meuse river basin
- Maximizing the use of satellite data and hydrological modelling for stream flow prediction: Case study of Dinder and Rahad rivers (tributaries of the Blue Nile, Ethiopia-Sudan)
- Recent Advances in Flood Forecasting and Early Warning Systems

Session 7B: Flood Forecast under Climate Change impact

- Verification of precipitation forecasted by the SOO/STRC Workstation Eta and five points over Blue Nile catchment
- Aridity trends amidst climate change in the eastern Nile region
- Effect of climate change on Long term trend of Climate variability's in the sub-catchment of Tekeze basin, Ethiopia
- Transboundary management of day-to-day variations in discharge and

water levels in the Blue Nile downstream the GERD

Session 8:Selected Paper presentations – parallel session

Session 8A: Improving Precipitation and Flood Forecasting

- Validation of multiple satellite rainfall products over the complex topography of Tekeze-Atbara tributary of the Nile basin
- The Potential of the GPM satellite rainfall products towards the enhancement of the precipitation measurement and flood forecasting
- Improving Satellite Rainfall Data to Predict Blue Nile River Flow
- Importance of Calibrated Satellite Data for Weather and Climate Monitoring and Forecasting

Session 8B: Flood Management and Preparedness Plan

- Community awareness for Managing Natural Disaster Risks of Flash in Sudan: Case of River Gash, Kassala State, Sudan
- Improved early warning communication and preparation for better flooding management
- Adaptive Flood Management Approach for the Eastern Nile
- Flashy Rivers Flood Forecasting using Open Source data: Gash River as Case Study, Sudan

Session 9: Enhance FFEW System (Plenary Sessions)

- Proposed FFEW System
- Flood Dashboard
- NBI – Seasonal River flow Forecast

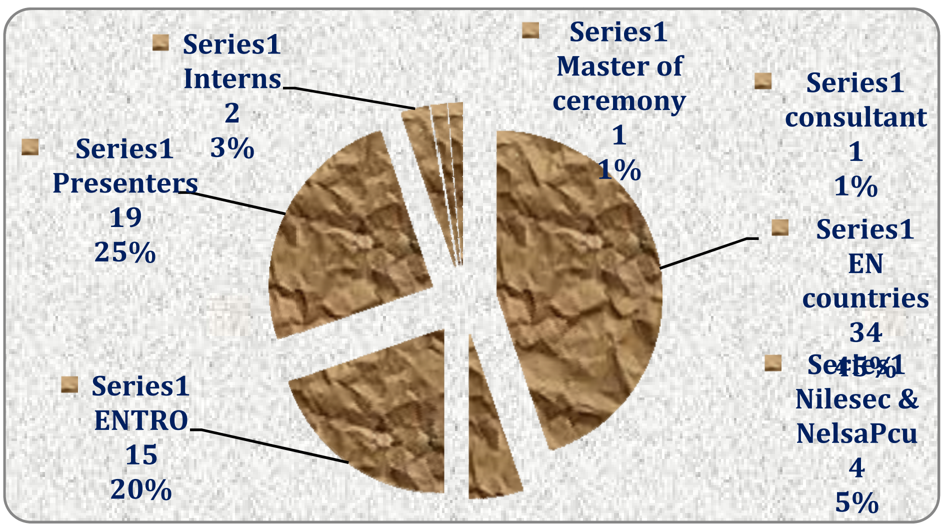
Session 10: Key messages and conclusion

- Way forward (Plenary Sessions)

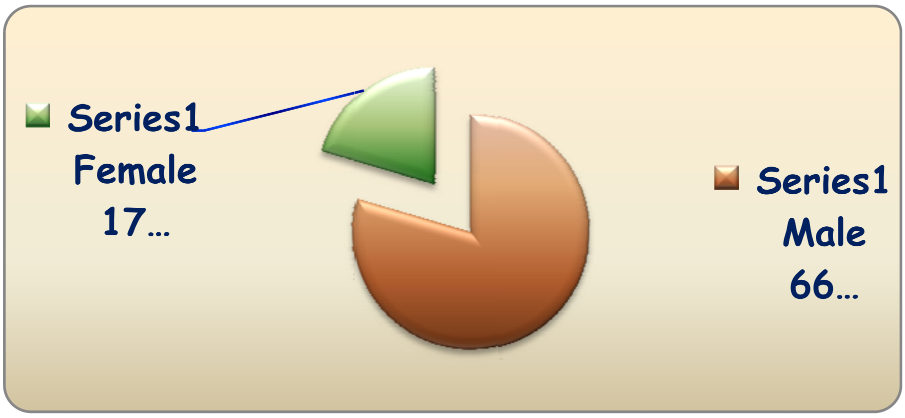
4. Composition of Participants:

4.1 Composition of Flood forum Participants:

A total of 83 participants attended the Flood Forum. Of whom, 34 were from government offices, Universities and other institutions in the Eastern Countries of Ethiopia, South Sudan and Sudan, 15 from ENTRO, and 4 from Nile Sec and NELSAP-CU, 19 paper presenters, 2 interns, 1 consultant and 1 master of ceremony. Out of the total Flood Forum participants, 20% were female.



4.2. Male and Female composition of participants:



5. Evaluation Points and Participants' feedback:

5.1Did the Flood Forum achieve its objectives? a) Yes   b) No

5.2What were the most positive elements/strengths of this Forum you would like us to

Suggestions by participants:

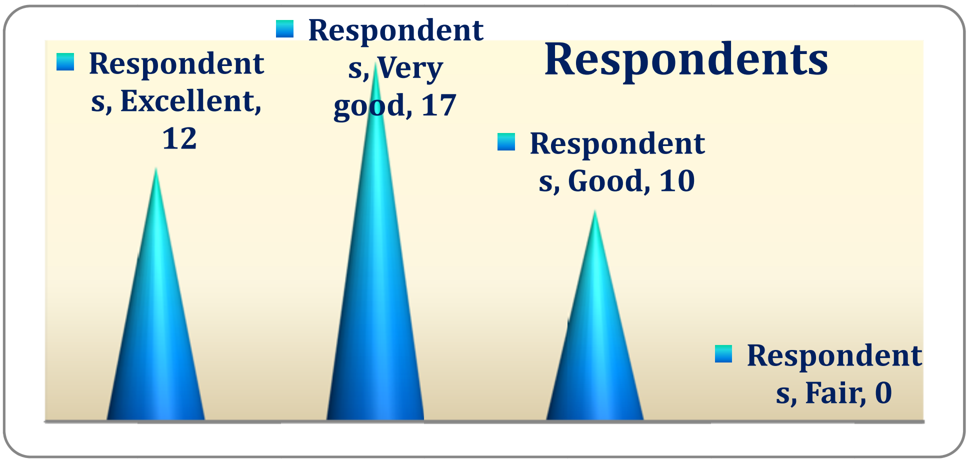
1. Time management was very good
2. Presentations were short and precise and backed up by flash disk
3. The topics selected for presentation and discussion were very important
4. The composition of participants and their active participation

5.3Reflecting on this Forum, please tell us what needs to be improved for the upcoming Similar Forum.

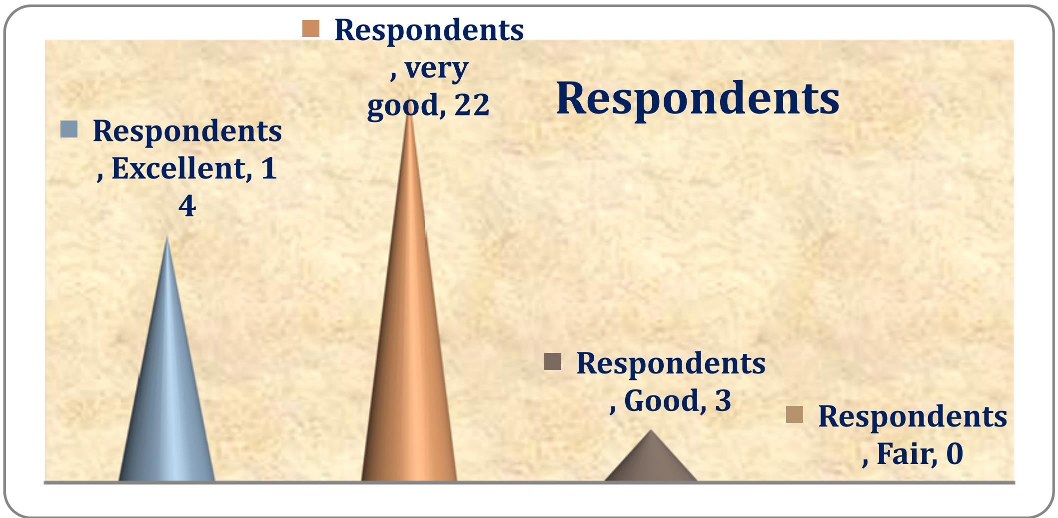
Suggestions by participants:

1. The duration of the forum was short, in particular the time allocated for discussion was short.
2. It was better if more case studies in the NBI was included
3. The integration of Watershed management with Flood management need to be included
4. It was better to invite ENTRO flood forecast users to share their experiences
5. The number of presented papers need to be reduced and provide more time for discussion
6. Some points came up/reflected over and again in different presentations, Avoid repeating same points

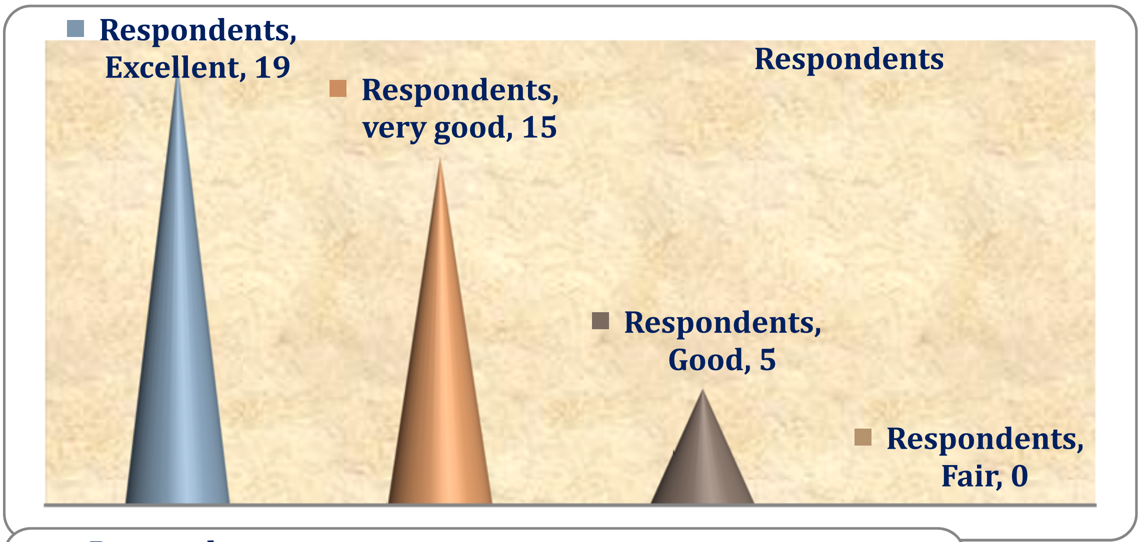
5.4Adequacy of time for presentation and discussion:



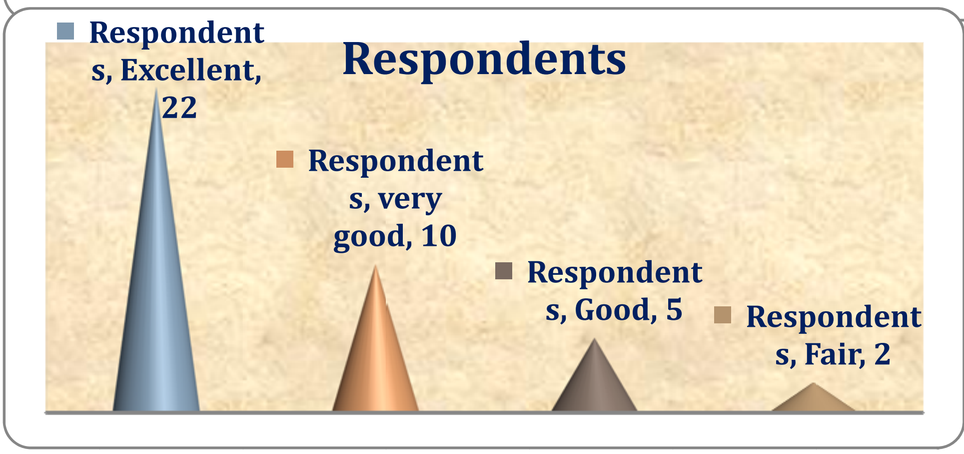
5.5Clarity and understandability of presentations:



5.6 The involvement of relevant stakeholders in this Forum:

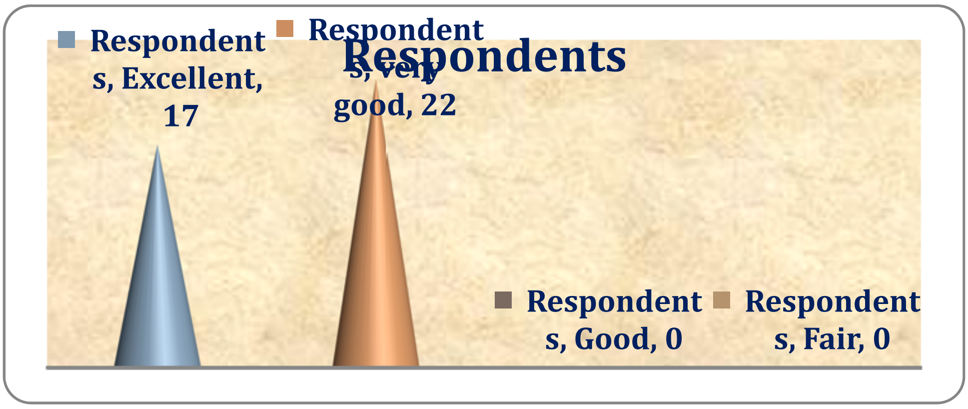


5.7 The



coordination of secretarial support (communication, Bookings, travel arrangements, etc)

5.8 Overall, your level of satisfaction in this Flood Forum



5.9 Any other Comments.

Any other comments:

1. It was more important if the Flood Forum was complemented with field trip in the Blue Nile.
2. It could be more helpful if the National Flood Forecasting and Early Warning centers were visited.
3. Create group pages thru Telegram, Face book, Viber, etc.
4. It needs more focus on social involvement regarding risk management, community involvement, and early preparedness of vulnerable communities.
5. Look forward to implement the key messages/outcomes reflected during this Flood Forum.
6. Try your level best to invite relevant stakeholders for the upcoming similar forum
7. Please consider different options on FFEW to come up with better results of flood forecast.

ANNEXIV.STAKEHOLDER MAPPING SURVEY

No					
1	Category of Institutions	**Cataegory1:**	**Category2:**	**Category 3:**	**Category4:** **:**
		Risk Knowledge	**Monitoring and Early Warning Services**	**Dissemination and Communication**	**Response Capability**
		30% institutions invited to the forum represented this category. These included universities and research institutions from the region	10% institutions invited to the forum represented this category. These are mainly meteorological institutions of the EN riparian countries of Ethiopia, South Sudan and Sudan	50% institutions invited to the forum represented this category. Invited institutions in this category included Ministries with mandate on water resources and dam operations as well as river basin organizations.	10% institutions invited to the forum represented this category. This category included disaster response and humanitarian organizations from the region
2.	Stakeholders roles	Majority of stakeholders from university and water related ministries water dealing with modeling and related capacity building activities			
3.	Stakeholders required for	Majority of the respondents agreed that communication and sharing of information is an issue in the region and real time data sharing framework should be established			

	real time data generation	
3.	Institutional arrangement and adequacy in relaying information	Majority (70%) of the respondents agreed having adequate institutional arrangement in place however (30%) suggested that clarity should be made on data sharing
4.	Inclusion of all relevant stakeholders in the forum	80% of the stakeholders agreed that there was a good representation of relevant stakeholders in the forum; however (20%) suggested direct inclusion of affected stakeholders by floods including women in flood prone areas.
5.	Geographical coverage : riverine flood hotspots to be included	Majority (80%) of respondents suggested inclusion of Bahr jabel region and rivers such as Gash ,Baraka, Alexandria, Atbara ,Awash,Omo and wetland areas such as the SUDD
6.	Flood Typology need for flash flood hotspots to be included	80% of the respondents agreed on the need for flash flood inclusion due to increased urbanization irrigation damages and loss of property and floods being trans boundary issue. 20% had no suggestion on flash floods
7	Regular Flood Bulletin received and how it is used	70% of the institution represented responded to have not been receiving the flood bulletin however a 30% who received used it to create awareness and inform disaster management in their respective countries

ANNEX B

EASTERN NILE RAINFALL FORECASTING REPORT

FLOOD FORECASTING AND EARLY WARNING ENHANCEMENT PROJECT

Submitted by

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ENTRO is an organ established to implement the Eastern Nile Subsidiary Action Program within the framework of Nile Basin Initiative

Egypt, Ethiopia, South Sudan, Sudan

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Acronyms and Abbreviations

CFS	Climate Forecasting System
CMA	China Meteorological Agency
CNR-ISAC	Institute of Atmospheric Sciences and Climate of the National Research Council
CNRM	Météo-France/Centre National de Recherche Meteorologiques
ECCC	Environment and Climate Change Canada
ECMWF	European Centre for Medium-range Weather Forecasting
EN	Eastern Nile
ENTRO	Eastern Nile Technical Regional Office
FPEW	Flood Preparedness and Early Warning
GFS	Global Forecasting System
GSMaP	Global Satellite Mapping of Precipitation
HMCR	Hydrometeorological Centre of Russia
ICPAC	IGAD Climate Prediction and Applications Centre
JAXA	Japan Aerospace Exploration Agency
JMA	Japan Meteorological Agency
KMA	Korea Meteorological Authority
KMD	Kenya Meteorological Department.
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NCL	NCAR-Command Language
NETCDF	Network Common Data Format
NMA	National Meteorological Agency – Ethiopia
NOAA	National Oceanic and Atmospheric Administration
NRT	Near Real Time
NWP	Numerical Weather Prediction
QPE	Quantitative Precipitation Estimate
UKMO	UK Met Office
WPS	WRF Preprocessing System
WRF	Weather Research and Forecasting

Executive Summary

The objective of the Flood Preparedness and Early Warning (FPEW) project at the Eastern Nile Technical Regional Office (ENTRO) is to reduce damage to infrastructure and environment, and alleviate human suffering caused by floods in the Eastern Nile (EN) region. The flood season usually lasts from June to September, coinciding with the major rainfall season in majority of Ethiopia, Sudan and South Sudan. Floods are re-current hazards in the EN region and the FPEW aims to improve early warning in the region in order to build resilience to floods. This is with major focus on flood hotspots in the Blue and Main Nile, Baro-Arobo-Sobat, Tana and Tekeze basins.

To build resilience to floods, ENTRO has invested in developing rainfall forecasting models, acquisition of near real-time satellite rainfall data and capacity building in these areas. This is on the basis that rainfall is key input for both riverine and flash flood modeling. Based on the review of previously existing rainfall forecast systems at ENTRO, it was identified that there was need to update the existing model and operate it from the server for improved efficiency. The Weather Research and Forecasting (WRF) model is currently updated daily to produce 3-day rainfall forecasts for the EN region at 6km spatial scale. This information is also automatically translated to netcdf format compatible with MIKE-Hydro for further input to the hydrology forecasts. Tools for access of near real-time (NRT) rainfall data, 30 minutes lagged JAXA GSMaP were also developed.

In addition to setting up the modeling systems, reference materials in form of manuals were also developed. The manuals provide guidelines for maintaining and operation of the WRF system, acquisition and analysis of NRT rainfall satellite data. Training on operation of the systems developed was also conducted to ensure that ENTRO has the capacity to effectively utilize the current tools to support flood early-warning. It is foreseen the availability of rainfall data, both forecasts and NRT, provides ENTRO with the capacity to effectivity prepare and respond to flood hazards in the EN. It is also recommended that ENTRO seeks to improve the internet speed connectivity as well as power backup in order to ensure that the computing facilities used are reliably powered so that forecasts are provided on schedule.

1. Introduction

Timely and accurate rainfall forecasts are a key component to flood early warning. In this regard, the FPEW project atENTRO identified the need for an effective rainfall forecasting system at ENTRO. ENTRO is part of the Eastern Nile Subsidiary Action Program (ENSAP) and has initiated the FPEW project in the EN to deal with flood hazards. The main objective of the project is to ensure that the flood management is enhanced to reduce damage to infrastructure and human suffering.In the Eastern Nile, the flood seasons lasts June through September and thus flood monitoring and early warning is an important aspect in managing the recurrent flood risks. Severe floods have been observed frequently in the past years resulting to losses of infrastructure and lives.

Based on the assessment carried during the inception of the FPEW, it was noted that there was need to upgrade the current rainfall forecasting systems to cover all the flood prone regions in EN. It was also noted that the modeling would be efficiently operated from ENTRO's server rather than single desktops. In this regard, taking advantage of the Weather Research and Forecasting (WRF) modelwas set up and customized for the EN region to provide rainfall forecasts.

WRF is a flexible weather/climate model that has been coupled with different applications such as agriculture (WRF-Crop, Liu *et al*., 2016), hydrology (WRF-Hydro, Silver *et al*., 2017), pollution (WRF-Chem), Urban meteorology (WRF-Urban, Barlage *et al*., 2016), solar and wind energy operations (Haupt, 2018), among other evolving fields. In this regard, WRF is a versatile tool that can be applied to support a wide range of sectors. For instance, Kerandi *et al* (2018), noted that coupled WRF-Hydro improved the skill of rainfall forecasts over the Tana basin in Kenya, translating to a better skill for the hydrological simulations. Fredj and Givati (2015) also demonstrated that the land-atmosphere WRF-Hydro is skillful in basin level flood forecasting over the Mediterranean region.

With this background, WRF was identified as the best tool to provide high resolution rainfall forecasts to support flood early warning operations at ENTRO. WRF is the preferred model as ENTRO has some capacity in using WRF which needs strengthening rather than adopting a new system. In addition, WRF is a community model thus open-source, and is continuously undergoing improvement to support a wide range of applications. Recent studies by Otieno *et al*., (2019), Blankenship *et al*., (2018) and Ntwali *et al*., (2016) have indicated that WRF is a robust model to utilize for both operational forecasting, research and climate change simulations especially over the complex-terrain regions in East Africa. In this regard, operational centres such as IGAD Climate Prediction and Applications Centre (ICPAC), Kenya Meteorological Department (KMD), Ethiopia National Meteorological Agency (NMA) and Meteo Rwanda, among others utilize WRF for operational rainfall forecasting. Other NWP models used around the globe are listed in Table 1. However, these models have restricted access due to the developer's policy and therefore not readily useful for operation outside the developers' institutions.

Table 1: NWP models applied around the globe.

Model	Centre
BoM	Australian Bureau of Meteorology
CMA	China Meteorological Agency
CNR-ISAC	Institute of Atmospheric Sciences and Climate of the National Research Council
CNRM	Météo-France/Centre National de Recherche Meteorologiques
ECCC	Environment and Climate Change Canada
ECMWF	European Centre for Medium-Range Weather Forecasts
HMCR	Hydrometeorological Centre of Russia
JMA	Japan Meteorological Agency
KMA	Korea Meteorological Agency

NCEP - GFS & CFS	National Centers for Environmental Prediction
UKMO- UM	UK Met Office
COSMO	Deutscher Wetterdienst, Germany

2. Rainfall Forecasting

This section highlights the rainfall forecast generation process that has been implemented at ENTRO. This process relies on the WRF model, a dynamical model that has been customized for the EN region. Since this is a regional model, global input from NCEP's GFS are utilized to provide the initial and boundary conditions. Figure 1 presents an overview of the forecast generation process.

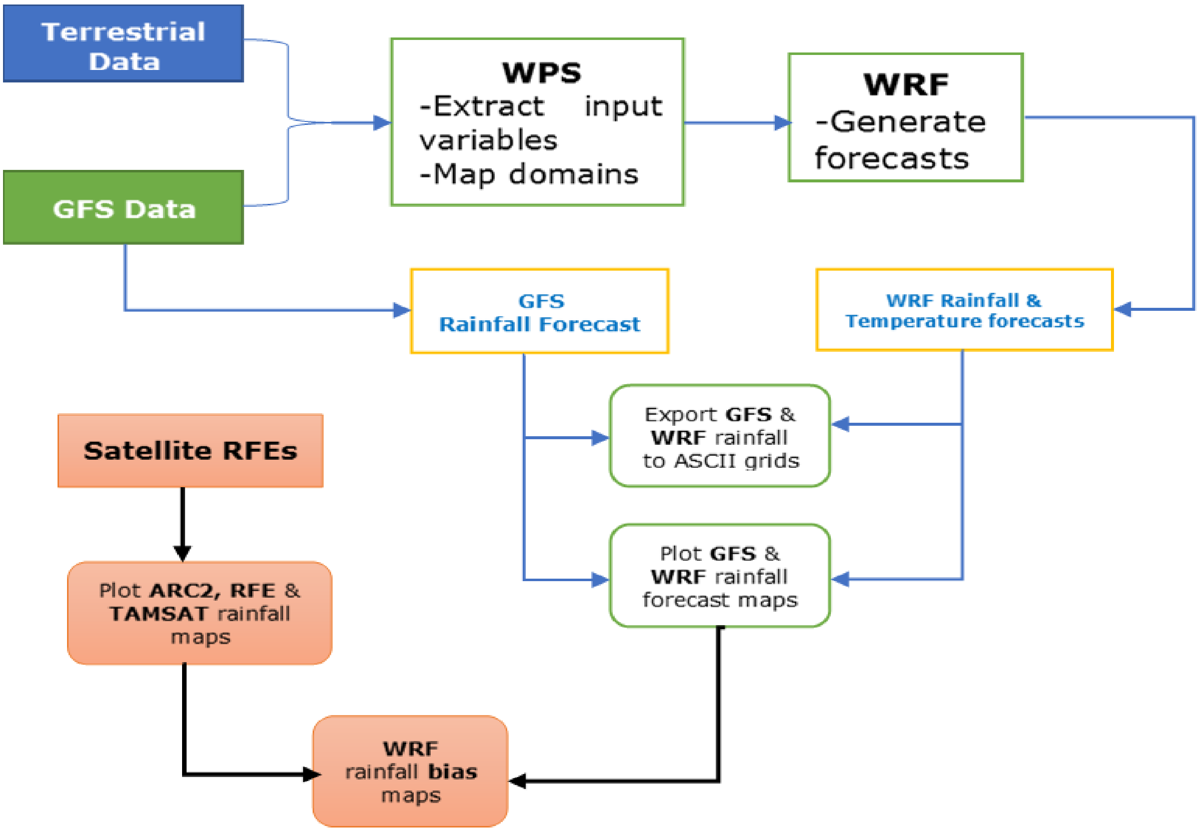

Figure 1: Operational rainfall forecast process implemented at ENTRO (NB: Black arrows indicate tasks that are accomplished at 3-5 days lag)

In Figure 1, operational forecast process starts by scheduling NCEP's Global Forecast System (GFS) data download on crontab, to provide the initial and boundary conditions. Once the data is successfully downloaded, it is seamlessly ingested in the WRF Pre-processing System (WPS), which extracts the relevant variables to initial the forecast for the region defined by the geographical data. The outputs of WPS are passed to the WRF proper, which upon completion of the simulation, generates a three-day forecast. The netcdf outputs from WRF are processed using NCL to extract rainfall data. These outputs are further processed to plot the daily total rainfall maps and archive the data for input to hydrological models. This process takes about 3 hours.

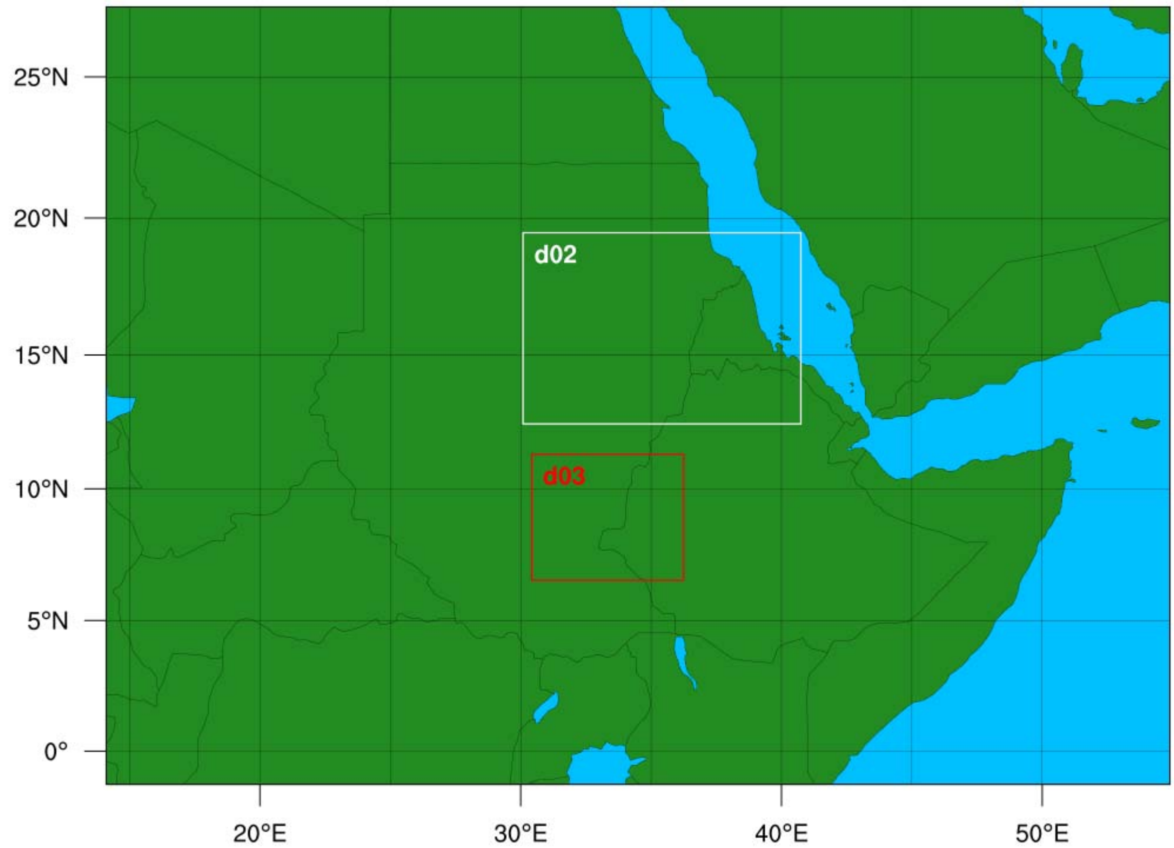

Figure 2: Updated WRF set-up configuration.

Previously, the operation of the existing WRF was not efficiently utilizing computing resources in the ENTRO server. This was occasioned by the small domain size for the Tana basin, and given the WRF domain decomposition technique, only a maximum of six processors were utilized. In this regard, 14 processors remained idle. It was therefore necessary to draw a balance between the domain sizes, hydrology requirements and the computing resources available. This was customized to ensure that a total of 12 processors are efficiently used to operate WRF. Sample rainfall forecasts from WRF are given in Figure 4.

Although thousands of permutations are possible in testing WRF physics, the selection of the choices to evaluate was based on recent studies over Eastern Africa such as Otieno *et al*., (2019). In this regard, cumulus physics schemes evaluated were Tiedtke (Tiedtke, M., 1989), Kain–Fritsch Cumulus Potential Scheme (Berg *et al*, 2013), Multi–scale Kain–Fritsch Scheme (Glotfelty *et al*., 2019) and Old Kain–Fritsch Scheme (Kain *et al*., 1990). These are abbreviated as TDK, KFP, MKF and KFO respectively.

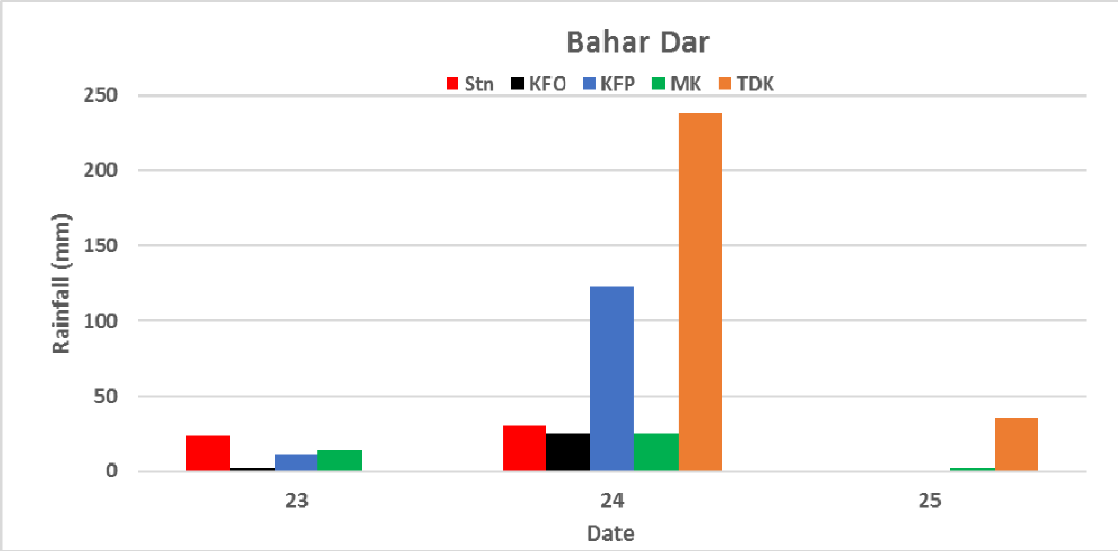

Figure 3: Daily data comparison between station records and WRF forecasts.

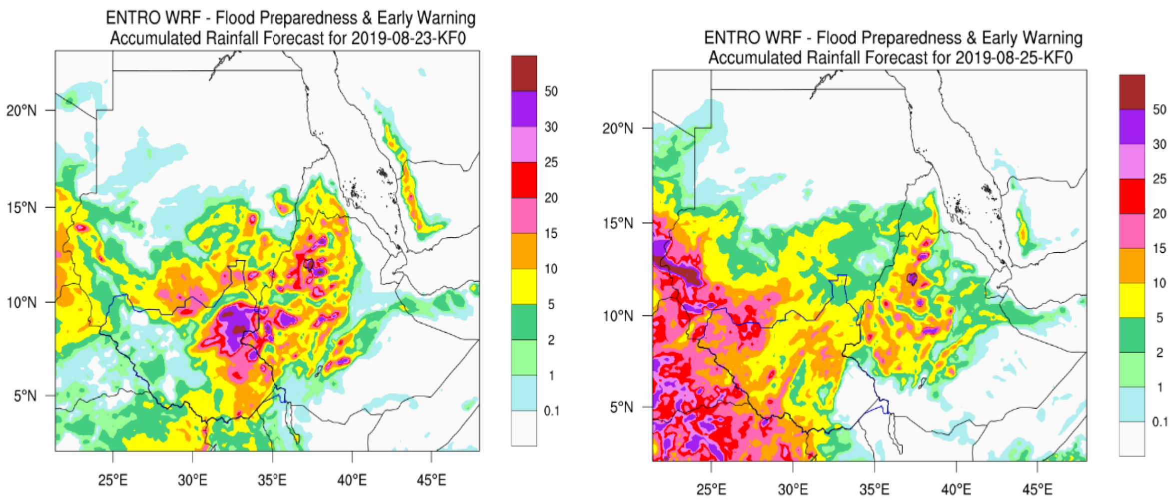

Figure 4: WRF forecasts for 23rd and 25th 2019

As an alternative measure, 25km GFS is rainfall forecasts for three days lead time can also be downloaded in the case whereby WRF may not run. This data can be available at https://nomads.ncep.noaa.gov/ or http://soostrc.comet.ucar.edu/data/grib/. An advantage of utilizing the GFS data is that it is provided from multiple servers that support automatic remote access and regional sub-setting of the data. Scripts were developed to automate the access, processing and packaging of the GFS 25km hourly data to the format suitable for HEC and MIKE models.

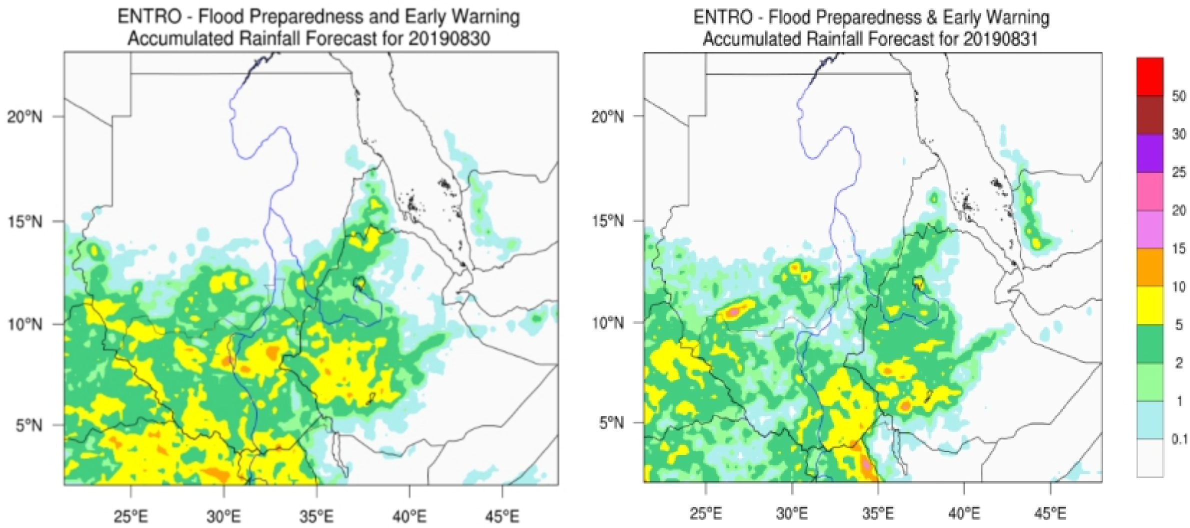

Figure 5: GFS Rainfall forecast for the EN for 30-31 August 2019

3. Access to Satellite Rainfall Estimates

NRT satellite provides important information for monitoring flood events as well as driving flood models. It is therefore important to consider the latency, spatial resolution and spatial coverage in selection of a suitable QPE. Tools for access of JAXA's GSMaP available at https://sharaku.eorc.jaxa.jp/GSMaP/index.htm were developed. For processing of the QSMaP QPE, ArcGIS software is needed. The raw data is provided text format (.csv) which is converted to raster format. The process also involves using a Python script in ArcGIS to process the data, which is readily compatible with the MIKE hydrological models. One major advantage of the GSMaP dataset is that on-the-fly plotting of the is available for a user selected period.

A summary of the process followed in the acquisition and analysis of the GSMaP QPE is

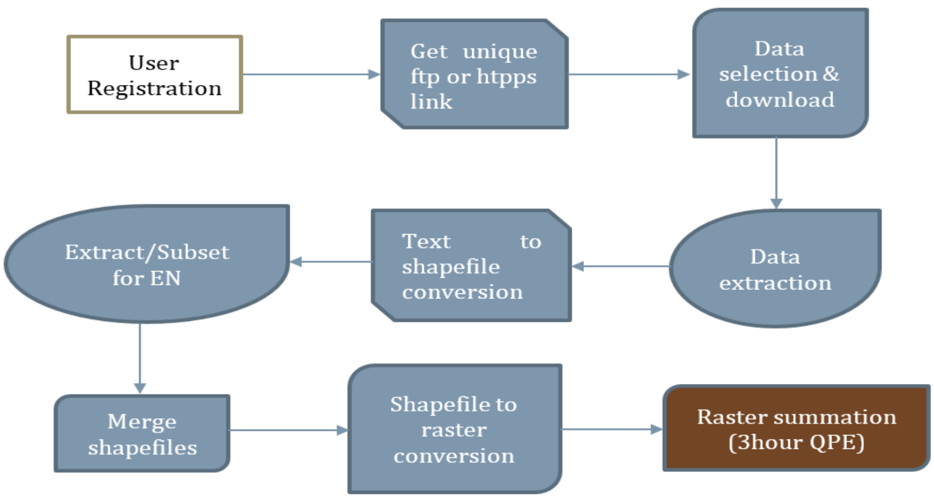

Figure 6: Workflow on acquisition and analysis of JAXA GSMaP Rainfall

presented in Figure 6 and a sample map in ArcGIS window is given in Figure 7.

In addition to NRT QPE, it is also important to maintain a database of gridded data that can be useful for long term analysis of climatological rainfall patterns. For this purpose, CHIRPS and TAMSAT data sets were adopted. Scripts based on the NCAR Command Language (NCL) were developed for this purpose. The tools were made in a flexible way such that the user is only required to specify the data range and the domain of interest before execution. It is important to note that the execution of the scripts requires internet connection as the data is sourced from the respective online portals. The successful execution saves selected data as netcdf file, and plots the daily rainfall maps for the period specified. Figure 8 presents a summary of the workflow involved in the acquisition and analysis of the satellite RFEs. It is important to note that these datasets are available with

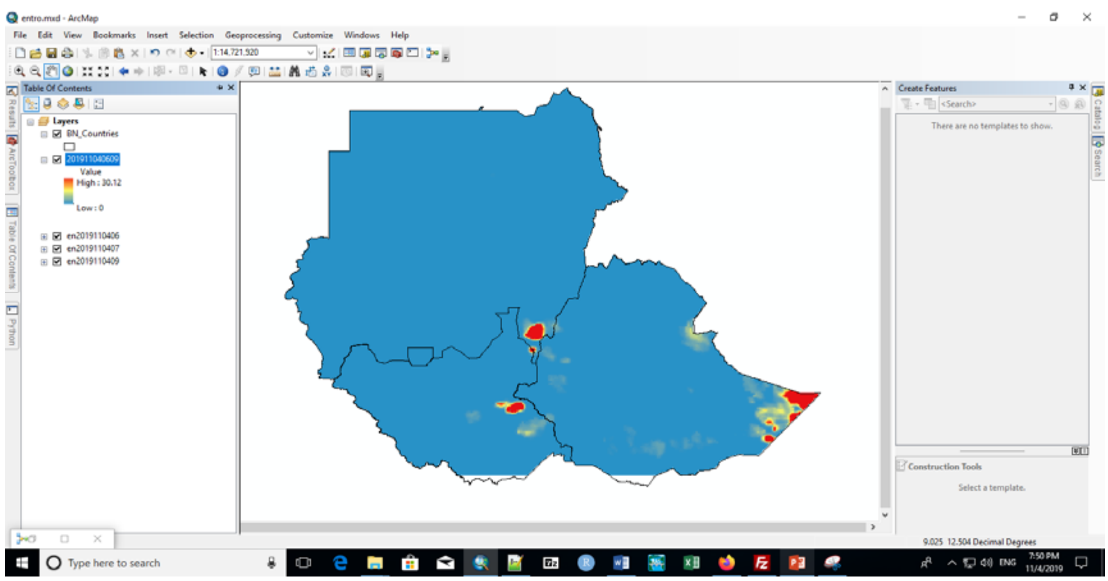

Figure 7: Three-hour EN total QPE from JAXA GSMaP for 20191104(06-09 hours)

1-day lag and therefore this should be incorporated in the data selection options. Once the date and domain selection are done, the rest of the processes are automated and the user is only required to execute the scrip. The utilization of these datasets will aid ENTRO to build a database of gridded rainfall data as well as utilize it for both climatological analysis and case studies.

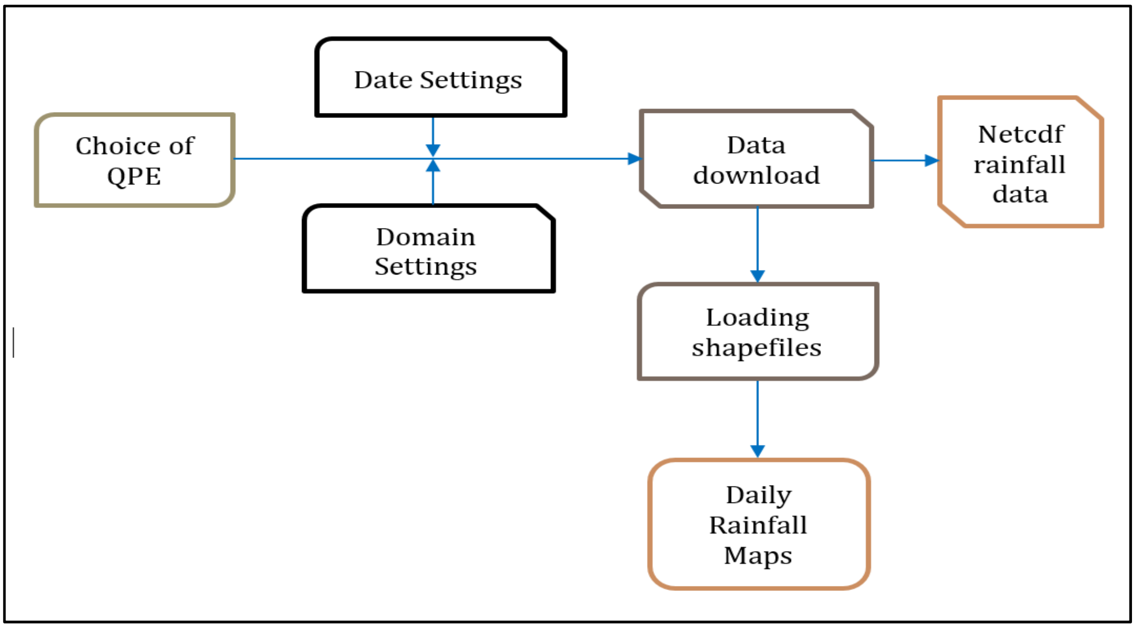

Figure 8: Workflow on acquisition and plotting of QPE data

4. Training on Systems Developed

Training was conducted to ensure that ENTRO acquired the capacity to manage and efficiently operate the developed forecasting and QPE systems. The training was conducted both on one-on-one and remote basis. During the week of 2-6 September 2019, a pool of staff from ENTRO and regional participants were trained on the concepts of running WRF, data post-processing for hydrology as well as accessing NRT satellite datasets. The training provided the participants with hands-on skills to ensure that they could effectively take over the operation of the rainfall forecasting systems. In addition, remote training has been conducted to one dedicated ENTRO staff for the subsequent months. This has ensured that ENTRO has the skills to operate, maintain and troubleshoot the WRF modelling system as need may arise. It is therefore foreseen that the operation of the rainfall forecasting systems at ENTRO will operate efficient since the right capacity at the institution has been established.,

5. Conclusion and Recommendations

The quality of rainfall input is an important consideration in flood early warning. In ENTRO, WRF was customized to provide 3-day forecasts to facilitate operational flood forecasting. The forecasts are updated daily at 6km based on GFS global model inputs and the rainfall outputs extracted in NETCDF format for input to hydrology models at hourly intervals. It is therefore envisioned that WRF will provide timely forecasts to aid in building resilience against flood hazards in the Eastern Nile region. Alternative forecasts from GFS were also incorporated into the rainfall forecasting system to ensure that the hydrology operations don't suffer lack of rainfall inputs. In addition, tools to efficiently access and analyses QPE were also developed to aid in monitoring of any extreme rainfall events.

In this regard, the following recommendations can be drawn: -

- That ENTRO improves the internet connection speeds and power backup systems in order to maintain the computing systems used for rainfall-flood forecasting operational.
- It is important that ENTRO trains a pool of staff on use of dynamical models such as WRF in order to maintain and update the current system, as need arises.
- ENTRO can network with climate centres in the region for exchange of meteorological data, both observed and forecasted.
- Improved computing facilities are needed, preferably high-performance computers for efficient operation of dynamical models.

REFERENCES

Barlage, M., S. Miao, and F. Chen, 2016: Impact of physics parameterizations on high-resolution weather prediction over complex urban areas. *J. Geophys. Res.,* 121, 4487–4498, doi:10.1002/2015JD024450.

Blankenship, C., Case, J., & Hain, C. (2018). Impact of SMAP Soil Moisture Assimilation on Numerical Weather Forecasts over the Contiguous United States and East Africa.

Fredj, E., & Givati, A. (2015, April). Application of a Coupled WRF-Hydro Model for Extreme Flood Events in the Mediterranean Basins. In *EGU General Assembly Conference Abstracts* (Vol. 17).

Hastenrath, S. (1991), *"Climate dynamics of the tropics"*. (p. 347–373)

Haupt, S. E. (2018). Short-range forecasting for energy. In *Weather & Climate Services for the Energy Industry* (pp. 97-107). Palgrave Macmillan, Cham.

Kerandi, N., Arnault, J., Laux, P., Wagner, S., Kitheka, J., & Kunstmann, H. (2018). Joint atmospheric-terrestrial water balances for East Africa: a WRF-Hydro case study for the upper Tana River basin. *Theoretical and applied climatology*, *131*(3-4), 1337-1355.

Liu, X., F. Chen, M. Barlage, G. Zhou, D. Niyogi, 2016: Noah-MP-Crop: Introducing Dynamic Crop Growth in the Noah-MP Land-Surface Model. *J. Geophys. Res., DOI: 10.1002/2016JD025597*

Mera, R., Laing, A. G., & Semazzi, F. (2014). Moisture variability and multiscale interactions during spring in West Africa. *Monthly Weather Review*, *142*(9), 3178-3198.

Mughal, M. O., Lynch, M., Yu, F., McGann, B., Jeanneret, F., & Sutton, J. (2017). Wind modelling, validation and sensitivity study using Weather Research and Forecasting model in complex terrain. *Environmental modelling & software*, *90*, 107-125.

Ntwali, D., Ogwang, B. A., & Ongoma, V. (2016). The impacts of topography on spatial and temporal rainfall distribution over Rwanda based on WRF model. *Atmospheric and Climate Sciences*, *6*(02), 145.

Otieno, G., Mutemi, J. N., Opijah, F. J., Ogallo, L. A., & Omondi, M. H. (2019). The Sensitivity of Rainfall Characteristics to Cumulus Parameterization Schemes from a WRF Model. Part I: A Case Study Over East Africa During Wet Years. *Pure and Applied Geophysics*, 1-16.

Pohl, B., Crétat, J., & Camberlin, P. (2011). Testing WRF capability in simulating the atmospheric water cycle over Equatorial East Africa. *Climate Dynamics*, *37*(7-8), 1357-1379.

Segele, Z. T., and P. J. Lamb 2005: Characterization and variability of Kiremt rainy season overEthiopia. Meteor. Atmos. Phys., 89, 153-180.

Silver, M., Karnieli, A., Ginat, H., Meiri, E., & Fredj, E. (2017). An innovative method for determining hydrological calibration parameters for the WRF-Hydro model in arid regions. *Environmental modelling & software*, *91*, 47-69.

Sunny Lim, K. S., Hong, S. Y., Yoon, J. H., & Han, J. (2014). Simulation of the summer monsoon rainfall over East Asia using the NCEP GFS cumulus parameterization at different horizontal resolutions. *Weather and Forecasting*, 29(5), 1143-1154.

Tiedtke, M., 1989: A comprehensive mass flux scheme for cumulus parameterization in large–scale models. *Mon. Wea. Rev.*, 117, 1779–1800.

Berg, L.K., W.I. Gustafson, E.I. Kassianov, E.I., and L. Deng, 2013: Evaluation of a modified scheme for shallow convection: Implementation of CuP and case studies. *Mon. Wea. Rev.*, 141, 134-147.

Glotfelty, T., K. Alapaty, J. He, P. Hawbecker, X. Song, and G. Zhang, 2019: The Weather Research and Forecasting Model with Aerosol–Cloud Interactions (WRF-ACI): Development, evaluation, and initial application. *Mon. Wea. Rev.* , 147, 1491-1511

Kain, John S., and J. Michael Fritsch, 1990: A one–dimensional entraining/detraining plume model and its application in convective parameterization. *J. Atmos. Sci.*, 47, 2784–2802.

ANNEX C

EASTERN NILE FLOOD FORECASTING SYSTEM REPORT

FLOOD FORECASTING AND EARLY WARNING ENHANCEMENT PROJECT

Submitted by

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ENTRO is an organ established to implement the Eastern Nile Subsidiary Action Program within the framework of Nile Basin Initiative

Egypt, Ethiopia, South Sudan, Sudan

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ACRONYMS AND ABBREVIATIONS

BCM	Billion Cubic Meter
CC	Country Consultation
CRA	Cooperative Regional Assessment
ENID	Eastern Nile Irrigation and Drainage
ENCOM	Eastern Nile Committee Of Ministers
ENSAP	Eastern Nile Subsidiary Action Plan
ENSAPT	Eastern Nile Subsidiary Action Plan Team
ENTRO	Eastern Nile Technical Regional Office (NBI)
FAO	Food and Agriculture Organization
NBI	Nile Basin Initiative
NCORE	Nile Cooperation for result project
NELCOM	Nile Equatorial Lakes Council of Ministers
NELSAP	Nile Equatorial Lakes Subsidiary Action Program
NELSAP-CU	NELSAP Coordination Unit
NGO	Non-Governmental Organization
NIB	National Irrigation Board
Nile-COM	Nile Council of Ministers
WB	World Bank

1. INTRODUCTION

East Nile Flood Forecasting and Early Warning system development project is the continuation of previously implemented flood forecasting system for Blue Nile watershed. The existing flood forecasting system consists of different software components that do not communicate well between one another and had issues with real time application. The East Nile watershed has 4 sub watersheds and each sub watershed has different models for producing forecast. The project herein build a unified forecasting model utilizing the software suit (MIKE Family) by DHI This software suit has been in used successfully for number of years in the and there may be many other places the suite has been used already.

The scope of the project is to develop an Early Flood Forecasting System (EWFFS) to four sub-basins of the Eastern Nile basins, namely Lake Tana, Blue Nile, Baro Akobo Sobat and Atabara Tekeze-setit. The development of EWFF system include the following tasks:

1. Sourcing of different data (e.g. climate, Digital Elevation Model (DEM))
2. Development of Rainfall-runoff model for the four sub-basins of the Eastern Nile basin.
3. Development of hydraulic model for the four sub-basins
4. Integration of developed models into an EWFFS platform
5. Automate the EWFFS to send Flood Warnings when the system predicts possible flood

Eastern Nile Sub-Basin within the overall Nile Basin

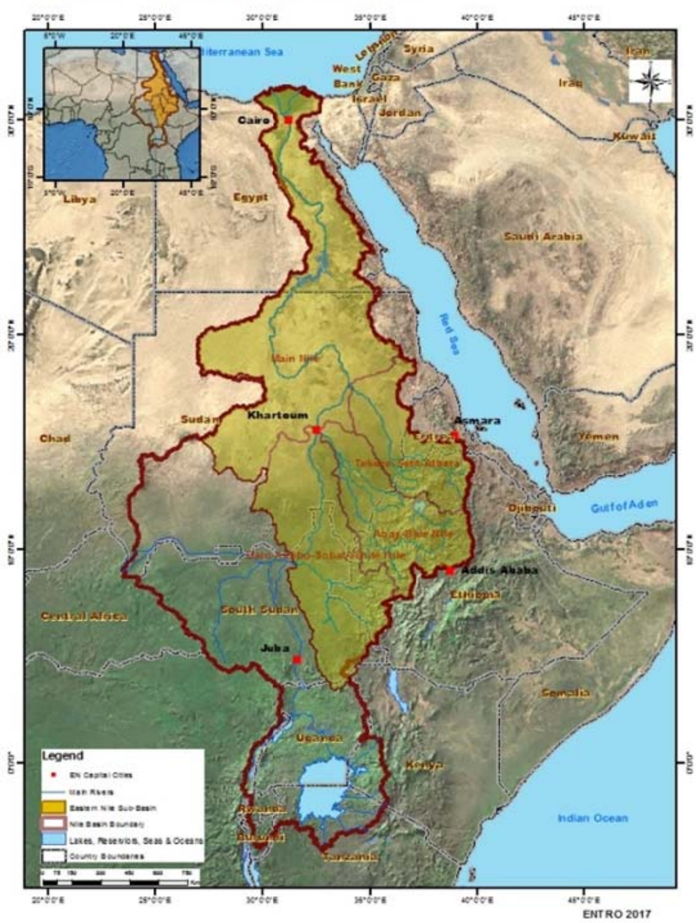


Figure 1.1: The Eastern Nile Basin and sub-basins

1.1 Objectives

The objective of this project is;

- To ensure a robust forecasting, issuing and warning system that effectively minimize loss of life and damage by enhancing, expanding and developing a unified Flood Forecast and Early Warning (FFEW) system for EN basin

- To support other studies under FFEW that contribute in addressing flash flood, stakeholder analysis and flood related DSS development.

1.2 Deliverables

The deliverables of the project are as stated below:

- Task 1 deliverables are:
    - Inception report on
    - Review and gap analysis on the current system
    - Review of best practices
    - Gather, review, analyses and process data for use in building of hydrological models for the Blue Nile, Main Nile, Lake Tana, Baro-Akobo- Sobat and Atbara-Tekeze-Setit systems under a unified modelling platform
    - Work with the team leader and other team members and submit a document with the models proposed methodology and list of models(hydrological, hydraulic and flood forecast system) with work plan
- Task 2 deliverables are:
    - Set-up and calibrate and validate hydrologic model for Blue Nile, Lake Tana, Baro-Akobo-Sobat and Tekeze-Setit-Atbara sub basin flood prone areas
    - Set-up and calibrate and validate hydraulic/hydrodynamic models for Blue Nile, Lake Tana and Baro-Akobo-Sobat
    - Set-up a forecasting system for integration of forecast models and easy dissemination of forecast results
- Task 3 deliverable are:
    - Test the hydrological, hydraulic models for Blue Nile, Lake Tana ,Baro-Akobo-Sobatand Atbara-Tekeze-Setit systems
    - Prepare floodplain inundation maps for each of the Flood prone areas in the Eastern Nile basin at various flood levels and various return periods

  - In collaboration with the Web expert and IT unit make hydrodynamic model outputs (water level, inundation and impact maps) available to integration with the ENTRO portal/website

  - In collaboration with the Web expert and IT unit test the integration of the forecast system with ENTRO portal/website

- Task 4 deliverables are:

  - Design and provide at least two necessary trainings and capacity development for sustainable operation of the flood forecast early warning system

  - Conduct at least one validation workshop

  - Participate and present in consultation workshops

  - Prepare relevant reports and prepare relevant section of modelling reports and user's manual

  - Other tasks requested by Senior FFEW Expert

  - Support procurement process of necessary equipment and software, in collaboration with the other team members and support the setting-up of the forecast models on the workstations

2. METHODOLOGY

The Early Warning Flood Forecasting System (EWFFS) of the four sub basins of the Eastern Nile has been setup using MIKE Operations, a product of DHI. The MIKE Operations platform allows an integration of data management, modelling or scenario manager and reporting on operational or real-time basis, which makes it a suitable platform to a flood forecasting system. In this section, the methodology that is implemented in setting up the real-time data acquisition, modelling and scenario manager, and the Flood forecasting system is discussed.

2.1 Data Acquisition

Data has been sourced from different source providers and will be stored in one central database. The types of data required to implement an EWFFS are as follows:

- Observed and forecasted rainfall, in this study the historical data will be sourced from NOAA RFE and the forecast rainfall will be used from Weather Research and Forecasting model (WRF).
- Observed evaporation, this has been sourced from satellite products
- Observed flow and gauge levels, where there is an observed flow or gauge levels the information was used for calibration and data assimilation. There is no telemetric real-time data that can used for the data assimilation, however, there are manual flow gauges that report on daily basis. An effort will be made to develop a mechanism for these gauges to report to the central database, and the data to be used for data assimilation.
- Observed inflow, outflow, releases and level of reservoirs are included in the models, wherever there a near-real time information available it will be used in the automated EWFF system otherwise the required data will estimated from historical information's.

MIKE Operations has functionality that allows to import different data formats to a central database. These functionalities was accessed through a script to automatize the import process from different sources to the central database that will be setup for this project.

2.1.1 Rainfall Data

A reliable and accurate rainfall dataset is the basis for accurate prediction of possible floods. The magnitude of these floods is determined by utilising Rainfall-runoff models, and these therefore form an integral part of any flood forecasting system. Both historical (which includes near-real time data) and forecasted rainfall is required for flood forecasting systems. The historical rainfall data is required for calibration of the Rainfall-runoff modelling, while the near-real time or forecasted rainfall are required for flood prediction on near-real time or forecast to next 5-7 days. The rainfall data that are used in this project for calibration and forecasting are satellite rainfall values.

There are no manual or tipping bucket point rainfall data that are provided for this project. Hence, it was decided the models are calibrated by the WRF rainfall data to mitigate the errors that will be exist when the WRF rainfall values are used in a the forecast of the flows.

Observed Point Rainfall Data

Traditionally flood forecasting system are based on ground-based telemetric point rainfall data. Setting up a densely network of ground-based rainfall measuring points is expensive and requires constant maintenance. In the Eastern Nile basin, there are very few manual rainfall measuring points, not dense enough to represent an accurate areal catchment rainfall in the basin. The rainfall measuring points are not well distributed over the basin. Furthermore, none of the measuring points are telemetric and transfer data on near-real time. Some of the disadvantage of using a ground based rainfall measurement for flood forecasting systems are as follows:

- can be unreliable, inconsistent, poorly maintained.
- is subject to local quality control methods that can contribute to heterogeneity in dataset
- don't represent long-range spatial distribution of meteorological properties.
- is limited to land masses.

Observed Spatial Rainfall Data

Rain gauges provide a direct measurement of rainfall; however, the spatial density of rain gauge networks is typically far too sparse to capture the spatial variability of rainfall at small scales. Radar provides an indirect measurement of rainfall, but only for regions within a few hundred km of a radar unit - and even less in mountainous regions due to blockage of the beam. Estimates of rainfall from satellite data are less direct and less accurate than either gauges or radar, but have the advantage of high spatial resolution and complete coverage over oceans, mountainous regions, and sparsely populated areas where other sources of rainfall data are not available. Since flash flood events often originate with heavy rainfall in sparsely instrumented areas that goes undetected, satellite-derived rainfall can be a critical tool for identifying hazards from smaller-scale rainfall and flood events (NOAA Center for Satellite Application and Research).

The three major advantages of using spatial rainfall data from radar or satellite over a ground based measurements are (Todini, 2001):

- A finer spatial resolution of the precipitation of the rainfall field
- Real time data availability or reliability
- The ability to track approaching storms even before they reach the boundary catchment of the interest

In this project, Weather Research and Forecasting (WRF) is used for calibration and forecasting. WRF is numerical weather prediction system designed for both atmospheric research and operational forecasting applications.

2.1.2 **Real-Time Flow gauges**

Historical water level and flow rate data from flow gauges/stations were used to calibrate the flood prediction from the Rainfall-runoff and hydraulic model of the flood forecasting system. There are a number of flow gauges/stations that record water level data within the Eastern Nile basin, where the water level data was converted to flow rate data using the rating table of the gauges. Near-real time flow gauges are fundamental part of a flood forecasting system, they are required to constantly update the accuracy of the prediction and measure the performance of the flood prediction by the flood forecasting system. They are used in Data assimilation process of the hydraulic modelling of the system. The near-real observed water level and flow rate data are used to calculate the error at the data assimilation points and re-calibrate the model flood prediction so that it represents a better performance.

There are no telemetric flow gauges in the Eastern Nile Basin, however there are a manual flow gauges as shown in Figure 2.1.

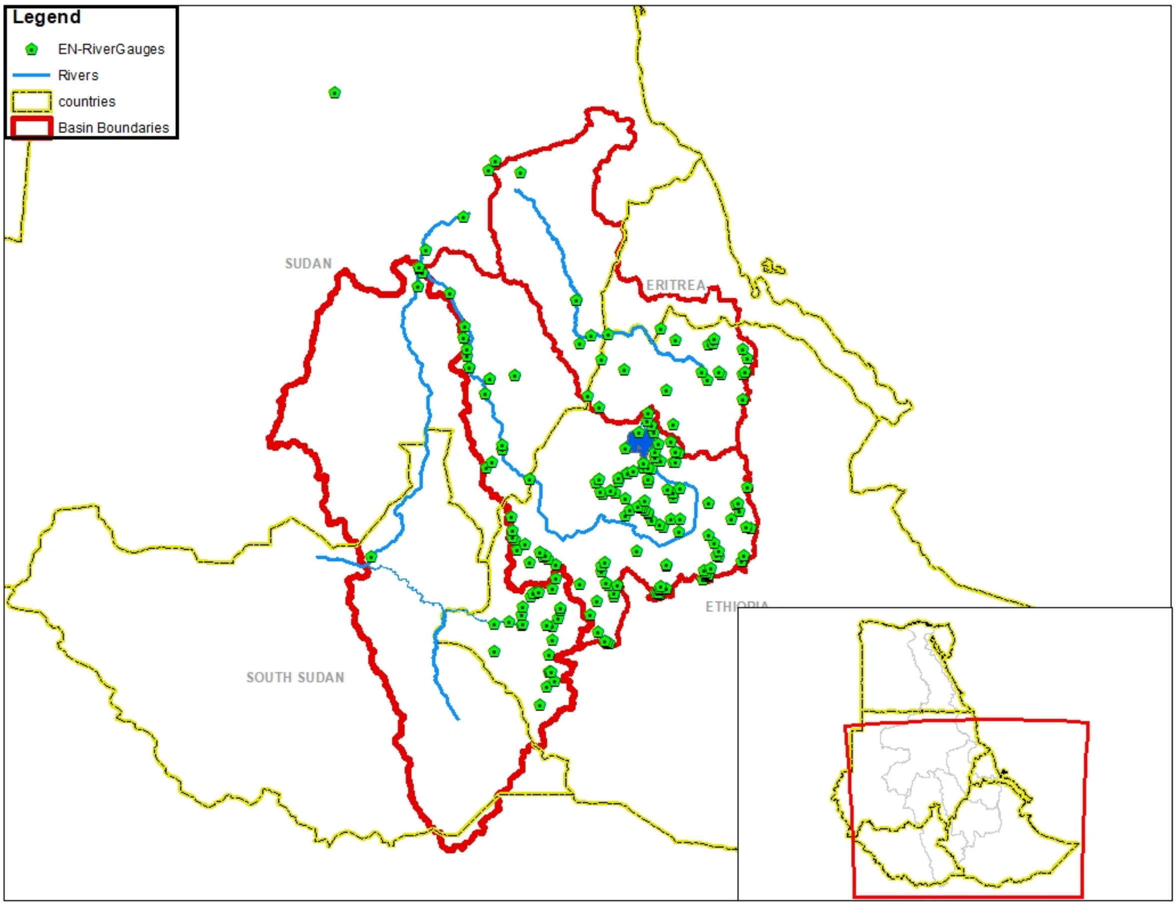


Figure 2.1: Available River Gauges in the Eastern Nile basins

2.1.3 **Evaporation**

Evaporation data from satellite are used for the calibration and forecasting. The evaporation data in rainfall-runoff data are used to estimate the water loss from the catchment and the rivers. The satellite data that was used in the modelling is USGS Global Potential

Evapotranspiration and the resolution of the data is 1 degree. The reason for the use of the satellite data, because there is no available ground measured evaporation data (e.g. A-pan).

2.1.4 Reservoir Stations Data

Reservoirs are built to conserve water for water supply purposes, as part an integrated water resource management of a system or a catchment. Reservoirs could be used as flood controlling structures if they are managed according to flood safety measures. A reservoir is required to have a flood safety level, to prevent flood damage downstream of the reservoir. There are several major dams that are built within the Eastern Nile basin for water supply purposes. These dams are modelled in the hydraulic modelling with all the physical feature representations. Observed water level and releases from the dams/reservoirs were used as calibration information for the model calibration period, as well as in the data assimilation process of the system. The list of reservoirs that are included in the EWFFS are shown below (Figure 2.2), where the map shows where these dams are positioned within the Eastern Nile basin (Figure 2.2), differentiating between dams included in EWFFS and those that are not.

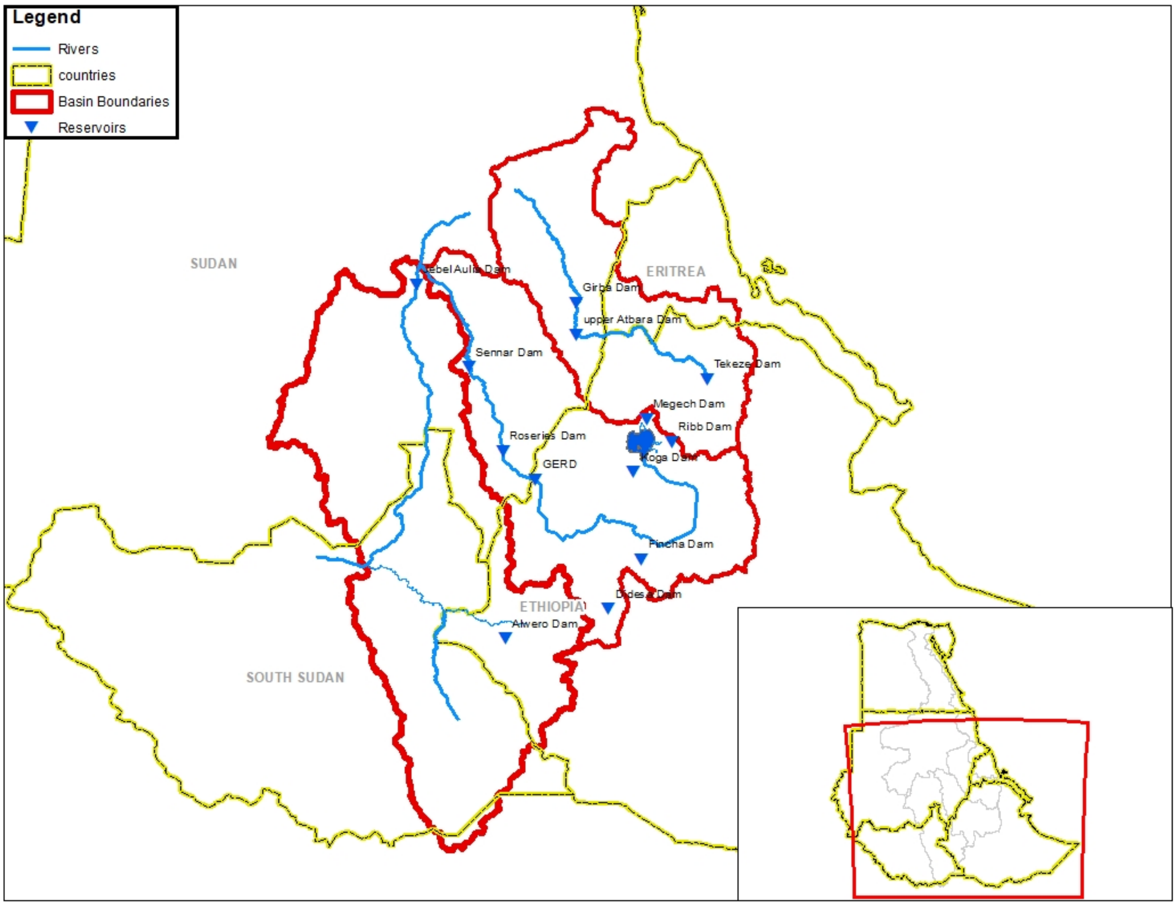


Figure 2.2: Reservoirs in the Eastern Nile basins

2.1.5 Topography

Topography is important input requirement of the hydraulic model of the flood forecasting system. The hydraulic models are setup to predict flow rates and water level at calculation points in a river stretch. Hence, the hydraulic model setup requires an accurate cross section derived from a Digital Elevation Models (DEMs) that represent well the topographic of the area in consideration. The river cross-sections for all the rivers in the four sub basins of the Eastern Nile basin are derived from a number of sources. Most of the river-cross sections are derived from Airbus DEM, the Airbus DEM is a DEM prepared by Airbus and the resolution of the DEM is 25 meters. The river cross sections from the DEM is complimented by survey data. The river cross-section from the DEM in the flat areas of the river don't always represent the cross-sections very well.

2.2 Modelling

Hydrological modelling has been used to simulate catchment runoff using observed and forecasted rainfall and evaporation, where there is no observed data available. The hydrological models have been coupled with a hydraulic models, to predict the transition of water in space and time. The modelling setup helps to predict the flows at different flood hotspots, with a reasonable lead time. The hydrology and hydraulic models that are used in this project are NAM rainfall-runoff and MIKE 11 models.

2.2.1 RAINFALL-RUNOFF MODEL - NAM Model

Some of the capability that is required from hydrological models that are used for the flood forecasting system are that the model has to predict the flows relatively accurate and the model has to have a hotstart capability. The hotstart capability allows the model to remember the state variables and it model do not have to run for a period of warming time to reach equilibrium state. The hydrological modelling that is used in the project is the NAM model. The NAM is the Danish abbreviation of "Nedbør-Afstrømnings-Model" which translates into English as "Rainfall-Runoff Model". NAM simulates the terrestrial phase of the hydrological cycle. It is a deterministic and lumped model; therefore, it is a catchment-based modelling system. The NAM model can be applied independently, or it can be used to generate lateral contributions to a river network. In this way, it is possible to model an individual catchment as well as a group of sub-catchments constituting a larger basin with a more complex river network.

The NAM model requires a limited quantity of data in order to be run:

- Model parameters
- Boundary conditions
- Meteorological data
- Streamflow data for calibration and verification purposes

The basic meteorological data requirements are:

- Rainfall
- Potential evapotranspiration

- In the case of snow modelling, the additional meteorological data requirements are:
- Temperature
- Radiation (optional)

The meteorological data are used in a time series format. Particularly precipitation data must have a sufficiently fine temporal resolution, in order to obtain a correct and desired result resolution and quality. Whereas evapotranspiration data is usually sufficient to utilize monthly values.

The NAM model also allows modelling of man-made interventions in the hydrological cycle in terms of irrigation and groundwater pumping. In this case, time series of irrigation and groundwater abstraction rates are required.

The relationship and water movement between the different water storages considered include surface-rootzone and groundwater storages. Each of these storages is defined by a set of model parameters. Being a lumped model, NAM treats each catchment as a unit, the units can be conceptualised to represent a homogenous hydrological response unit. As a consequence, the model parameters correspond to average values for the whole catchment. These values can be acquired from physical characteristics of the catchment, but their final determination must be done through calibration using hydrological observations, since they are a product of empirical and conceptual considerations.

Finally, the following figure shows the structure of the NAM model representing the four different water storages and the corresponding governing parameters (Figure 2.3).

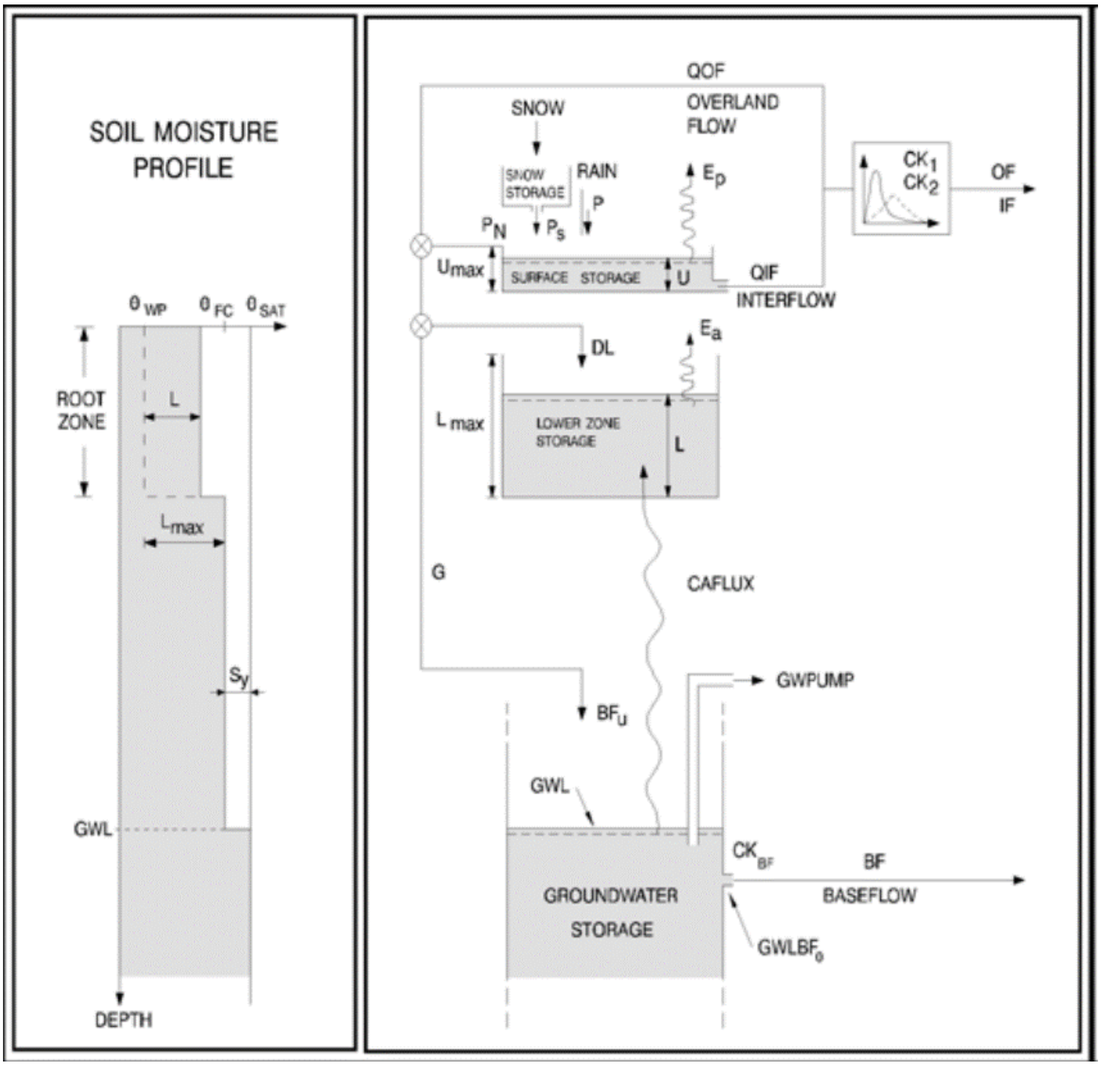


Figure 2.3: The structure of the NAM rainfall-runoff model.

2.2.2 **Hydrodynamic Model - MIKE 11 Hydraulic Model**

The MIKE 11 Hydraulic model is the software that is used to develop the 1-dimensional hydraulic model for the four sub-basins of the Easter Nile river. The final MIKE 11 setup is developed jointly with the rainfall-runoff model that is developed to enable integration between the models.

Secondly, the MIKE 11 Data Assimilation module (MIKE 11 DA), extensively used in flood forecasting modelling applications, is setup at points where it is assumed a near-real time information will be sourced. The MIKE 11 DA module is designed to perform the calculations required to predict the variation in discharges and water levels in a river system as a result of catchment rainfall and inflow/outflow through boundaries in the river system.

In real-time forecasting, the simulated discharge/water level generally deviates from the measured discharge/water level. Data assimilation consists of conditioning the model predictions to the observed data prior to the Time of Forecast (ToF) (Figure 2.4). The accuracy of the forecasts will depend on the accuracy of the boundary and rainfall forecasts, the model (calibration and structure) and efficiency of the updating routine.

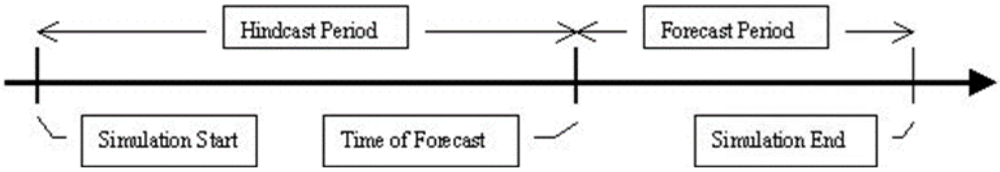


Figure 2.4: Definition of the time of forecast

Accurate forecasting requires that the rainfall-runoff model as well as the hydrodynamic model are well calibrated on historical data i.e. that they are able to simulate the water flow very accurately up to the time of forecast.

Deviations between measured and simulated water levels/discharges will occur, and it is important that these errors are corrected before forecasts are calculated. Differences in the simulated and observed discharges prior to the time of forecast (ToF) can be attributed to four sources:

- Errors in the model input data;
- Errors in the model parameters due to data limitations, sub-optimal calibrations, etc.
- Errors in the output variables due to the uncertainty in the rating curves and other uncertainties arising from the measurement process.
- Errors in the model structure due to lumping, inappropriate conceptualisation of the flood-producing processes, etc.

Forecast updating procedures can be classified according to whether the input variables, state variables, model parameters or output variables are modified. The standard updating procedure provided by MIKE 11 is an improved error correction routine(output updating) capable of distinguishing between phase and amplitude errors. In addition, updating can be carried out directly on either water level or discharge. The two types of errors are illustrated below (Figure 2.5).

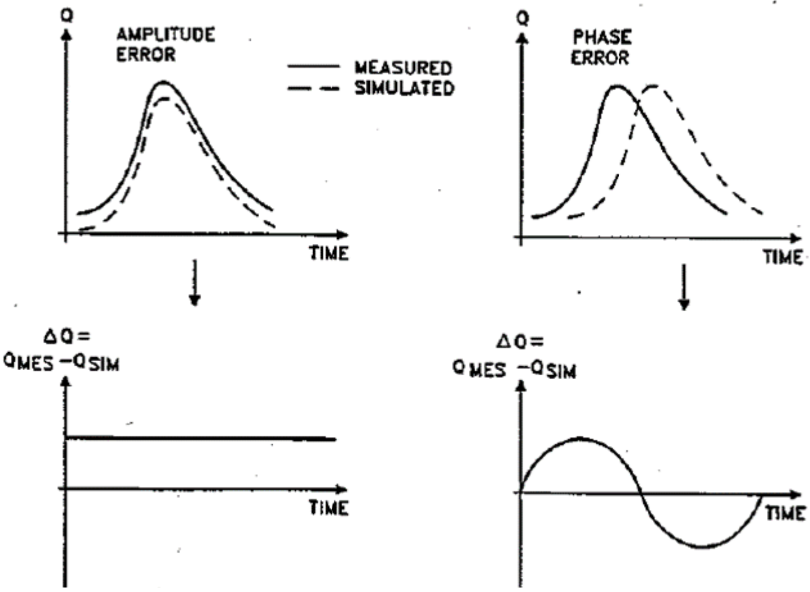


Figure 2.5: Illustration of amplitude and phase errors

2.3 **Eastern Nile Flood Prone Areas**

2.3.1 **Lake Tana**

Lake tana sub-basin experience frequent flooding and the four major rivers are the most susceptible to the flooding in the sub-basin. The sub-catchment that are used in the NAM Rainfall-runoff model are delineated using the Airbus DEM 25 horizontal resolution. The rivers and sub-catchment that are implemented in the Rainfall-runoff and the hydraulic model are described in the Figure 2.6. The delineation of the basin was guided by the need to break to catchment into smaller sub-catchment to identify the flood that occur downstream as earliest as possible. As well, the delineation was also guided by available infrastructures within the catchment/basin to isolate the inflow to the infrastructures. The rainfall-runoff model setup for the Lake Tana basin. The Rainfall-runoff model for the Lake Tana basin was setup for each subcatchment of the basin as a lumped catchment, where the soil layer is divided into two layers one for the top soil where overland flow is generated and the second for the soil layer where the interflow layer is generated. Each of the subcatchments of the basin have one ground water layer

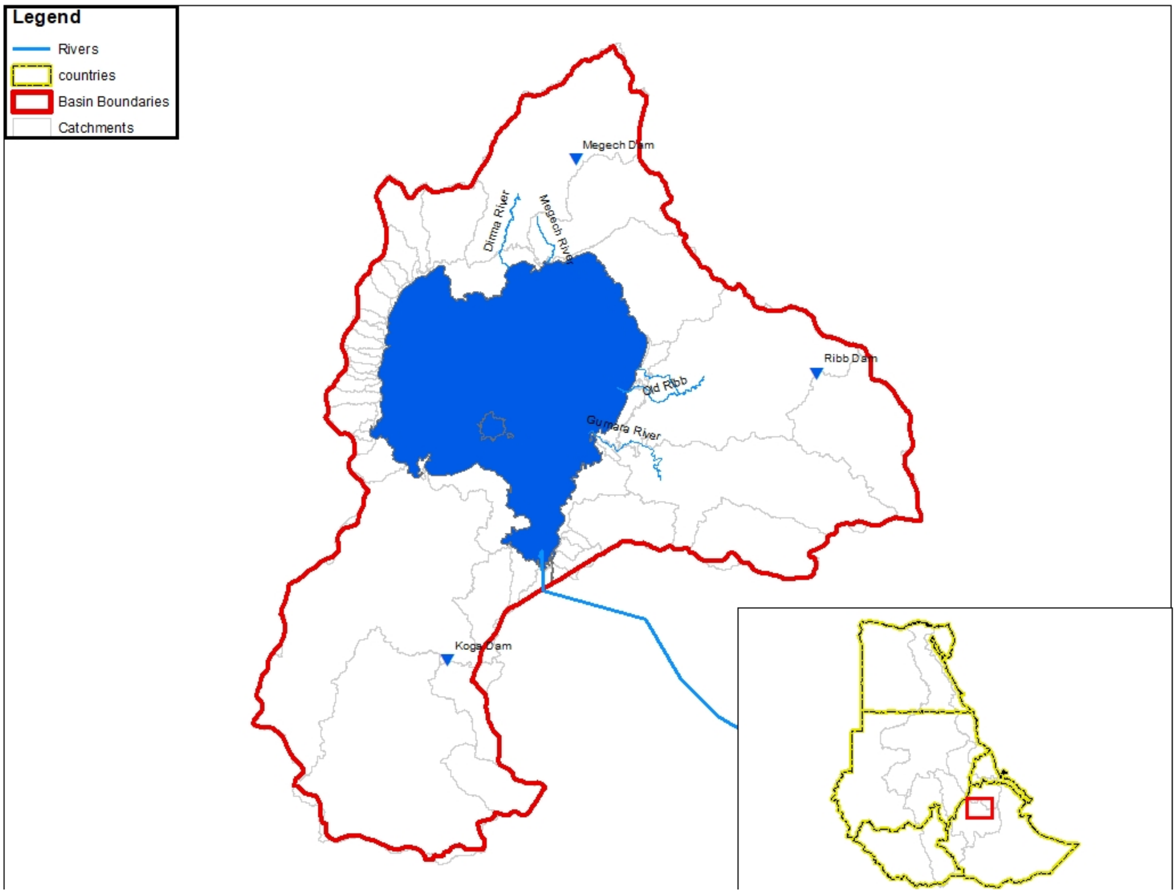


Figure 2.6: Lake Tana Sub catchments used within the NAM Rainfall-runoff model

A 1D hydraulic model for the four major rivers, namely Megech, Dirma, Ribb and Gumera rivers, in the sub basin is setup in MIKE 11 hydraulic modelling platform. The following data were sourced to build the hydraulic model for Lake Tana basin (Figure 2.7 and 2.8).

- Cross sections of the four rivers, which is sourced from surveyed data, HEC-RAS model of the lake and Airbus DEM
- River bed resistance, sourced from HEC-RAS model of the Lake Tana basin
- Water level, flow data and Q-h relationship for gauges that were used in the data assimilation of the model
    a. Megech, Dirma, Gumera and Rib stations were used for calibration, verification and validation of the model setup. These stations are not realltime stations, however a mechanism can be setup to report on daily basis to assist data assimilation in the model setup
- Height, volume, area relationships, dam water level, operational release, the Q-h relationship of the control structures (e.g. spillway) of the dams in the Lake Tana
    a. The dam include in the Lake Tana model setup is Megech dam. Megech dam is not completed yet, but the structure is placed in the setup and it will be activated once the construction is completed.

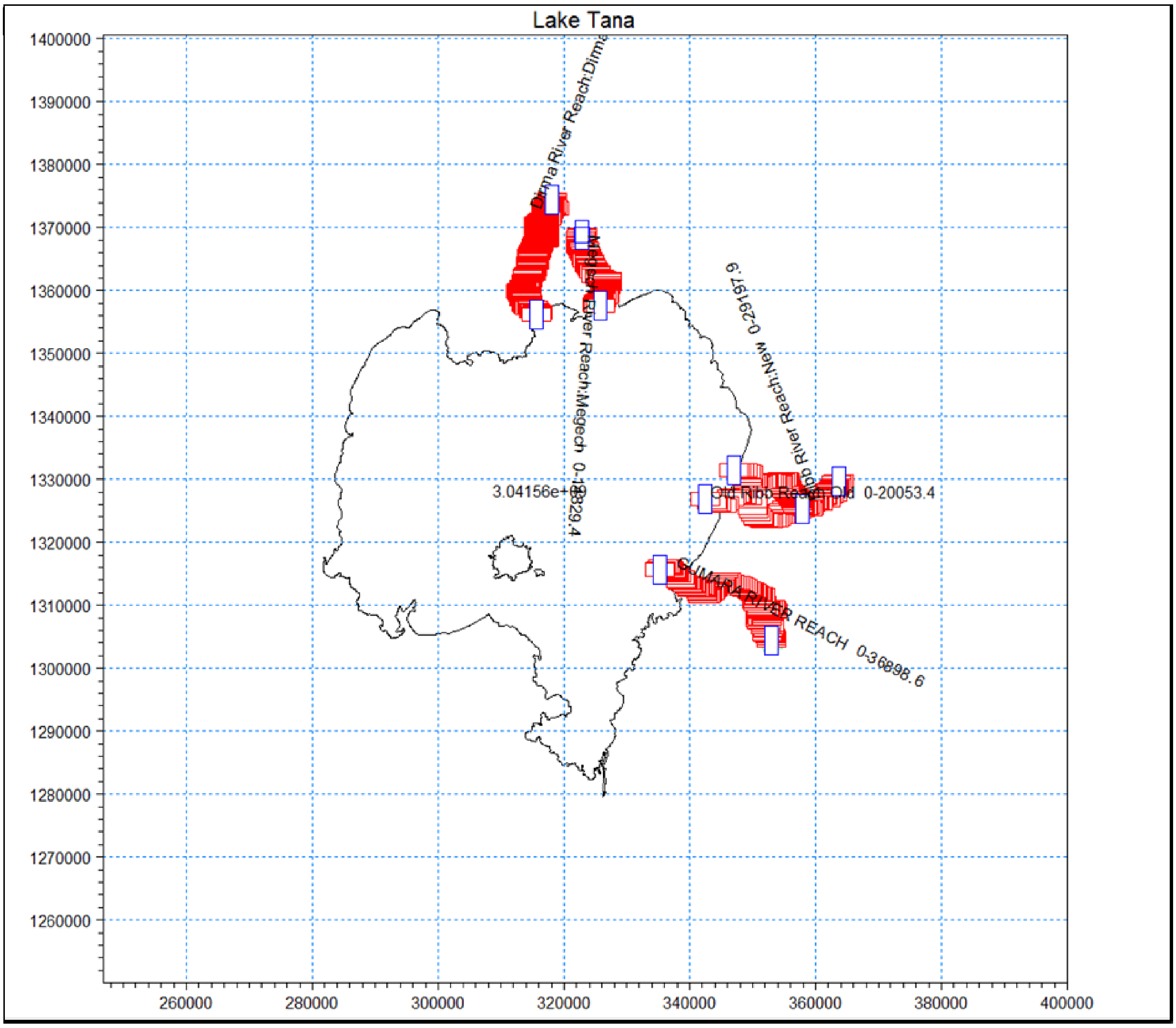


Figure 2.7: Lake Tana Sub basin network file in the MIKE 11hydraulic model

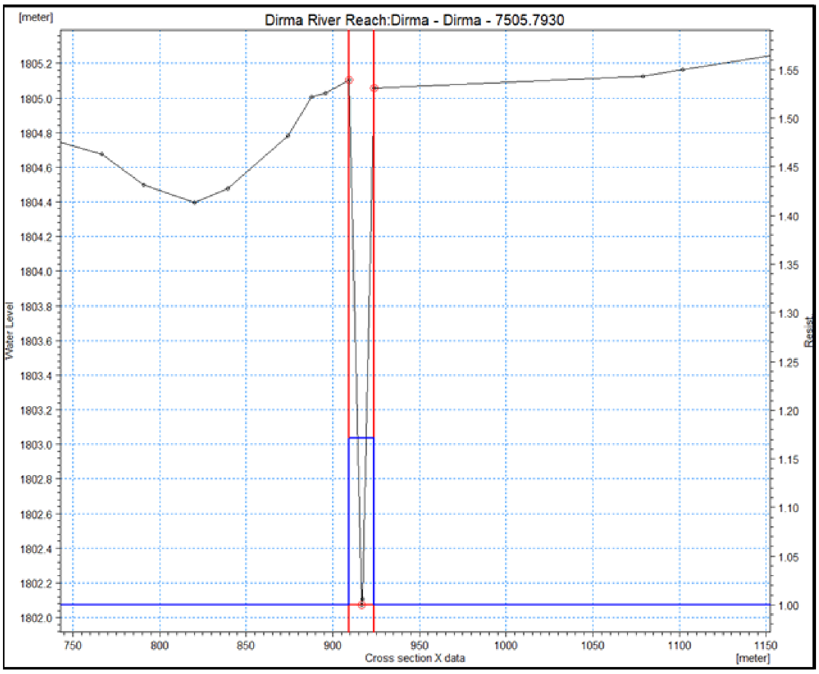


Figure 2.8: example of the cross-section used in the Dirma river of the Lake Tana sub-basin

2.3.2 Blue Nile Basin

The Blue Nile river is a large river, where most of the flow is generated in the upper catchments of the Blue Nile Basin. The river flooding that occur in Blue Nile river, occurs in the downstream of the river within the Sudan boundaries. There is relatively a bigger Leadtime between where the flow are generated to where the flooding occurs. There are two dams, namely Roseires and Sennar dam, that regulate the flow at the downstream of the river, in addition once the GERD (Grand Ethiopian Renaissance Dam) is complete the operation of the river could change drastically. GERD will help with regulating flow in the downstream of the river which could reduce the present flood impact in the catchment. An Airbus DEM was used to delineate the sub-catchments of the Blue Nile Basin that are used in the NAM Rainfall-runoff model as described in Figure 2.9.The delineation of the Blue Nile Basin was guided by the need to break to catchment into smaller sub-catchment to identify the flood that occur downstream as earliest as possible. As well, the delineation was also guided by available infrastructures within the catchment/basin to isolate the inflow to the infrastructures. The rainfall-runoff model setup for the Blue Nile basin in NAM hydrology model. The Rainfall-runoff model for the Blue Nile basin was setup for each subcatchment of the basin as a lumped catchment, where the soil layer is divided into two layers one for the top soil where overland flow is generated and the second for the soil layer where the interflow layer is generated. Each of the subcatchments of the basin have one ground water layer

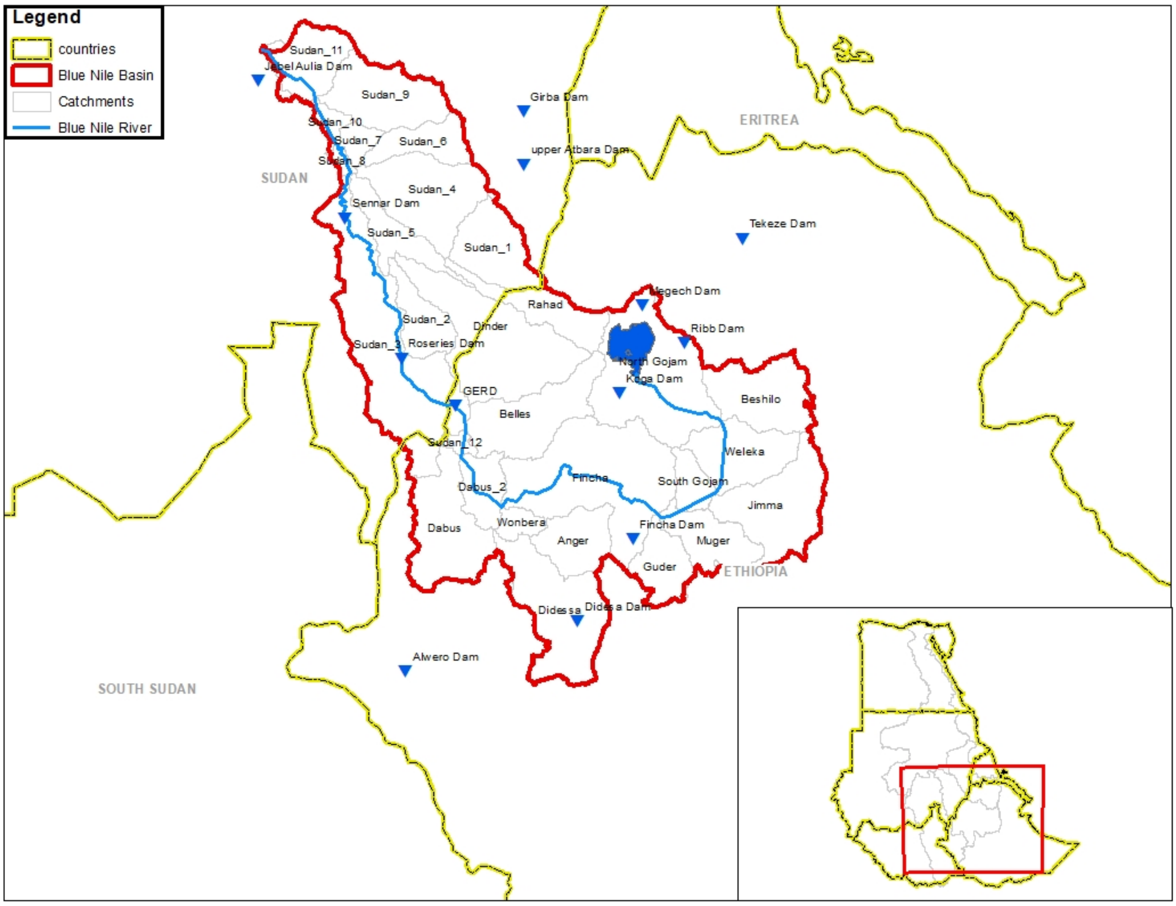


Figure 2.9: Blue Nile Sub catchments used within the NAM Rainfall-runoff model

The 1D hydraulic model of the Blue Nile river of the Blue Nile sub basin is setup in MIKE 11 hydraulic modelling platform. The following data were sourced to build the hydraulic model for Blue Nile sub basin (Figure 2.10 and 2.11).

- Cross sections of the Blue Nile river, is sourceBlue Nile sub basin HEC-RAS model
- River bed resistance, sourced from HEC-RAS model of the Blue Nile sub basin
- Water level, flow data and Q-h relationship for gauges that were used in the data assimilation of the model
    a. The stations that are identified to be used for calibration, verification and validation of the model setup for the Blue Nile are:
        i. Eddiem station
        ii. Upstream and Downstream Roseires dam
        iii. Wad Elais station
        iv. Upstream and Downstream of Sennar Dam

    However, data for these stations was not provided.
- Height, volume, area relationships, dam water level, operational release, the Q-h relationship of the control structures (e.g. spillway) of the dams in the Blue Nile sub basin
    a. The two dams that are included in the model setup are Roseires and Sennar dam. The spillway Q-H relationships for these two dams was not provided as yet. The GERD is under construction, this is not included as yet and it need to be discussed how should it be added in the model as it is not operational.

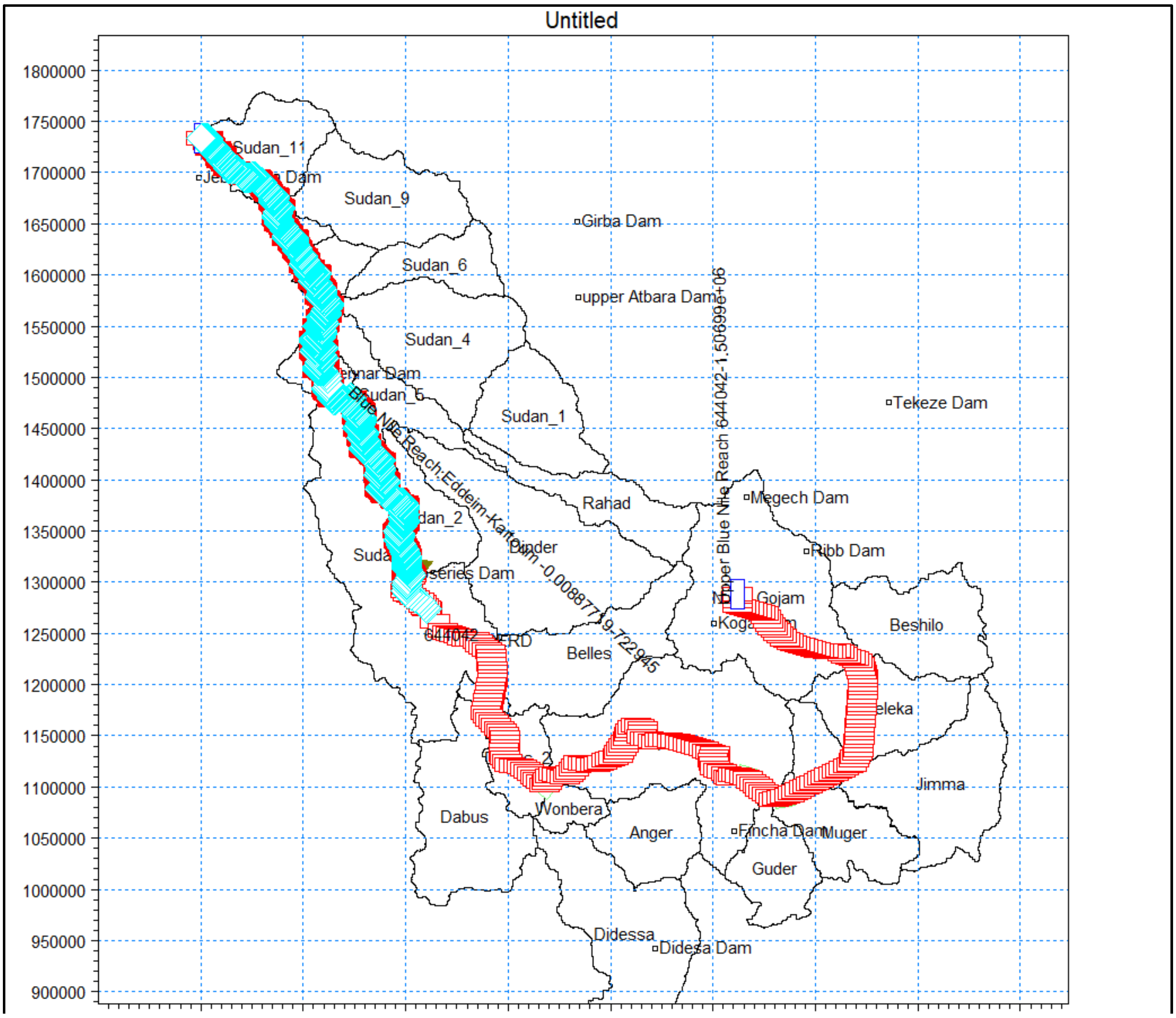


Figure 2.10: Blue Nile Sub basin network file in the MIKE 11hydraulic model

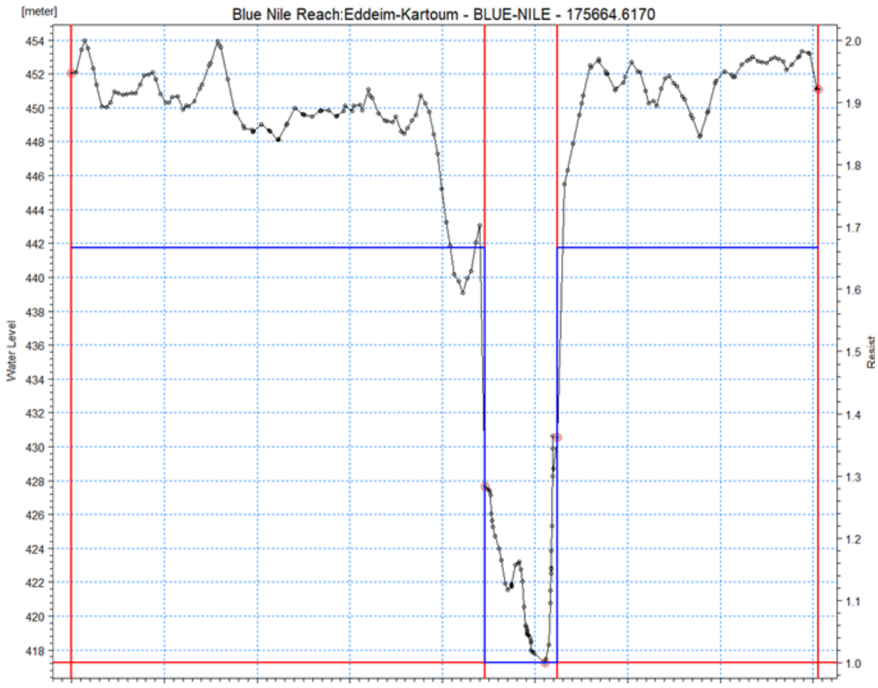


Figure 2.11: example of the cross-section used in the Blue Nile river of the Blue Nile sub-basin

2.3.3 **Baro-Akobo-Sobat Basin**

The Baro-Akobo-Sobat is one of the sub basins of the Eastern Nile where Bahr el Ghazal and Sobat rivers are tributaries to the white river. An Airbus DEM was used to delineate the sub-catchments of the Baro-Akobo-sobat Basin that are used in the NAM Rainfall-runoff model as described in Figure 2.12.The delineation of the Baro-Akobo-Sobat Basin was guided by the need to break to catchment into smaller sub-catchment to identify the flood that occur downstream as earliest as possible. As well, the delineation was also guided by available infrastructures within the catchment/basin to isolate the inflow to the infrastructures. The rainfall-runoff model setup for the Baro-Akobo-Sobat basin in NAM hydrology model. The Rainfall-runoff model for the Baro_Akobo_Sobat basin was setup for each subcatchment of the basin as a lumped catchment, where the soil layer is divided into two layers one for the top soil where overland flow is generated and the second for the soil layer where the interflow layer is generated. Each of the subcatchments of the basin have one ground water layer

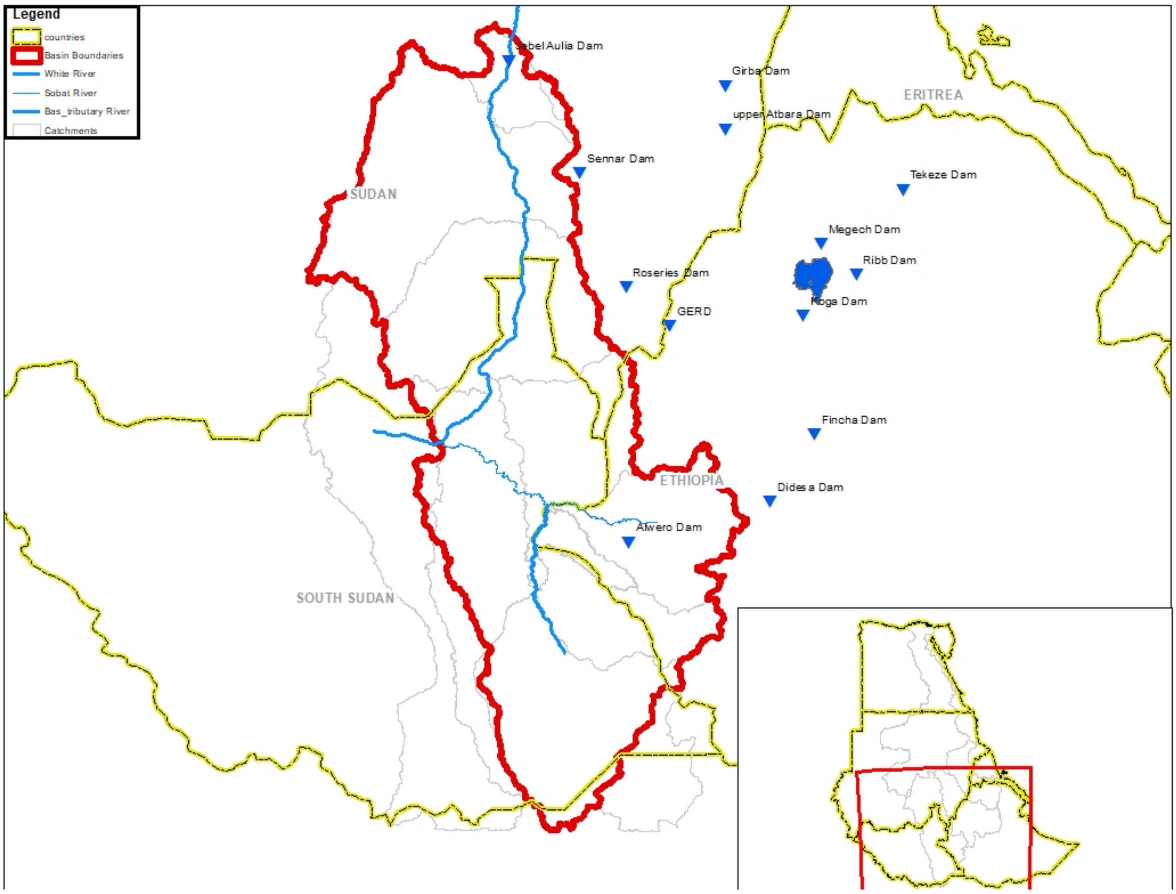


Figure 2.12: Baro-Akobo-Sobat Sub catchments used within the NAM Rainfall-runoff model

The 1D hydraulic model of the Baro-Akobo-Sobat sub basin include three rivers namely sobat river, white river and a tributary to the sobat river, which is setup in MIKE 11 hydraulic modelling platform. The flow from Bahr el Ghazal is modelled as a boundary flow that is entering into the white river. The following data were sourced to build the hydraulic model for Baro-Akobo-Sobat sub basin (Figure 2.13 and 2.14)..

- Cross sections of the white river, sobat river and the tributary river to sobat, is generated from Airbus DEM. The Cross section that are generated from the Airbus DEM seem to be reasonable where there is a gorge and not good in the flat part of the rivers.
- River bed resistance is derived from the land use of the river riparian and river bed
- Water level, flow data and Q-h relationship for gauges that were used in the data assimilation of the model

    a. The available stations at the Baro-Akobo-sobat basin are stationed in the updtream of the Sobat river and two stations located at downstream of the White river. The stations in Sobat river could not be used in the model as their in upper part of the catchment and it will not assist with calibration, verification and validation and data assimilation of the model. The stations upstream of Jebel Aulia Dam could be used to calibrate the overflow from the Baro-Akobo-sobat basin, however data is not provided for this station.

- Height, volume, area relationships, dam water level, operational release, the Q-h relationship of the control structures (e.g. spillway) of the dams in the Baro-Akobo-sobat sub basin

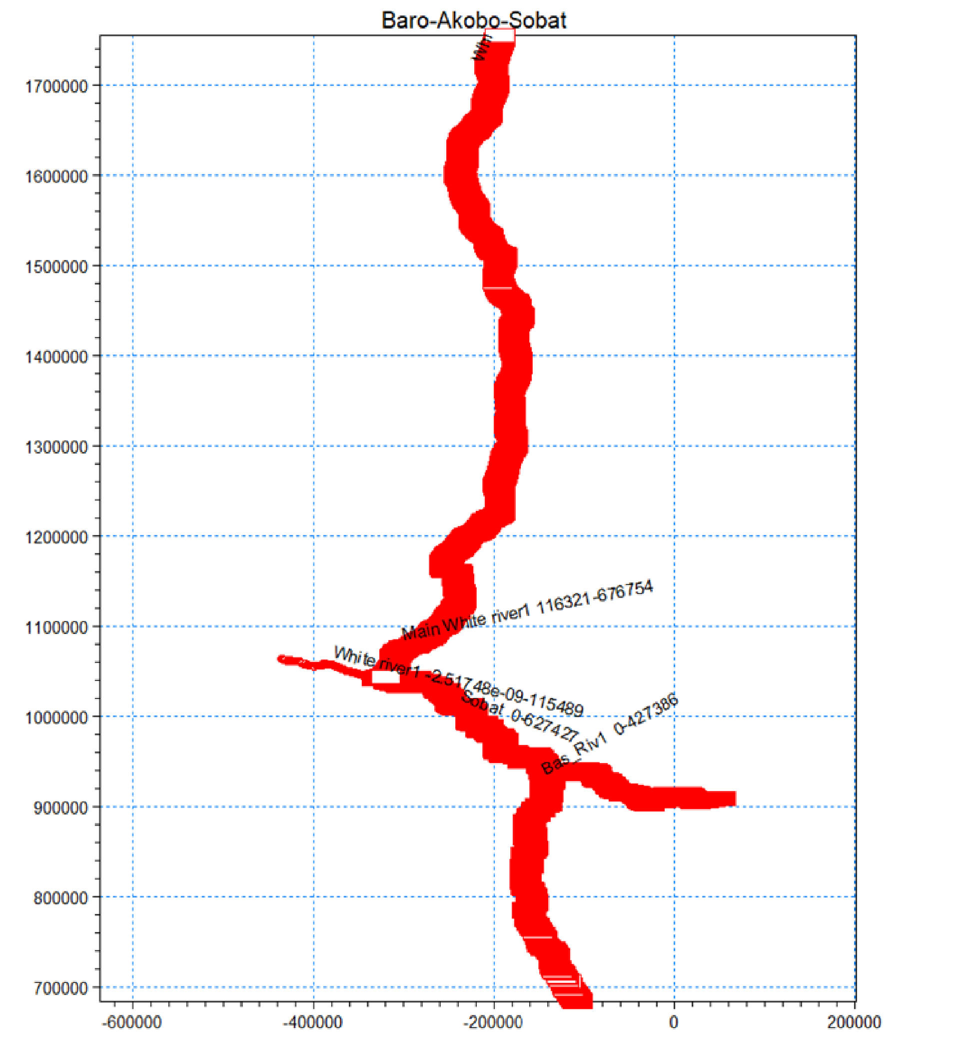


Figure 2.13: Baro-Akobo-Sobat Sub basin network file in the MIKE 11hydraulic model

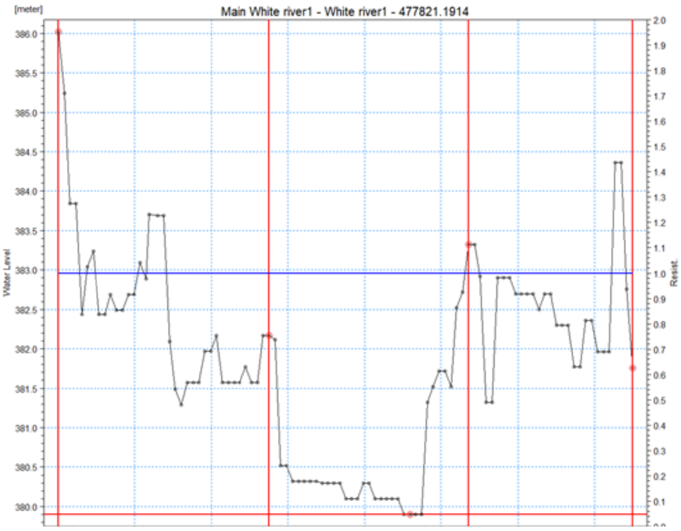


Figure 2.14: example of the cross-section used in the White river of the Baro-Akobo-Sobat sub-basin

2.3.4 **Atbara-Tekeze -Setit Basin**

The Atbara-Tekeze-Setit sub basin starts with Tekeze river from the highlands of Ethiopia and Eritrea, and joins the Atabara river in Sudan. An Airbus DEM was used to delineate the sub-catchments of the Atbara-Tekeze-Setit basin that are used in the NAM Rainfall-runoff model as described in Figure 2.15.The delineation of the Atbara-Tekeze-Setit basin was guided by the need to break to catchment into smaller sub-catchment to identify the flood that occur downstream as earliest as possible. As well, the delineation was also guided by available infrastructures within the catchment/basin to isolate the inflow to the infrastructures. The rainfall-runoff model setup for the Atbara-Tekeze-Setit basin in NAM hydrology model. The Rainfall-runoff model for the Atbara-Tekeze-Setit basin was setup for each subcatchment of the basin as a lumped catchment, where the soil layer is divided into two layers one for the top soil where overland flow is generated and the second for the soil layer where the interflow layer is generated. Each of the subcatchments of the basin have one ground water layer

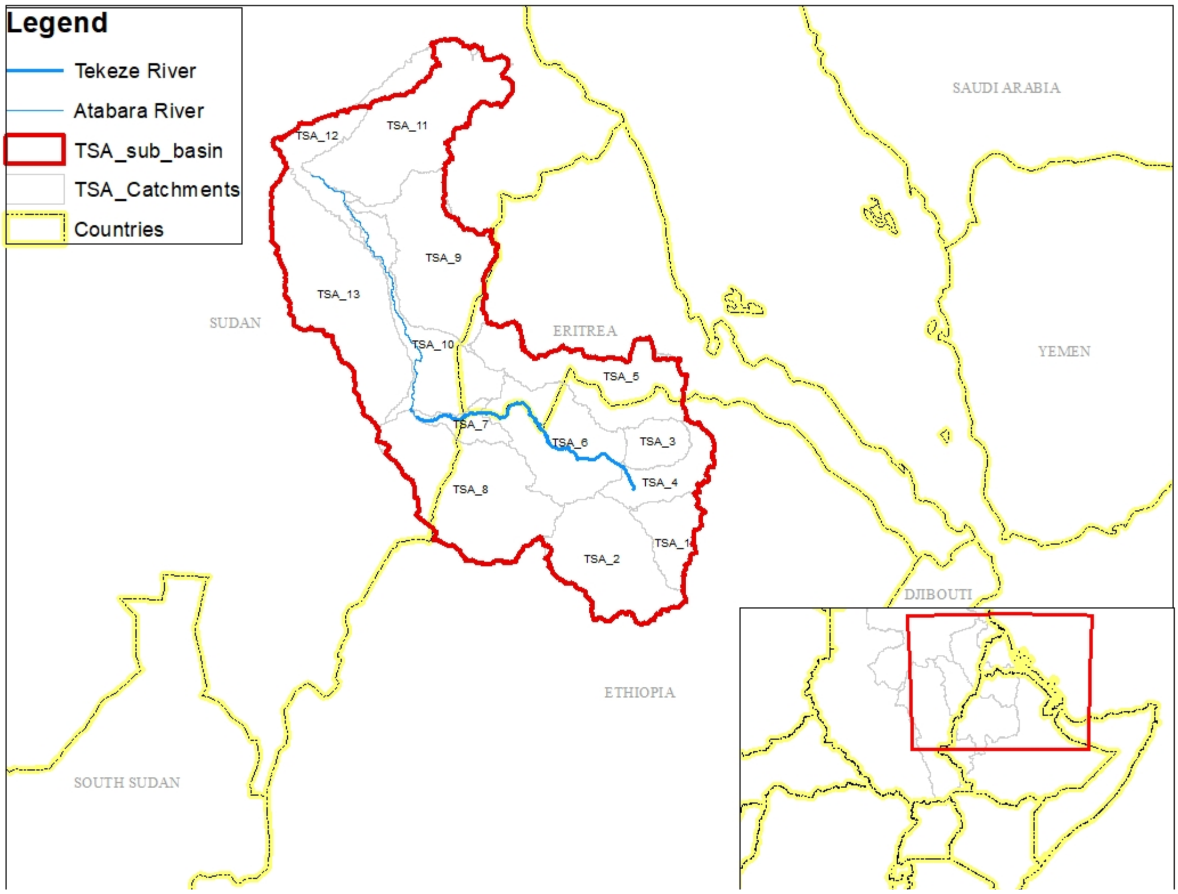


Figure 2.15: Atbara-Tekeze-Setit sub catchments used within the NAM Rainfall-runoff model

The 1D hydraulic model of the Atbara-Tekeze-Setit sub basin include two rivers namely Tekeze river, and Ataba river, which is setup in MIKE 11 hydraulic modelling platform. The flows that are simulated from the sub-catchment are linked to the rivers at different positions. The following data were sourced to build the hydraulic model for Atbara-Tekeze-Setit sub basin (Figure 2.16 and 2.17)..

- Cross sections of the Tekeze river and Atbara river, is generated from Airbus DEM. The Cross section that are generated from the Airbus DEM seem to be reasonable where there is a gorge and not good in the flat part of the rivers.
- River bed resistance is derived from the land use of the river riparian and river bed
- Water level, flow data and Q-h relationship for gauges that were used in the data assimilation of the model
    a. The stations that are selected to be used for calibration, verification and validation process of the model are upstream/downstream of Atabara dam, upstream/downstream of Girba dam, and Tekeze at Humera. However, data was not provided.
- Height, volume, area relationships, dam water level, operational release, the Q-h relationship of the control structures (e.g. spillway) of the dams in the Baro-Akobo-sobat sub basin

a. The dams that are include in the model are Atabara and Girba, however the spillway Q-H relationship not provided.

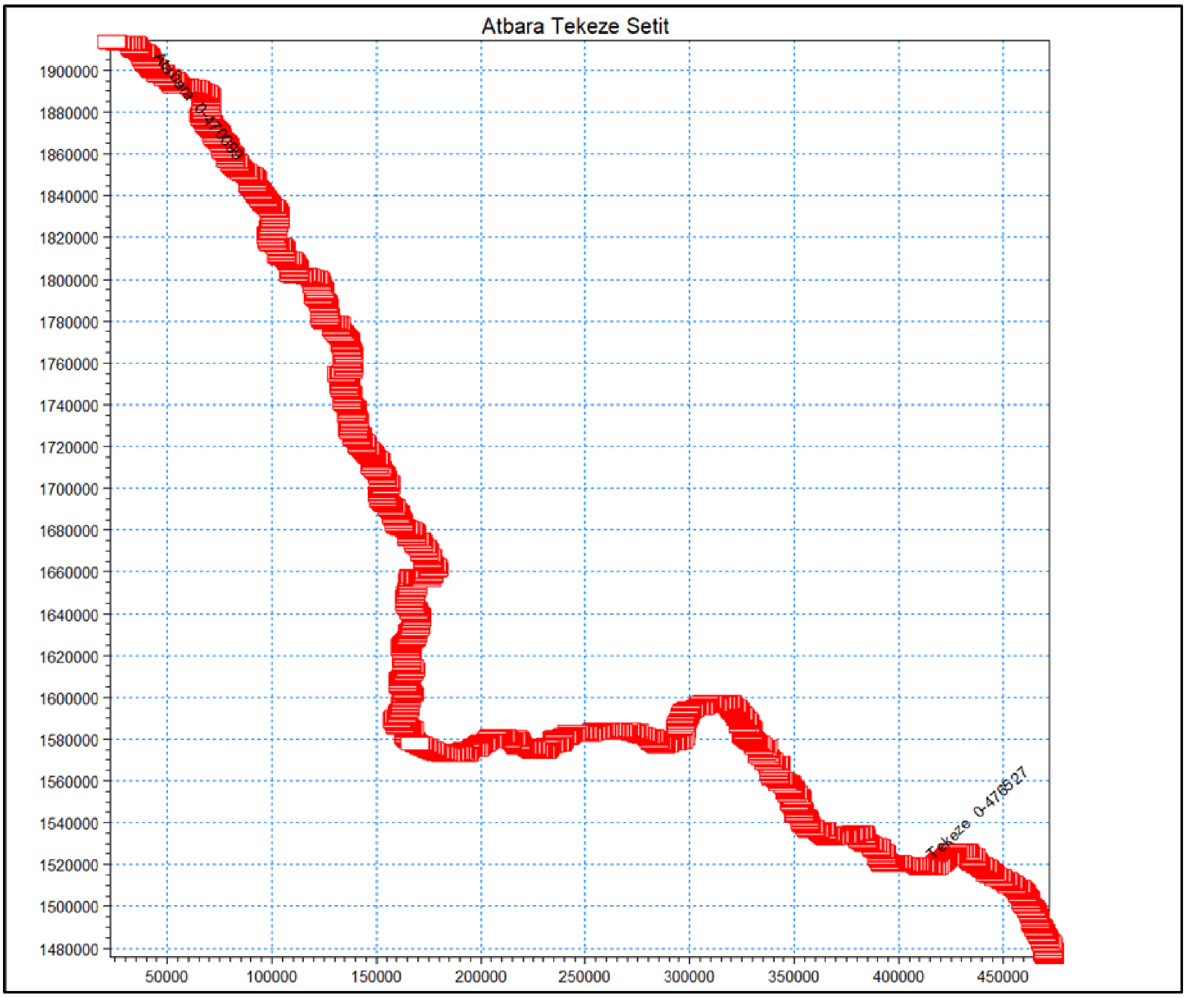


Figure 2.16: Atbara Tekeze Setit sub basin network file in the MIKE 11hydraulic model

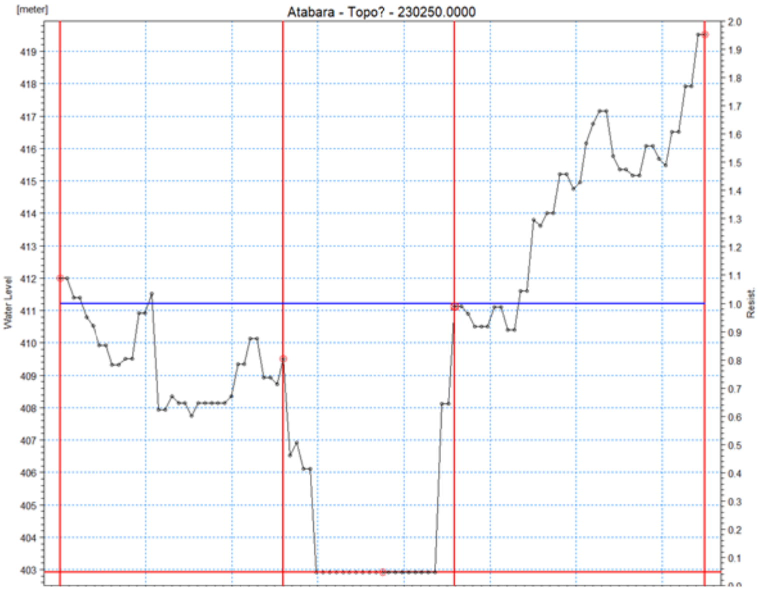


Figure 2.17: example of the cross-section used in the Atbara river of the Atabara Tkeze Setit sub-basin

3. MODEL CALIBRATION AND VALIDATION

NAM Rainfall-runoff model is a deterministic mathematical model. The parameters that are used in the model have a lower and upper bounds that are extrapolated from hydrological experience. Each catchment has its own soil, land cover and geological characteristics. The NAM Rainfall-runoff parameters are dependent of the catchment characteristics, which can be unique for a catchment. A calibration exercise was used to determine the parameters for the sub catchments of the four basins of the Eastern Nile.

Separate NAM Rainfall-runoff models were setup for each sub catchment for all the four basin of the Eastern Nile, where the calibration and verification of the model was conducted for each model separately. Rainfall for 2013, 2014 and 2018 was generated from WRF for all the sub catchments of the four basins of the Eastern Nile, and the calibration of the flows at gauges with available data was conducted. The validation and verification process of the simulated flow is conducted once the Rainfall-Runoff and the hydraulic model is integrated to simulate the flow. The parameters that are adjusted in the Rainfall-runoff and the hydraulic model include the following:

- Lmax - Maximumsoil moisture content in root zone
- Umax -Maximum water content in surface storage
- CQOF – Overland flow coefficient
- CQIF - Interflow drainage coefficient
- TOF – Overland Flow
- TIF- Threshold values for Interflow
- TG - Threshold for Ground water recharge
- Manning value for the river reach and flood plains in the hydraulic model

In this process of calibration and validation process, it is important to note that the rainfall data that is used for the subcatchment in the rainfall-runoff model is a satellite generated data (values) NOAA RFE for calibration purpose and the WRF rainfall forecast data for the forecast period. Satellite data in general are good in showing the spatial distribution of the rain that falls over a catchment, however, it is not always accurate in estimate the rainfall values. Moreover, Satellite sometimes could miss an event and some cases it can report an event that has not occurred. Hence, it paramount important to verify the NOAA RFE rainfall data and the WRF data against an observed/ground truth rainfall data measured by raingauge.

Calibration is a process of standardizing predicted values, using deviations from observed values for a particulararea to derive correction factors that can be applied to generate predicted values that are consistent with the observedvalues. Once the MIKE 11 NAM model was set up with the input information, the model was calibrated for one year period of2013. The model output simulation results during calibration were checked for coefficient ofdetermination (R^2) value and graphically analysed for degree of agreement between simulated and observed runoff.The model parameters were again adjusted one by one using trial and error method to obtain the set of best fit modelparameters which could simulate runoff with high degree of agreement with observed runoff in term of timings,peaks and total volume.

Model validation means judging the performance of the calibrated model over the portion of historical records which have not been used for the calibration. The MIKE 11 NAM model thus calibrated was then validated for a period where there is an observed data outside the calibration period. During validation the set of model parameters obtained during the calibration was used and model was run to simulate runoff. The statistics of the simulated results were analysed and output of the model were checked to compare the simulated and observed runoff to verify the capability of calibrated model to simulate the runoff.

Accuracy of the model can be examined on the basis of coefficient of determination (R^2), Efficiency Index (EI) and Sum of Square of Error (SSE). The use of the coefficient of determination is to test the goodness of fit of the model and to assess how well a model explains and predicts future outcomes. It is expressed as a value between zero and one.

3.1 Lake Tana Basin

The calibration and validation of the Lake Tana model was conducted at four stations of the four rives that are modelled in the setup, namely Megech, Dirma, Gumera and Rib stations, as shown in Figure 3.1. The comparison of the simulated against the observed are described from Figure 3.2 to Figure 3.9. What is clear in the comparison of the WRF rainfall data and the Observed flow is that the WRF misses to register some of the events where the observed flow shows that there was a rainfall event and in some cases the WRF rainfall registers a rainfall where the observed flow shows that there is no rainfall event. Figure 3.6 and Figure 3.7 shows a bad correlation between the WRF Rainfall and the observed point rainfall data. Though, it is important to compare the WRF catchment rainfall against catchment estimated ground measured data, the comparison against the point rainfall data is made to establish if there is a trend correlation. The use of the NOAA RFE rainfall data was discussed with the ENTRO team and has approved the NOAA RFE use for the calibration purpose. It is widely researched that the NOAA RFE rainfall data under estimated the actual rain fall data. This is confirmed on the calibration results produced. The comparison of the simulated flow that are shown below against the observed flow data, generally show the simulated flow is underestimating the observed flow. Otherwise, the simulated flow at the Gamara and Ribb river estimated the observed flow reasonably well. The two statistics that are used to measure the accuracy and reliability of the simulated are presented in Table 3.1, the statistics show that the simulated flow is reasonably accurate and reliable.

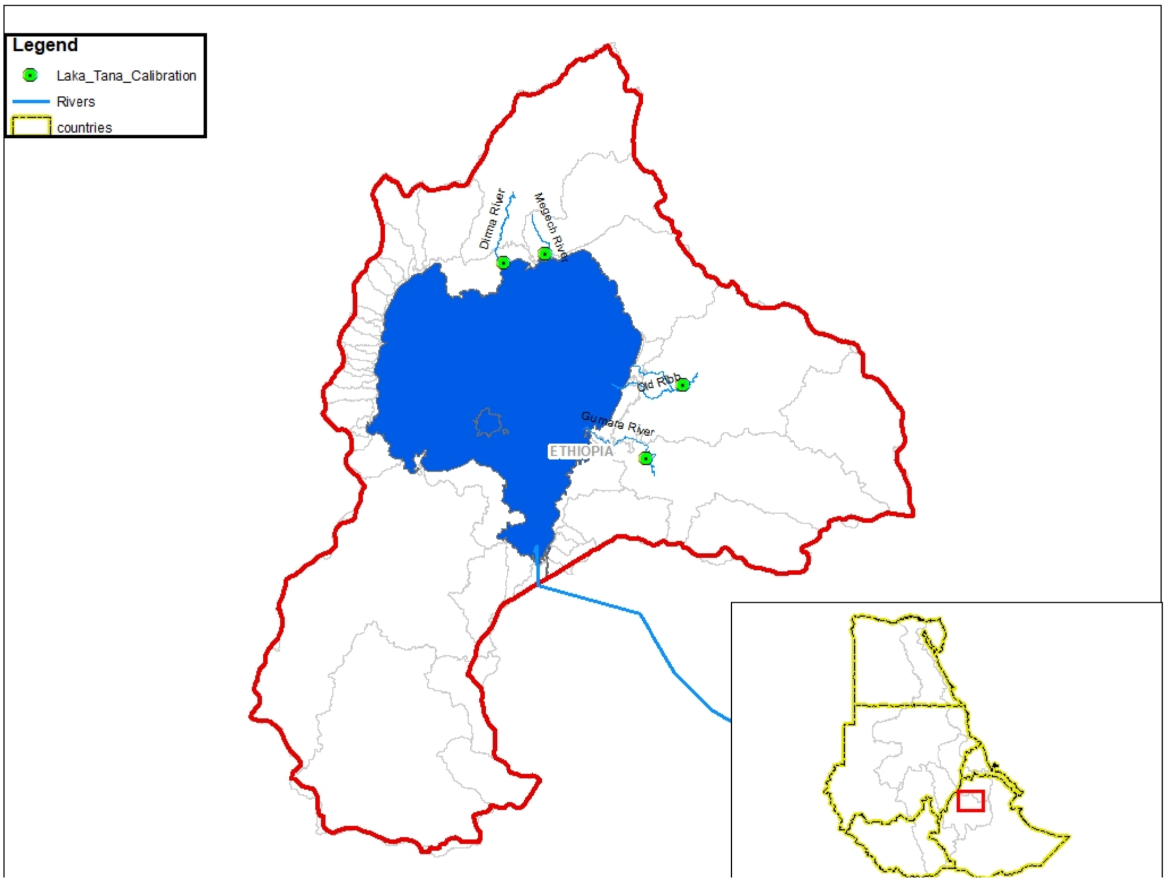


Figure 3.1 – Calibration and validation points used for the Lake Tana MIKE 11 model

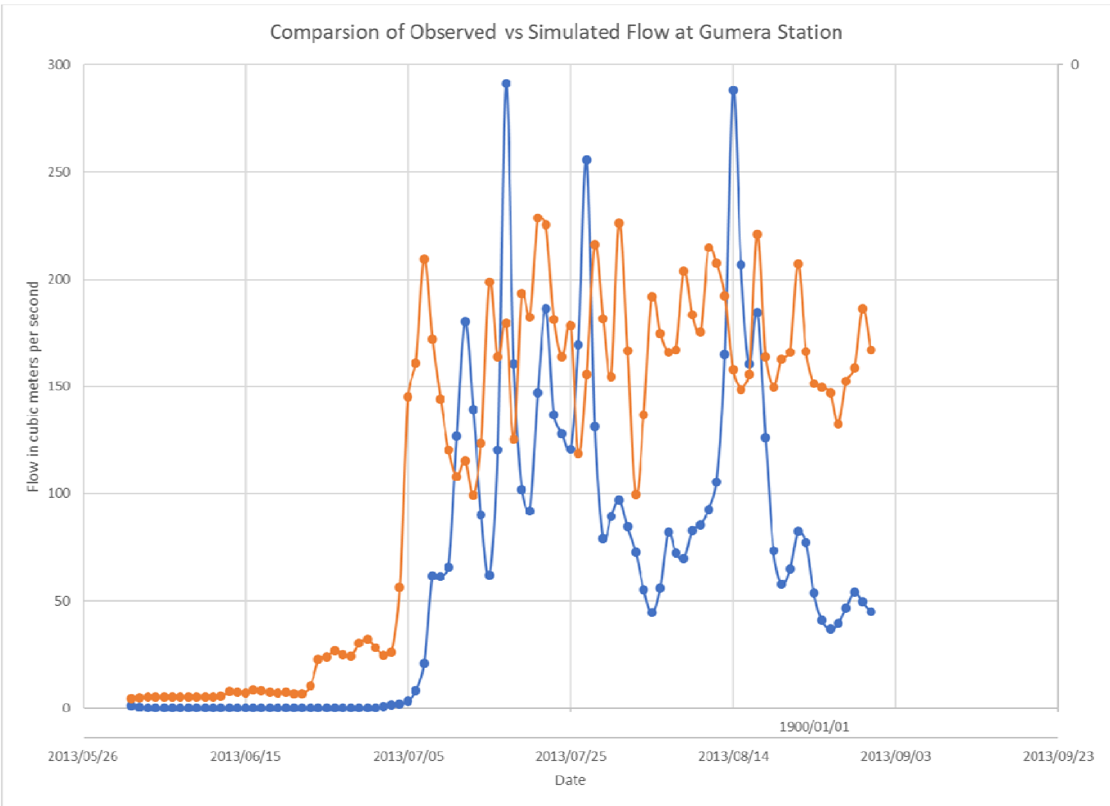


Figure 3.2: Comparison of Observed vs Simulated flow at Gumera station

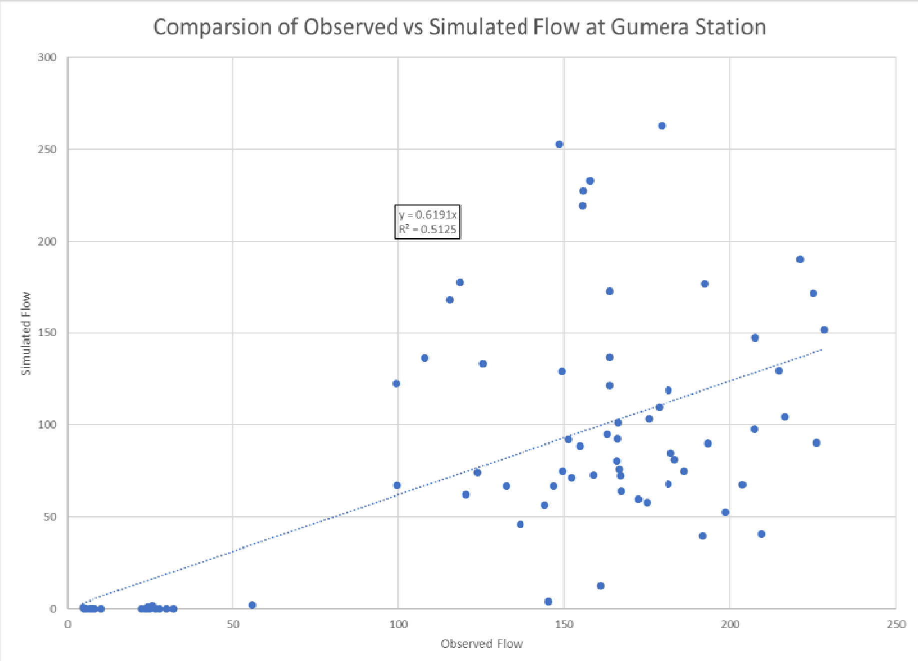


Figure 3.3: Comparison of Observed vs Simulated flow at Gumera station showing the coefficient of determination

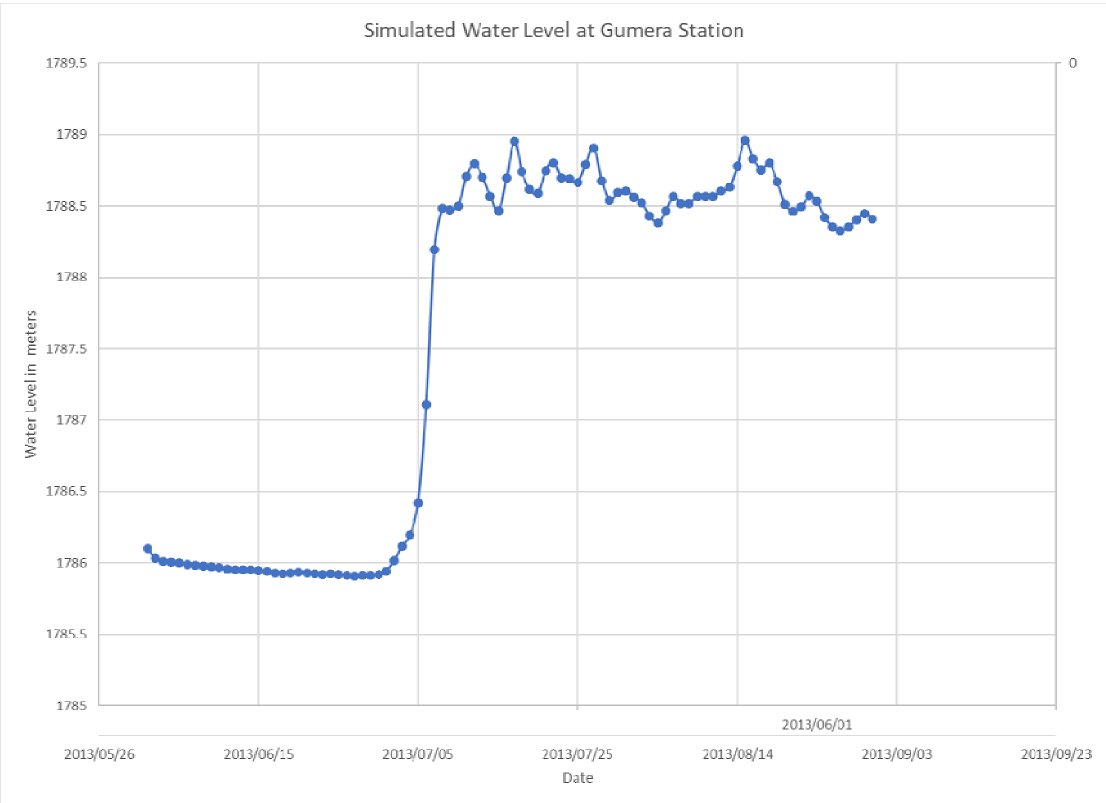


Figure 3.4: Simulated Water Level at Gumera station

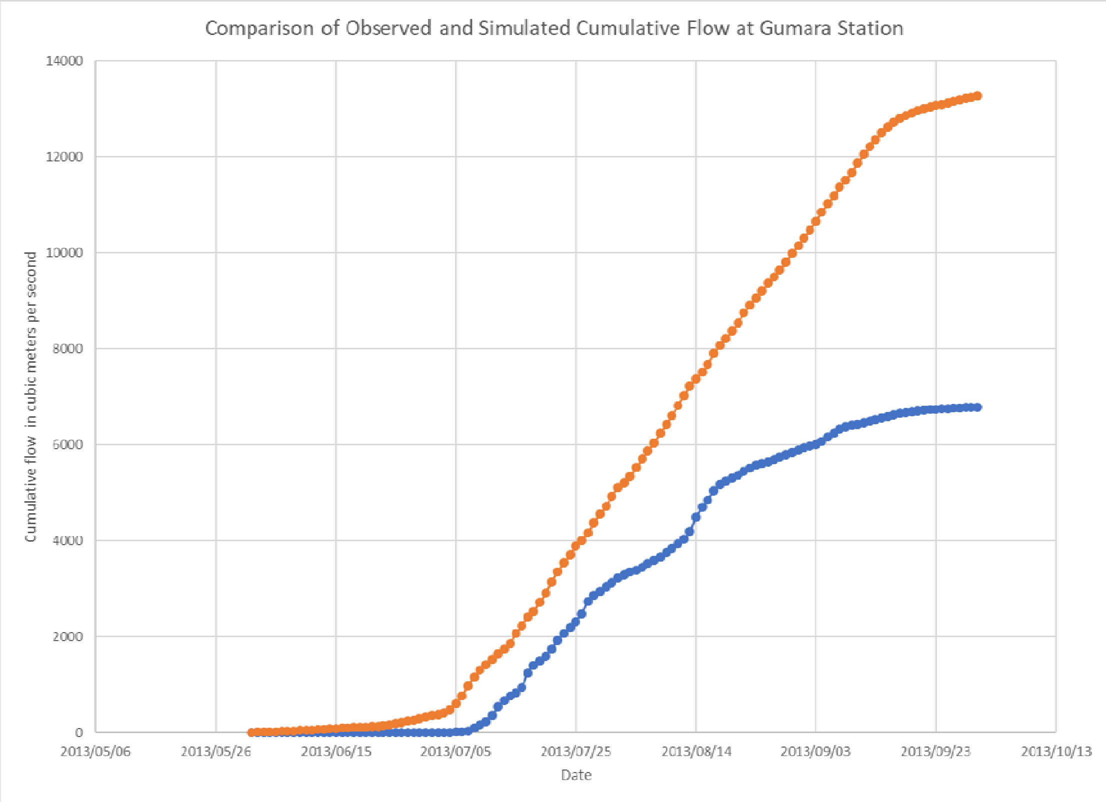


Figure 3.5: Comparison of Observed vs Simulated Cumulative flow at Gumera station showing the coefficient of determination

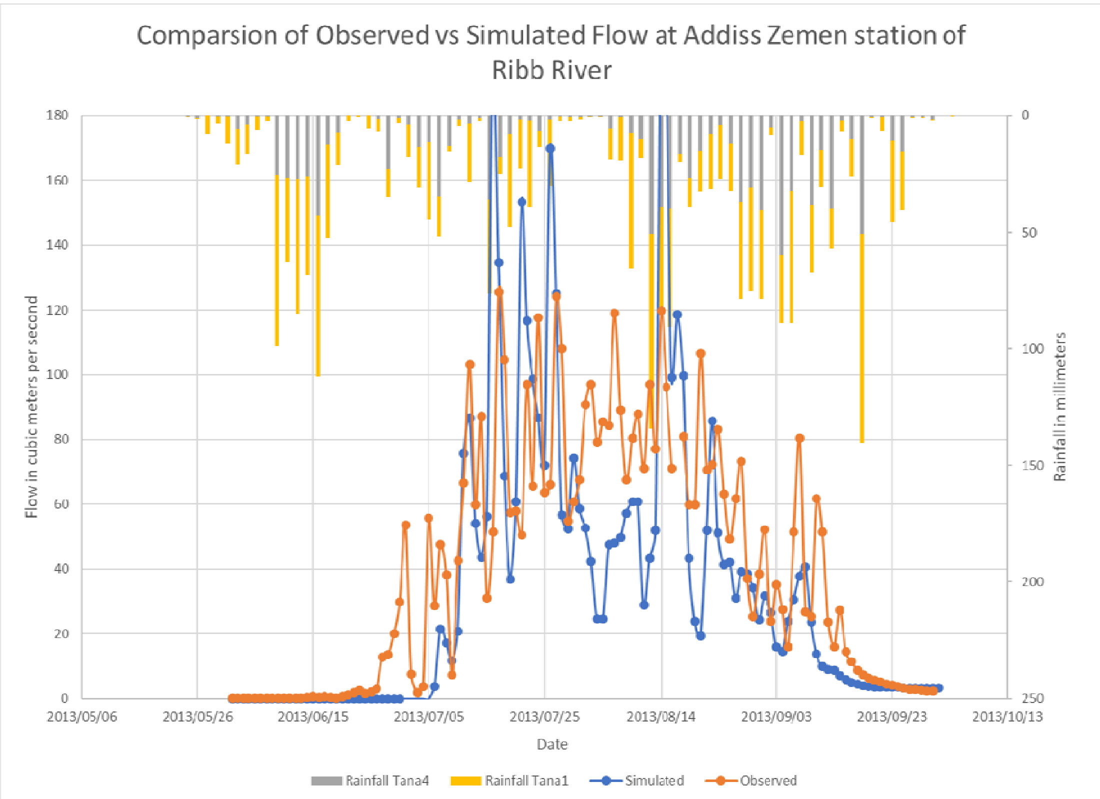


Figure 3.6: Comparison of Observed vs Simulated flow for Ribb River at Addiss zemen station

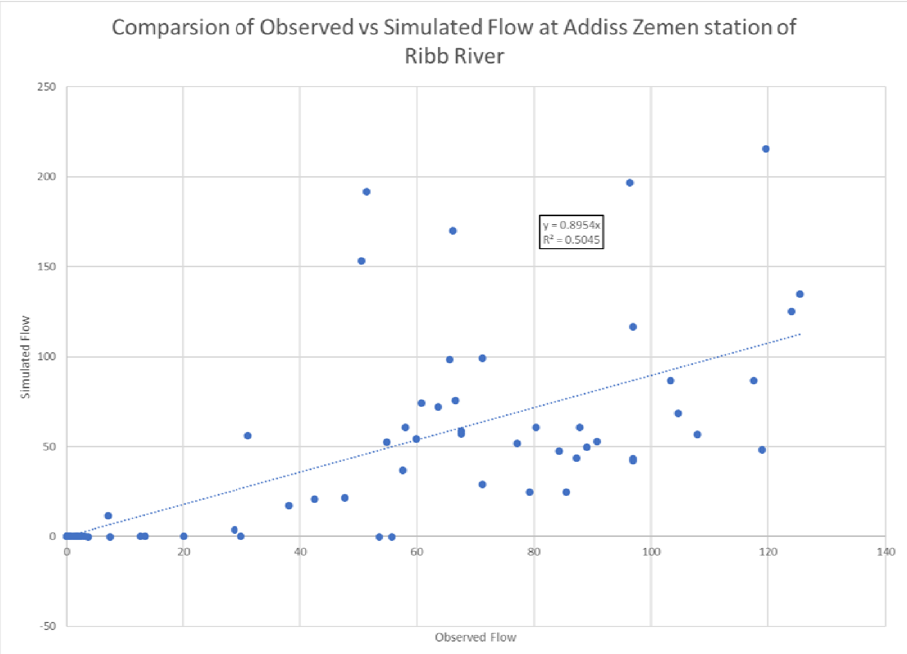


Figure 3.7: Comparison of Observed vs Simulated flow at Addiss zemen station of Ribb River showing the coefficient of determination

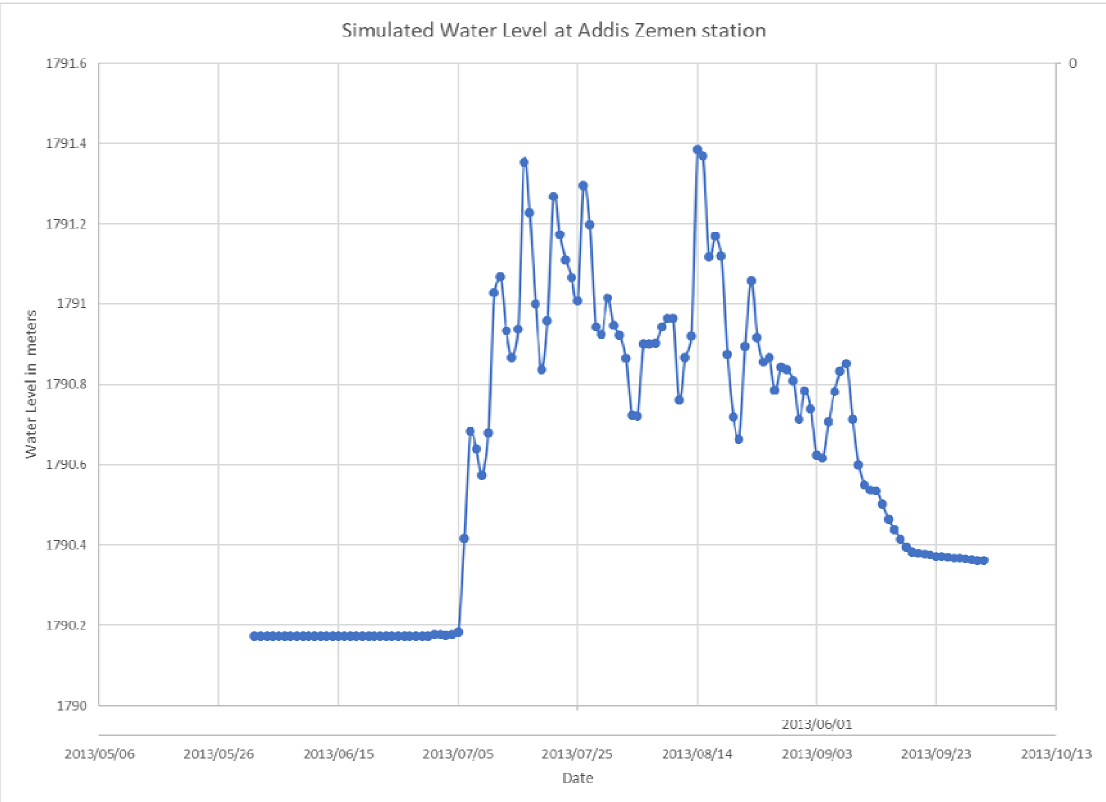


Figure 3.8: Simulated Water Level at Addis zemen station of Ribb River

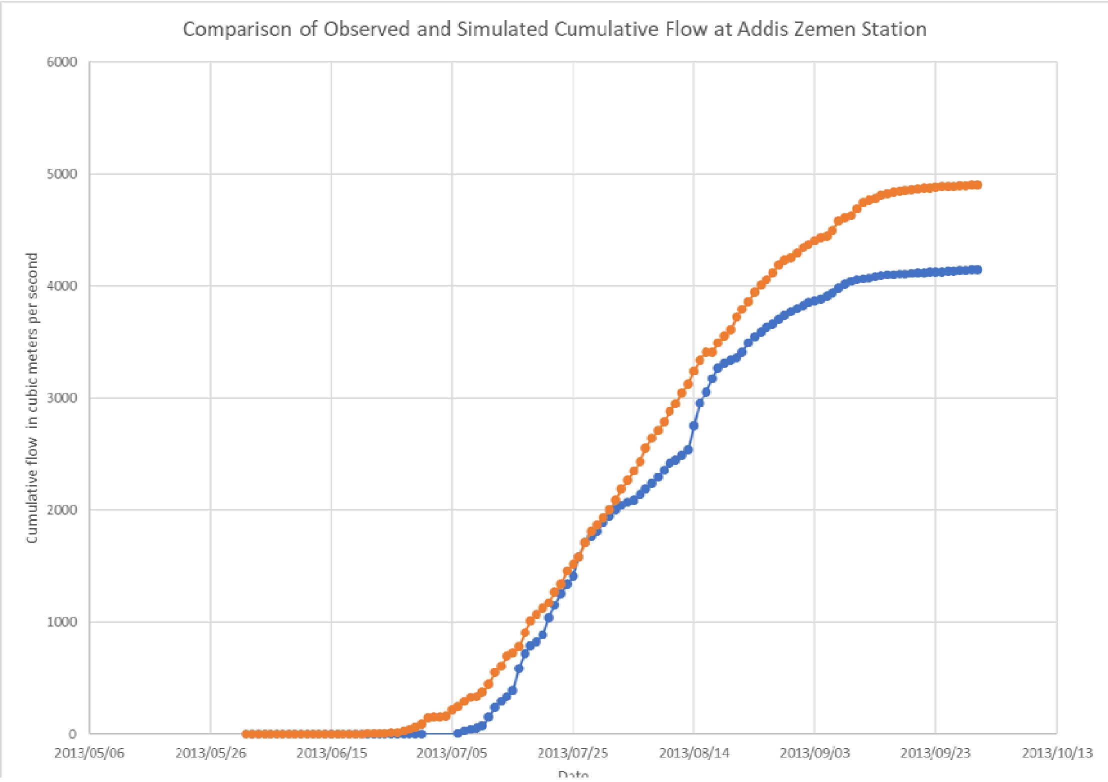


Figure 3.9: Comparison of Cumulative Observed vs Simulated flow for Ribb River at Addiss zemen station

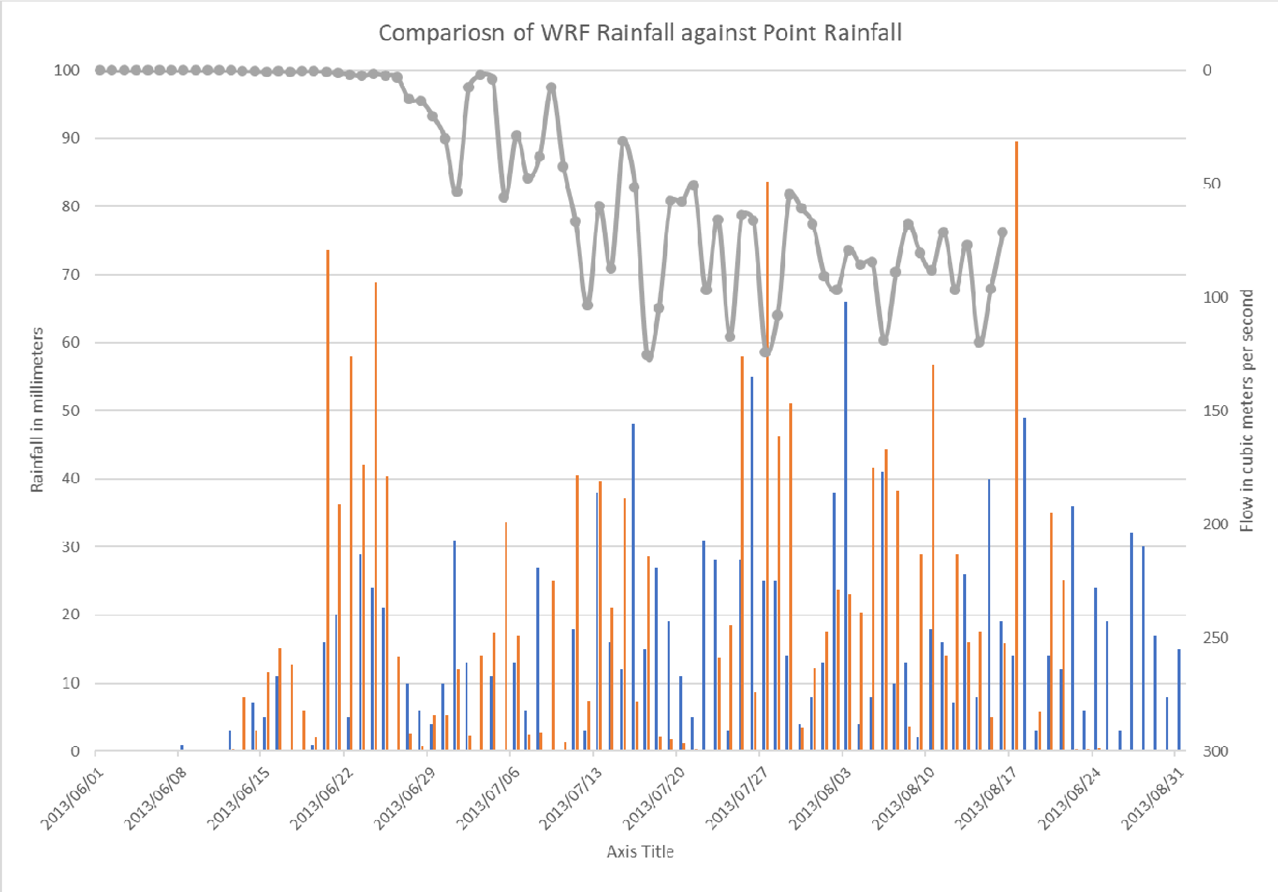


Figure 3.10: Comparison of Observed Point Rainfall vs WRF Rainfall within the Rib river catchment

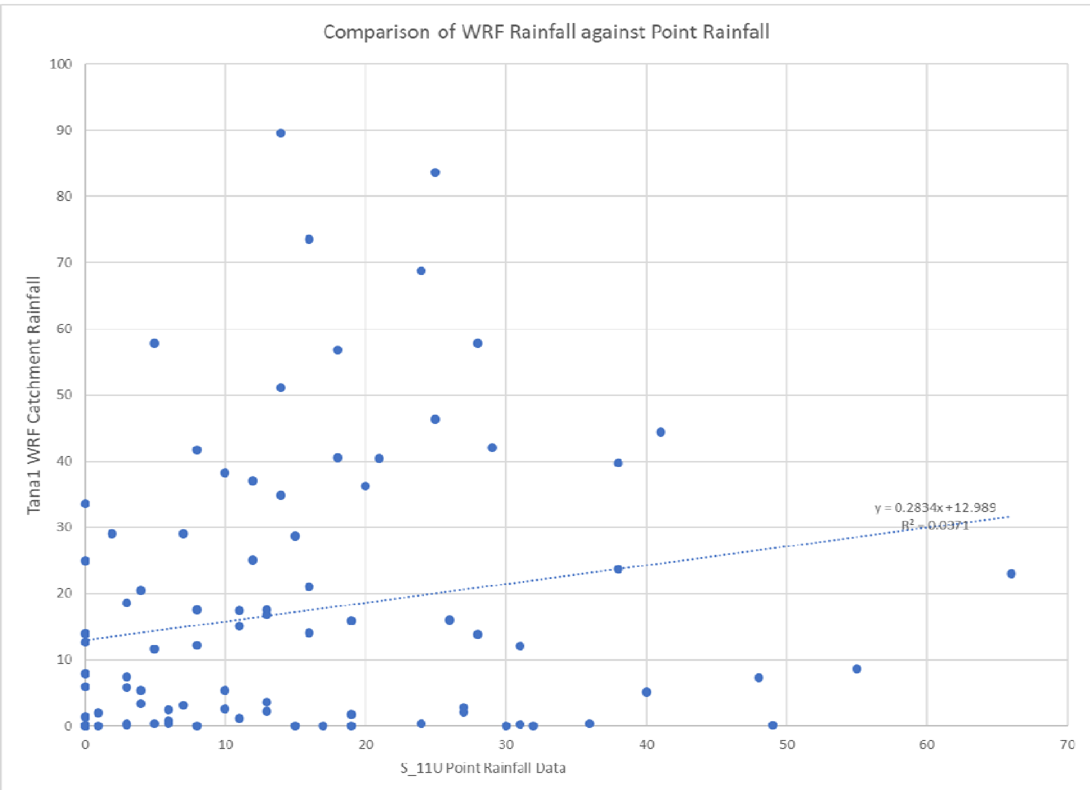


Figure 3.11: Comparison of Observed Point Rainfall at S_11u gauge vs WRF Rainfall within the Ribb river catchment

Table 3.1 Accuracy and reliability measurement of the simulated flow

River Name	Coefficient of determination (R^2)	Efficiency Index (EI)
Ribb River	0.5	0.61
Gumara	0.51	0.70

3.2 Blue Nile Basin

The calibration and validation model of the Blue Nile model was expected to be conducted on the following stations, namely Eddiem station, upstream and downstream Roseires dam, Wad Elais station and upstream and downstream of Sennar Dam as shown in Figure 3.12. However, no flow data was received for the 2013, 2014 or 2018. Hence, no comparison was made between the observed and simulated for these years. However, a result are shown in figure 3.13, the comparison is at the border of Ethiopia and Sudan to show the result produced from the model.

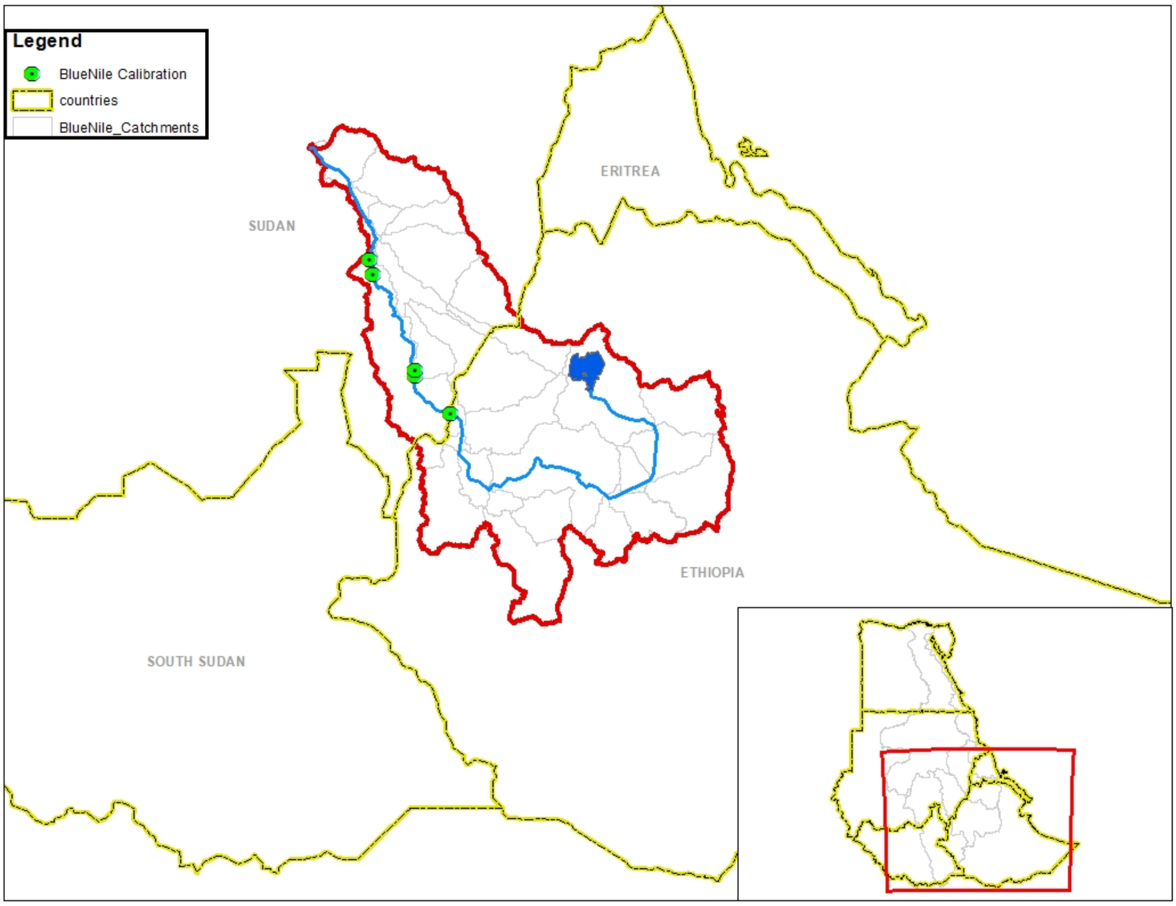


Figure 3.12 – Calibration and validation points used for the Blue Nile River MIKE 11 model

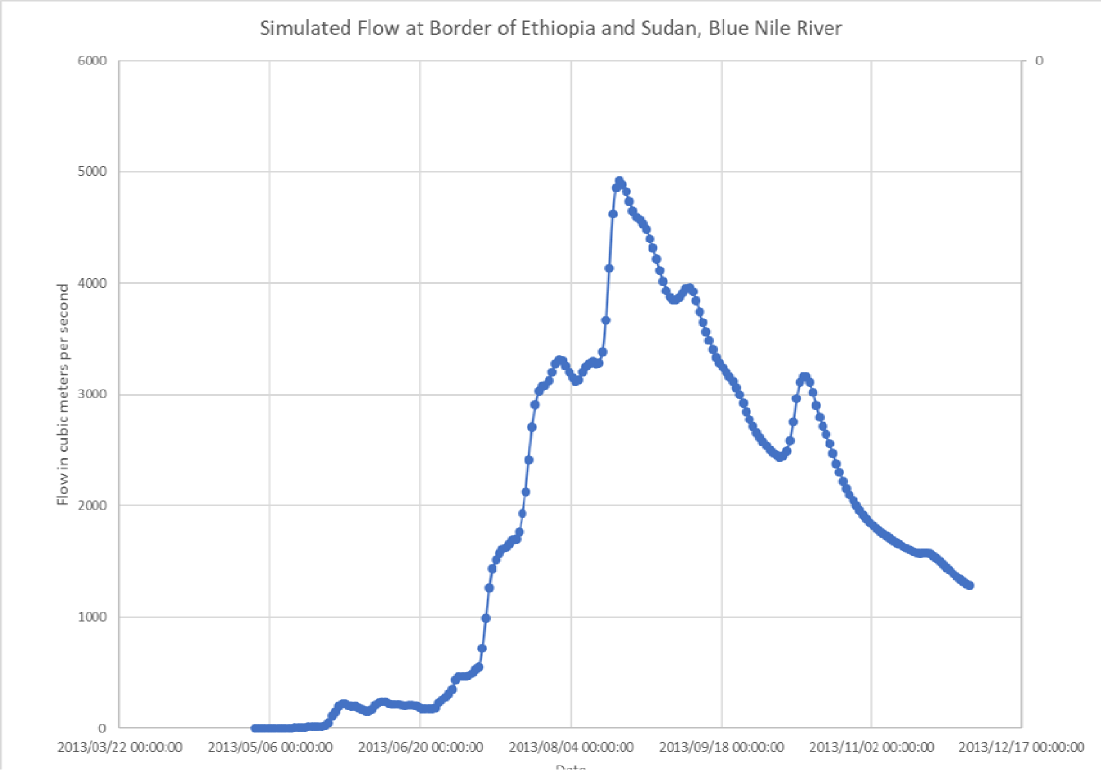


Figure 3.13: Simulated flow at the border of Ethiopia and Sudan border of Blue Nile River

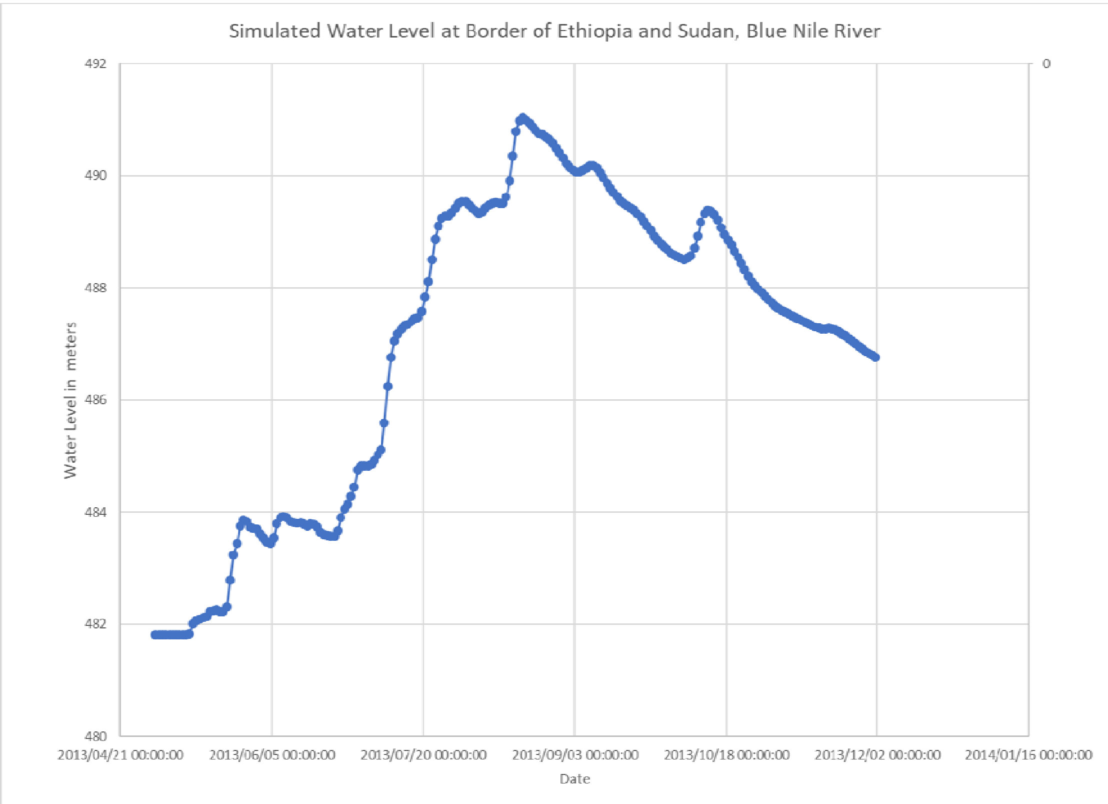
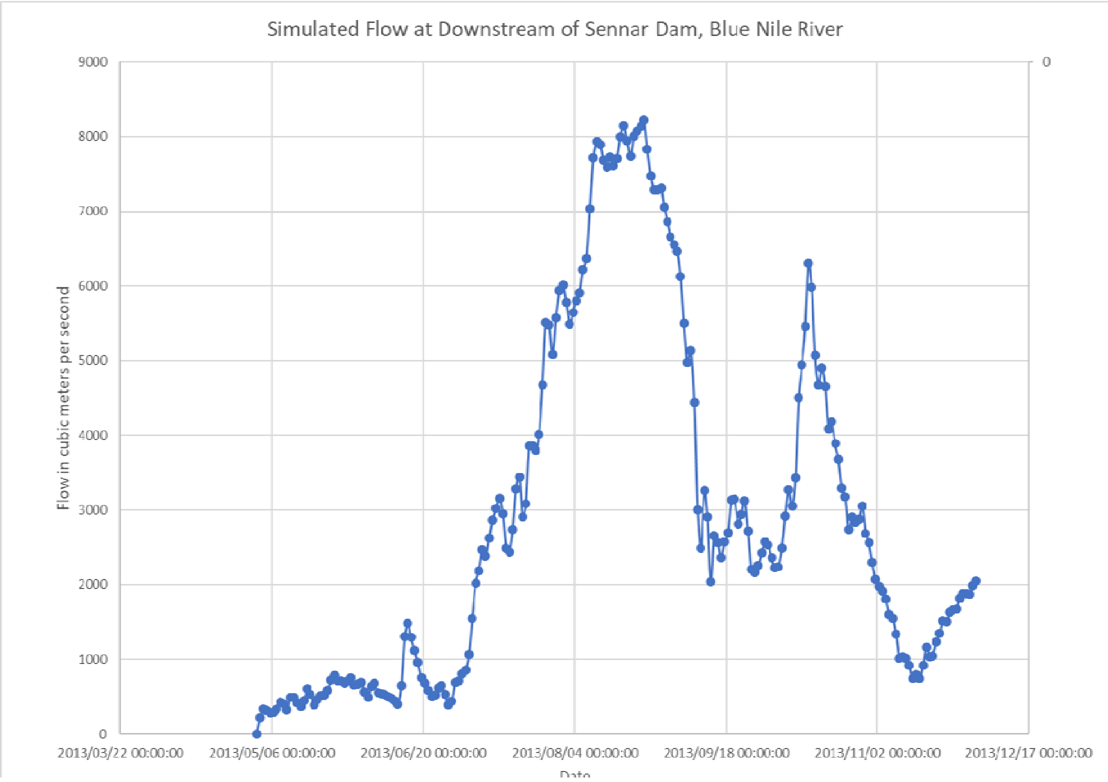
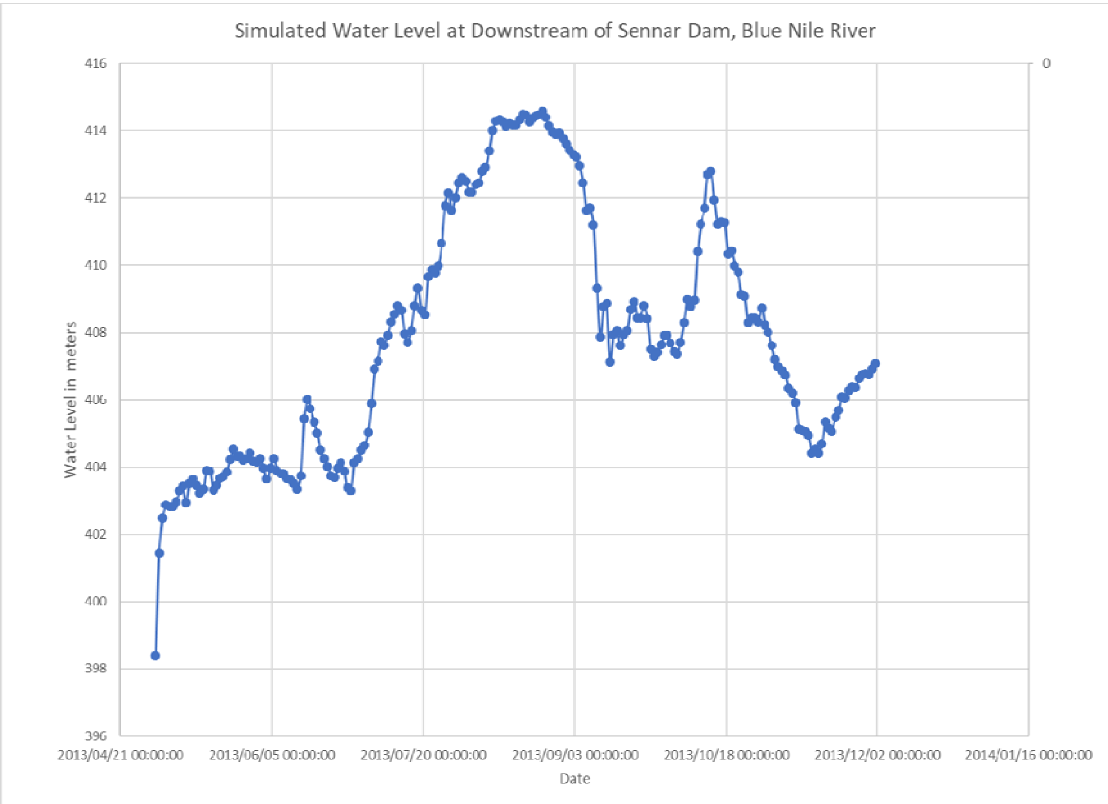


Figure 3.13: Simulated Water Level at the border of Ethiopia and Sudan border of Blue Nile River



Simulated Flow at Downstream of Sennar Dam, Blue Nile River
Flow in cubic meters per second
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
2013/03/22 00:00:00
2013/05/06 00:00:00
2013/06/20 00:00:00
2013/08/04 00:00:00
2013/09/18 00:00:00
2013/11/02 00:00:00
2013/12/17 00:00:00



Simulated Water Level at Downstream of Sennar Dam, Blue Nile River
Water Level in meters
416
414
412
410
408
406
404
402
400
398
396
0
2013/04/21 00:00:00
2013/06/05 00:00:00
2013/07/20 00:00:00
2013/09/03 00:00:00
2013/10/18 00:00:00
2013/12/02 00:00:00
2014/01/16 00:00:00
Date

3.3 **Atabara-Tekeze Setit Basin**

The calibration and validation model of the Atabara-Tekeze Setit Basin model was expected to be conducted on the following stations, namely upstream/downstream of Atabara dam, upstream/downstream of Girba dam, and Tekeze at Humera. However, no flow data was received for the 2013, 2014 or 2018. Hence, no comparison was made between the observed and simulated for these years. However, a result are shown in figure below at the border of Ethiopia and Sudan to show the result produced from the model.

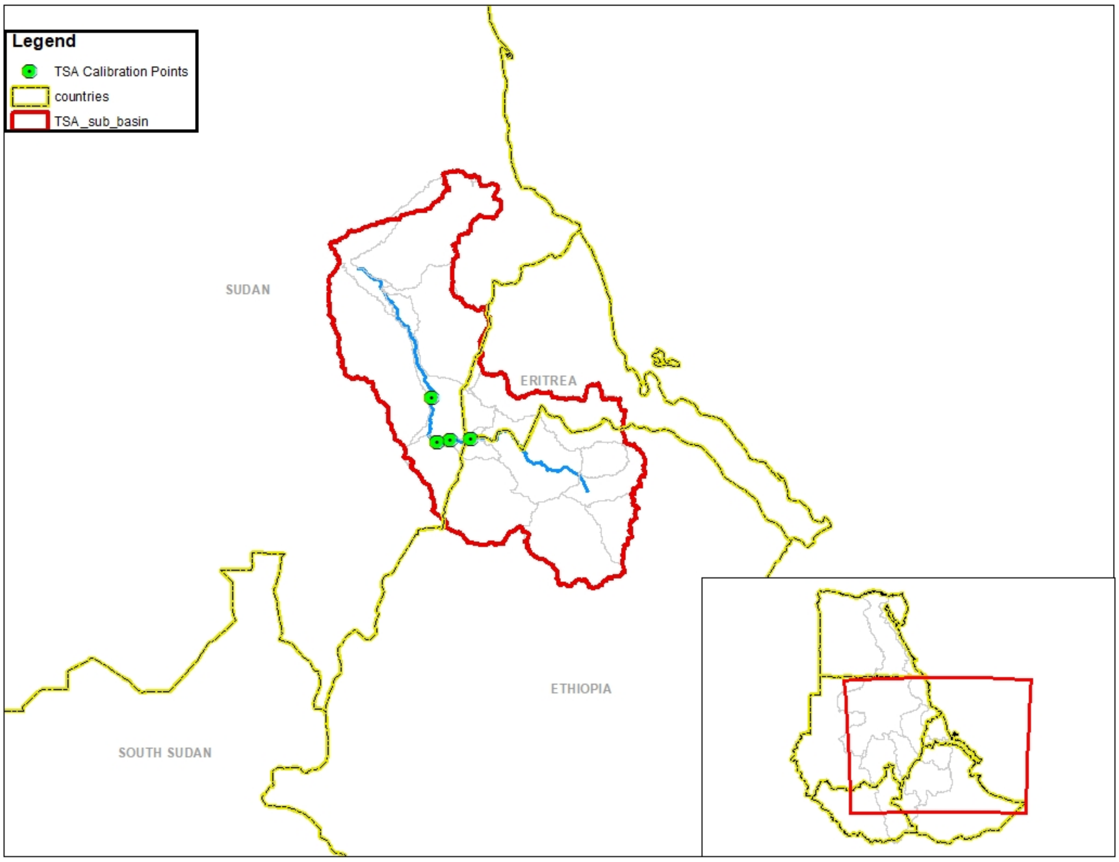


Figure 3.14 – Calibration and validation points used for the Atabara-Tekeze Setit basin MIKE 11 model

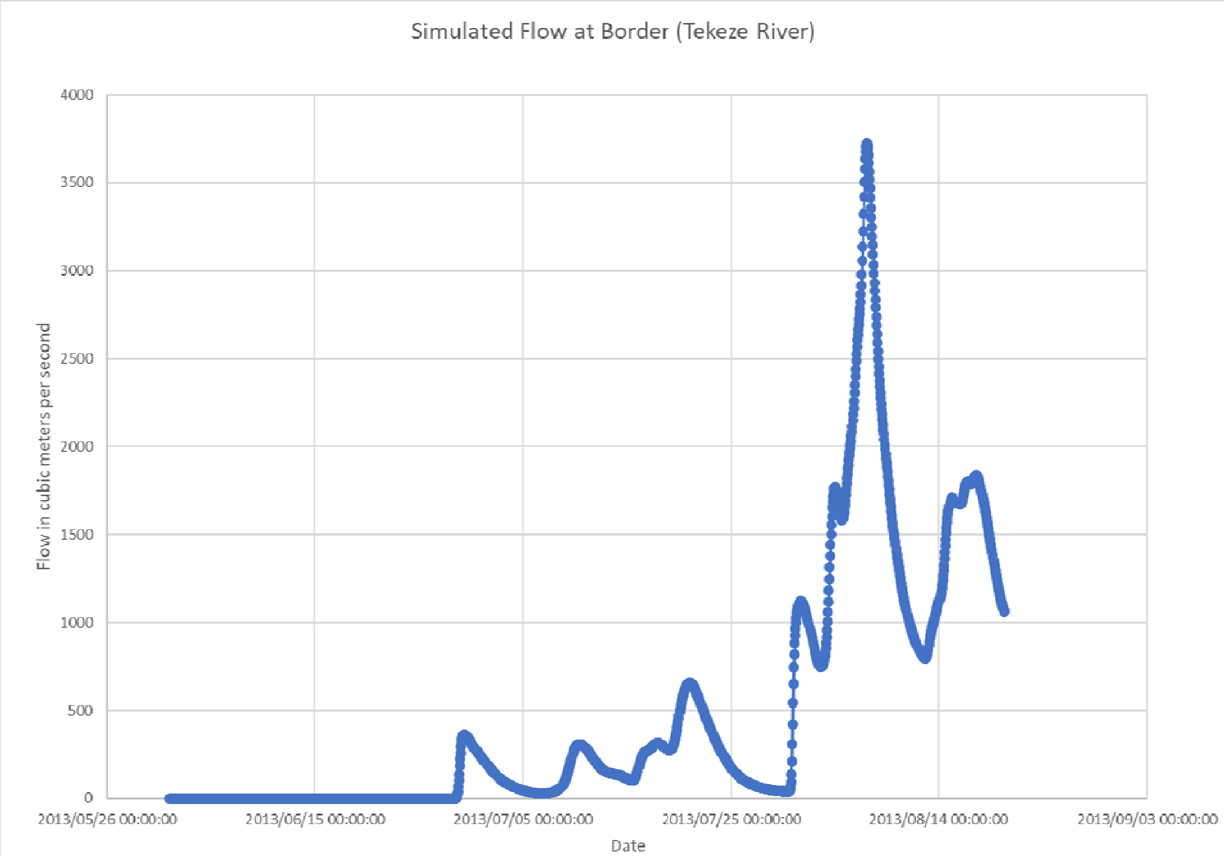


Figure 3.15: Simulated flow at the border of Ethiopia and Sudan border of Tekeze Setit River

3.4 Baro-Akobo Sobat Basin

The calibration and validation model of the Baro-AkobosobatBasin model was expected to be conducted at upstream of Jebel Aulia Dam and at Gambela station. However, there is no flow data was received for the 2013, 2014 or 2018 for the Jebl Aulia upstream and downstream stations. Hence, the comparison was made at the Gambela station of Sobat river between the observed and simulated for 2013 year. the results of the comparison are shown in Figure 3.17 to 3.19. The simulated flow at Gambela station of Sobat river represents the observed flow reasonable well with R^2 0.68 and efficiency index 0.89. As in the Lake Tana case, the simulated flow does under estimate the observed flow at Gambela station.

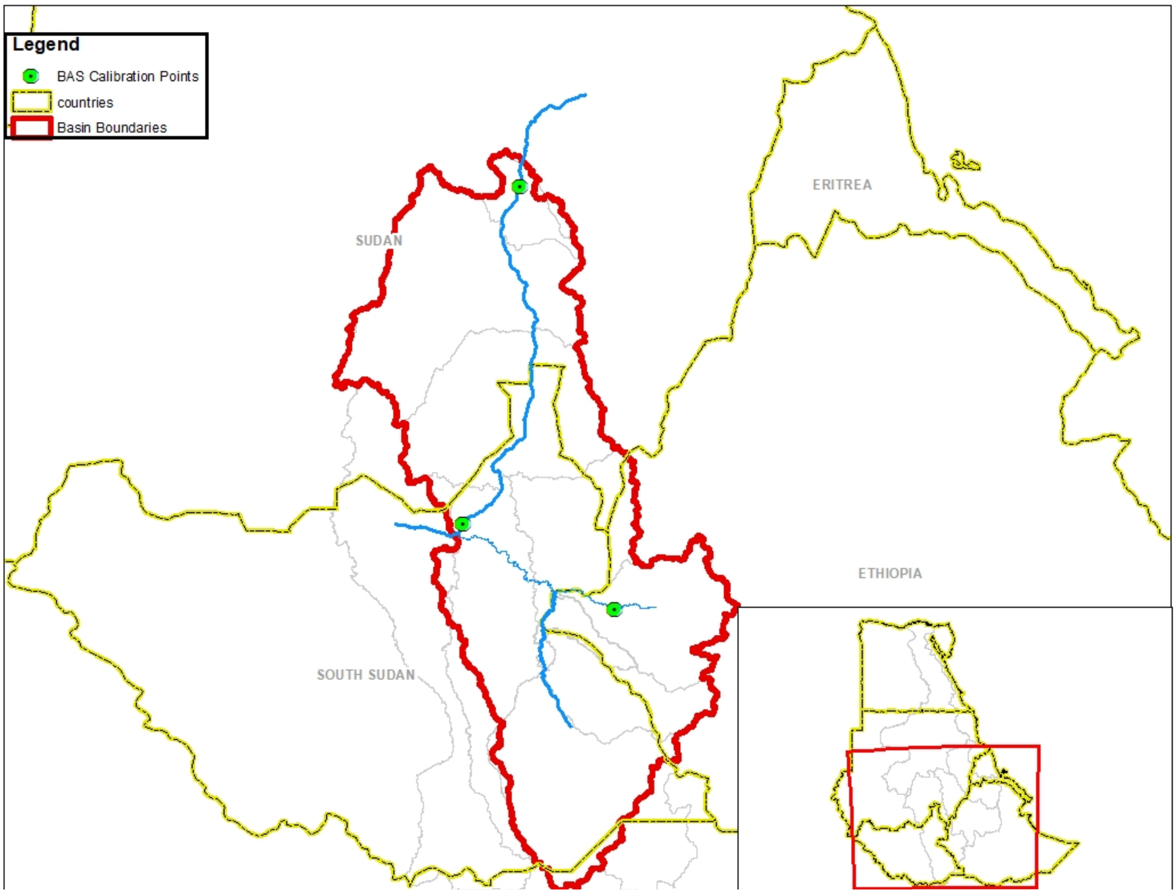


Figure 3.16– Calibration and validation points used for the Baro-AkobosobatBasin MIKE 11 model

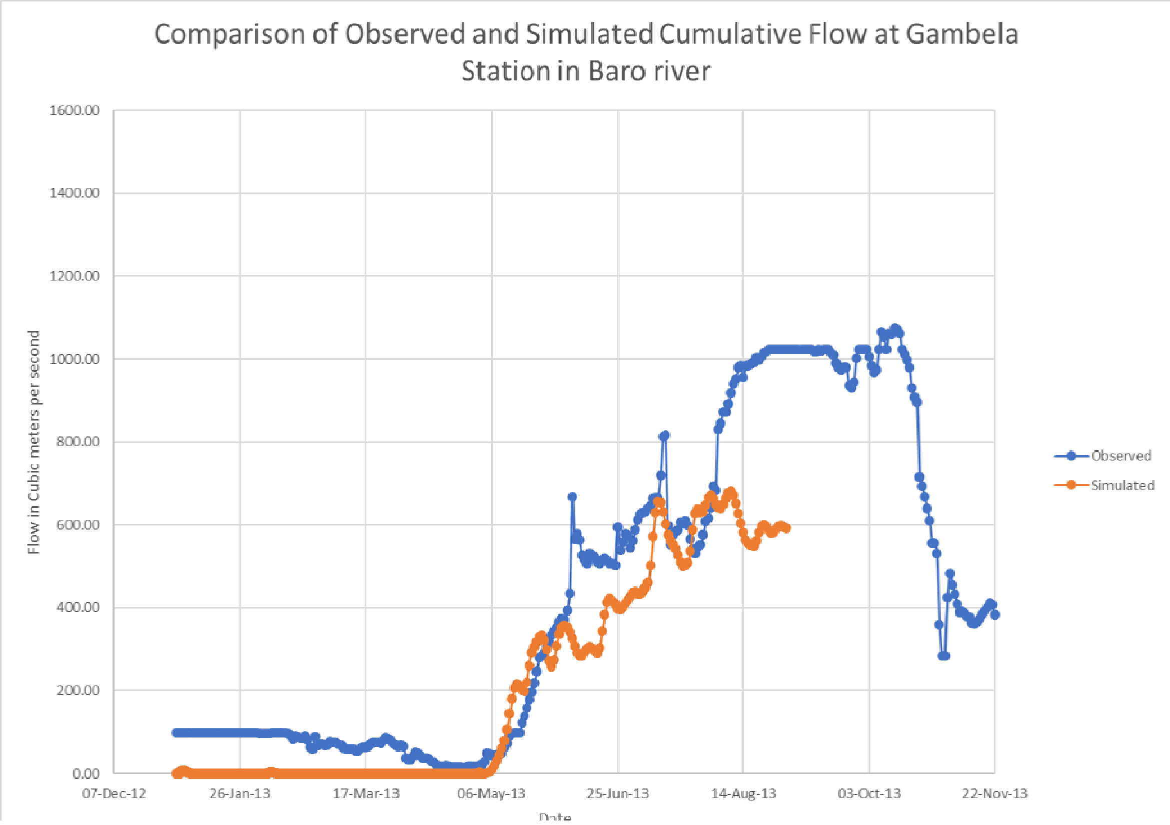


Figure 3.17: Comparison of Observed vs Simulated flow for Sobat River at Gambela station

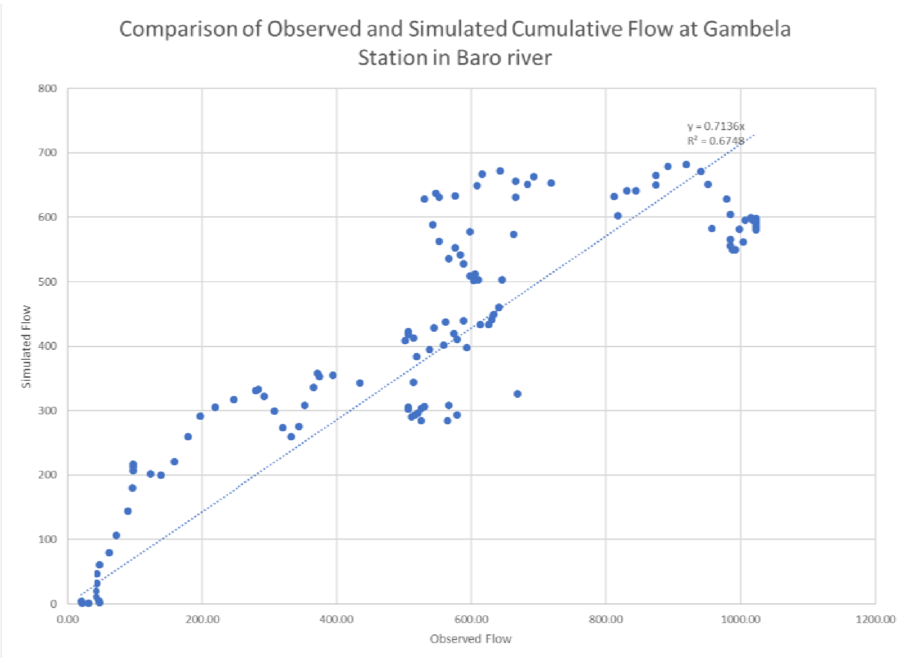


Figure 3.18: Comparison of Observed vs Simulated flow at Gambela station of Sobat River showing the coefficient of determination

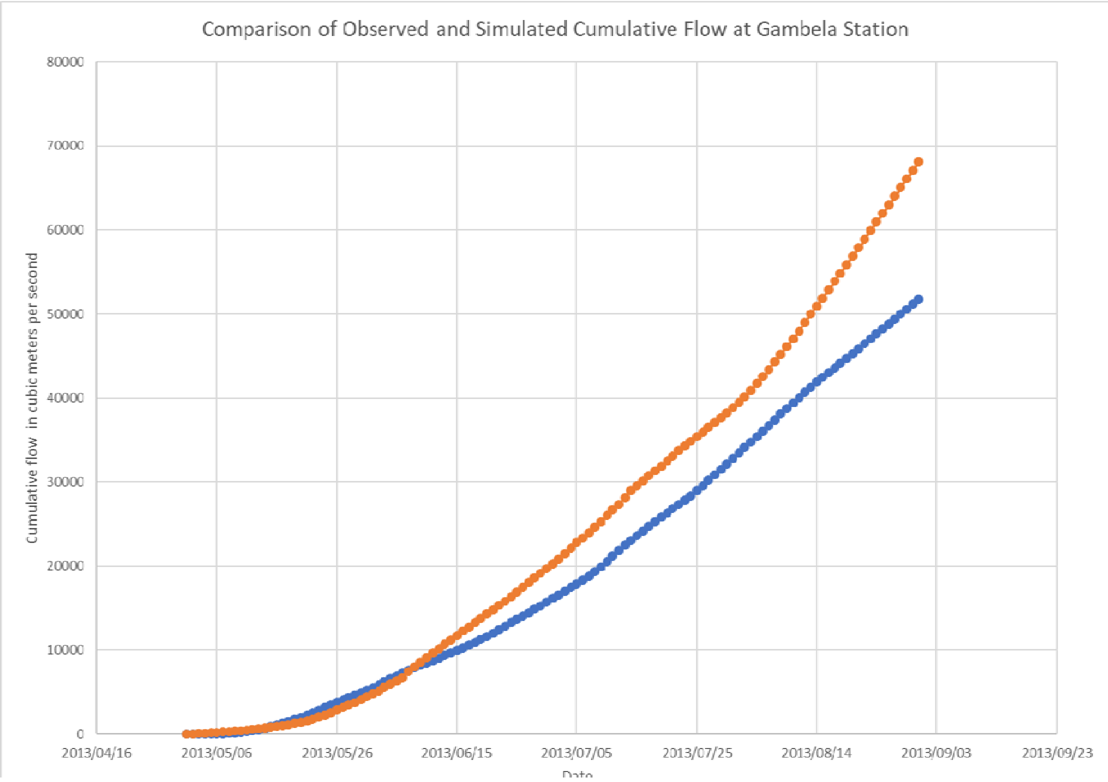
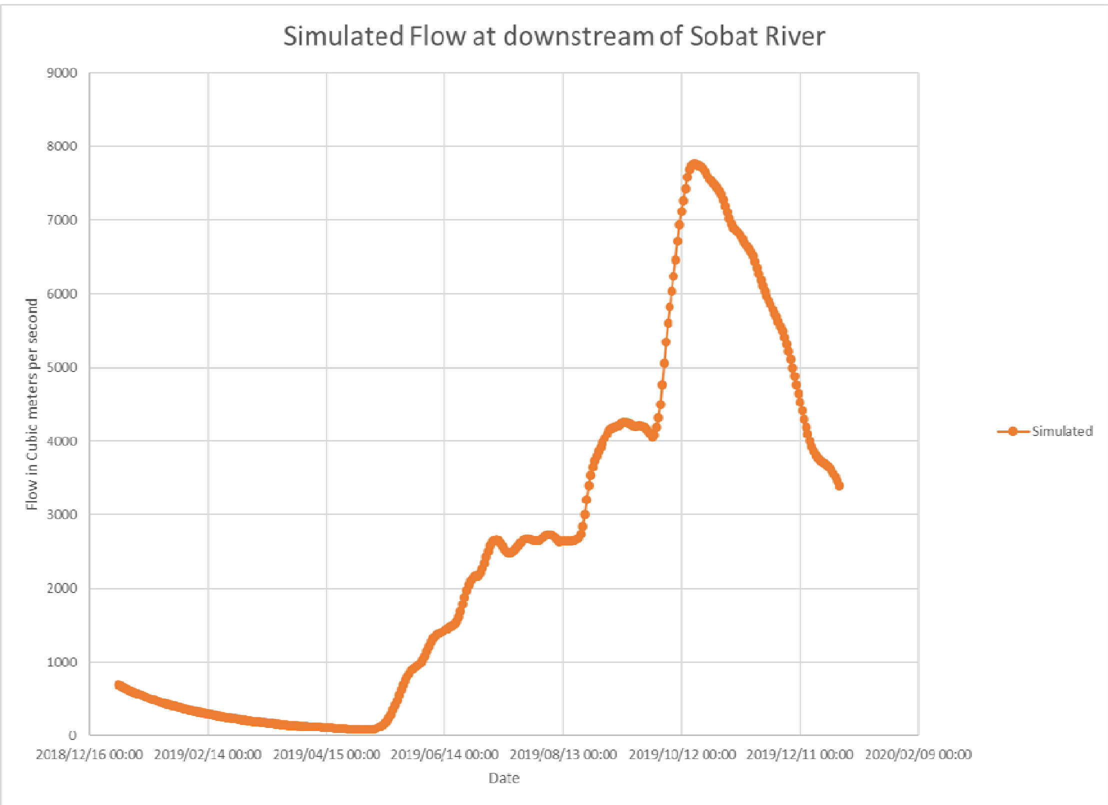
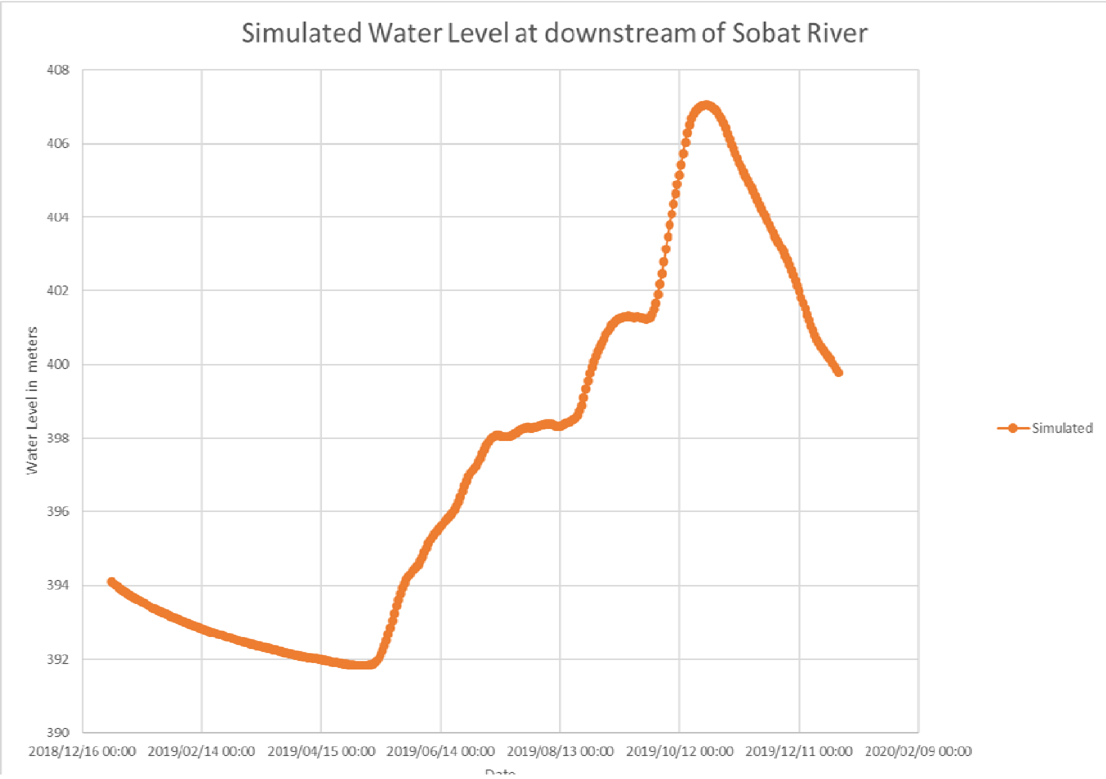


Figure 3.19: Comparison of Cumulative Observed vs Simulated flow for Ribb River at Gambela station




Simulated Water Level at downstream of Sobat River
Water Level in meters
408
406
404
402
400
398
396
394
392
390
2018/12/16 00:00
2019/02/14 00:00
2019/04/15 00:00
2019/06/14 00:00
2019/08/13 00:00
2019/10/12 00:00
2019/12/11 00:00
2020/02/09 00:00
Simulated

4. EASTERN NILE EARLY WARNING FLOOD FORECASTING SYSTEM

The Eastern Nile trans-boundary basin EWFFS is setup in MIKE Operation platform. The MIKE Operation platform is a platform that is designed to integrate operation and planning tools or models with near-real time, forecasted and historical observed data and the platform produce reports from model results and raw and processed data that will assist managers and technical personnel to make the required decisions or planning. The platform is for establishing customised outputs – generally referred to as decision support systems or information management systems - based on standardised functionality.

The architecture of the EWFFS is shown in Figure 4.1, where near-real-time and forecasted data are regularly imported from different sources to the central database via scheduled data import jobs. The scheduled interval for these jobs are depends on how frequently the data is made available at the source. The Rainfall-runoff and hydrodynamic model, in this case Eastern Nile four basins NAM Rainfall-runoff and MIKE 11, setup was registered and imported to the central database and is being set up to run from the platform, where the input time series are regularly updated using the real-time and forecasted data. The four basins of the Eastern Nile NAM Rainfall-runoff and MIKE 11 hydrodynamic model was configured to run every 6 hours. Once the model run/simulation is completed, results are summarised to be analysed on MIKE Operation User Interface and the Eastern Nile web portal. If simulated or observed streamflow values exceed the pre-defined threshold values, warning triggers are sent to the appropriate bodies by SMS or Email.

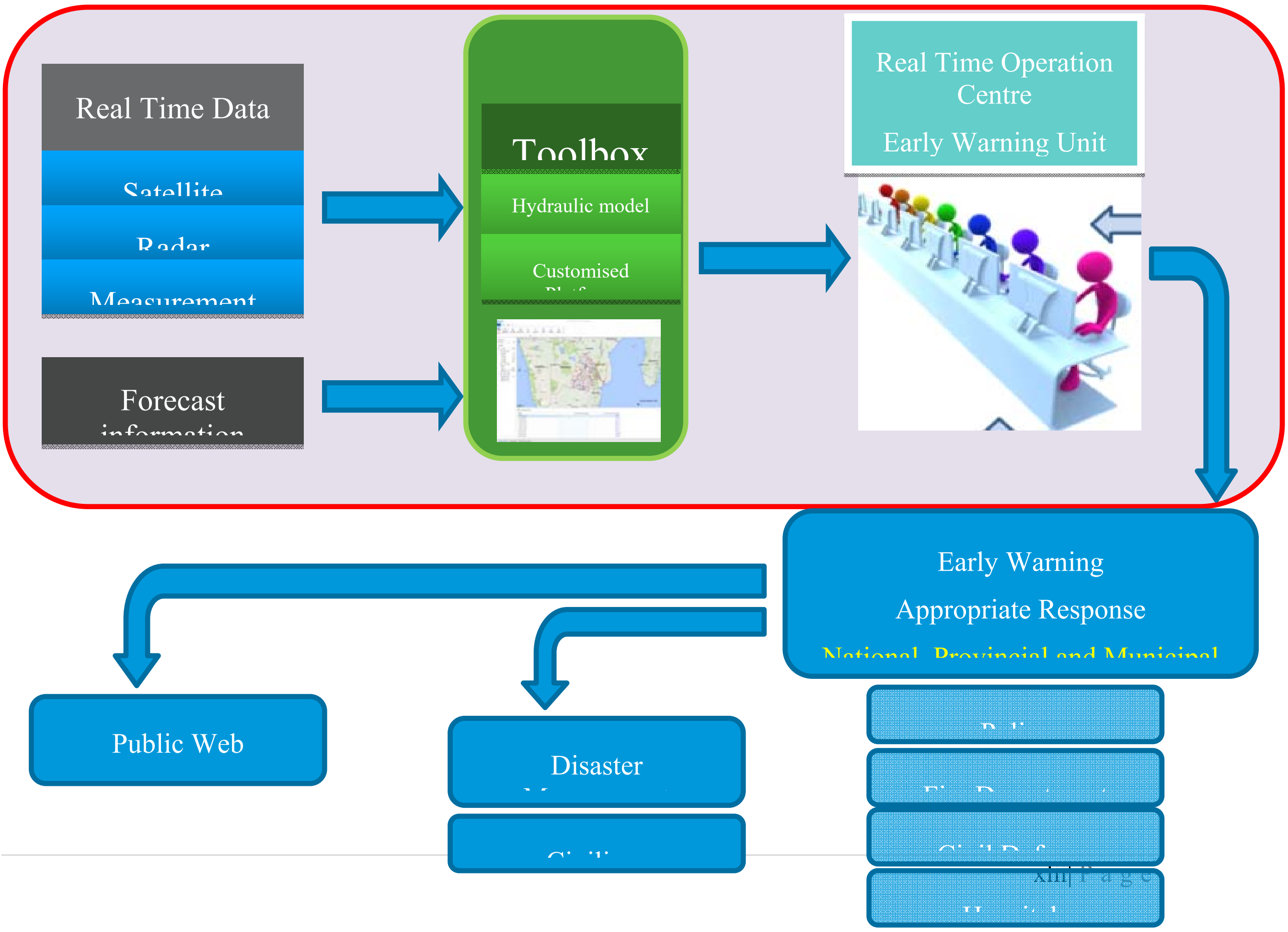


Figure 4.1: Architecture of the Eastern Nile Early Warning Flood Forecasting System

4.1 Data Acquisition Process

Near real time, historical and forecasted data are acquired through the "Script and Job Manager" of the MIKE Operation backend and stored into a central database. The main monitoring data that are stored in the central database are as follows:

- Real time Rainfall Data (NOAA RFE, GEFS and WRF)

4.2 Modelling Integration

The NAM Rainfall-runoff and MIKE 1-D hydraulic models that were setup were registered and imported to the MIKE Operation platform through a "Scenario Manger", as shown in Figure 4.2. Scenarios are defined in the platform where all the input time series that expected to be updated by the near real-time and forecasted information are linked to appropriate timeserie/s in the model. In some cases, where the input timeseries are required to be built from more than one source(for example, combining observed and forecast rainfall into one timeseries), a hierarchy tool in the "Scenario manager" is used to build the input timeseries.

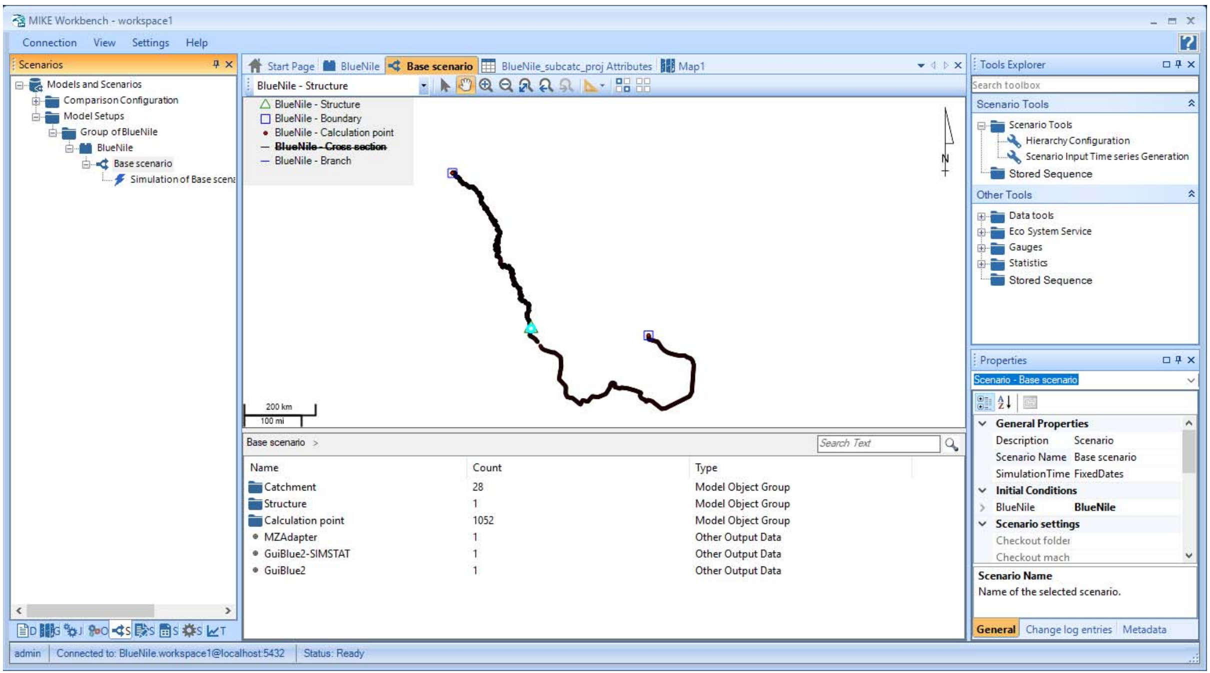


Figure 4.2: Blue Nile River Model Integration in MIKE Operation platform

4.3 Setup of Eastern Nile EWFFS and Forecast Dissemination

Once the prediction models had been imported and integrated with the near real time and forecasted data. The remaining components that complete the setup of the Eastern Nile EWFFS were configured. These items were::

- Thresholds
- Forecast Dissemination
- Desktop User interface
- Web Portal
- SMS and Emails

4.3.1 Thresholds

Thresholds were setup for all the gauges, and catchment rainfall that are required in early flood warning to communicate with stakeholders. An extreme value analysis was conducted for selected gauges and rainfall stations to set thresholds. In line with the threshold configuration, an alarm/alert requirement was set. An alert is only triggered for gauges with thresholds defined. Once an alarm is flagged, an SMS and/or Email notification could be send for that specific threshold transgression. A view of the GUI where the thresholds are defined for rainfall stations is shown in Figure 4.4.

The Extreme value analysis was performed to determine the extreme value for each return period, a Lognormal probability distribution was selected as an appropriate distribution for the area based on a literature review. In the case of the Rainfall, we have used the NOAA RFE data (2000-2020) to determine the extreme values for each return period (Fig 4.3 and Fig 4.4). With Regard to the thresholds for the flows at different points of the river, observed data was used even though the data have short records. Where there is no Observed data is available and considered the point in the river is important, simulated flow is used to generate the thresholds.

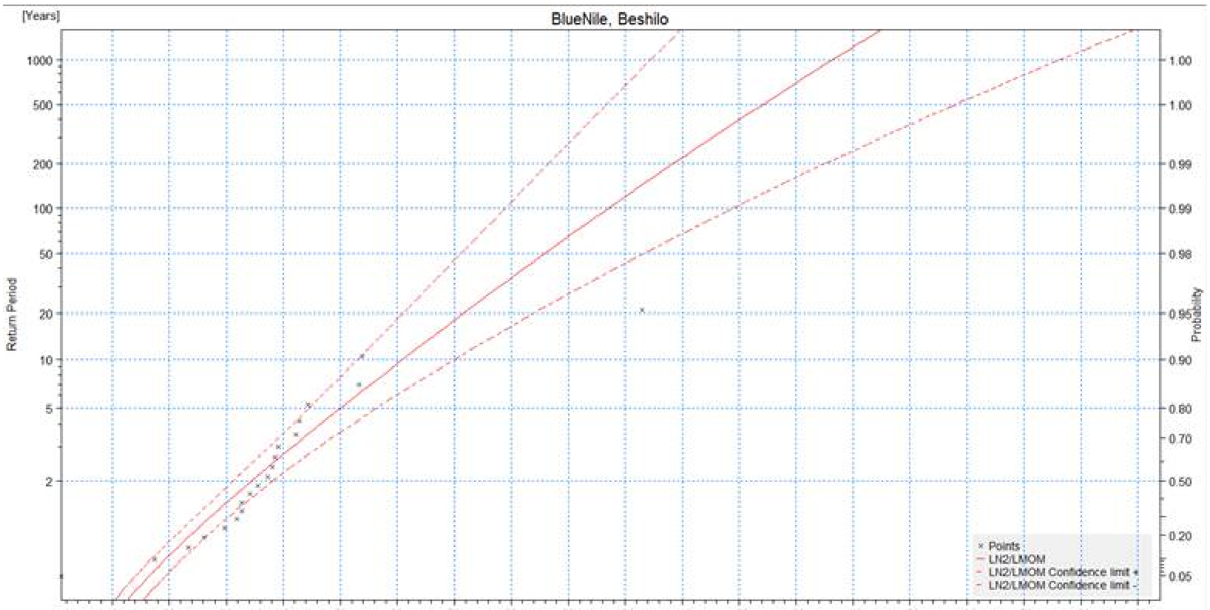
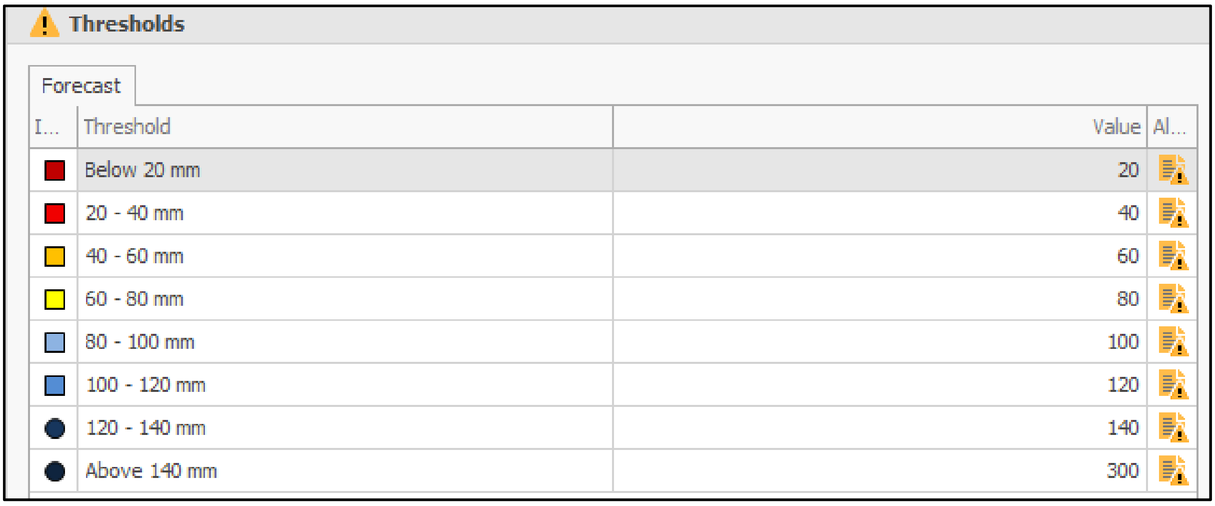


Figure 4.3 : Example of Rainfall Thresholds



Thresholds

Forecast

I...	Threshold	Value	Al...
	Below 20 mm	20	
	20 - 40 mm	40	
	40 - 60 mm	60	
	60 - 80 mm	80	
	80 - 100 mm	100	
	100 - 120 mm	120	
	120 - 140 mm	140	
	Above 140 mm	300	

Figure 4.4 : Example of Thresholds set in the EWFFS

4.3.2 **Forecast Dissemination**

4.3.2.1 Easter Nile EWFFS Desktop User interface

A simplified user interface which enables everyday users to configure specific elements within the model and to maintain the system has been developed. This is the "MIKE Operation Real-Time User Interface". It is quick and easy to teach potential users to operate the system effectively and thus ensures that system operators can effectively run and maintain the system. . It is designed to display real-time data, model time series input and model simulation results linked to spatial features (Figure 4.5).

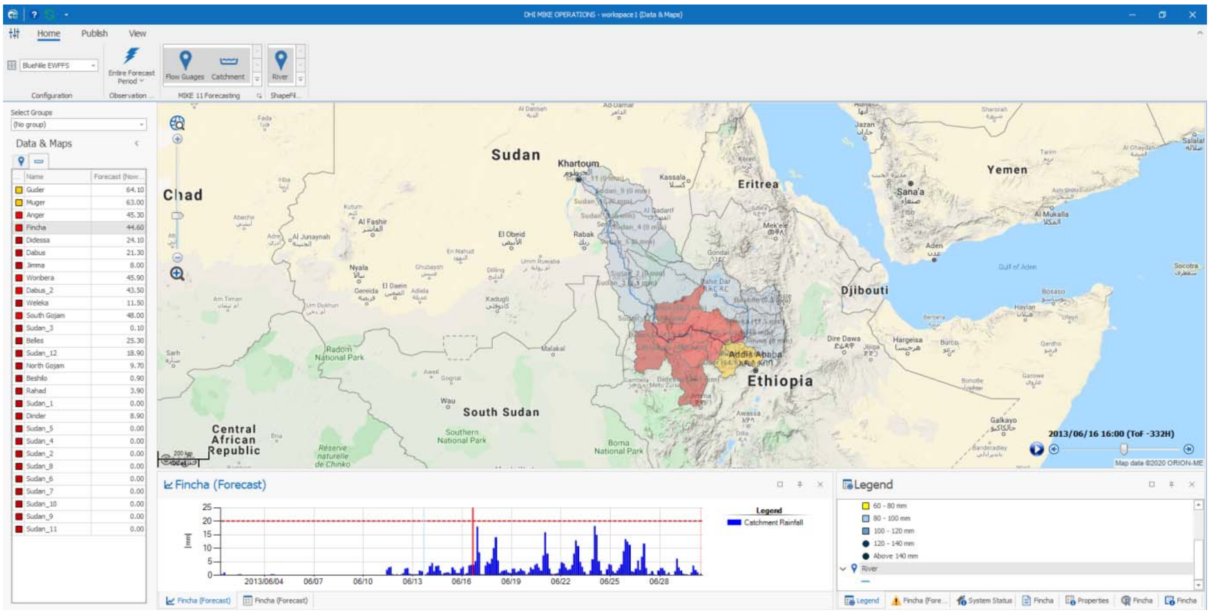


Figure 4.5:Blue Nile River basin EWFFS Desktop User interface

4.3.2.2 Easter Nile EWFFS Web Portal

The Easter Nile web portal (Figure 4.6) is a replica of the Easter Nile EWFFS desktop user interface. The web portal displays all information that is included in the desktop user interface. The web portal will be made available through internet to a wider stakeholder audience.

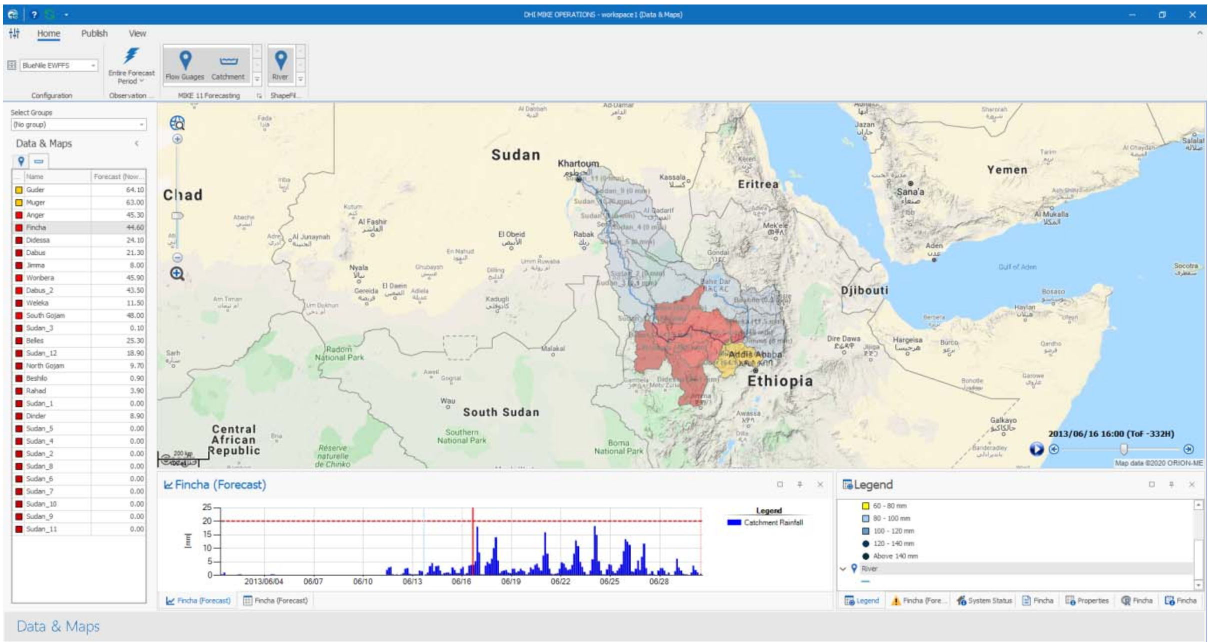


Figure 4.6: Blue Nile River basin EWFFS web portal

4.3.2.3 Setup of Forecasting Performance Measurement

The simplest flood forecasting accuracy measure is constructed by transforming a forecast into a categorical (e.g. flood/no flood) forecast through the selection of a threshold. Once the forecasts have been categorized, probability of detection and false alarm rate can again be computed. MIKE Operation platform have a statistical tools that allow the setup of forecasting performance measurement. One of these tools is “Skill Scores/Categorical forecast” tool.

The skill of a forecast expresses the relative accuracy of a set of forecasts compared to a reference forecast. Often the value of a given measure in itself is hard to assess but by referencing to another forecast the relative improvement is found which is easier to evaluate. The formula that is commonly used to assess the skill scores is as follows:

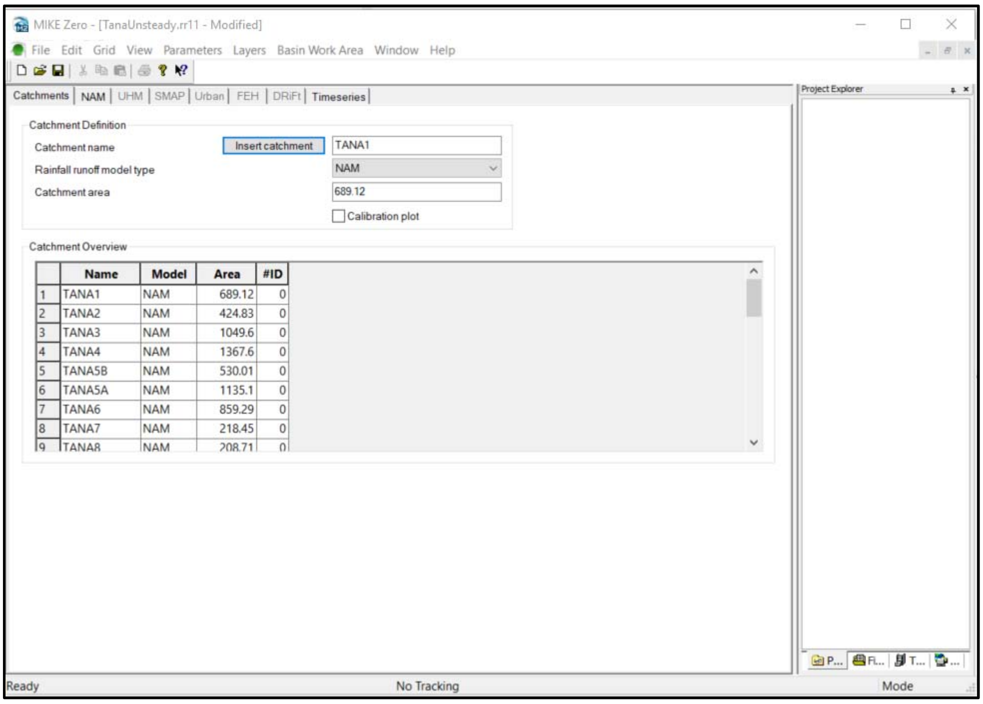
$$ss_{ref} = \frac{A - A_{ref}}{A_{\,perf} - A_{ref}} * 100$$

Where A is the accuracy of the forecast, Aref the reference and Aperf the value a forecast would take if it was perfect. The skill score therefore measure the improvement over a reference forecast compared to that of a perfect forecast set. Any quality measure can be used as accuracy, both goodness of fit measures and quality attributes for the joint distributions.

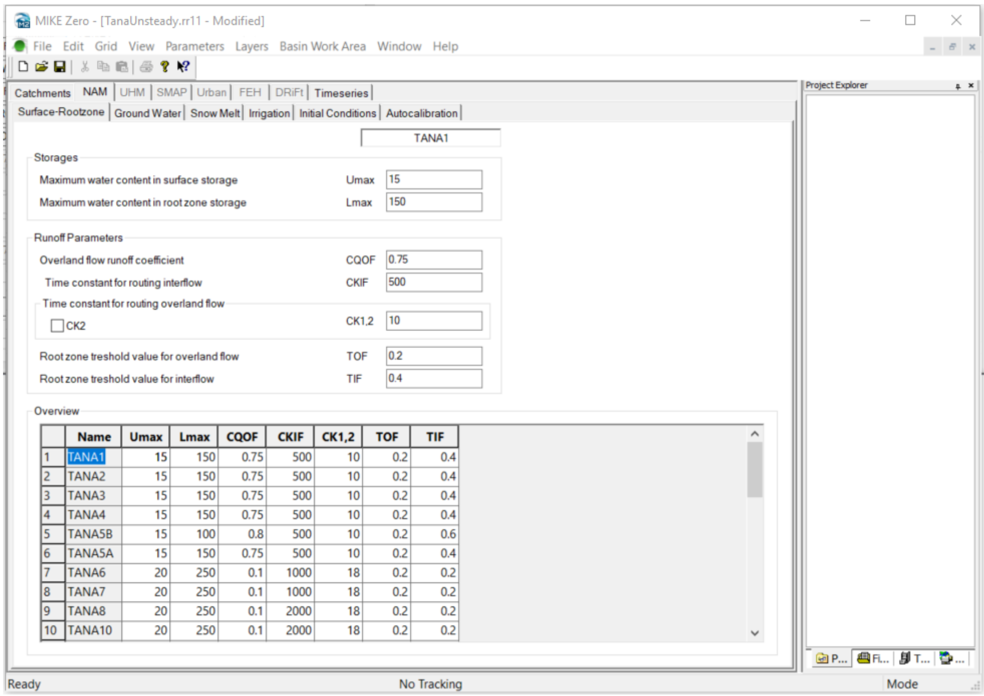
The Skill scores as a forecasting performance measurement is setup for the Eastern Nile EWFFS at a number of flood forecasting points/stations in a spreadsheet to measure the accuracy of flow/flood predication within the different threshold category.

APPENDIX
Rainfall- Runoff Model Setup

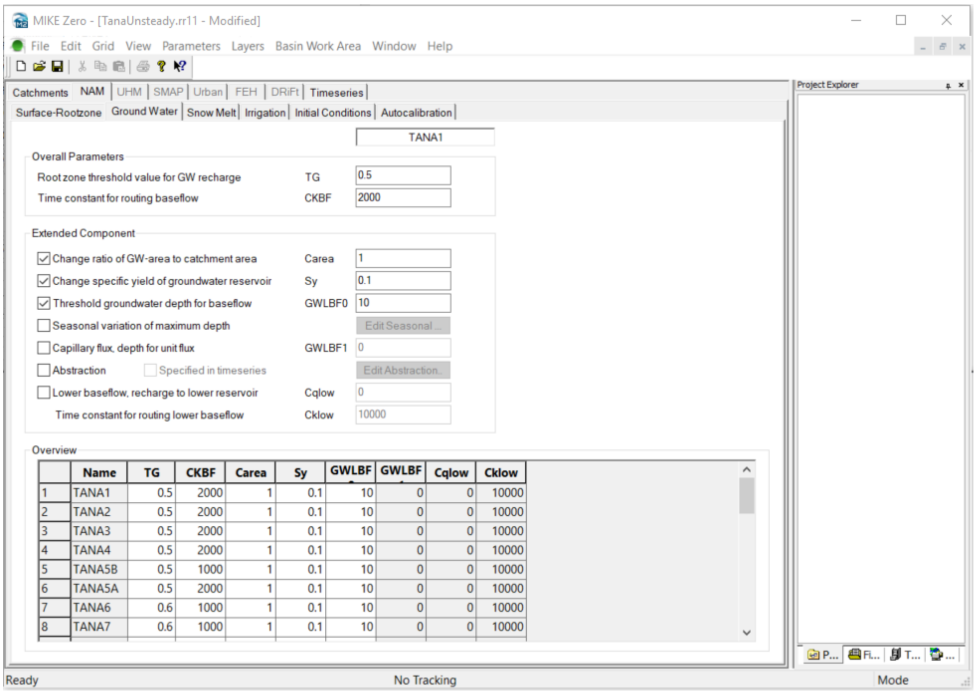
Lake Tana Catchment definition



Lake Tana Surface-Rootzone Parameters

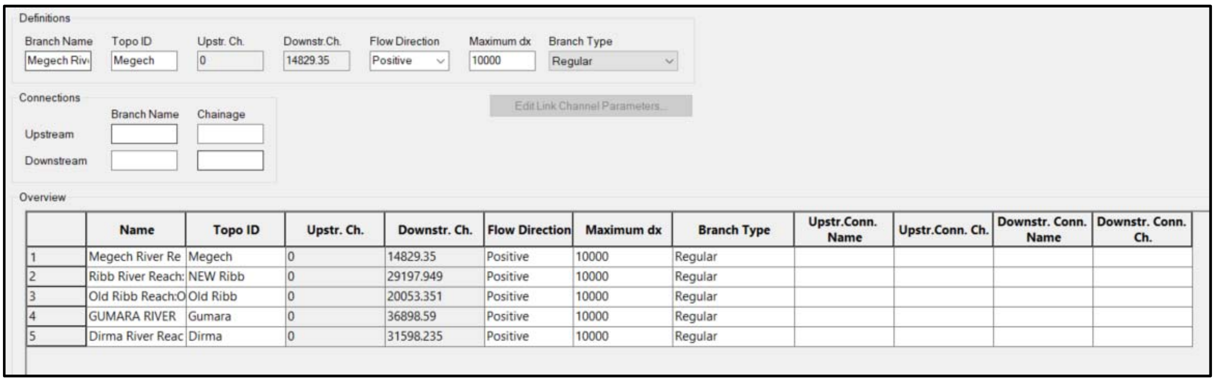


Lake Tana Ground Water Parameters



Lake Tana MIKE 11 Setup

Network File



Definitions

Branch Name	Topo ID	Upstr. Ch.	Downstr. Ch.	Flow Direction	Maximum dx	Branch Type
Megech Riv	Megech	0	14829.35	Positive	10000	Regular

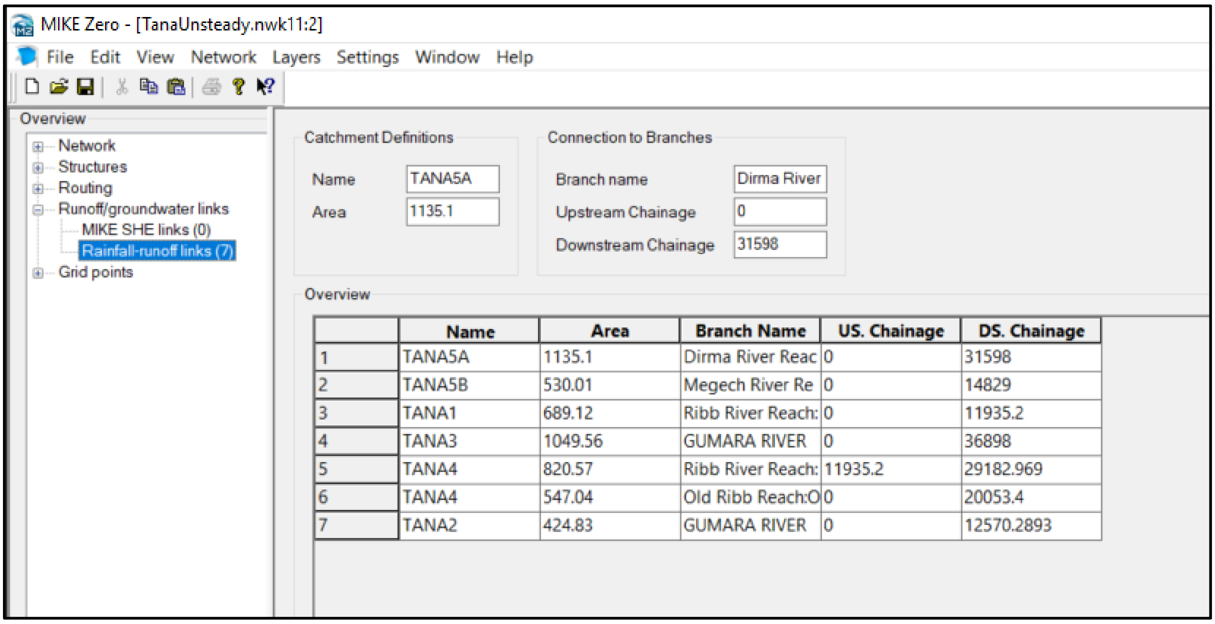
Connections

	Branch Name	Chainage
Upstream		
Downstream		

Edit Link Channel Parameters...

Overview

	Name	Topo ID	Upstr. Ch.	Downstr. Ch.	Flow Direction	Maximum dx	Branch Type	Upstr.Conn. Name	Upstr.Conn. Ch.	Downstr. Conn. Name	Downstr. Conn. Ch.
1	Megech River Re	Megech	0	14829.35	Positive	10000	Regular				
2	Ribb River Reach:	NEW Ribb	0	29197.949	Positive	10000	Regular				
3	Old Ribb Reach:O	Old Ribb	0	20053.351	Positive	10000	Regular				
4	GUMARA RIVER	Gumara	0	36898.59	Positive	10000	Regular				
5	Dirma River Reac	Dirma	0	31598.235	Positive	10000	Regular				



MIKE Zero - [TanaUnsteady.nwk11:2]

File Edit View Network Layers Settings Window Help

Overview

Network

Structures

Routing

Runoff/groundwater links

MIKE SHE links (0)

Rainfall-runoff links (7)

Grid points

Catchment Definitions

Name TANA5A

Area 1135.1

Connection to Branches

Branch name Dirma River

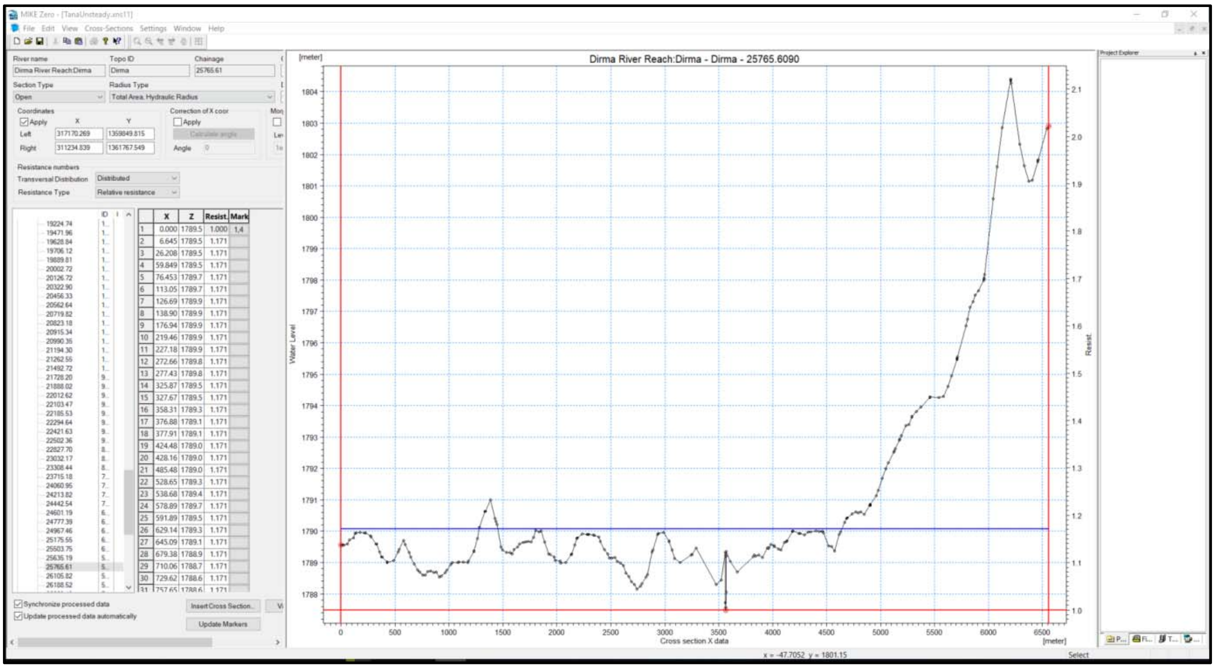
Upstream Chainage 0

Downstream Chainage 31598

Overview

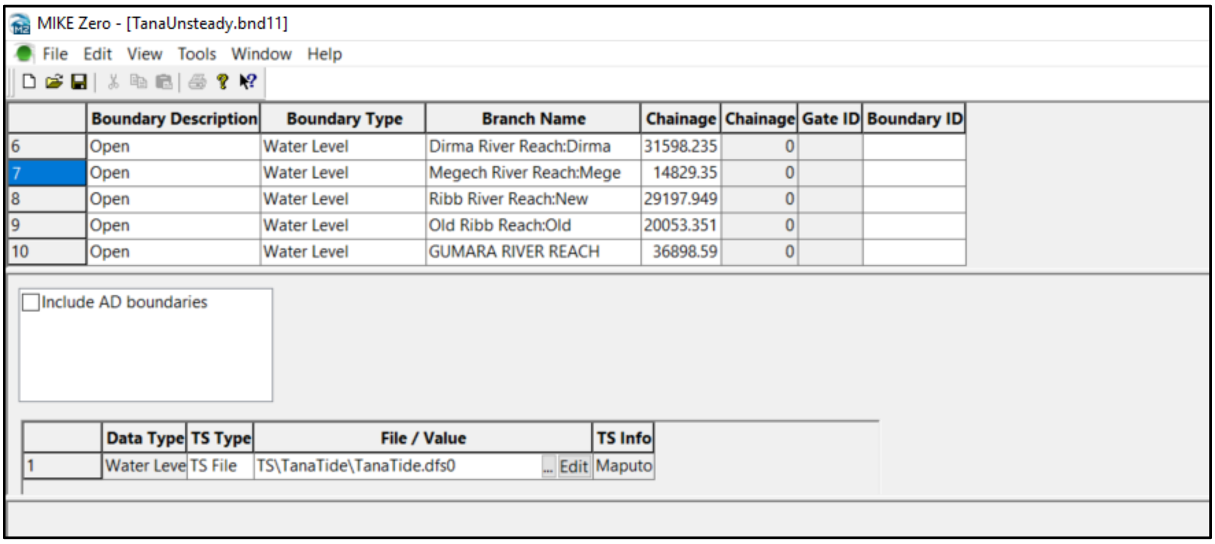
	Name	Area	Branch Name	US. Chainage	DS. Chainage
1	TANA5A	1135.1	Dirma River Reac	0	31598
2	TANA5B	530.01	Megech River Re	0	14829
3	TANA1	689.12	Ribb River Reach:	0	11935.2
4	TANA3	1049.56	GUMARA RIVER	0	36898
5	TANA4	820.57	Ribb River Reach:	11935.2	29182.969
6	TANA4	547.04	Old Ribb Reach:O	0	20053.4
7	TANA2	424.83	GUMARA RIVER	0	12570.2893

Cross-section file



Dirma River Reach:Dirma - Dirma - 25765.6090
Water Level
Resist
Cross section X data

Boundary File



Hydrodynamic File

Input Data Set

A number of data set are used for the setup of Rainfall-Runoff and MIKE 11 Hydraulic models. The list of the input data set are as follows:

- Observed Spatial Rainfall dataset
  - o Catchment NOAA RFE rainfall dataset for all catchments in the four basins of the Eastern Nile was sourced from NOAA FTP servers
- Forecast WRF Spatial Rainfall Data set

- WRF model was setup in the ENTRO servers for the Eastern Nile Basin to estimate three day rainfall

- Observed Spatial Evaporation dataset
- Observed Flow Gauges
- Observed Reservoir Releases
- Catchment physical conceptual parameters
    - Conceptual two layered catchment soil
    - One groundwater catchment layer

- River vegetation cover
- Reservoir Volumes
- Reservoir Spillway Characteristics

List of Data

Table of Thresholds

ANNEX D
EASTERN NILE FLASH FLOODS ASSESSMENT STUDY

FLOOD FORECASTING AND EARLY WARNING ENHANCEMENT PROJECT

Submitted by

Eng. Elhadi Eisa Adam

ENTRO
NILE BASIN INITIATIVE
INITIATIVE DU BASSIN DU NIL

P.O. Box 27173/1000
Addis Ababa
Ethiopia

ENTRO is an organ established to implement the Eastern Nile Subsidiary Action Program within the framework of Nile Basin Initiative

Egypt, Ethiopia, South Sudan, Sudan

EXECUTIVE SUMMARY

This is the final report of the Flash Floods Consultancy for the EN basin. The report discusses the flash floods situation in the EN countries, flood types, flash floods prone sites, existing flood EWS, mitigation measures and ends up with guide lines for developing effective flash floods EWS to reduce the loss in human livesand properties in the region.

Two types of flash floods were observed in the EN basin; riverine flash floods and storm flash floods. Most of the flash floods in EN are as a result of torrential rainfall for short period of time. Flash floods prone sites were delineated; most of the flash floods prone areas are urban areas across wadi systems and along the River Nile floodplains.

The dominant trend of floods management practices in EN is only concentrated on the course of major rivers, high rainfall in tributary river and seasonal wadi has been an area that not always received adequate focus. This effect needs to be kept in view while preparing flood management plans at state/ provincial/regional level.Structural and non-structural flood mitigation measures are practiced in the region. The main structural measures are flood protection works such as embankment, levees, earth dams and river training works. The non-structural measures like floodplain mapping, preparedness, and flood EWS.

In the backdrop of increasingly alarming flash floods risk in the EN member states, it is necessary to design new development and coping strategies; modify the existing ones and make flash floods risk management an integral part of development plans. The existing structural flood management system in the EN region should be reviewed in the present flood risk perspective. The watershed and flood management practices in the countries need to be reviewed and evolved keeping in view the high rates of urban growth and stress on land use patterns. The land use plans should be based on intensive assessment of flood risk in the region and it would be a better idea to make the land use plans based on multi hazard risk assessment for sustainable use of economic resources for development. The infrastructure and plans in major cities should be reviewed at regular intervals and should be designed to make room for improvements in future. The existing plans should be upgraded to withstand flash floods risk.

This report has raised many critical gaps, community awareness regarding flash floods gaps, hydro-meteorological data gaps, capacity building gaps, institutional arrangement and communication between different stakeholder's gaps. The major gap raised by this report is absent of flash flood forecast and early warning system.

Regarding the hydro-meteorological capacity, ground-based meteorological networks often have incomplete observations that commonly are available at point scale and fixed intervals, the network coverage is sparse, especially in flash flood prone areas. There were gaps in hydrological data, most of the flash floods were from isolated rainstorm, many wadis and khores which carry the generated runoff are ungauged.

Flood Early Warning Systems are well installed and established for most of the river systems in the EN, butis in the sub-basin that there are no unified operational flood forecasting & and early warning system in the whole EN. Currently, ENTRO implementing a project for enhancing the existing FEWS to cover the entire basin. The FEWS systems are mainly depending on the monitoring and forecasting of the rainfall on the upper catchment. WRF model is commonly used for rainfall forecast in EN, new WRF model was developed for the entire EN. The newly developed model will contribute a lot to the flash floods forecasting and EWS.

Hydrological models based on HEC-HMS are used for rainfall-runoff transformation, while hydraulic models (HEC-RAS and USGS- Global Flood Tool) for flood routing and inundation extend. The main source of input rainfall forecast is provided by Local Meteorological Authorities, ENTRO and IGAD Climate Prediction and Applications Centre (ICPAC) in Nairobi. Most of this information is related to riverine forecast not flash flood forecast.

Making the vulnerable communities aware of flash floods risk is a major area of focus. A multi prong approach for spreading awareness: through print and electronic media, distribution of information material, community workshops, street shows should be made an intrinsic part of DRR activities in the EN countries in the context of flash floods risk management. The preparedness, rescue and relief contingency plans should have special emphasis on the vulnerable segment of the communities likely to be affected by floods: the poor, old, women, pregnant, children and the disabled.

Flash floods EWS worldwide and regionally were reviewed. There isa rich experience in the field of flash floods EWS, the Flash Floods Guidance System (FFGS) was found to be the best state-of-the-art technique for global application for flash floods forecast and EWS. Few limited instance of flash floods EWS were observed in the EN, these instance are site-specific and as a result of research projects;One case in Egypt for wad Watier and another case in Sudan for Gash river.

Guide lines for developing effective flash floods EWS for the EN were proposed. Two types of flash floods EWS is suggested; Local and Regional flash floods EWSs. The local flash floods EWS is a site-specific, it is based on the hydrodynamic modeling. Fortunately, all the software and models used by ENTRO to address riverine flood are applicable for the flash floods modeling. For regional flash floods EWS, the global Flash Floods Guidance System (FFGS) is proposed to be implemented in the EN basin. The global FFGS is based on the monitoring and watching of weather condition over the region using remote sense data, it gives necessary warnings for imminent flood risk.

One of the major areas of future focus should be the exchange and transfer of collaborative exercises to improve the existing flash floods risk management and preparedness mechanism in the region. The indigenous knowledge available with the communities in EN has been very effective in historical and ancient times in protecting the villages and towns from flood risk. It is imperative to document the wealth of indigenous knowledge available in the region and integrate them into the developmental and management plans of the flood prone areas.

Mainstreaming Disaster Risk Reduction (DRR) into the developmental plans is recommended for long term flood risk resilience in the risk prone areas at national, regional and local level. Application of DRR in flood management will have great impact on rapid recovery, rehabilitation, reconstruction and economic growth.

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ABBREVIATIONS AND ACRONYMS

BAS	Baro-Akobo-Sobat
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EN	Eastern Nile
ENTRO	Eastern Nile Technical Regional Office
EWS	Early Warning System
FEWS	Flood Early Warning System
FFEW	Flood Forecast and Early Warning
FFGS	Flash Flood Guidance System
HAD	High Aswan Dam
HEC-HMS	Hydraulic Engineering Center's-Hydrologic Modeling System
HEC-RAS	River Analysis System
HRC	Hydraulic Research Center
GIS	Geographic Information System
GSMaP	Global Satellite Mapping of Precipitation
ICPAC	IGAD Climate Prediction and Applications Centre
IPCC	Intergovernmental Panel on Climate Change
ISFF	International Symposium on Flash Floods
JICA	Japan International Cooperation Agency
MoIWR	Ministry of Irrigation and Water Resources (Sudan)
MWRI	Ministry of Water Resources and Irrigation and (Egypt)
NDMA	National Disaster Management Authority
NFC	Nile Forecast Center
NFS	Nile Forecast System
NGOs	Non-Governmental Organizations
NMA	National Meteorological Authority
NMHSs	National Meteorological and Hydrological Systems
NOAA	National Oceanic and Aeronautics Agency

SREs	Satellite Rainfall Estimates
TRMM	Tropical Rainfall Measuring Mission
UN	United Nation
UNESCO	United Nation Education, Sciences and Culture Organization
UNICEF	United Nation International Children Emergency Funds
USGS	United States Geological Survey
WHS	World Heritage Sites
WMO	World Meteorological Organization
WRF	Weather Research and Forecasting model

Chapter 1: INTRODUCTION

1.1. Background

On the global scale the number of recorded extreme events of flash flood and droughts have increased significantly over the last 50 years representing the greatest rise of all natural disasters. Recent studies using climate models, predict that through climate change and variability as a result of global warming, the hydrological cycle will become more intensified resulting in more weather extremes hence more flood and drought events (IPCC, 2012). To date, despite the great advancement in flood and drought management, we still experience catastrophic losses of human life, livelihoods and property as a result of these extremes every year. It is understood that flood risks will not subside in the future, the situation is worsening each year. History shows that communities that fail to recognize and adequately plan for these hazards can suffer horrendous losses in life and property, as well as response and post-disaster clean-up costs that decimate federal, state and local protection budgets.

In response to the frequent flash floods phenomena that striking The Eastern Nile (EN) basin countries, Eastern Nile Technical Regional Office, located in Addis Ababa, Ethiopia, has taken the initiative to address the flash floods in the region. The EN basin consisting of Egypt, Ethiopia, South Sudan and Sudan, and with a population of over a quarter of a billion inhabitants (expected to double in less than two decades) is perhaps the most important part of the Nile Basin. Its significance is not only because of its geo-hydro-political relevance or the fact that it is home to over half the population of the entire Nile Basin (important as these are), but also because of the hydrological significance of the river Nile that courses through it.

The ENB has been the site of the some of the most advanced civilizations of the ancient world. The annual Nile flood that carried fertile sediment from the Ethiopian Highlands transformed the deserts of Sudan and Egypt into rich agricultural lands along its course. Apart from the Nile River itself, the ENB encompasses an extraordinary range of ecosystems from high mountain moorlands, montane forests, savanna woodlands, extensive wetlands and arid deserts. Within the ENB, most of the people in Ethiopia, Sudan and the newly-independent South Sudan are rural, depending largely on the natural resource base for their livelihoods, while in Egypt nearly half the population is urbanized, although the Nile provides the basis for agriculture, power generation and water transport. The richness of the natural and human resource base notwithstanding, the basin's peoples face huge challenges:

The ENB with these huge wealth of natural resource, frequently suffer frequent flash floods disasters, which endangering its future development and resources potential. The existing Flood Forecasting and Early Warning (FFEW) address and covers only riverine flooding for selected flood prone areas. While evidence shows significant portion of the Eastern Nile basin is frequently affected by flash floods. Flooding events in 1998, 2006, 2010, 2013 and 2014 in different parts of the basin has shown as urbanizing grows many more areas in the basin are expected to be affected by more frequent flash floods. Therefore, is necessary to start assessing the vulnerable areas for flash flood and develop strategies to implement a system that mitigate flash flood threat.

1.2. Objectives of the Consultancy Service

The overall objectives of this consultancy work are to assess the extend and identify types of flash flood in Eastern Nile basin and to develop guidelines for effective flash floods early warning system to minimize loss of life and infrastructure damage.

The specific objectives are:

- ✓ Mapping of frequent flash flood prone areas in EN basin.
- ✓ Identify types of flash floods in EN basin
- ✓ Guide line on availability of flash flood early warning system in EN basin.
- ✓ Development of guide line to be implemented for development of flash flood early warning system in EN.

1.3. Scope of the Consultancy Service

The study can be achieved through three tasks as given in TOR (Annex B), and as detailed below:

Task I: Flash flood assessment; review flash flood event in the ENB. Carry out a study on classifying types of floods, map out sub catchments with frequents flash floods occurrence. Assess the current hydro-meteorological infrastructure in these sub catchments and any existing early warning systems. Assess current practice to mitigate flash floods. Identifying flash flood measures before, during and after floods.

Task II: Guideline to address flash flood; review both regional and international methods in addressing flash flood with proper forecast and early warning system. Develop a guideline to ensure up to date methodology that can be adopted with for ENB to address flash flood of different types. Identify the best practices for short, medium and long term relief activities. Provide policy advice in relation to flash flood management in ENB for the different relevant stakeholders and institution involved in flash flood.

Task III: Capacity building activities.

1.4. Methodology of the Study

A qualitative methodological approach was adopted based on the scope of work, objectives, criteria and deliverables of the Study. The study mainly focused on mapping of frequent flash floods sites, the current practice in flood & flash floods early warning system, assessment of hydro-meteorological capacity and mitigation measures in EN and development of guide lines to address flash floods.

Primary and secondary data were collected. The primary data was gathered through face-to-face and telephone interviews with key informant including officials, experts, and researchers involved in flood forecasting and early warning. Secondary data was obtained through reviewing of documents including ENTRO reports, government reports, NGO's reports, books, internet, and other published and unpublished documents.

A questionnaire was designed to collect Key information such like;

- ✓ Questionnaire regarding the flash floods; Availability of flash floods EWS, institutions responsible for EWS, data providers, communication methods.
- ✓ Questionnaire regarding the floods mitigation measures; Structural/non-structural, effectiveness of the measure used.
- ✓ Questionnaire regarding flood affected areas and communities; which area are frequently flooded, how frequent and long it was flooded.
- ✓ Questionnaire regarding hydro-met data, density of network, frequency of records etc.

1.5. Structure of the Report

This report gives a detailed description of flash floods situation in the EN with special focus on the flash floods prone sites, management and mitigation measures used, existing EWS and proposed guide line to develop effective flash floods EWS in the region. The report consists of eight Chapters as follows:

The current chapter (Chapter 1) is a general introduction about the consultancy, its rationale, objectives and methodology.

Chapter 2; Discusses the flash floods science, definition, types, causes and consequences etc.

Chapter 3; Presents different flash floods prone sites in the EN.

Chapter 4; Discusses the different management and mitigations practices in the region and worldwide.

Chapter 5; An overview of the existing hydro-metrological stations and the gaps in EN.

Chapter 6; Discusses flood early warning systems, definition of EWS, elements of EWS and the existing FEWS in the EN.

Chapter 7; is a review of the existing flash floods EWS in the region and worldwide, and guide lines for developing effective flash floods EWS for the EN.

Chapter 8t; is the conclusion and recommendations of the report.

Chapter 2: FLASH FLOODS SCIENCE

2.1. Definition of Flash Floods

A flood, in general, occurs when water overflows or inundates land that's normally dry. The flash flood can be defined as "a flood of short duration with a relatively high peak discharge" (WMO-UNESCO, 1974). More extensive definition was given by the National Weather Service of the USA, "a flash flood is a flood that follows the causative event (excessive rain, dam or levee failure, etc...) within a few hours". Two essential differences between a flash flood and a normal flood can be distinguished: the speed with which it occurs and the time interval between the observable causative event and the flood, which is less than four to six hours. The six-hours duration is generally proposed as the best 'break point duration' between a normal flood and a flash flood. This means, in particular, that the standard and conventional flood warning techniques, models and organizations are not suitable for use with flash floods. The two best words describe a flash flood and its hydrographs are "Sharp and unexpected". In this respect, it is usually difficult to forecast because the time to peak is very short and the rate of flood rise is very great.

2.2. Flash Floods Causes and Consequences

Flash flood can happen in a multitude of ways, most common from excessive rainfall, failure of hydraulic infrastructure, rapid ice melting in mountainous region and even an unfortunately placed beaver dam can overwhelm a river and send it spreading over adjacent flood plain. Coastal flooding occurs when a large storm or tsunami causes the see to surge.

Flash floods occur throughout the world, and the time thresholds vary across regions from minutes to several hours. The time duration of flash flood depends on many factors; land surface, geomorphological, and hydro climatological characteristics of the region. However, for the majority of these areas there exists no formal process for flash flood warnings, there is a lack of general capacity to develop effective warnings for these quick response events.

In the ENB e.g., Floods is caused by two sources; River flooding, i.e., high waters spell over the banks, and flash floods caused by torrential storm rainfall over rural or urban areas. Although it is difficult to assess accurately the flood damage, in particular in far past, huge flood damages were reported during high rain storms. Damage consists of; loss of human lives, loss of agricultural lands (crops and fruit trees along the rivers banks),loss of live stocks, damages to building, infrastructures and public services. High floods, usually accompanied by spread of diseases and outbreak of epidemics such like (Malaria, diarrhea, bilharzias, and other water borne diseases).

Sometimes flash floods cause more damage than river floods. In 2007 in Sudan, while river flooding is below critical level, the torrential rainfall over Sudan brought what the Sudanese Government called the worst flash floods in living memory. The United Nations reported large damages in different States: half million people affected, 64 people died, and about 30,000 houses destroyed (source: Sudan Floods-Bulletin# 2, United Nations, 2007).

2.3. Differences Between Flash Floods and Normal Floods

The distinctive feature of the flash flood is the rapid rising of its hydrograph (figure 1). The hydrograph of a flash flood is very sharp, with peak discharge higher than for normal floods and with the total flood volume quite small. The rising and falling limbs of the hydrographs of flash floods are very steep, with time-to-peak generally not more than 1 to 6 hours. Natural flash floods generally occur on catchments of small to moderate size whereas normal floods may occur at any type of catchment.

Flash floods frequently occur in basins with large impermeable areas, sparse vegetation, and steep slopes. Flash floods happen very suddenly and are usually difficult to forecast. The damages incurred are often very serious, including loss of human life. Normal floods can be forecast to give some warning and thus a certain amount of protection. Flash floods generally arise from extreme rainfall events and intensities. In arid and semi-arid areas, the meteorological and hydrological regime is conducive to flash flood generation.

Governments in all countries of the world are paying increasing attention to research into flash floods. There is a shortage of hydrological and meteorological data, hydrological research is very deficient. Flash flood research is becoming increasingly important, particularly with regard to improved data collection techniques, defining flash flood types and the reasons for their formation, properties, and spatial and temporal distribution, forecasting techniques and warning system.

2.4. Characteristics of Flash Floods

2.4.1. Suddenness of occurrence

Flash floods generally result from high-intensity storms of limited area1 extent or perhaps through a glacier-dammed lake outburst. The time to peak may be only a few hours or even tens of minutes. Conventional forecasting methods cannot provide adequate warning and people have insufficient time to move away from the floods. Floods arising from glacier-dammed lake outbursts are similar to dam-break floods but the suddenness is more significant.

2.4.2. Randomness of area1 distribution

The number of flash floods in large arid and semi-arid zones is not insignificant the frequency of occurrence is indeed very small, perhaps only once in many years. Although flash floods at specific sites and during a certain period occur for specific reasons, the area1 distribution is statistically random .

2.5. Types of Flash Floods

Flash floods can be considered under five categories based on the type of causative event:

- ***River flash floods*** (when rivers overflow and inundates the surrounding areas). It usually originates from heavy rainfall in the upper catchment, which causes unpredictable surges in the rivers.
- ***Heavy rainflash floods*** (storm flash flood), which is generally short in duration and can cause major damage in villages and urban areas.
- ***Dam Break***, this rarely happen because of comprehensive risk analysis and dam safety.
- ***Snow melting***, particularly in polar regions
- ***Tsunamis and surges*** due to oceanic cyclones and earth quake

The first and second types of flash floods are predominant in the Eastern Nile Basin. River floods were much discussed and well covered in the Eastern Nile Basin. FFEW was developed and well established for most of the riverinesystem of River Nile (Verkade & Werner, 2010). This report will intensively discuss *Storm Flash floods* and EWS in the ENB.

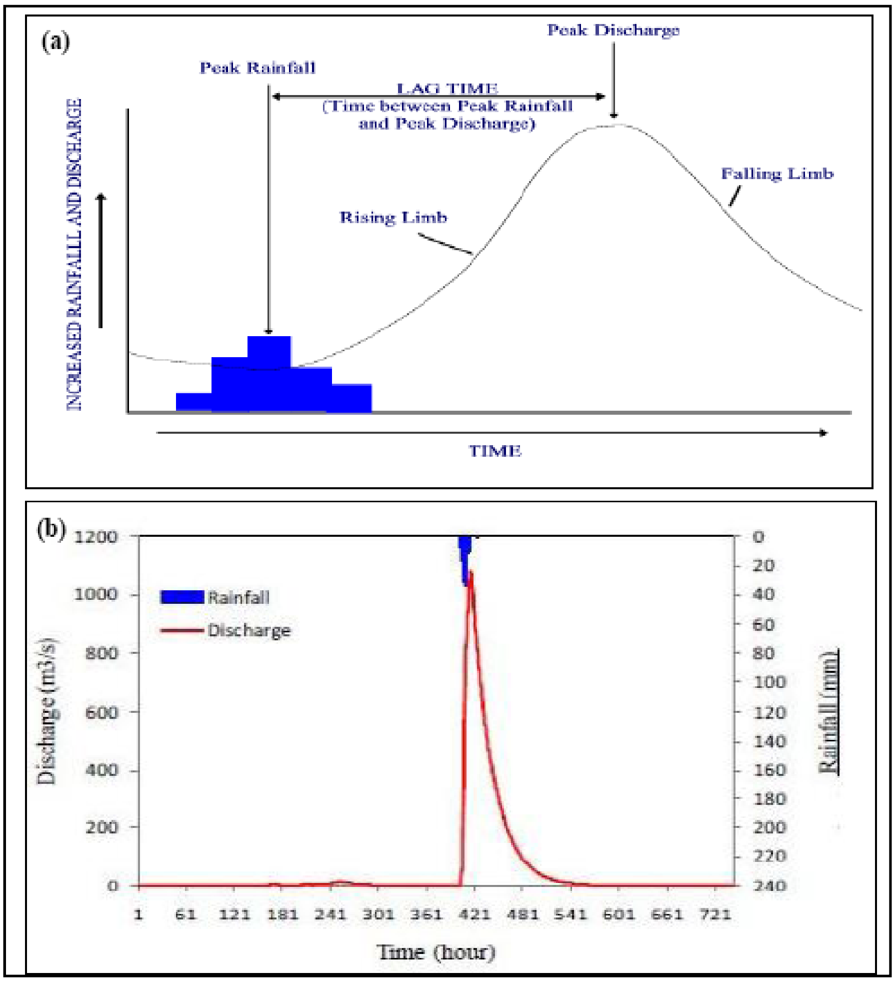

Figure 1: Typical normal food hydrograph (a) and flash flood hydrograph (b)

2.6. Strom Flash Floods

Floods are natural phenomena that have always been an integral part of the geological history of the earth. Flash Floods occur along the rivers, streams, and lakes and coastal areas, in alluvial fan, in ground-failure areas such as subsidence, in areas influenced by structural measures, and in areas having inadequate urban drainage systems (Satish et al., 2009).

In the ENB e.g., Floods is caused by two sources; River flooding, i.e., high waters spell over the banks, and flash floods caused by torrential storm rainfall over rural or urban areas. Sometimes storm rainfall flash floods cause more damage than river floods. In 2007 in Sudan, while river flooding is below critical level, the torrential rainfall over Sudan brought what the Sudanese Government called the worst flash floods in living memory. The United Nations reported large damages in different States: half million people affected, 64 people died, and about 30,000 houses destroyed (source: Sudan Floods-Bulletin# 2, United Nations, 2007).

Although it is difficult to assess accurately the storm flood damage, in particular in far past, huge flood damages were reported during high rain storms. Damage consists of; loss of agricultural lands (crops and fruit trees along the rivers banks), loss of live stocks, damages to building, infrastructures and public services. High storm floods, usually accompanied by spread of diseases and outbreak of epidemics such like (Malaria, diarrhea, bilharzias, and other water borne diseases).

2.6.1. Causes of storm flash floods

The causes of storm flash floods may be broadly categorized as natural and anthropogenic.

Natural causes are:

i) High intensity rainfall
ii) Erratic spatial distribution of rainfall
iii) Inflows from rivers in the urban drainage system during high stages.
iv) General topography (slopes) of the land surfaces.
v) Orientation and movement of the rain storm.

Anthropogenic causes are:

i) Increase in imperviousness due to urban growth results in large quantities of storm water.
ii) Unplanned settlement which leads to obstruction of natural waterways.
iii) Inadequately and improperly designed drainage system.
iv) Human behavior which leads to blockage of drainage system

2.6.2. Impact of storm flash floods

The impacts of storm flash flooding can be summarized as follows:

i) Direct damages, i.e., the damage caused to human lives and the property due to increase in velocity of flow and depth of inundation.
ii) Indirect damages, i.e., damages due to disruption of services and its consequences such as the loss incurred due to traffic disruptions, administrative costs involved in bringing back the normalcy of the life, poor turnout in industries leading to productivity loss, spread of epidemic etc.
iii) Long term damages due to social consequences, like delays in economic development and low property value in frequently flooded regions.
iv) Flash floods represent a constraint on regional development.
v) Major source of erosion and pollution.
vi) Environment, health and socioeconomic impacts include; loss of life and properties, displacement, lack of clean potable water due the collapse of pit latrines that pollute the water and so enhancing the spread of diseases such as diarrhea and cholera.

Chapter 3: FLASH FLOODS PRONE AREAS IN EASTERN NILE BASIN

3.1. Introduction

Heavy rainfall and runoff of the large volume, improper land use and the absence of scientific soil conservation practices are identified as the major factors for flash floods in EN basin. Urbanization with the insufficient infrastructure facilities such as drainage system triggers the urban flash floods together with global phenomena like climate change, which has increased rainfall intensities. The increase in population and subsequent need for land have forced more and more people to live and work in these vulnerable areas, thereby intensifying the risk to life and property in the event of major floods

The Eastern Nile constitute all rivers that originate in the Ethiopian highlands and flow towards the main Nile in the west. Four sub-basin systems that make up the Eastern Nile namely; the Main Nile, the Blue Nile, the Tekezze-Atbara, and the Baro-Akobo-Sobat. Figure 2 shows these sub-basins and their major tributaries and flood prone sites, details of sub-catchment with frequent flooding country-wise also were given.

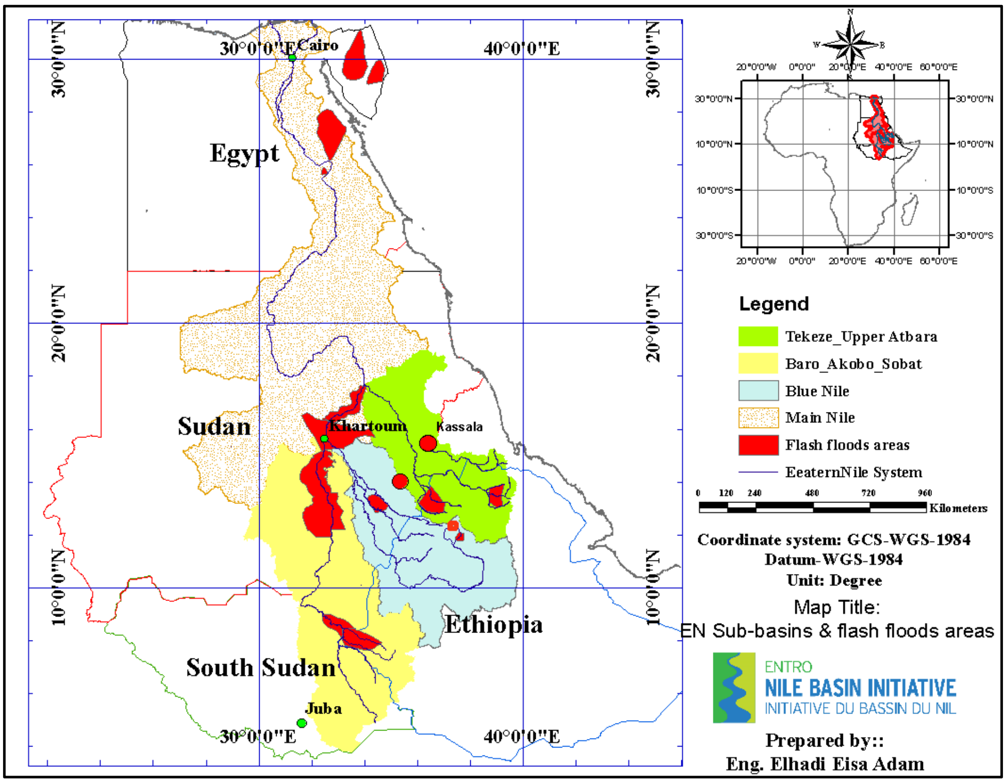

Figure 2: Eastern Nile Sub-basins with flash floods sites

3.2. Egypt

Flash Floods in Egypt are common natural disaster occurring in most parts of the arid and hyper-arid regions of East Desert, West desert, Sinai Peninsula and Red Sea (Samir et al., 2013). The flashfloods severely threaten the infrastructures, human lives and destroying their livelihood, moreover affecting the country's business, economy and threaten the archaeological sites (Vanderkimpen et al., 2010). Egypt economy depends on archaeological tourism because it represents one of the very important resources of national income (Kantouch et. al., 2020; Sumi et al., 2013; Youssef et al., 2005).Figure 2 shows mapping of flash floods prone sites in Egypt.

3.2.1. WadiWatier (Sinai Peninsula)

WadiWatier is situated in the South Sinai governorate of Egypt (Figure 3). It is one of the most active wadis in Sinai with respect to flash floods. The catchment has an area of 3580 km2 and classifies as a hyper-arid catchment. During flash floods, a high-velocity flood wave with a high sediment load is channeled along the canyon. The flood wave can reach a height of 1–2 m. This usually results in severe damage to the international road, which in some parts is totally washed away (Cools et al., 2012).

3.2.2. Wadi El-Arish (Sinai Peninsula)

Wadi El-Arish is located on the Sinai Peninsula, Egypt, it flows toward the Mediterranean Sea and its downstream part is El-Arish City. This wadi infrequently receives flash flood water from much of northern and central Sinai which make a great threat to the life and property of El-Arish City residents. It is the largest ephemeral stream system on the Sinai Peninsula, its catchment area is calculated to be 20,700 km^2.

3.2.3. WadiQena (Main Nile)

WadiQena, is located at the eastern side of Qena meander of the River Nile, between Red Sea in the east and River Nile in the west. Although, the Eastern Desert of Egypt is located in the arid and the hyper arid region, the region occasionally subjected to intense rainfall events over fairly short duration. These rainfall events, as in many other arid regions, resulted in severe local thunderstorms due to unstable weather conditions (Samir et al., 1991).

Another flash flood prone area is, ***Wadi Abu- Hasah*** on Tell El-Amarna archaeological sites especially, tombs of the kings, as well as the highways connecting and crossing the towns of El-Menya. Tell El-Amarna archaeological area, which frequently damaged by flashfloods of Wadi Abu Hasah, is located in the west central part of the Eastern Desert, in El-Menya Governorate, Egypt.

3.2.4. The Valley of the Kings (Main Nile)

The Valley of the Kings is a UNESCO World Heritage Site with more than 60 open tombs in Luxor, Egypt. In 1994, most of these tombs have been damage by flash floods (Kantoush et al., 2020).

Recently this year, 2020, storms have caused damage and havoc in several parts of the country namely; in the governorates of Qena, New Valley, Sohag and Monifia, where authorities report 5 people have died. Dozens of trees were uprooted and at least 5 buildings destroyed. Flooding was reported in parts of the governorates of Suez and Cairo, where the drainage system was overwhelmed and water supply cut. Schools, public offices and some air- and seaports were closed and train services suspended.http://floodlist.com/africa/Egypt-floods

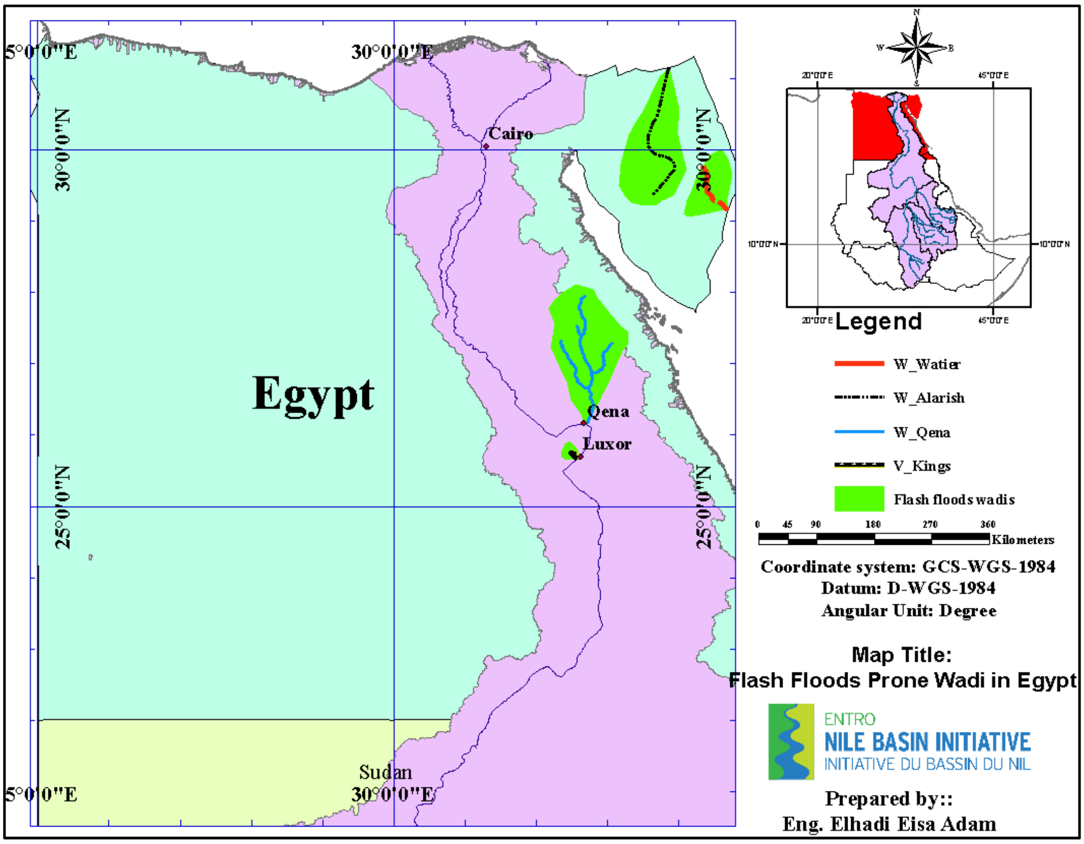

Figure 3: Flash floods prone areas in Egypt

3.3. Ethiopia

The rainy season in Ethiopian context is concentrated in 'kiremt' period, when about 80% of the rainwere received.Rainy season flooding is one of the major environmental problems of the people living in the most part of Ethiopia. Many factors responsible for the high flash flood in the country, which can be enumerated as; the intensive rainfall in the up lands of the watershed, sparse vegetation cover, steep slopes and low infiltration capacity of the ground surface. This floods at times of unusually high rainy days overtop the normal flood ways and create a lot of damage and loss of lives.

Flash floods are more commonly associated with isolated and localized intense convective rainfalls in Ethiopia. They occur both in highland and lowland areas and their occurrence is very random. They cause life loss as well as property damage. They can better be mitigated through watershed management instead of flood protection works (Teshome, 2020). Figure 4 shows flash floods prone areas in Ethiopia.

3.3.1. GambellaRegion (Baro-Akobo)

Gambella plain lies in the western part of Ethiopia and is part of the Baro-Akobo river basin. Gambella city, which is the regional capital, lies about 800 km from Addis Ababa, capital of Ethiopia. Major rivers in the areas are Baro, Akobo, and Gilo. Most of the plain is subject to seasonal flooding, which is also attributed to poor drainage condition. The city of Gambella is subject to occasional flooding caused by the Baro river and some of its tributaries. Most important causes of flooding in the Gambella area are flooding resulting from rivers overflowing their banks and flooding due to inadequate drainage. The riverine flooding is further aggravated due to the backwater effect from Pibor and Sobat rivers. Severe flooding, estimated to be a 50-year event, occurred in 1988 with the following consequences (Abdulkarim, 2004).

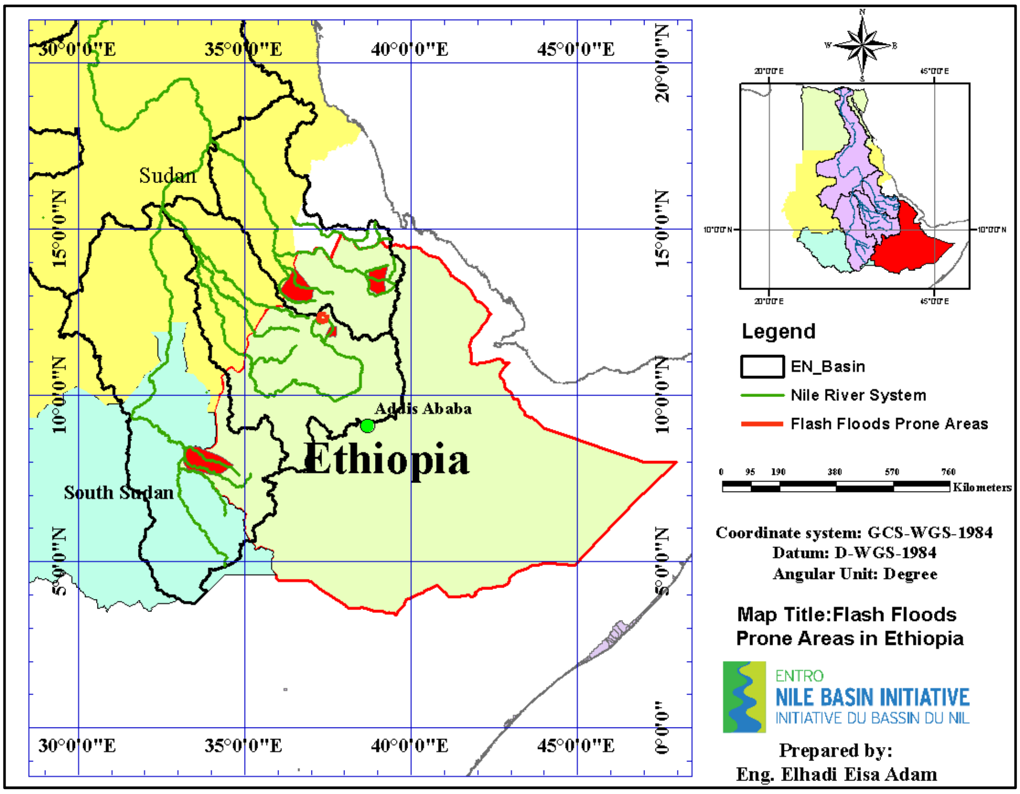

Figure 4: Flash floods prone areas in Ethiopia

3.3.2. Lake Tana (Blue Nile)

Lake Tana, is located in the northern half of Ethiopia. There are many rivers draining into the lake, some of which are causing huge damage to property and life to the surrounding farming community. There are several flood risk areas around Lake Tana, two areas were frequently flooded resulting in great damage; the floodplains of the Fogeraworedas and the floodplains of the Dembiaworedas (RIVERSIDE, 2010). Severe flooding has occurred in the Fogera floodplain and the Dembia floodplain. The causes of flooding are believed to be ponding of excess rainfall in floodplain depressions, rise of lake level and overflow of the rivers draining into the lake.

In the Fogera plain, overflow from the Gumera and the Ribb Rivers resulted in flooding on FogeraWoredas. The flooding in the northern part of the floodplain is primarily caused by bank overflow of the Ribb river and tributaries to the Ribb in the lower stretch of the river near Lake Tana.

In the Dembia plain, flooding occurs mostly on the lower part of the Megech and the Dirma Rivers. During high flows and high lake levels especially flooding occurs in areas near the lake due to overbank flow of the rivers in combination with the backwater effect of the lake.

3.3.3. Humera (Tekeze-Setit-Atbara)

Humera, in Tekeze-Atbara sub-basin, is frequently flooded site in the north-east part of Ethiopia. The flat area at Humera (near Ethio-Sudan boarder) is flooded from overflow of Tekeze River over its banks. This will occur during extreme rainfall conditions in the upper catchment of Tekeze basin.

3.4. South Sudan

3.4.1. Baro-Kobo-Sobat plain (BAS)

South Sudanis one of the countries with a unique setting for flooding. Most part of the country is low lying and 80% of the landmass is flood plain thereby leaving the country highly vulnerable to the threat of repeated floods. The pattern of flooding in the country also points towards an increase frequency of floods. Being located in the lower stretch where the river floor gradient is very gentle, this in turn results in less flow of water into the White Nile and the rivers attempt to adjust the water volume by overflowing their banks and nearby plains. Figure 5 shows mapping of flash floods prone areas in South Sudan plains of BAS.

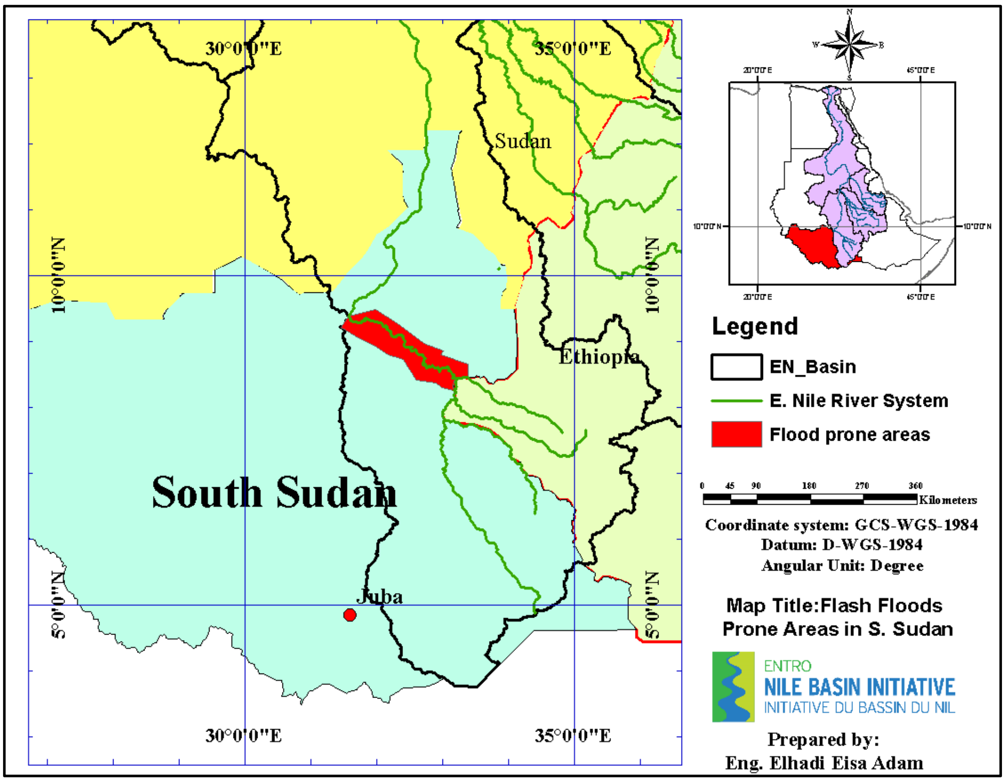

Figure 5: Flash floods prone areas in South Sudan

As of late October 2019, unusually heavy seasonal flooding is affecting large areas of South Sudan, flooding has since been reported in a total of 27 counties, in eastern and northern parts of the country. Estimates that between 600,000 and 800,000 people have been affected, according to authorities. Ayod, Maban, Mayom, Nyirol, Pibor and Uror in Greater Upper Nile were among the counties most heavily affected by the floods.

According to report by MSF, floods are a regular occurrence across the country, last year's rainy season has been unusually heavy, bringing flash floods that have inundated whole towns (https://www.msf.org.uk/article/south-sudan-msf-assessing-emergency-needs-after-severe-flooding) . Hundreds of thousands have lost their homes, crops and cattle. Many have been left stranded by the floods, marooned on small islands of land and cut off from basic services and healthcare. Flooding is limiting access to basic services and restricting the ability of humanitarian agencies to assess and respond to needs.

It is also worth mentioning that the most types of floods that are very common in the Republic of South Sudan are the rain floods which happen almost in most parts of South Sudan. The second part of the floods occurring in South Sudan is the river floods. This type of floods mostly happens around Bor, Malakal etc.This is because of the overflow of the rivers. The third type of flood is the flash floods, this mainly happens in the arid and some semi-arid floods. This type of floods is common in places such as Kapoeta in the former Eastern Equatoria States

The main causes of these frequent occurrences of these floods were due to poor drainage system and topography of land which enable the river banks to overflow.

3.5. Sudan

Like other EN member states, Sudan also has long history of floods. In the years the country has faced major flash flood events resulting into loss precious livestock's and infrastructures. Flash floods in Sudan are generally caused by heavy concentrated rainfall during the rainy season and flooding from seasonal wadis. Floods are regularly occurring during the period from July to September every year. Both riverine and flash floods cause great damage to life and properties especially in lower area along the Nile river and its tributaries. Flash Floods in Sudan affect considerable number of people, damaging of thousands of homes and causing the deaths of herds of cattle. Ecosystem and environment may also be affected negatively by some metrological parameters that increase the risk and pressure on the hydrological system.

The sequences of severe floods in Sudan were recorded in 1946, 1962, 1965, 1975, 1978, 1979, 1988, 1994, 1998, 1999, 2006 and 2013. However, in 2019, the climatic variability through intensified rainfall regimes together with urban development has made many states in Sudan increasingly exposed and vulnerable to extreme flash floods.

Rapid urbanization and reclaiming of areas close to riverbanks has added a new dimension in the country as seen recently in Khartoum flooding in 2015 and the threats of urban floods in Kassala in the year 2018. Floods have caused loss of infrastructure and livelihood, led to large scale migration and, in some cases, relocation of affected communities (El hadi et al., 2018; Elhag and Eljack, 2016). The states in Sudan most vulnerable to flash floods are; Khartoum, Kassala, White Nile, Nile River, Gadarif and Sennar; many other parts of the country have also experienced floods in recent or historic. Figure 6 shows mapping of flash floods prone sites in Sudan.

3.5.1. Sharq Al-NeelLocality, Khartoum State

Sharg Al-Neel area, in Khartoum State, is one of the most flood prone areas. The locality is frequently affected by heavy flash floods during the rainy season. East Soba, ElfakiHashim, MarabeeElshareef, Wad-Ramli and Wawisi, represent the main areas that frequently affected by flash flooding due to wadis flooding. Several wadis dominate the area towards River Nile, the most famous are; Soba, Green Valley, and Hasseb (figure 6). The area experienced major floods during the years 1988, 2007, 2013 and 2014. Last year, 2019, both floods and heavy rainfall swept through areas which located in the North of the locality (Wad Ramli). This flash flood led to collapse of a large number of houses and residents, people were displaced, and some families were forced to take shelter and protect themselves in schools and other save buildings (Redwan, 2020).

3.5.2. Gash River, Kassala State

The Gash, in Kassala State, Eastern Sudan- is a seasonal flashy river, originates from the Eritrean and Ethiopian highland, and flows during the period from July to September. The Gash river crosses Kassala city, the capital of Kassala State, and divided it into to part; east and west. Despite the intensive flood protection work, the city is still under a high risk of catastrophic flooding causing great damages to properties, infrastructures and endangering human lives (Elhadi et al., 2018; Isam et al., 2012).

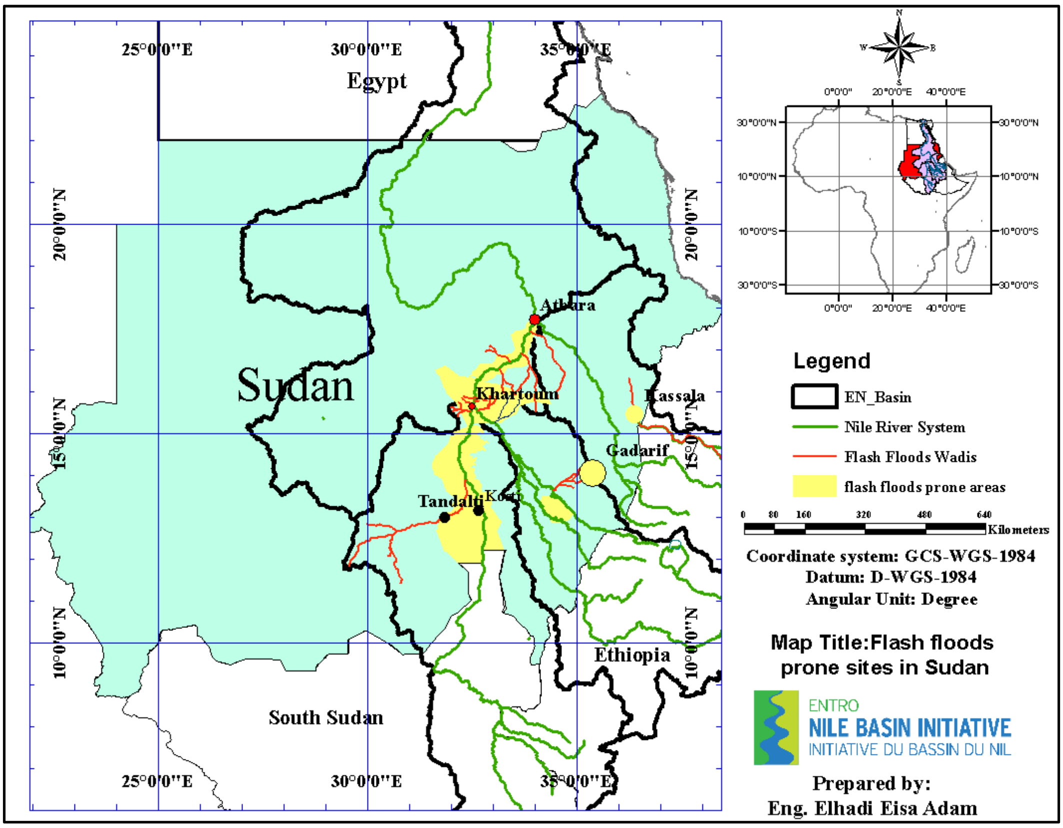

Figure 6: Flash floods prone areas in Sudan

3.5.3. White Nile State

Many seasonal flashy wadis cross White Nile State from south and south-west directions. Last year, 2019, heavy rainfall generated tremendous flash floods which cut the export highway road linking Khartoum to North Kordufan State for many weeks. More than 25 villages were washed out, the Governor of the White Nile state declared state of emergency, the relief activities distributed by Helicopters because all the roads were unpassable.

Khore Abu Habilone of the seasonal flashy wadis, it is originating from the South Kordufan State mountain in the south west part of the Sudan, and takes it is way through North Kordufan State till discharge into the While Nile River in White Nile State North of Kosti city. During rainy season when flooding, it causes great damage to cities and rural areas located along its course like Tendalti city.

Chapter 4: FLASH FLOODS MANAGEMENT AND MITIGATION MEASURES

This sectionsummarizes the situation on exiting management and mitigation measures in the EN countries. It largely documents the knowledge gained by the author through review of available documents, discussions with concerned people, and visits to some of the flood prone sites. An attempt is made to give an overview of the different aspects of flood preparedness, mitigation planning and management practices. A general observation by the author is that most of the activities related to disaster management in the region are response-oriented, reactive measures.

4.1. Introduction

Flood mitigation is the process under which different bodies try to reduce the current and the future vulnerability of the communities to natural hazards. The promotion of the mitigation planning helps to ensure a safe and a responsible development. The advantages of the different mitigation systems are to decrease flood water velocity, to increase the time before the flood peak reaches lower parts of the drainage system.

The key characteristics of flash floods that should be taken into consideration when developing a management strategy are: the unforeseeability of the place, local scale of the event, and particularly the violence of the phenomenon, as well as the very short response time and the great threat to human lives. The solutions developed for the management of river floods do not prove effective in dealing with flash floods, which require separate means.

The flood mitigation measures can be broadly classified as structural and non-structural measures; the latter would seem to be the key deserving particular attention in effectively limiting the damage caused by flash floods. This does not mean that structural measures are of no assistance, but the typical procedures, like the building of reservoirs and embankments, cannot always be adopted in areas susceptible to flash floods. Small scale structural measures can, on the other hand, play an essential role in delaying the flow of water, allowing it to be locally retained, or diverting it from places where it could pose a threat to people or properties. Operations to limit the shifting of debris, or to stabilize hillsides in areas at risk of landslides are important. The flood resistance of buildings potentially at risk (flood proofing) should also be secured. It should, however, be noted that flood proofing may not be considered an option where high flow velocities and associated debris loads of flood water can be expected. The dynamic forces of such conditions on structures in general and on residential buildings in particular are very uncertain and difficult to assess. The structural method of flood management is very expensive and laborious that is why most of the time non-structural methods are adopted. Building of flood early warning system (FEWS) is the most effective and easiest way for managing flooding.

What is considered key in managing flash floods is the activity of local authorities in warning and responding to floods, with their main goal being to limit the danger to human lives. The activity of local authorities in warning and responding to floods is essential to limit the danger to human lives and property. Flash flood warnings are generated on both a national (and international) level, generally assigned to meteorological and hydrological services, and on a local level. Local warning systems allow us to, on the one hand, to adapt solutions to the locally existing risk, and, to the capabilities of the local communities.

4.2. Flash Flood Mitigation and Management Cycle

Flood has been identified as one of the major disasters in EN basin exposing the communities to very high degree of risk. However, it has often been seen that the measures undertaken are not enough and they fail at times to give way to flood hazards. Floods have occurred in the protected areas due to overtopping, breaching or in some cases, failure of the protection structures. Land use practices need to be projected with foresight keeping in mind the future areas of concentrated growth and their proximity to flood risk zones. It is also found that the flood related data collection and transmission networks need to be strengthened and augmented for generation of more effective flood warnings.

4.2.1. Proactive paradigm

The pro-active paradigm includes; preparedness, prediction & warning, and prevention & mitigation. Figure 7 shows the flood management cycle which can be followed to reduce the damage incurred by flash floods (Satish et al., 2009).

Preparedness**,** preparedness measures attempt to prevent potential risks turning into disasters, both at societal level as well as at individual level. It involves resource inventory, logistical planning, evacuation planning etc. well ahead of any potential flood event. Making the vulnerable communities aware of flash floods risk is a major area of focus. A multi prong approach for spreading awareness: through print and electronic media, distribution of information material, community workshops, street shows should be made an intrinsic part of DRR activities. The preparedness and contingency plans should have special emphasis on the vulnerable segment of the communities likely to be affected by floods: the poor, old, women, pregnant, children and the disabled.

Prediction and Warning,prediction and warning were done just hours before and immediately at the start of an event. This includes flood forecasting by accounting the upstream stages of the streams and rainfall forecasts. Early warning systems include the dissemination of correct information to the target user on the duration of occurrence of the event through media, World Wide Web, Messaging Services etc.

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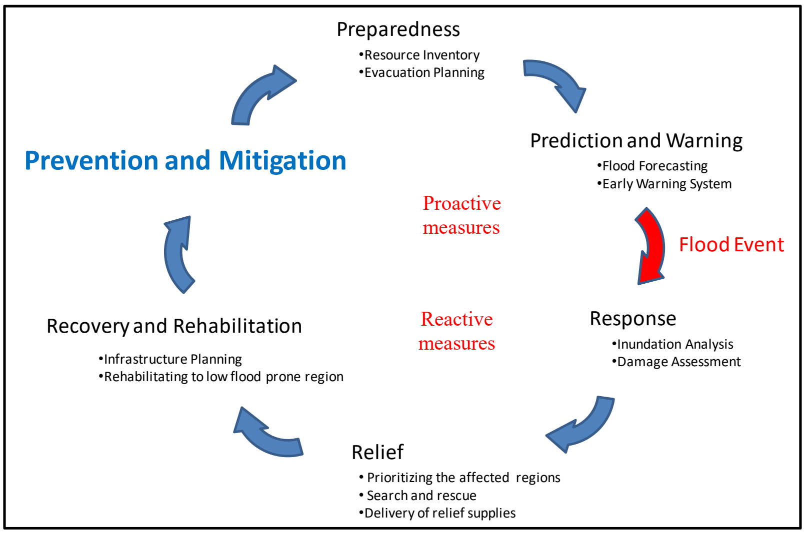

Figure 7: Flash flood mitigation and management cycle (Source: Satish et al., 2009)

4.2.2. Reactive paradigm

Emergency Response, response measures are implemented during or directly after a flooding incidence. They need advance planning and preparedness to respond to the emergency. Inundation analysis and preliminary damage assessment were carried out to provide relief measures.

Relief, flood effected regions were prioritized for evacuation, search and rescue operations were carried out. Delivery of relief supplies were done based on the needs. This process requires advance planning for identifying safe zones and stock piling to meet the demand during emergency.

Recovery and Rehabilitation, recovery measures include provisional reconditioning of the basic services and infrastructure and proper infrastructure planning to reduce the risk. Rehabilitation is carried at a better location where the risk of flooding is minimal. Livelihood options in frequently flooded areas are a major concern and affect the communities. The paradigm for flash floods risk management need to be broadened from simply post-disaster response to a more comprehensive approach that also includes prevention and preparedness measures.More effective prevention strategies would save not only tens of billions of dollars, but save tens of thousands of lives. Funds currently spent on intervention and relief could be devoted to enhancing equitable and sustainable development instead, which would further reduce the risk and disaster.

4.3. Worldwide Experience on Flash Floods Management and Mitigation

4.3.1. Experience from Japan, *Disaster Risk Reduction (DRR) and Disaster Risk Management (DRM)*

As natural disasters have become more frequent and intense, causing substantial impact and losses, the world has commonly recognized that prevention and mitigation is crucial in disaster management, realizing the need to strengthen not only the post-disaster measures, but also proactive measures for reducing risk. Most approaches followed worldwide for flood management can be categorized as response-oriented(after occurrence of disasters, reactive measures; DRM). In case of DRM approach, disasters can repeat itself.

Mainstreaming DRR into the developmental plans are a must for long term flood risk resilience in the risk prone areas at national, regional and local level.

Japanese International Cooperation Agency (JICA) has fast experience in DRR worldwide. Figure 8 below presented by JICA, the figure represents the JICA experience in DRR investment. The figure shows the benefits when investment in DRR is applied against DRM. From the figure, it is clear how the economic growth significantly affected.

The important of mainstreaming of DRR has begun to be recognized internationally as many nations have realized that disaster damage hinders their economic growth significantly. One dollar of investment in DRR can saves around 7 dollars of damage due to disaster (Suzuki, 2020). The mainstreaming of DRR suggests the following three goals, though there is no clear definition yet:

- ✓ Each government should address DRR as a highest political agenda.
- ✓ All development policies and plans should include DRR as integral element
- ✓ More investment should be made for DRR (river improvement, diversions, bank maintenance etc.)

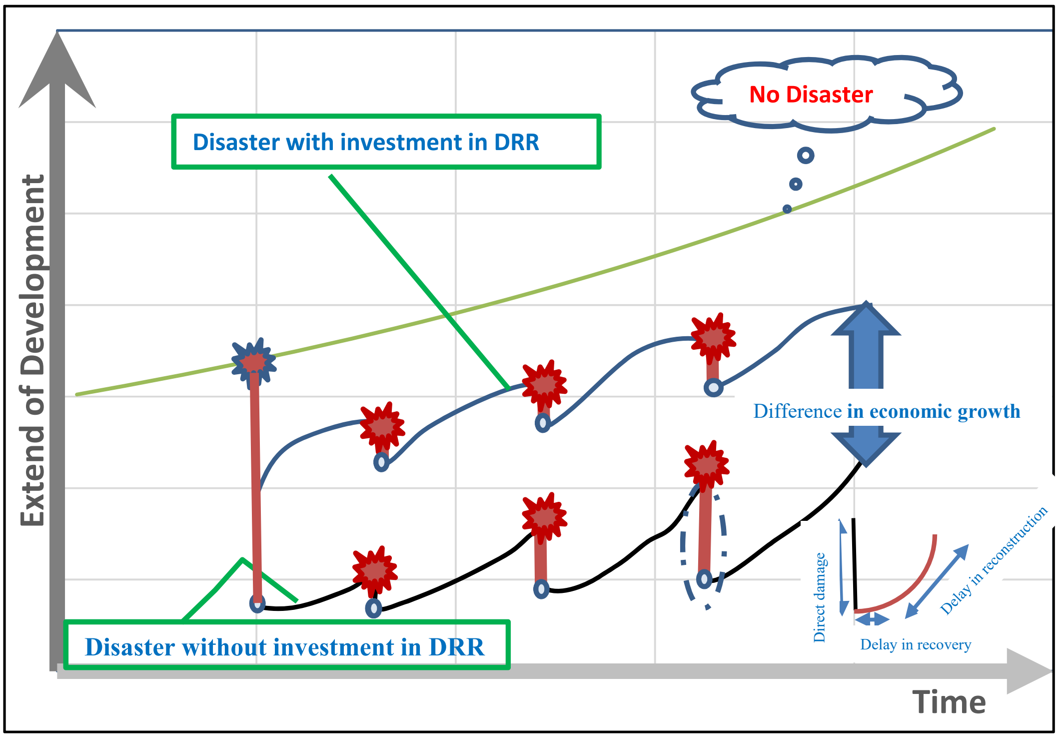

Figure 8: Typical figure for importance of investment in DRR (Source: Suzuki, 2020).

4.3.2. Experience from USA

Most of the flash floods in USA is on Alluvial Fans (AF) and Flood Plains (FP) (Thomas, 2002). AF and FP management includes actions to reduce losses to human resources and/or protect benefits to natural resources associated within the floodplain. The objectives of the AP and FP management are to;

minimizing impacts of flows; maintaining or restoring natural floodplain processes; removing obstacles within the floodplain voluntarily or with just compensation; keeping obstacles out of the floodplain; Educating and planning for emergency preparedness; and ensuring that operations of floodwater management systems are not compromised by activities that interfere with, or are damaged by, design floods of these systems (Jeremy et al., 2015; Thomas, 2002)

Management and mitigation measuresin USA are based on three pillars:

- Better understanding of and reducing risks from reasonably foreseeable flooding; this can be achieved through increase of awareness, mapping of flood prone areas, monitoring,executive orders, flood warning, community response program etc.
- Multi-objective-management approach for flood prone areas;This should be promoted by flood management approaches to ecosystem restoration and agricultural conservation, Best Management Practices (BMP), proactive and adaptive management of flood prone areas, vector control (water borne diseases), watershed monitoring, coordination among agencies and groups, state general plan guidelines and training, education, and professional certification for Multi-Objective floodplain management.
- Local assistance, funding, and legislation; This includes, new and existing funding sources, Task Force (TF) recommendation priorities, outreach programs, National Flood Insurance Program Compliance Encouragement (NFIPC), establishment of advisory committee and interagency barriers.

4.3.3. Experience from Europe

In Central and Eastern Europe, flash floods are a phenomenon that takes place in small regions, characterized by limited spatial extent, and this is why the damage they cause can best be limited on the local level (Skøien et al., 2018). The main tool in this effort are flood preparedness and response plans on the local level. These plans should come about in co-operation with various actors: local self-governments, river administrators, crisis services, residents of the areas at risk, owners of companies located on these terrains, local NGOs, private companies involved in emergency response and recovery as well as meteorological and hydrological services, and geological ones. It is essential that the state creates a coherent legal framework and support for local activities, particularly in terms of division of competencies between particular administrative levels and sectors. The relevant legal solutions concerning spatial planning will also provide support, including the mapping of high-risk areas and restrictions in their use. An additional factor supporting local communities if damage is caused should be a financial system, including an insurance system to provide the possibility of speedy recovery after a flood and sharing of risk.

Flash floods management as part of overall flood management policy and strategy

The minimization of human loss of life represents one of the core aims of an integrated approach to flood management. Loss statistics indicate that flash floods are in fact the most lethal flood type. Therefore, for regions prone to flash floods, governmental flood management policy should explicitly specify the Government's approach and applicable measures to work towards this aim as part of its overall flood management policy and strategy. Government should on the appropriate institutional levels comprehensively address all flood issues. In this it needs to be recognized that the traditional flood management approach employed for low-land riverine floods proves ineffective for flash floods, mainly due to difficulties with accurate forecasting for flash floods, the short warning lead-times, and consequently the requirement to involve much more closely local knowledge, and foster the local preparedness and response capacities.

Another aim of flood management policy that emerged later and is still evolving in various countries points at maximizing the net-benefits from flood plains, rather than aiming solely at minimizing flood damage. This results from the recognition that land resources in many countries are scarce and the development pressure on those land resources keeps on growing. In the mountainous regions where flash floods are most common, floodplains usually represent valuable development assets for settlements, infrastructure, industry and agriculture. In other terms, the comparably low costs of developing and exploiting the floodplains, has attracted humankind for centuries, and will do so in the future.

Example of structural measures in Europe**;** river channel improvement, dams and retention reservoirs, training works, flood protection and drainage projects, flood proofing and abatement. Non-structural measures can be summarized as:flood forecasting and early warning, disaster planning and preparedness, public awareness raising, land use and planning control, acquisition of flood land and property relocation, flood insurance and social security measures (e.g. compensation).

4.3.4. Experience fromSouth Asia

The recurring floods in South Asian countries inflict heavy degree of economic losses, loss of lives; disruption of community development processes; evacuation and in some cases rehabilitation of communities; renewed investment in developmental processes to name a few. The strategies for flood risk management in South Asia has been in the form of; Flood prevention which reduces the risk of overbank capacity from being breached; Flood abatement by reducing storm flow and peak discharge rates and Societal responses whereby the communities develop strategies to cope and live with this hazard in areas of low recurrence interval and history of repeated flooding (Mriganka et al., 2012).

Various flood protection measures have been adopted in the region, which are mainly structural in nature. Construction of flood levees to reduce bank overflow, construction of dams to facilitate controlled flow of water downstream, check dams to reduce sediment discharge in the main course of the river, construction of spurs to train river flows, gabion walls and dykes to ensure aligned and directed flood water flows, bypass channels to relief main control structures from flood water pressure, effective flood discharge routing from dams etc. are some of the popular measures that have been around in the region for past century.

Some non-structural measures have also been adopted in the region for flood management. Afforestation or reforestation of the upper catchment areas is adopted by many countries to reduce surface run off. Terracing of the slopes and contour plantation are also attempted to meet this objective. One of the important non-structural measures adapted to a large extent is advance Flood Forecasting and Warning System (FFWS). The FFWS is a combination of rainfall runoff computer models, numerical models, weather surveillance radars, quantitative precipitation measurement radars, High Resolution Picture transmission system, High Frequency Radio transmission.

4.4. Flash Floods Mitigation Measures in EN

4.4.1. Introduction

The recurring floods and flash floods in EN basin countries inflict heavy degree of economic losses, loss of lives; disruption of community development processes; evacuation and in some cases rehabilitation of communities; renewed investment in developmental processes to name a few. The strategies for flood risk management in EN basin has been in the form of flood prevention which reduces the risk of overbank capacity from being breached; Flood abatement by reducing storm flow and peak discharge rates and societal responses whereby the communities develop strategies to cope and live with this hazard in areas of low recurrence interval and history of repeated flooding.

The existing flood control facilities in EN should be reviewed in the present flash floods risk perspective. The dominant trend of river management practices is only concentrated on the course of major rivers, high rainfall in tributary river and flash floods sites has been an area that not always received adequate focus. This effect needs to be kept in view while preparing flood management plans at state/ provincial/regional level. The land use plans should be based on intensive assessment of flood risk in the region and it would be a better idea to make the land use plans based on multi hazard risk assessment for sustainable use of economic resources for development. The infrastructure and plans in major cities should be reviewed at regular intervals and should be designed to make room for improvements in future.

Some non-structural measures have also been adopted in the EN region for flood management in riverine system and flash floods prone areas. One of the important non-structural measures adapted to a large extent is advance flood forecasting and warning system. Two recent projects supported by ENTRO has developed a hydrologic model (using HEC-HMS) for the entire Blue Nile catchment, including the portions of the basin in Ethiopia, and a hydraulic model (using HEC-RAS) for the Blue Nile from El Diem to Khartoum. The system is a combination of rainfall runoff computer models, numerical models, satellite rainfall products, quantitative precipitation measurement by virtue of which rain and flood forecasting & warning is issued by mandated national agencies to facilitate evacuation of people from low lying areas likely to be flooded.

Recently, ENTRO developed flood risk maps,for different return periods, for some flood sites as one of non-structural measures to mitigate flood consequences. Flood risk maps is highly recommended to be developed in whole EN region, it will to some degree be used as a planning tool for future flood protection from flash flood hazards.

4.4.2. Egypt

Various flood protection measures have been adopted in Egypt, which are mainly structural in nature. Construction of flood levees to reduce bank overflow, construction of dams to facilitate controlled flow of water downstream, construction of spurs to train river flows, gabion walls and dykes to ensure aligned and directed flood water flows (Kantouch et. al., 2020) etc. are some of the measures that have been used in Egypt.

The Nile Forecast Center (NFC) is responsible for issuing warning message for imminent riverine flood wave in the Nile. There is a large coverage of weather forecast all over the country but limited flash flood forecast system, which cover some tourist and UNESCO World Heritage Site (WHS) (El Quosy, 2020). One of the successful instance of non-structural measures of flash floods mitigation, Egypt developed an early warning system called Flash Flood Manager, acronym “FlaFloM. The “FlaFloM” was proposed by a project co-funded by the EU and Egypt in 2012. The FlaFloM was developed for forecasting flash floods in wadiWatier catchment, located in the Sinai Peninsula. It is the first of its kind in the Arab world and the entire Nile Basin (Cools et al., 2012). The system consists of a number of components, which are automatically activated and linked: a rainfall forecasting model (Weather Research and Forecast model), a hydrological model (custom-built to reflect arid region conditions), a hydraulic model (Info Works-RS) and a warning module (Flood Works). Though the wadi is not contributing to the Nile system, but still it is the only systematic flash flood early warning system in the region.

The Valley of the Kings (VOK), UWHsite, is one of the most vulnerable areas to flash floods in Egypt. Protection walls have built there to protect the tombs from frequent flooding of the VOK. Kantoush et al. (2020) have carried hydrological study for the assessment of protecting work of the tombs. They used TELEMAC-2D model and 50 and 100 years return period floods. They are more than 60 tombs scattered around the valley, it is difficult to protect all this number of tombs through structural measures. They used two criteria for ranking the tombs; cultural (number of publications about the tomb) and economical (number of visitors), accordingly, they selected two tombs for protection. Based on the results of hydrological modeling, they suggested heightening of the existing walls to protect the tombs from flash floods.

4.4.3. Ethiopia

Various flood protection measures have been adopted in Ethiopia, both structural as well non-structural measures have been practiced in Ethiopia. In most of the cases, structural flood mitigation measures are used as part of other multi-purpose water resources projects under the domain of the Ministry of Water Resources. In the Gambella plain, structural measures in the form of dikes have been recommended to protect the city of Gambella from flooding. The system composed of dikes, drains, pumps, and floodwalls.

Construction of flood levees to reduce bank overflow, construction of dams to facilitate controlled flow of water downstreametc. are some of the measures that have been used.

National Disaster Management Authority (NDMA) ensures timely preparedness and dissemination of related forecasts and warnings to district administration through provincial disaster management authorities' issues flood forecasts and warnings through a country-wide network of stations.

Flood Early Warning System models was developed for Lake Tanaarea as one of non-structural measures. These models were developed using HEC HMS, HEC RAS and WRF rainfall data as input. Combination of these tools produce flood forecast with 3 days' lead time. Recently, ENTRO developed flood risk maps around Lake Tana and some other floods sites as one of non-structural measures used for flash floods risk management.

4.4.4. South Sudan

Floods are a regular occurrence across the country, but last year's rainy season has been unusually heavy, bringing flash floods that have inundated whole towns (https://www.msf.org.uk/article/south-sudan-msf-assessing-emergency-needs-after-severe-flooding) . Most of the flash floods occurred in the low land and flood plain of the Baro-Akobo-Sobat (BAS), where structural mitigation measures are very expensive and not viable. Models for flood forecast and early warning were developed for BAS, the features of the models were based on the hydrological model developed in HEC-HMS software for rainfall runoff transformation and the hydraulic based USGS GIS flood tool for flood wave routing and inundation extend. The hydrology of the BAS model was based on HEC-HMS software and hydraulic was based USGS GIS flood Tool. The water elevation from the model is transpose to digital elevation model to find inundations extent for this basin area.

4.4.5. Sudan

Like any other ENB countries, Sudan frequently suffer from torrential flash floods from seasonal rivers and wadis (Bashar, et al., 2011; Abdo, 2015). Both structural and non-structural measures have been practiced in Sudan. Construction of flood levees to reduce bank overflow, construction of spurs to train river flows, gabion walls and dykes to ensure aligned and directed flood water flows (e.g. Gash river), construction of dams to facilitate controlled flow of water downstream (Khartoum wadis), diversion structures (e.g. Khor Abu Habil) etc. are some of the popular measures that have been around in the Sudan for past century. Figure 9 shows some of the existing and proposed earth dams across different wadis that flows towards Khartoum. The storage of the reservoirs is used for different purposes, like agriculture, fishery, recreation and reducing flood peaks

As a result of the frequent flooding in the Gash river, many researchers address the importance of developing FEWS for the Gash using different modeling environments (Abdo et al. 2008; Bashar et al., 2011; Giriraj, 2013; Rokaya, 2014). But the absence of reliable hydro-meteorological data is a common limitation among these studies. Recently, a flash flood early warning system was developed for Gash river

(Elhadi et al., 2018). Reliable discharge data were obtained for the calibration of the hydrologic model, which developed using HEC-HMS software. TRMM-3B42RT V7 data set after bias correction were use as input for the hydrologic model (Elhadi et al., 2019). The model simulates the rainfall-runoff process well, the simulated hydrograph very close to the observed one. The system operated in the last flood season 2019, using TRMM as well as GSMaP data sets, most of the time the peak rainfall reasonably coincides with the observed peak runoff, and reasonable lead time was obtained.

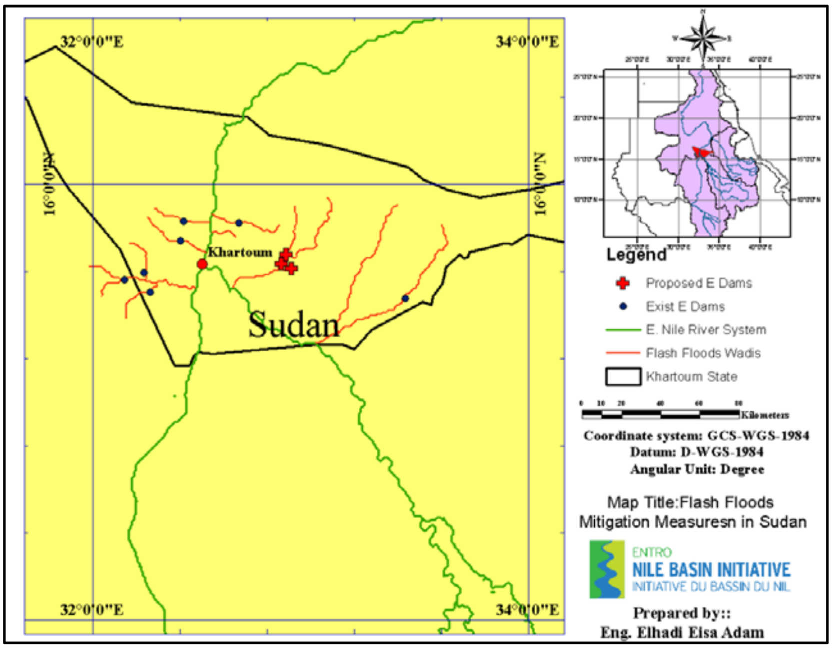

Figure 9: Example of different flood protection earth dams across wadis (Khartoum State).

4.5. Proposed Flash Floods Best-Management-Practices (BMPs)for EN

In the backdrop of increasingly alarming flash floods risk in the EN member states it is necessary to design new coping paradigm or modify the existing management and mitigation practices. The end point of this guide lines is to reduce the vulnerability of EN communities to flash floods disasters. From the lessons learnt regionally as well asworldwide practice, following are import hints to be implemented for best management practice in the region:

- Flash floods risk management should be an integral part of developmental plans in the region.
- Establishment of unit be responsible for flash floods management regionally or at national levels with clear mandate.
- Mapping and delineation of flash floods prone areas for different return period. (e.g. 50, 100 years etc.)
- Implementation of proactive measures (preparedness) will effectively reducethe response efforts.
- Integration of the indigenous practice in flood management and EWS in any future strategies.

- Encourage the investment in Disaster Risk Reduction (DRR), enhancing disaster preparedness for effective response, and to "building back better" in recovery, rehabilitation and reconstructions.
- Science and knowledge; which can be summarized as: increase awareness in disaster risk, data platforms, climate change and adaptation measures, etc.
- Involvement of stakeholders in all stages of management activities, and encourage community based disaster risk management.
- Strengthening disaster risk governance to manage disaster risk (e.g. councils).
- Local assistance, funding, and legislation; this includes, new and existing funding sources, Task Force (TF) recommendation priorities, outreach programs, National Flood Insurance Program Compliance Encouragement, establishment of advisory committee and interagency barriers.

Chapter 5: HYDRO-METEOROLOGICAL DATA

5.1. Introduction

Data and statistics are important in understanding the impacts and costs of disasters. Systematic disaster data collection and analysis can be used to inform policy decisions to help reduce disaster risks and build resilience. Novel statement given by Margareta Wahlström, United Nations Special Representative of the Secretary-General for Disaster Risk Reduction, 2019 “Access to information is critical to successful disaster risk management. You cannot manage what you cannot measure".

Flash flood forecasting is data-intensive and highly dependent upon the timely processing of a variety of information before and during flash flood events. Some types of data are available in real time through the internet and satellite downlinks. Most types of data, however, are collected using local sensors and communicated using regional wired and wireless infrastructure. Multiple-sensor networks are critical to thesuccess of an end-to-end system. The Most important data for flash floods management are rainfall and runoff.

It has been observed that Hydro-meteorological are well documented in the EN. Figure 10 shows rain gauge network in EN, at national level, National Meteorological Authorities are taking the responsibility of installing, maintaining and monitoring the network, while Ministries of Water Resources responsible for hydrological data.

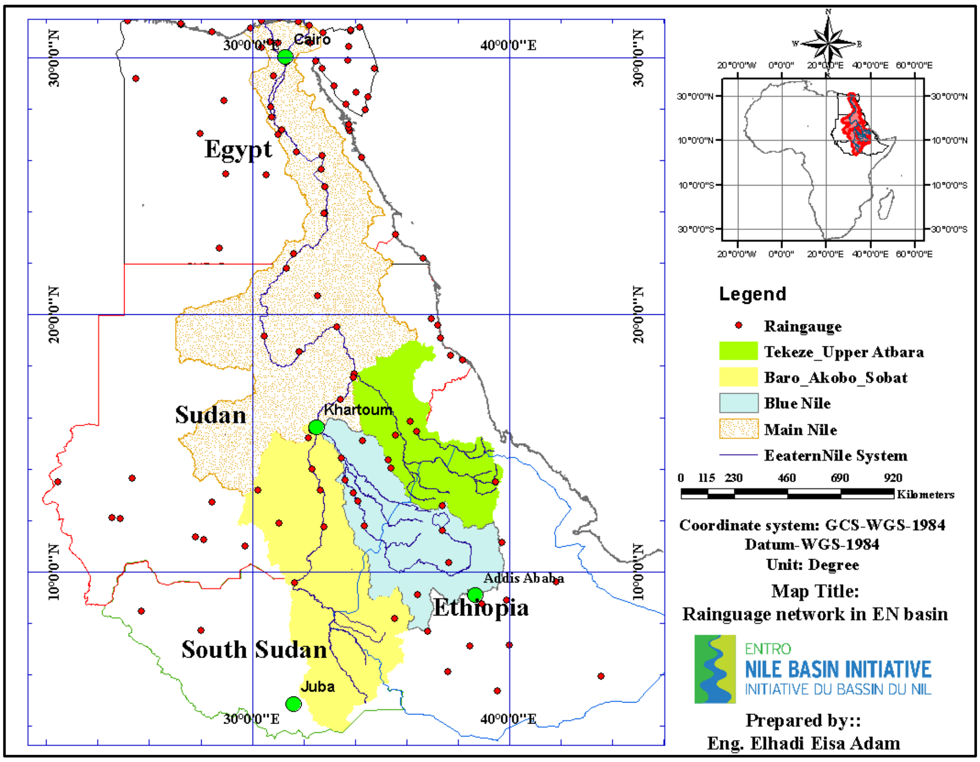

Figure 10: Rain gauge network in the EN basin (Source: WMO web site, https://oscar.wmo.int/surface/#/)

5.2. Egypt

5.2.1. Weather data

The Egyptian Meteorological Authority (EMA) operates the climatic stations which are distribution in the country. Many institutions benefit from the observations and forecasts made by the EMA such as the aviation industry, tourism industry, for the agriculture sector, for environmental protection, for estimation of lake Nasser evaporation losses and thereby aiding in the operation of the reservoir. EMA operates weather forecasting centers also.

5.2.2. Flow data

The river Nile is regulated by the HAD in Egypt and any downstream gauging on the main river measures the releases and spills. There are seasonal wadis that cause occasional flash floods damage. There are two classes of river gauging stations, those that measure river stage only and those that measure stage and discharge. There are river gauging stations at most of the control barrages downstream of the HAD.

5.3. Ethiopia.

5.3.1. Rainfall data

There are two rainy periods in Ethiopia, the ‘Belg’, which is for most part of the country the smaller rain period, and the ‘kiremt’, which is the main wet season (Abdulkarim, 2004). The National Meteorological Agency of Ethiopia (NMA) has setup wider coverage of meteorological stations nationwide. Various weather elements that routinely recorded at these stations enable the Agency to monitor day to day variation of weather as well as climatic fluctuations in long-term. Major portions of Ethiopia that prone to droughts as well as floods are not yet well covered with standard stations.

Rainfall in Ethiopia is highly influenced by altitude. The highlands generally receive more rainfall than the low lands. There are two rainy periods, the ‘Belg’, which is for most part of the country the smaller rain period, and the ‘kiremt’, which is the main wet season.

5.3.2. Flow data

The Hydrology Department, Ministry of Water Resources, operates the gauging stations in all the basins in the country. Most of these stations are equipped with staff gauges for daily measurement of river/lake levels. Overhead and bank-operated cableways are used for discharge measurement, which are then used for the development of rating curves. For most of the stations, flow data is compiled as average daily flow.

A few stations, may have continuous hydrographs resulting from Automatic Level Recorders (Abdulkarim, 2004).

5.4. Sudan

5.4.1 Rainfall data

In Sudan the existing precipitation network is part of the climatic network of the Sudanese Meteorological Authority (SMA). The SMA is responsible for installing and maintaining weather stations, for collecting, archiving, and disseminating meteorological data. “Other related institutions are installing rain gauge for certain job of function within framework of projects, sometimes these data sets are not part of the SMA network”, said officer in SMA. These stations are operated by fulltime staff of the SMA who report the measurements every three hours using radio communication and/or telephone lines. These modes of communication seem to work well for the daily use to which the data are made. Basic data collected include: daily rainfall, humidity, soil temperature, air temperature, etc. The observations are automated as telemetry systems but not cover the catchments of flash floods sites.

With support from IGAD Remote Sensing project, SMA forecasting unit build a forecast center. The center receives satellite imagery and rainfall estimation/forecasting from ICPAC and produces daily forecast. The system accessible to other institutions and stakeholder involved in FEWS, such as the MoIWR and can get data in the form of rainfall estimates, in real-time. This system could make a very good starting point for the forecasting component of the FFEW.

The gaps regarding Rainfall data

- There is a distinct gab in network coverage in the flash flood prone areas
- Necessary coordination with other related institutions that installed rain gauge for certain job or function and make data available for different users.

5.4.2 Flow data

Within the Nile system, hydrological data is collected and maintained by the Nile Waters Directorate of the Ministry of Irrigation and Water Resources. The hydrometric network consists of gauging stations (which can be stage-only measuring type or stage-and-discharge measuring ones). Stations are typically equipped with a stone or concrete staff gauge that is read manually by an observer. Some stations are equipped with radios so that the observer can report daily measurements to MoIWR in Khartoum. Discharge measurement equipment is maintained locallyat some sites and varies from current meters on bank operated cableways to current meters operated from boats or ADCP.

The gaps regarding hydrological gauges’ data

The major gab is in the monitoring of flash floods stream. There is a directorate in the MoIWR responsible for wadi “Grownd water and wadi directorate”, they have many gauging stations in the major wadis, but unfortunately currently most of them are not working.

5.5. Satellite Rainfall Estimates (SREs).

The global systematic decline of in situ networks for hydrologic measurements made the hydrologists today to realize that rainfall data from the vantage of space has the potential to become a cost-effective source of input for hydrological modeling and flood prediction in data scarce region.

In the last decades, there are trends towards trust in using real time SREs in hydrological modeling and operational flood forecasting & FEWS after the good performance which they have shown (Grime, 2003; Guleid, et al., 2002; Ledesma and Futter, 2017; Hossain et al., 2007; Li et al., 2009). Satellite rainfall products are available from near-real time (hourly) to monthly average for different spatial resolution (grid cells).

The advances in remote sense added more advantages to rainfall observation, meteorological satellites expand the coverage and time span of conventional ground based rainfall data for a number of applications. In the regions of poor coverage of rain gauge network or areas with scarcity of ground rainfall data, the SREs is the best alternative and supplement to the ground-based observations in order to implement a cost-effective flood prediction (Li et al., 2009; Ledesma and Futter, 2017). There are three main data sources for SREs; geostationary thermal infrared (TIR), Passive Microwave (PMW), and rain gauges (Thiemig et al., 2013). The primary scope of satellite rainfall monitoring is to provide information on rainfall occurrence, amount and distribution over the globe for meteorological applications at all scales.

SREs and RADAR rainfall are becoming an alternative to ground rainfall observations in poor coverage regions. The main advantage of these SREs is that they overcome data shortages due to low density of installed rain gauges, and discontinuities and lack of immediate access to data due to political boundaries that divide trans-boundary catchments. Although satellite rainfall data offers an effective and economical method for observing rainfall rates and amounts over large areas, the use of satellite rainfall data in hydrologic studies and FEWS remains limited because of the uncertainty associated with SREs (Theming, 2013). Systematic bias might introduce unwanted uncertainties in the results of hydrological applications which may lead to wrong results, which could subsequently result in devastating consequences in the case of flood forecasting. That is why validation of the SRE is required before use. The use of rainfall RADAR is highly recommended in the region, it will enhance the monitoring system and can provide accurate and continuous coverage.

5.6. Study and Validationof SREs in the Region

Many researchers studied different SREs data set over the EN; In study carried by Dinku et al., (2007) to validate different SREs data sets (CMORPH, CPC, GSMaP, PERCIANN & TRMM-3B42)using ground monthly data over East Africa (Ethiopia). However, the SREswere over estimating the rainfall but it looks relatively good for application.

Other researchers studied SREs data sets (CMORPH & TMPA) over the Nile Basin (Haile et al., 2013; Habib et al, 2013; Habib et al, 2014; Theming, 2013), the products after bias correction found to be good assets for hydrological modeling. One of the important point that they have mentioned, SREs were sensitive to topography. Elhadi et al., (2019) validatedTRMM-3B42RT V7over Gash basin, the bias computed for monthly data then the obtained values were used to correct daily data because daily observed data are not available.

However, these products cannot be used confidently without calibration; ground rainfall or observed hydrograph can be used for calibration of SRE (Artan et al., 2007; Habib et al., 2014).

SREs were contaminated, the products should be evaluated against ground observation prior uses for any hydrological studies (Hughes, 2006; li et al., 2009; Vernimmen et al, 2012; Theming, 2013). Generally, there are two approaches for validation of satellite rainfall namely; ground truthing and Hydrological modelling. The former is to compare the SREs data set directly to ground observation, and the later based on the ability of SREs to reproduce the outflow hydrograph at the basin outlet (Nguyen, 2015).

The statistical tests of error functions can be used to evaluate the performance of the satellite rainfall data. Many statistics are available like; Nash-Sutcliffe Efficiency (NSE), Root Mean Square Error (RMSE) and coefficient of determination (R^2). There are three methods to compare SREs to ground rainfall observations namely; point-grid, grid-grid and areal-average.

5.7. Weather Forecast Models Used by ENTRO

Forecasted rainfall in the Upper Blue Nile and BAS in Ethiopia, as well as over other catchments in EN basin were done using Operational Numerical Weather Prediction Models. Currently a regional numerical weather prediction model from Weather Research and Forecasting model (WRF) is used by ENTRO, which gives 3-day ahead forecasted rainfall.However, the use of forecasted rainfall can increase the lead time noticeably for flash floods forecast and early warning system.

Recently in 2020, ENTRO has developed a regional rainfall forecast model with in the "***Flood Forecasting and Early Warning Enhancement Project"***using Weather Research and Forecasting model (WRF).This developed model is very important for the flash flood early warning system for the EN, it will providethe necessary input near real time QPEs.As we have seen from the literature review WRF model is very important for both; local and regional flash floods forecasting system.

Fortunately, tools to acquire and process the GFS 25km rainfall forecast data were developed within the above mentioned project. Tools for acquisition and analysis of TAMSAT, CHIPRS, CMORPH, ARC2, RFE2 and GsMAP rainfall estimates were developed for the EN to provide near real time QPEs.The data is downloaded in its native, then processed for the Eastern Nile region at hourly intervals, this will add more to the forecasting capability of the flash floods forecasting system

Chapter 6: FLOOD EARLY WARNING SYSTEMS IN EN

6.1. Early Warning System

Early Warning System (EWS) can be defined as a system of data collection to monitor hazards in order to provide timely notice when a crisis threaten to elicit an appropriate response (NOAA, 2010). It can also be defined as the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threated by a hazard to prepare and to act appropriately and in a sufficient time to reduce the possibility of harm or loss. Determining the need to warn, even need issuing an accurate and timely warning, is not the end goal of an early warning system. The ultimate goal is to save life and property.

6.2. Elements of Early Warning Systems

There is general agreement on the structure of people centered early warning systems; namely, risk knowledge, monitoring and warning service, dissemination and communication, and response capability. Since the concept was introduced the capacity to provide tailored information to individuals has increased along with an ever expanding access to mobile technology. Thus it is now possible to be increasingly specific about warnings to individuals at risk, increasing the importance of the concept of people centric warning systems. It also means that individuals need to be more aware of their risks and the warning systems must increasingly support forecasts of impacts so that those at risk can fully understand the consequences and actions that need to be taken.

6.2.1. Risk knowledge

Risks arise from the combination of hazards and vulnerabilities at a particular location. Identification and assessments of risk require systematic collection and analysis of data and should consider the dynamic nature of hazards and vulnerabilities that arise from processes such as urbanization, rural land-use change, environmental degradation and climate change. Risk assessments and maps help to motivate people, prioritize early warning system needs and guide preparations for disaster prevention and responses.

6.2.2. Monitoring and warning services

Warning services lie at the core of the system. There must be a sound scientific basis for predicting and forecasting hazards and reliable forecasting and warning systems that operate 24 hours a day. Continuous monitoring of hazard parameters and precursors is essential to generate accurate warnings in a timely fashion. Warning services for different hazards should be coordinated where possible to gain the benefit of shared institutional, procedural and communication networks. This can be achieved through a multi-hazard early warning system that coordinates and integrates the needs of different stakeholders.

The impact of heavy precipitation, for example, will vary over a catchment area depending on many factors that contribute to the vulnerability of people. Some will have little risk others may be in life-threatening situations. It is very important to make sure that those at risk are properly informed and actions are taken to protect them. Targeting those at risk also creates a more effective response and reduces the risk of warning fatigue and false alarms.

6.2.3. Dissemination and communication

Warnings must reach those at risk. Clear messages containing simple, useful information are critical to enable proper responses that will help safeguard lives and livelihoods. Regional, national and community level communication systems must be pre-identified and appropriate authoritative voices established. The use of multiple communication channels is necessary to ensure as many people as possible are warned, to avoid failure of any one channel, and to reinforce the warning message.

6.2.4. Response capability

It is essential that communities understand their risks; respect the warning service and know how to react. Education and preparedness programs play a key role. It is also essential that disaster management plans are in place, well-practiced and tested. The community should be well informed on options for safe behavior, available escape routes, and how best to avoid damage and loss to property.

6.3. Current PracticedFlood EWSin EN

There is no unified operational flood forecasting system for the whole Eastern Nile basin. Current Flood Forecast and Early Warning activities does not cover the entire Eastern Nile. Models have been developed for upstream of Lake Tana basin, Upper Blue Nile (U/S El diem) and Baro Akobo Sobat (BAS).One of the gabs of this available forecasting tools is lacking of flash flood forecast as presented by many studies conducted by ENTRO.

Reliable, real-time flash floods forecasting on a time scale of hours or even part of hours can provide enormous humanitarian and economic benefits. The catastrophic loss of life and property brought about by flooding can be greatly reduced by timely warnings. Effective FEWS should include detecting and forecasting flood hazards and developing warning messages. The warning messages should be disseminated at sufficient lead time and in understandable language to authorities and at-risk public. This will help to prepare a community-based emergency planning so as to reduce potential impact on lives, livelihood, and socioeconomic aspects. Such type of flash flood early warning system is absent in the entire EN basin. There were few instance of flood forecast.

6.3.1. Egypt experience in flood EWS

Real-time forecasting of inflows into the High Aswan Dam (HAD) is made by Nile Forecast Center (NFC), where statistical techniques are used which relate flow at a number upstream gauging stations in the Sudan to those at the entrance to the lake.

6.3.1.1. The Nile Forecast Center (NFC)

It is a more sophisticated and well-equipped forecasting center within the planning sector of Ministry of Water Resources and Irrigation (MWRI) of Egypt, which is responsible for monitoring, forecasting and simulation of the Nile flow with special mandate of forecasting the flows into HAD. NFC started operation in 1990 with the following main objectives(El Quosy, 2020).

- ✓ To provide a routine forecast of inflow into lake Nasser, which will be used for planning reservoir operation activities.
- ✓ To bring the various forecasting activities in earlier times under one roof, where both meteorological as well as hydrological forecasts are made.
- ✓ To enhance the capacity of the ministry in flow simulation and forecasting activities

Other Institutions are collaborating in flood mitigation and planning activities through a permanent committee that is composed of Nile water sector, planning sector, irrigation sector, research institutions, HAD authority, and others. The mandate of this committee is to set policy and take decisions about flood management, lake level and water allocation.The NFC is a multidisciplinary center, with good representation of meteorology, hydrology, hydraulic engineering, and information technology.

6.3.1.2. The Nile Forecast System (NFS)

The NFS is a system of hardware and software (including system of models) that are used to forecast rainfall as well as inflow into the HAD in real-time, in short- to medium- term and seasonally. Major limitations in the estimation of rainfall from satellite imagery arise due to the small number of rain gauge stations in Ethiopian highlands that report to the GTS and, thus, become available to the NFC. The primary purpose of the forecasts made by the NFC is for planning the management of the High Aswan Dam.

The commissioning of the high Aswan dam (HAD) has changed the flow regimes of the Nile river in Egypt significantly. Obviously the regulation of the flow and thereby the damping out of the fluctuations in the flow rates between the seasons is the main positive impact of the dam. Real-time forecasting of inflows into the HAD is made by the Nile Water Sector, where statistical techniques are used which relate flow at a number upstream gauging stations in the Sudan to those at the entrance to the lake. There is a more sophisticated and well-equipped forecasting center within the planning sector of MWRI, which is responsible for monitoring, forecasting and simulation of the Nile flow with special mandate of forecasting the flows into High Aswan Dam (HAD). Other Institutions are collaborating in flood mitigation and planning activities through a permanent committee that is composed of Nile water sector, planning sector, irrigation sector, research institutions, HAD authority, and others. The mandate of this committee is to set policy and take decisions about flood management, lake level and water allocation.

6.3.1.3. Stream flow forecasts:

Forecasts/predictions are made with various lead times:

- Real time forecasting of runoff: this is made using the real time estimation of rainfall. The real time satellite images, which are input to the rainfall estimation over the Ethiopian highlands are the ones taken from previous day. Data from about 6 climatic stations in Ethiopia, which are part of the GTS, are also used to calibrate the estimate. Flows estimated using the water-balance models at the NFC could be compared with the actual observations. The most upstream hydrometric station for which the NFC can get flow data is the Eddeim station on Blue Nile close to the Ethio-Sudanese border. By forecasting the flow at Eddeim, the gain in lead-time is estimated to be about two days.
- Short-term forecast of rainfall: forecast of rainfall for a period of up to three days ahead. The forecasts are used, mainly, as qualitative indications of rainfall patterns in forecast periods and no quantitative conclusions are drawn from them
- Seasonal forecasts: these are forecasts for up to 9 months ahead, of inflow into lake Nasser. Forecasts are updated (improved) every 10 days as actual observed flow data become for stations upstream of the lake.

6.3.2. Ethiopian experience in flood EWS

From the available literature operational flash forecast system is not exist in Ethiopia.The National Disaster Risk Reduction and Management Council (NDRMC) of Ethiopia led multi-sector National Flood Task Force issued flood alert based on the National Meteorology Agency (NMA). The system issuesfirst alert at the beginning of rainy season (April) for specific regions (Teshome, 2020). Subsequently, by the end of May, the National Flood Task Force updated and issued a second Flood Alert based on the monthly NMA weather update for the month of May when there is indication of a geographic shift in rainfall from the southeastern parts of Ethiopia (Somali region) towards the western, central and some parts of northern Ethiopia. The Flood Alert has therefore been revised to provide updated information on the probable weather condition and identify areas likely to be affected in the country to prompt timely mitigation, preparedness and response measures. The Alert updated regularly based on revisions in the NMA forecast and changes in the situation on the ground.

6.3.2.1. Flood forecast warning and communication

There is no systematic real-time flood forecasting system in Ethiopia, which can be used in the overall management of flood disasters. Seasonal and short-term forecasts of rainfall by the NM A are frequently used to issue warning regarding likelihood of flooding. These warning messages are issued through the national radio and are often not in the form that could be used for planning emergency response activities. Below are outlined the forecasting activities of the NMA:

- Now casting weather forecast: up to twelve hours (upon request)
- Short-range weather forecast: 1-3 days
- Medium-range weather forecast: up to ten days
- Long-range climate prediction: from one month-four months (one season lead time)

6.3.2.2. Major gaps in Flood EWS in Ethiopia

- The existing early warning system does not facilitate effective co-ordination between stakeholders. Data sharing and collaboration between institutions, ministries and ENTRO is not institutionalized.
- Major limitation of the flood alert system issued by NDRMC it is too general, which does not indicate a particular area that could be affected by the flood.
- Flood early warning is not issued on flash floods.
- The warning practice does not encourage the participation of the public and non-governmental organizations.
- The emphasis of the EWSs is response rather that preventive actions.

6.3.3. South Sudan experience in flood EWS

A flood forecast models were built for the Baro-Akobo-Sobat (BAS).The features of the models were based on the well-known quasi-distributed hydrological model developed in HMS software and the hydraulic based USGS GIS flood Tool. In the development of BAS flood forecast model forGambella and Sobat Floodplains, the anticipated relative peak runoff during the forecast period were used as input to the hydrodynamic model component that was developed for Gambella Floodplain and the Sobat areas. Hence, verification was done with mean daily gauge readings from Gambella and Itang Stations. Alternatively, Global Flood Tool from USGS was used to model the inundation patterns for different depths of the rivers(Abdulkarim, 2004).

6.3.4. Sudanexperience in flood EWS

In Sudan there is a systematic arrangement for flood forecasting, warning communication, and emergency response. As a result of the severe flooding during August 1988 along the River Nile plain in Sudan, the Ministry of Irrigation and Water Resources (MoIWR), of the Sudan, installed a Flood Early Warning System (FEWS) at the Nile River system in 1991. The "FEWS-Sudan" model is used to enable more advanced warning for future floods from the Nile (Saghayroon& Adam, 1996; Abdo and Ahmed, 2008) The objective of the project is to discuss the main concept of the modeling systems required for the "FEWS-Sudan". The system, "FEWS-Sudan",in operation since 1992 and stopped some years later then reinstalled in year 2010 by Deltares of Netherlands and the Hydraulic Research Center (HRC) of the MoIWR of the Sudan (Verkade & Werner, 2010).The system, FEWS_Sudan, is still working but it was influenced by the construction of GERD and Heightening of the Roseirse dam besides absent of observed rainfall from Ethiopia Plateau.

6.3.4.1. Flood forecast warning and communication

- Real-time flood forecasting is made at the forecasting unit at the Nile Water Directorate, Ministry of Irrigation and Water Resources. The forecasts are disseminated to beneficiaries through diverse media, telephone, through radio and the TV. Flood levels at different damage sites have been divided into zones: ALERT, CRITICAL, and FLOODING. The threshold stage for each level is determined based on the elevation of the riverbank at the point of interest, which are usually the flood damage centers.
- Short-term forecast of rainfall: forecast of rainfall for a period of up to three days ahead. The forecasts are used, mainly, as qualitative indications of rainfall patterns in forecast periods and no quantitative conclusions are drawn from them
- Seasonal forecasts: these are forecasts for up to 6 months ahead, of inflow at the Blue Nile and tributaries. Forecasts are updated every 10 days as actual observed flow data become for stations upstream of the lake. This forecast is normally used for planning.

6.3.4.2. Major gaps in Flood EWS in Sudan

- The flood EWS covers only River Nile and major tributaries, flash floods areas are not covered
- All the catchments outside Sudanese borders, there is a problem in data sharing.
- Inadequate observation, monitoring and forecasting systems in highly vulnerable/risky areas,
- Upgrading of forecasting procedures to ensure effective use of local and regional products, and systematic forecast verification.
- Data collection and communications are manual, real-time data are not available for both river and rain gauges.

- Inadequate forecasting frequency (one per day) and coverage and sustainability of monitoring system.

Chapter 7: GUIDE LINES FOR EEFECTIVE FLASH FLOODS EWS FOR EN

7.1. Introduction

There is a growing interest in the establishment of effective flash FEWS in EN. Up to now, no comprehensive guideline on how to establish and run such a system in the EN context. Flash floods have a different character than river floods, notably short time scales and occurring in small spatial scales. Forecasting of flash flood is quite a different and complicated challenge than traditional flood forecasting approaches. In forecasting of flash floods, we are concerned foremost with the forecast of occurrence of heavy rainfall in short duration. Warning systems related to river flooding have a longer lead time than those for flash floods events, which may have very short warning periods.

There is no single solution to the problems of warning systems for flash floods. Flash floods are site specific and each problem area must be evaluated by competent personnel who can decide which of the available methods is most appropriate. Generally speaking, the greatest benefit will come from adequate technical advice and community preparedness in advance of floods and the establishment of the appropriate flash flood warning system. In every case, the local community must be closely involved in the effective use of community action plans that guide the emergency measures required by the local situation. The importance of the advanced preparation cannot be over-emphasized, because the time scale of the flash flood is too short to permit the development of an action plan, deployment of equipment, and establishment of communication channels after the flood threat becomes evident.

Generally, no matter which measures are used in the system, advanced or retrograde, complicated or simple, automatic or manual, it must transmit the flash flood messages immediately and accurately to the flood prevention administrations, community and people under risk in advance, so that there is enough time to make efficient preparations and plans to evacuate from the flood plain to nearby highlands or some other safe place. In this way, flash flood consequences can be minimized and flash flood prevention benefit maximized.

7.2. Flash Floods EWS Practice

7.2.1. Worldwide experience in flash floods EWS

Flash floods causes annually an average of 5,000 deaths and inflict heavy economical losses worldwide, exceeding any other flood-related event. They have enough power to change the course of rivers, bury houses in mud, and sweep away or destroy whatever is on their path. They are among the world's deadliest disasters and result in significant social, economic and environmental impacts. Accounting for approximately 85% of the flooding cases, flash floods also have the highest mortality rate (Joost et al., 2014, WMO, 2019).

As the global population increases, especially in urban areas, and societies continue to encroach upon floodplains, the need for flash flood early warning systems becomes more paramount. In response to this need, the World Meteorological Organization, the U.S. National Weather Service, the Office of U.S. Foreign Disaster Assistance, and the Hydrologic Research Center formed a partnership in 2007 to develop and implement an early warning flash flood forecasting system (Flash Flood Guidance System – FFGS) for global application (WMO, 2019).

7.2.1.1. Flash Flood Guidance System (FFGS)

The Flash Flood Guidance System (or shortly – FFGS) is a forecaster's tool designed to provide hydrological and meteorological forecasters with readily and accessible quality controlled precipitation estimates from weather radars and satellites, precipitation measurements (rain gauges), forecast data from Numerical Weather Prediction models, and other information to produce timely and accurate flash flood warnings worldwide (WMO, 2019).

Flash Flood Guidance System with global coverage enhances early warning capabilities of the National Meteorological and Hydrological Services (NMHSs). Currently over 3 billion people in 67 countries are being provided early warnings of potential flash flooding through their NMHSs working in concert with their National Disaster Management Agencies. FFGS systems have been implemented for multi-country regions around the world as shown in the following map (Figure 11). The general implementation approach is designed to support capacity building in the regions and aims at the reduction of flash flood hazard impacts to life.

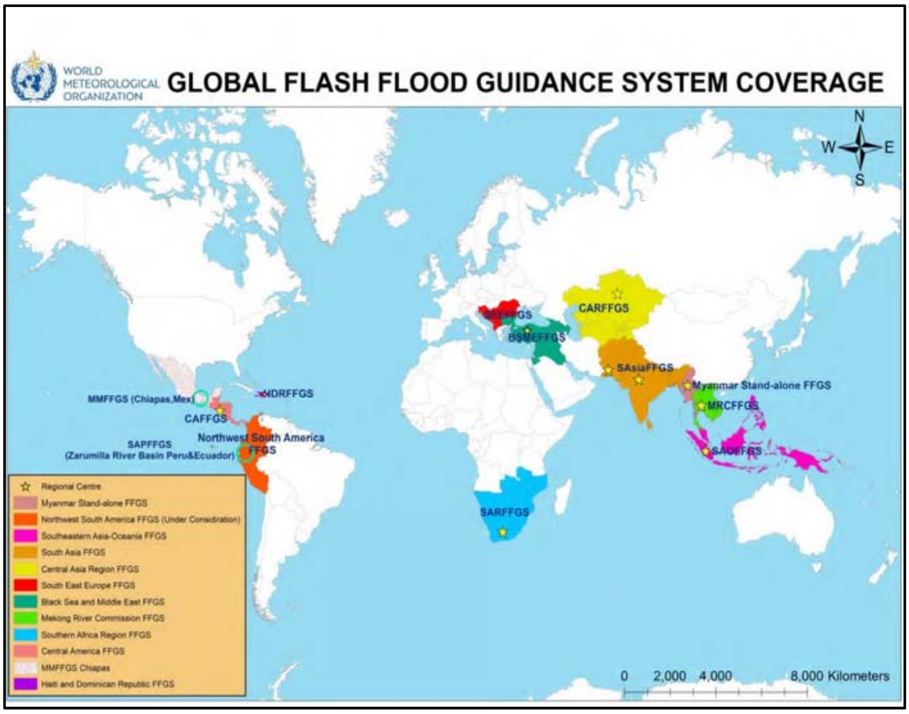

Figure 11: Flash Flood Guidance System (FFGS) with Global Coverage (WMO web site)

The main objectives of the FFGS are:

- Enhance NMHSs capacity to issue flash flood warnings and alerts;
- Mitigate adverse impacts of hydro-meteorological hazards;
- Enhance collaborations between NMHSs and Emergency Management Agencies;
- Generate flash flood early warning products by using state-of-the-art hydro-meteorological forecasting models;
- Provide extensive training including on-line training to the hydro-meteorological forecasters;
- Foster regional developments and collaborations; and
- Support WMO Flood Forecasting Initiative.
- Encourage transboundary collaboration.
- Improve community awareness of flash flood disasters to permit action

The primary purpose of the FFGS is to provide operational forecasters and disaster management agencies with real-time informational guidance products pertaining to the threat of small-scale flash flooding throughout a specified region (e.g., country or portion of a country, several countries combined). The FFGS provides the necessary products to support the development of warnings for flash floods from rainfall events through the use of remote-sensed precipitation (e.g., radar and satellite-based rainfall estimates) and hydrologic models. The system supports evaluations of the threat of flash flooding over hourly to six-hourly time scales for stream basins that range in size from 25 to 200 km^2 in size.

The FFGS outputs are made available to users to support their analysis of weather-related events that can initiate flash floods (e.g., heavy rainfall, rainfall on saturated soils) and then to make a rapid evaluation of the potential for a flash flood at a location. To assess the threat of a local flash flood, the FFGS is designed to allow product adjustments based on the forecaster's experience with local conditions, incorporation of other information (e.g., numerical weather prediction output) and any last minute local observations (e.g., non-traditional rain gauge data) or local observer reports. Important technical elements of the flash flood guidance system are the development and use of a bias-corrected radar and/or satellite precipitation estimate field and the use of land-surface hydrologic modeling.

The system provides information on rainfall and hydrologic response, the two important factors in determining the potential for a flash flood. The system is based on the concept of *flash flood guidance* and *flash flood threat*. Both indices provide the user with the information needed to evaluate the potential for a flash flood, including assessing the uncertainty associated with the data.

- ***Flash Flood Guidance***is the amount of rainfall of a given duration over a small stream basin needed to create minor flooding (bank full) conditions at the outlet of the stream basin. For flash flood occurrence, durations up to six hours are evaluated and the stream basin areas are of such a size to allow reasonably accurate precipitation estimates from remotely sensed data and in-situ data. Flash flood guidance then is an index that indicates how much rainfall is needed to overcome soil and channel storage capacities and to cause minimal flooding in a basin.

- ***Flash Flood Threat*** is the amount of rainfall of a given duration in excess of the corresponding Flash Flood Guidance value. The flash flood threat when used with existing or forecast rainfall then is an index that provides an indication of areas where flooding is imminent or occurring and where immediate action is or will be shortly needed.

FFGS Major Components

- Meteorological components which comprises of two major components of Weather Research Forecast (WRF) model for grid based prediction through numerical schemes and multi-parametric synoptic weather monitoring for overall probability of rainfall in particular region.
- The hydrological component comprises of a hybrid approach of lumped grey box model known a rational model in combination with a quasi-distributed hydrological model known as the HEC-HMS in Arc GIS platform. While the first approach provides the forecast for the peak value for the river basin, the distributed model provides the forecast for the daily hydrograph for that basin. Comparing both the forecast with the established flooding thresholds for that river, issue of flood waring is decided.
- The third component is the post flooding identification of embankment breaches and general monitoring of embankment. Figure 12 below shows the flow chart and component of the FFGS.

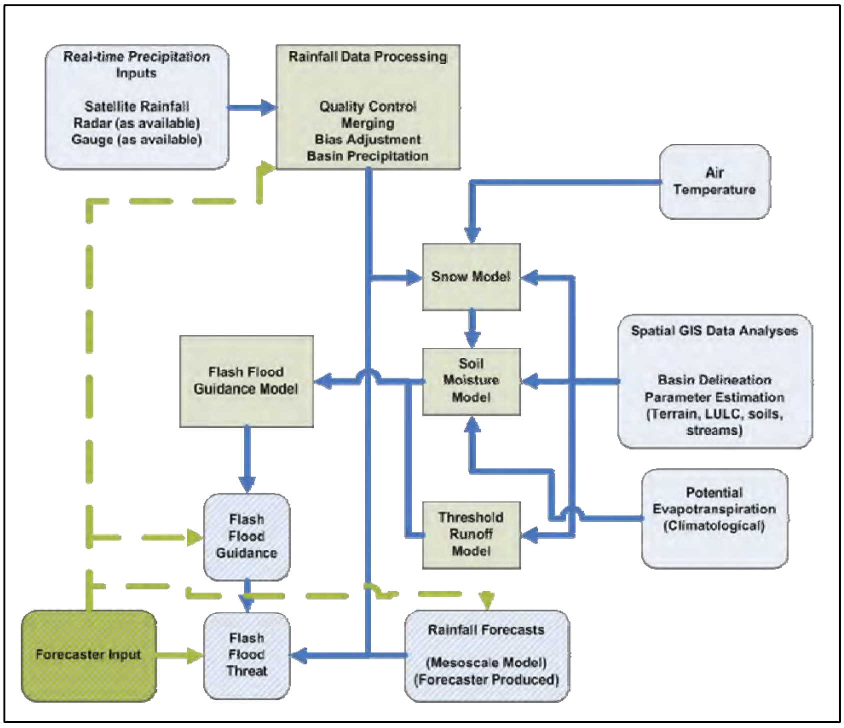

Figure 12: Schematic Flow Chart of the Flash Flood Guidance System (Source: WMO, 2018).

WMO's FFGS seeks to strengthen the capabilities of National Meteorological and Hydrological Services (NMHSs) to issue timely and accurate flash flood warnings and to integrate these in their operational activities. It also seeks to foster coordination between NMHSs and disaster management authorities (DMAs). Figure 13show the implementation of the FFGS at regional/global scale.

The Flash Flood Guidance System is an efficacious means of reducing the loss of lives and property, over the past decade has led to a significant reduction in the loss of life and property in those countries where it is being used. By the end of 2019, WMO has produced an animation explaining the challenges of flash floods and the benefits of the Flash Flood Guidance System as an important disaster management tool to save lives and decreasing economic losses. This is now available in Arabic, French, Spanish and Russian (WMO, 2019).

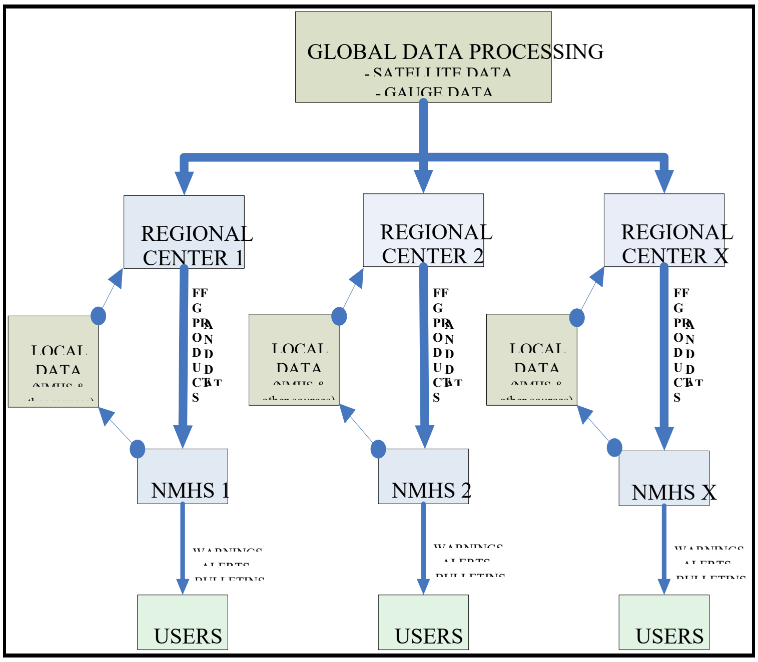

Figure 13:FFG System Schematic – Global Implementation (Source: WMO, 2018).

FFGS Forecaster Products

The types of products available to forecaster vary by FFGS based on needs and requirements. The types of products available to a forecaster through the interface of the FFGS include the following:

- ✓ RADAR Precipitation – Radar-based precipitation estimates
- ✓ MWGHE Precipitation – Satellite-based precipitation estimates
- ✓ GHE Precipitation – U.S. NOAA-NESDIS Global Hydro Estimator SATELLITE Precipitation estimates
- ✓ Gauge MAP – Gauge-based mean areal precipitation (MAP) for stream basin areas
- ✓ Merged MAP – Merged mean areal precipitation for stream basin areas.
- ✓ ASM – Average soil moisture (model-based)
- ✓ FFG – Flash flood guidance
- ✓ IFFT – Imminent flash flood threat (a current “observation” of flash flood threat)
- ✓ PFFT – Persistence flash flood threat.
- ✓ ALADIN forecast – Quantitative precipitation forecast
- ✓ FMAP – Forecast mean areal precipitation for stream basin areas (using mesoscale model rainfall forecasts)
- ✓ FFFT – Forecast flash flood threat (using mesoscale model rainfall forecasts)
- ✓ Gauge MAT – Gauge-based mean areal temperature for stream basin areas
- ✓ Latest IMS SCA – Fraction of stream basin area snow cover (from U.S. NOAA-NESDIS)

- ✓ SWE – Model-based snow water equivalent for stream basin areas (reflects the state of the snowpack)
- ✓ Melt – Snow melt (cumulative melt over the period of 24–96 hours for each stream basin area)
- ✓ Surf Met gauge stations – surface meteorological stations available.

7.2.1.2. Korean Experience in Flash Floods Early Warning System

Korea Flash Flood Guidance (KoFFG) has developed over Han River basin. KoFFG consider all components of FFGS mentioned in previous paragraph and schematized in figures 12&13 (Threshold runoff, soil moisture accounting and radar rainfall estimates) and composed of Regional Data Assimilation and Prediction System (RDAPS) to forecast a flash flood warning and watching.

Azama et al., (2017) developed flash flood early warning system for Mushim river in Korea. The system is developed to inform people about ongoing and upcoming flash flood events to avoid the loss of life and property. Hardware and software based smart technology is used to develop an early flood warning system for Mushim stream watershed to send to end users early flood warning messages about potentially impacted areas. Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) is the core of flood alert application provides the forecast with sufficient lead time and decides the threshold conditions of runoff/stage. Short range weather forecasts from Korea Meteorological Administration (KMA) at every three hours' interval, are stored in hydro-meteorological database and fed in HEC-HMS for identification of flood risks. Server-Client based program used to visualize the real time flood condition and to deliver the early warning message. Flood hazard maps thus developed which can be used by policy-makers and responsible authorities, as well as to local residents in finding suitable measures for reducing flood risk in the study area.

7.2.1.3. Thailand Experience in Floods Early Warning System

Sunkpho (2011), developed a real-time flood monitoring and warning system for a selected area of the southern part of Thailand. The system developed to monitoring water conditions: water level; flow; and precipitation level, in Nakhon Si Thammarat, a southern province in Thailand. The developed system is composed of three major components: sensor network, processing/transmission unit, and database/ application server. These real-time data of water condition can be monitored remotely by utilizing wireless sensors network that utilizes the mobile General Packet Radio Service (GPRS) communication in order to transmit measured data to the application server. The application server is a web-based system implemented using PHP and JAVA as the web application and MySQL as its relational database. Users can view real-time water condition as well as the forecasting of the water condition directly from the web via web browser or via WAP. The developed system has demonstrated the applicability of today's sensors in wirelessly monitor real-time water conditions.

7.2.2. Flash Floods EWS in the EN

7.2.2.1. Egypt Experience in Flash Floods Early Warning System

WadiWatier Flash Floods Manager (FlaFloM)

An early warning system for flash floods has been developed for WadiWatier in Sinai Peninsula, Egypt (figure 14). The Flash Flood Manager (FlaFloM) developed within a framework of joint project co-funded by the EU under the LIFE Third Countries Fund (Cools et al., 2012). The system is aimed at developing an early warning system for forecasting flash floods in the WadiWatier catchment. The system consists of a number of components, which are automatically activated and linked: a rainfall forecasting model (Weather Research and Forecast model), a hydrological model (custom-built to reflect arid region conditions), a hydraulic model (InfoWorks-RS) and a warning module (FloodWorks).

WadiWatier is one of the most active wadis in Sinai with respect to flash floods. The Wadi is a hyper-arid catchment with an area of 3580 km^2. The EWS is automated one, which designed to deliver forecasts in less than 15min and forecasts 24h in advance. Considering that the required lead time for an effective response is about 2h, the system meets the lead time requirements. Rainfall forecasts are produced by means of the Weather Research and Forecasting model (WRF). Every day, a rainfall forecast for the next 48 hours is prepared.

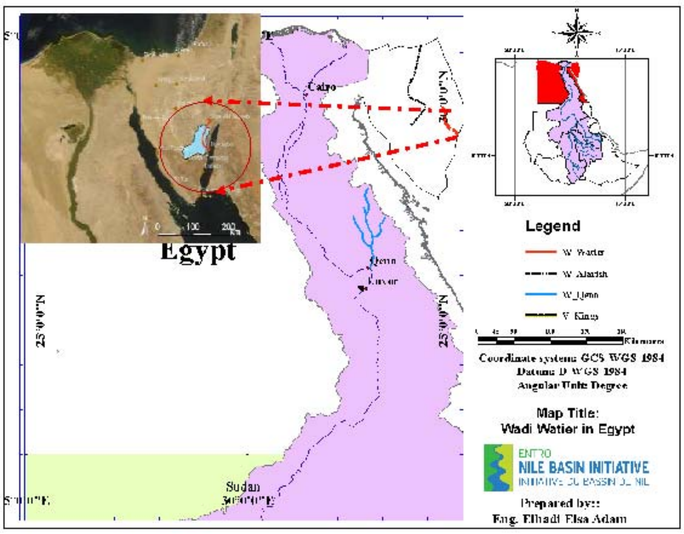

Figure 14: Location Map of WadiWatier, Egypt

The EWS automatically activates and links all the components in real time, whenever a new rainfall forecast is submitted. The results from the models and the warnings issued by the warning module can be viewed by means of a flexible and user-friendly graphical user interface (GUI). This GUI was constructed by means of the software package “FloodWorks”, figure 15 below shows the early warning system components (Cools et al., 2012). The system is capable of gathering data, generating forecasts, displaying visual warnings or alerts on the GUI, sending e-mails to a pre-defined address list and generating reports.

The EWS issues warnings whenever pre-defined thresholds are exceeded. Thresholds can be defined for rainfall, runoff, water level, and discharge and can be issued from each component of the chain that composes the EWS. For each of these, three different thresholds can be defined. The first threshold (*start*) indicates the onset of rainfall, runoff, and discharge or the presence of some water in the reservoirs; the second threshold (*warning*) indicates the possibility of dangerous floods; the third threshold (*alert*) indicates a high likelihood of dangerous floods.

In the current operational system of the FlaFloM, only a rainfall threshold has been applied. Based on local experience with flash floods in the Sinai Peninsula, a warning is issued when the cumulative rainfall over a 6h period exceeds 10mm. When the cumulative rainfall exceeds 15mm, an alert is issued (Cools et al., 2012).

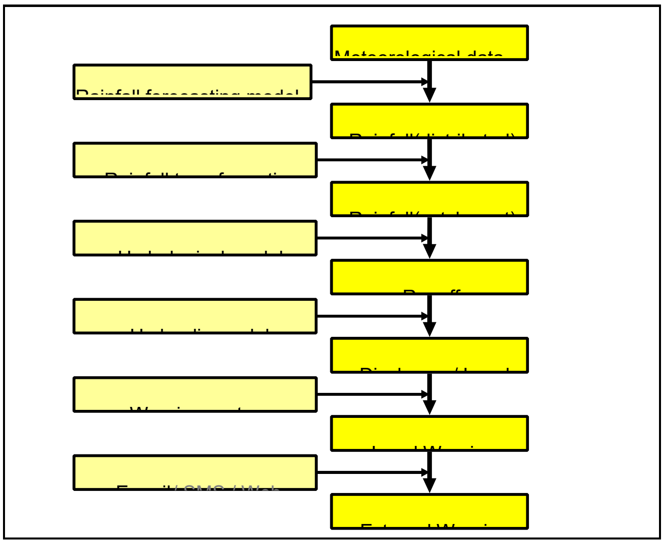

Figure 15: Early warning system components for WadiWatier, Egypt (cools et al, 2012).

7.2.2.2. Sudan Experience in Flash Floods Early Warning System

Gash River Flash Floods EWS, Kassala State

The Gash, in Kassala State, Eastern Sudan- is a seasonal (flashy) river, originates from the Eritrean and Ethiopian highland, and flows during the period from July to September. The Gash river crosses Kassala city, the capital of Kassala State, and divided it into to part; east and west (figure 16). Despite the intensive flood protection work, the city is still under a high risk of catastrophic flooding causing great damages to properties, infrastructures and endangering human lives (Elhadi et al., 2018; Isam et al., 2012).

In the last five decades, the major floods that had been experienced in Gash with great damages were in:1975,1983,1988,1993,1998, 2003, 2007,2014. In 2003, the flash floods from the Gash river swept 50 %

of the city of Kassala (Abdo, 2015; Isam et al., 2012). In 2016, the flood water cuts the main highway road which links Kassala and Port Sudan, the main Sudan Sea Port (Elhadi et al., 2018).

As a result of the frequent flooding that strikes Kassala city and its surrounding areas, there were many studies that highlight the importance of developing forecast models for the river. Bashar, et al. (2011) tested the utility of space technology in managing the water resources in Gash river. The study used Geo-spatial stream flow model, which developed by United States Geological Survey department (USGS), as simulation tool and Rain Fall Estimate (RFE) data sets as input. One thing that has been noticed in his study, RFEs were not validated against ground rainfall. The model capture the peak well (R^2= 0.56) and reproduced the observed situation with reasonable accuracy. Rokaya (2014), tried to simulate rainfall-runoff process and develop flood simulation model for flood forecast and irrigation water management in Gash basin. He used four different SREs; RFE, TRMM, ARC-2 and ECMWT as input to run HEC-HMS model. SREs is validated using Kassala station data only. TRMM and RFE showed good performance as well as events hydrological modeling with HEC-HMS. Giriraj and Sharma (2013), tried to develop a flood simulation model for best water allocation for spate irrigation in Gash scheme. Absence of reliable observed discharge and rainfall data were the common limitations among these studies.

Recently in 2018, a robust Flash Flood Early Warning System was developed for the Gash river for the first time based on hydrologic modeling (Elhadi et al., 2018). The Gash FEWS was developed by the Water Research Center of the University of Khartoum under a research project funded by the Ministry of Higher Education and Scientific Research of the Sudan. The Hydrologic Modeling System (HEC-HMS) software of the United State Army Corps of Engineer - Hydrologic Engineering Center was used for rainfall-runoff simulation. The Hydraulic Engineering Center's River Analysis System (HEC-RAS) was used for routing the outflow hydrograph in the river reach further downstream. The study used near-real-time Satellite Rainfall Estimates (SREs) data fromthe source "Tropical Rainfall Measuring Mission (TRMM-3B42RT V7)" to generate point as well as area-average rainfall over the catchment. A multiplicative bias procedure was adopted to validate the TRMM data sets (Elhadi et al., 2019).

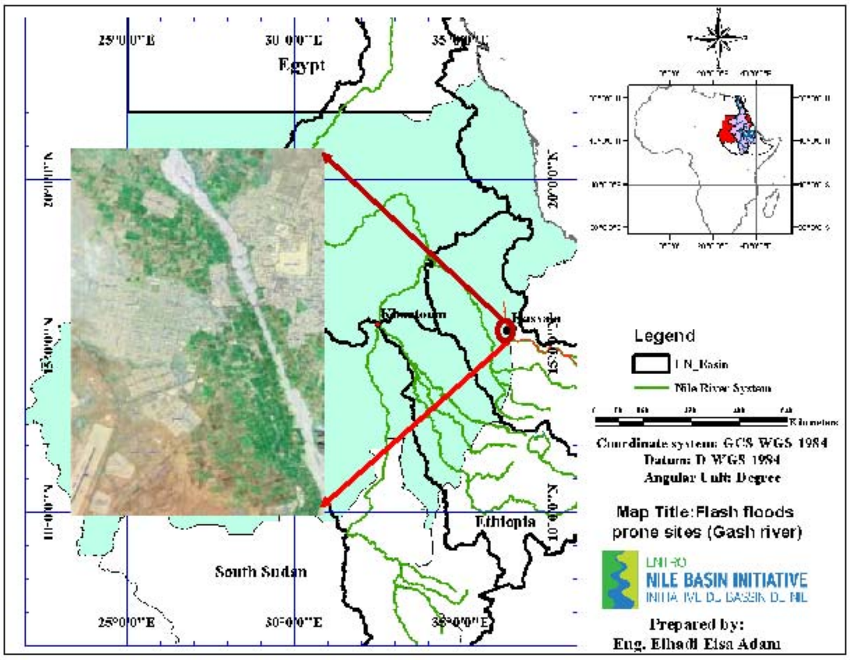

Figure 16: Location of Kassala city in Gash plain

Discharge data are available fromGash River Training Unit (GRTU) of the Ministry of Water Resources and Irrigation (MoWRI), in Sudan for a considerable period of time which used for calibration of the models. A semi-distributed rainfall-runoff model based on HEC-HMS software was developed. The results of hydrological modeling indicate reasonable correspondence between observed discharge and SRE in terms of peak and time to peak.

Rainfall-Runoff analysis showed a lead time in Gash basin – time from rainfall event, in upstream of catchment, to arrival of flood at Gera Station of 20 hours. Based on the lag time obtained, a manual FEWS for the Gash river was developed .The FEWS depends on the forecasted flow from the hydrologic model. The main function of the proposed FEWS is to issue warning message when threshold stage values are recorded at Gera station to prevent disasters flooding further downstream.

The model performed well in simulating the timing and magnitude of the stream during flooding. It provides improved monitoring and forecast information to guide relief activities (Elhadi, et al., 2018). The developed FEWS for Gash river is a manual type, it was designed in a such way to monitor the occurrence of flood waves, and issuing warning message when the hazardous flood event is imminent or already happening.

The alert level at Gera and Kassala Bridge stations

According to the GRTU practice there are some alert levels, above which the flood wave might break the embankment. At Gera station the level of 536.00 meter is the alert level, where at Kassala Bridge the level is 507.00 meter. Figure 17 shows the staff gauge at Kassala Bridge gauging station. These photos were taken on Monday 11, July 2019, when a flood wave reach value of 506.8 m. In the picture, the alert level is painted in red (507.00).

Gash River FEWS and FEWS-Sudan, as a result of the severe flooding during August 1988 along the River Nile plain in Sudan, the Ministry of Water Resources and Irrigation (MOWRI), of the Sudan, installed a Flood Early Warning System (FEWS) at the Nile River system in 1991. The "FEWS Sudan" model is used to enable more advanced warning for future floods from the Nile (Saghayroon& Adam, 1996; Abdo and Ahmed, 2008) The objective of the project is to discuss the main concept of the modeling systems required for the "FEWS-Sudan". The system, "FEWS Sudan", in operation since 1992 and stopped some years later then reinstalled in year 2010 by Deltares of Netherlands and the Hydraulic Research Center (HRC) of the MoWRI of the Sudan (UKCC, 2010; Verkade & Werner, 2010).

Figure 17: The alert level at Kassala Bridge gauging station.

Attempt has been made to add Gash river model in "FEWS-Sudan" model to be run within the system (figure 18). All the necessary changes to accommodate the model had been made according to Deltares guide lines (Verkade & Werner, 2010). HEC-HMS model was added to the "FEWS Sudan" interface, the SRE data source were connected and added to the model, but unfortunately the model was not run, this issue is recommended for further investigation (Figure 18). This effort opens the window for the researchers to attempt incorporating the flash floods prone catchment to the existing FEWS environment and run the forecast using same procedure for FEWS.

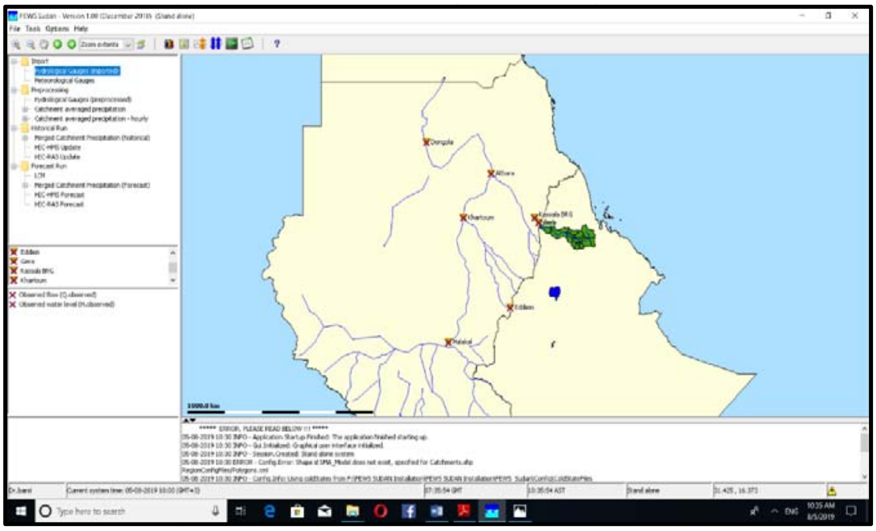

Figure 18: Gash catchment in the FEWS_Sudan interface (source: Elhadi et al 2018)

7.2.3. Stakeholders Need and Requirements in EN.

Flash floods EWS is very important for community, it can help in the following aspects:

- ✓ Planning flood response activities
- ✓ Taking necessary precautions to protect infrastructures
- ✓ Taking preventive measures against water borne diseases
- ✓ Encourage the appropriate response by the recipients

7.3. Possible Types of Flash Floods Forecasting Techniques for EN

Two types of flash floods forecast are applicable for the EN; Real-time and short-term. The two types are important for flood hazard management. Flood hazard management is primarily aimed at making plans to reduce flood hazard and control exposure. Flood forecasting is an essential tool for providing people still exposed to risk with advance notice of flooding, in an effort to save life and property.

7.3.1. Real-time flash floods forecasting

Real-time flood forecasting can be classified into three main categories (Andre et al, 2020):

Empirical scenarios; The empirical scenario approach relies on experience and observations of the past. This approach uses knowledge of previous flood events (e.g. accumulated rainfall in one hour, water levels) and establishes threshold levels based on historical accounts. Once these thresholds are exceeded a warning is issued.

Pre-simulated scenarios; In the pre-simulated scenario approach a scenario catalogue is created covering a range of flood events. As the name suggests, this approach requires some form of hydrological and hydrodynamic simulation. The modelling approach is based on data availability and a library of scenarios is created and stored. In general, this approach uses information about the given rainfall forecast along with a set of rules for selecting the probable scenario. This can be done manually or by an automated system, and based on the results of the selected scenario, a warning is issued.

Real-time simulations using NWP models (WRF) or SREs (Now- cast); In the real-time simulation approach, hydrodynamic simulations are performed in real-time and their results are disseminated to responsible authorities and/or to the public through web services or as a SMS-message on mobile phones. The calibrated hydrological and hydrodynamic simulation model is fed with rainfall information in real-time and the simulations are performed and flood locations are identified. Areas or facilities with greater risk are usually identified in pre-studies and once the water level exceeds a certain threshold at that facility a warning is issued.

7.3.2. Short-term flash floods forecasting

Short term forecast gives advance warning of one up to three days of imminent flood hazard. The accuracy of short-term forecasts is generally lower than the real-time forecasts and mostly provide a tendency of upcoming rainfall. Two approaches can be used to carry out short-range forecasts; Hydrological modelling and, Streamflow correlation / routing (translation of flow). Short-term operational prediction of flash floods is different from that of large river floods in several aspects. Notably, short lead times for forecast, warning and response make operational flash flood prediction challenging, while they also make it a hydro meteorological problem, rather than a purely hydrological prediction problem.Furthermore, their potential occurrence at any time during a day or night also necessitates 24x7 operations for flash flood forecasting and warning.

Typically, the choice of a particular flood forecasting approach is based on the desired accuracy, forecast horizon, degree of complexity required, cost of producing the forecast, technological capacity and finally the available data. Each approach for flood forecasting has its advantages and disadvantages, but data constraints, technological capacity and the desired level of accuracy will ultimately determine the approach that can be implemented.

7.4. Input Data Sources for the EWS

7.4.1. Ground stations

The primary basic inputs to flash flood forecasting systems are rainfall, river stage/discharge, or both. These are the same basic requirements as for conventional flood forecasting systems, and although the same equipment is often used, these data collection systems can be manual or automated. Because of the short time interval (less than six hours) between the observed rainfall or upstream river height and the flood at the point of interest, the delays inherent in manual observation, reporting and recording systems are usually too great for useful forecasts and warnings to be made in time that is why automated system (telemetry) is preferred.

Automatic data-collection systems are usually based on a digital output from the sensor. Rain gauges are primarily of the tipping bucket type which provide a convenient incremental pulse count. River stage sensors, are usually a shaft rotation type which require a digital attachment from a flat well or a pressure transducer from a pressure line, either closed or a gas-purged line. These digital outputs can be telemetered by land-line (dedicated, telephone or telex lines), or by radio using ground or satellite repeaters.

The design of ground station networks for flash flood forecasting follows the same principles and techniques as those applied to conventional flood forecasting systems. The arrangements of rainfall stations network should take into consideration the areal variation of rainfall and the topographical catchment features.

7.4.2. Radar

As many flash flood situations result from thunderstorm rainfall, the accurate assessment of areal rainfall is a major problem in flash flood forecasting. Although the catchments are often small, many of them are in mountainous areas where orographic effects will increase the areal variability of rainfall. The use of RADAR in the EN basin is not much seen, it would be better to enhance the monitoring systems with such technology. Radar can be especially useful in assessing areal rainfall because it gives an aerial perspective and has the facility to estimate areal rainfall quickly

7.4.3. Satellite Rainfall Estimates (SREs)

Satellite data may also be used for estimating rainfall amounts and areal distribution. Recently, SREs has been used as alternative for regions with poor coverage of ground rainfall. As with radar, it is necessary to automate this technique using digital imagery data to provide the real-time speed and accuracy required for flash flood forecasting.

7.4.4. Quantitative Precipitation Forecasting (QPF)

Quantitative precipitation forecast (QPF) products are frequently considered to be part of the data available for flash floods forecasters. However, QPF plays an important role in flash flood forecasting. As a flash flood by definition is a flood which occurs after a short time interval between the causative event (usually heavy rainfall) and the flood at the point of interest, QPF is an extremely useful tool for both the meteorologist and the hydrologist. QPF shows both the areal distribution and the amount of the rainfall expected to occur over a given time period. The most important feature of QPFs is that they alert the forecaster to the potential for excessive rainfall.

7.5. Flash Floods Forecasting Techniques

Flash flood forecasting techniques can generally be considered as one of four groups: (Hall, 1981). First group, those based on meteorological input only, essentially the forecasting of heavy rainfall over an area. Second group, those based on hydrological techniques which use observed rainfall and/or river stage data to predict the flood height or to warn of impending river rises; and. The third group, those which are a combination of meteorological and hydrological techniques. The third group is generally the most useful as it has the advantages of additional warning time based on forecast rainfall and of specific flood forecasts based on predicted and observed rainfall, usually verified against observed river height. A fourth group covers those hydrological and hydraulic models which can be applied to the "dam break" situation.

7.5.1. Meteorological techniques

Meteorological techniques are essentially the forecasting and/or the advice of heavy rainfall. If meteorological conditions conducive to heavy, intense rainfall are observed or forecast for an area, a flash flood watch is issued. The flash floods watch alert residents of the area to the potential occurrence of rainfall which could result in flooding. Flash flood watches are usually valid for periods of 12 hours or less and may cover all or part of the forecast area.

The greater the lead time the more useful the watch, hence flash flood watches are more effective if issued prior to the onset of heavy rainfall. If excessive rainfall or actual flooding is reported a flash flood "warning" is issued. These are normally issued for periods of less than four hours and may be made for a single drainage basin although they usually cover several districts or counties. Flash flood warnings require residents of the area to take necessary precautions against flooding. Rainfall observers and automated rain gauges that can be interrogated by the meteorologist on demand or which warn of heavy rainfall, are the main source of data. Radar is especially useful as it gives an aerial perspective with a wide coverage and can delineate potential trouble areas.

7.5.2. Hydrological techniques

The simplest hydrological technique is to monitor the river upstream of the point of interest and to base flash flood warnings on stream rises. In view of the short times involved and in order to provide continuous monitoring, this system should be automated. A simple flash flood alarm system can include three components: a river station, an intermediate station and an alarm station (Abhas et al., 2012). The river station used for sensing the critical water level, and connected to the intermediate station. The alarm station can be located in an appropriate place in the community with continuous staffing, it receives a continuous signal from the river station. When the critical level is reached at the river station an audible and visible alarm can be activated.

The observation of rainfall rather than upstream river rises requires some form of hydrological model or assessment to determine the resulting flood potential. These may range from a simple "rule of thumb" of rainfall rates exceeding a given value over a given period to a complex hydrological model. To eliminate the delays inherent in centralized data collection, analysis and forecasting and warning, flash flood forecasting systems generally need to be developed on a local basis or, as “a local flash flood warning system”.

In flash flood forecasting the main requirement may be the quick identification of the fact that critical danger thresholds will be surpassed rather than the accurate definition of the magnitude and timing of the flood peak. Thus flash flood forecasting does not necessarily have to be complex, simple models may sufficient.

7.5.3. Meteorological - hydrological techniques

The most effective means of flash flood forecasting is to combine both meteorological and hydrological forecasting techniques. The use of QPF can extend the watch lead time which is the key parameter in forecasting flash floods. A flash flood warning system which has the advantages of a combined approach is consisting of three tasks:

- ✓ Collection of event-reporting data (sensors)
- ✓ Transfer of the data to the computer at the River Forecasting Centre (RFC) (processing)
- ✓ Streamflow forecast/flash flood warning generation.

The latter involves the input of WRF from the Weather Service Forecast Office and observed rainfall and river stage data.

7.5.4. Dam-break techniques

Catastrophic flash flooding results when a dam (either man-made or artificial - ice walls, jammed debris, etc.) fails and the outflow through the breach in the dam inundates the downstream valley. Usually the dam-break outflow is several times greater than any previous flood. Flooding due to dam break is a mega-disaster as it is associated with huge loss of life and property. An unusual high peak in a short duration and presence of a moving hydraulic shock/bore make it a different problem as compared to other natural floods. Little is known of failure modes of artificial or natural dams and failure may not occur until a certain flow over the crest of the dam is attained for an undetermined duration of time. Sometimes, blockage of water due to deposits caused by landslide takes place. When this natural blockage fails due to increased amount of water at the upstream, huge flooding occurs. The behavior of this flood is similar to that of dam break floods. Hence, forecasting of dam break floods is almost always limited to occasions when failure of the dam has actually been observed. Software such MIKE-11 can be used for dam break modeling.

7.6. Models and Software for Flash Floods Forecasting

Different flood forecasting service models exist based on the needs of end users: a system may be developed for the public or strictly dedicated to the authorities. There is no single consistent approach worldwide but the basic principles of a good warning system are shared by all. All the software used in the existing ENTRO FEWS are applicable for flash floods forecasting (hydrological models such as HEC-HMS and Hydraulic models such HEC-RAS and USGS tools). Even the existing FEWS system used for the Blue Nile, can be modified and used for modeling the rainfall-runoff process and routing the output hydrograph in the flash floods sites (Deltares, 2010, Elhadi et al, 2018).

Besides above mentioned software, variety of models are available which can be sued for flash floods modeling.Two-dimensional (2D) models are much suitable for floodplains, because they can determine the inundation extend beside simulating the rainfall runoff process such as; HEC-GeoRAS, TELEMAC 2D, SOBEK 1D2D, Delft 3D and RRI.

7.7. Proposed Flash Floods EWS for EN.

7.7.1. Introduction

The objective of the early warning systems is to empower individuals and communities threatened by hazards to act in sufficient time and in an appropriate manner so as to reduce the possibility of personal injury, loss of life, damage to property and the environment and loss of livelihoods (UN, 2006). A complete and effective early warning system comprises four key essentials and inter-related elements:

- Risk Knowledge; Detection of the conditions likely to lead to potential flooding, such as intense rainfall, prolonged rainfall, storms or snowmelt
- Monitoring and warning; Forecasting how those conditions will translate into flood hazards using modeling systems, pre-prepared scenarios or historical comparisons
- Dissemination and communication; Warning information via messages and broadcasting these warnings as appropriate
- Response to the actions of those who receive the warnings based on specific instructions or pre-prepared emergency plans.

Failure in any one of the four key elements of an EWS will lead to a lack of effectiveness. Inaccurate forecasts may lead to populations ignoring warnings issued subsequently. The lack of clear warning and instruction may have resulted, for example, in the deaths of people.

From the lesson learned from literature review through this study, two possible types of flash floods EWS can be proposed to be applied to address the flash floods in the EN; local flash floods EWS and regional flash floods EWS.

7.7.2. Local flash floods EWS

As it is obvious, the eastern Nile basin comprises many regions. These regions differ significantly regarding their hydrological processes, scale, landscape characteristics, infrastructure and identified user needs. The design of local flash flood warning systems will depend upon site specific problems, such as topography, climate, flood plain population, flood control structures, warning time and the resources available for program implementation. The systems can range from simple networks and procedures to sophisticated computer-based automatic systems.

The local flash floods EWS for the EN can be developed through multiple techniques and methods. As many flash floods EWS, the system can include data collection module which receive the weather data and SREs, necessary bias correction should be made to validate the SREs. The rainfall data is sued as input to hydrological model, which can be developed in specific software such as HEC-HMS. The produced hydrograph can be used directly or introduced to hydraulic model, here one can use specific software such HEC-RAS for routing the hydrograph and determine the water levels and inundation extend from predefined flood risk maps. Consequently, people at risk will be warned to take necessary response and actions.

EN Region Rainfall Forecast program provides a platform to share its information with Eastern Nile communities and to deliver a useful service to them. Continuously monitored for potential severe weather using WRF model and other regional and global NWP models is available which can be used by the system.

The local flash floods EWS can be manual or automated. In manual type, data collection, processing and dissemination of warning is manually. While in automated type, sensors can be used for data collection and system of computer hard ware and software for data processing and warning dissemination. The conceptual design of the proposed local flash floods EWSfor EN is illustrated diagrammatically in figure 19below.

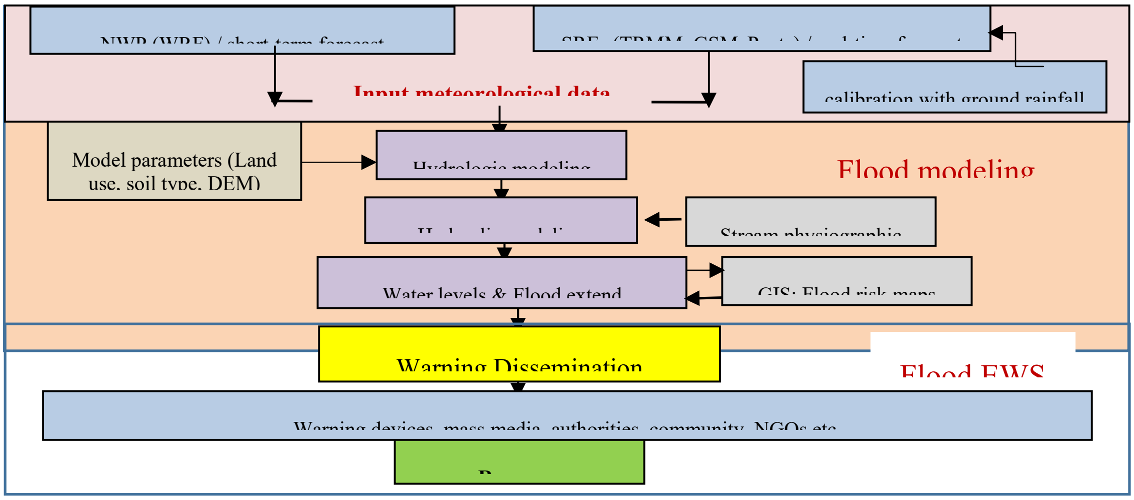

Figure 19: Conceptual design of the proposed local flash floods EWS for EN.

7.7.3. Regional Flash Floods EWS

The regional flash floods EWS can be used to cover the entire EN basin countries as we have seen in the Global FFGS. The Regional Flash Floods EWS can use the available Region Rainfall Forecast program provided by ENTRO and shared with eastern Nile communities to reflect the weather situation over the entire EN. The system can provide advance watch of imminent flood events to floodplain dwellers at the community level to be prepared.

The system can be schematized as given in figure 12&13, in this regard, ENTRO can approach the developer of the Global FFGS for possible implementation of the FFGS in the EN.

7.8. Warning Communication and Dissemination

The final forecasts are being communicated to the concerned administrative and engineering authorities of the state and other agencies concerned with the flood control and management work. EN countries already use a wide range of dissemination channels and it should be considered to use these channels as well to make sure no recipients of the forecast information are bypassed. Traditional communication method also can be used such as, telephone or by special messenger/telegram/wireless depending upon local factors like vulnerability of the area and availability of communication facilities etc. On receipt of flood forecasts, the above agencies disseminate flood warnings to the officers concerned and people likely to be affected and take necessary measures like strengthening of the flood protection and control works and evacuation of the people to safer places etc. before they are engulfed by floods.

Chapter 8: CONCLUSION AND RECOMMENDATIONS

8.1. Conclusion

The objective of this report is to assess the flash floods situation and develop guide lines to address flash floods in the Eastern Nile (EN). This report is based on literature review of key documents, field survey and investigations for some flash floods prone areas. The conclusion of the report can be summarized as follows:

8.1.1. Eastern Nile countries frequently experience catastrophic losses of human life, livelihoods and property as a result of flash floods. It is understood that flood risks will not subside in the future, as a result of climate change and variability, the hydrological cycle will become more intensified resulting in more weather extremes hence more flood and drought events.Two types of flash floods were observed in the EN basin; riverine flash floods and storm flash floods. Most of the flash floods in EN are as a result of torrential rainfall for short period of time.

8.1.2. The most vulnerable areas to flash floods in the EN basin were delineated, most flash floods prone areas are urban areas subjected to intense rainfall with poor drainage system and areas along the Nile system plains.Documentation of floods in terms of flood depth, area affected, damage to crops, damage to infrastructures, number of people affected, and overall monetary damage started recently by ENTRO for riverine floods. When flash floods are concerned, few data are available, historic records regarding frequency, magnitude, and duration of flash floods are very scarce. However, the available data showing the total affected area has increased significantly, there is a general trend of increased flash floods propensity in the EN.

8.1.3. Many critical gaps were raised, community awareness regarding flash floods gaps, hydro-meteorological data gaps, capacity building gaps, institutional arrangement and communication between different stakeholder’s gaps. The major gap raised by this report is absent of flash flood forecast and early warning system.

8.1.4. Rainfall data is the most crucial atmospheric driver for hydrological modelling. Ground-based meteorological networks often have incomplete observations that commonly are available at point scale and fixed intervals, the network coverage is sparse, especially in flash flood prone areas. There were gaps in hydrological data, most of the flash floods were from isolated rainstorm, many wadis and khores which carry the generated runoff are ungauged.

8.1.5. Flood Early Warning Systems are well installed and established for most of the river systems in the EN, but it is sub-basin-wise there is no unified operational flood forecasting & and early warning system in the whole EN. Currently, ENTRO implementing a project for enhancing the existing FEWS to cover the entire basin.The FEWS systems are mainly depending on the monitoring and forecasting of the rainfall on the upper catchment in Ethiopia. WRF model is commonly used for rainfall forecast, SREs from different sources also were used. Hydrological models based on HEC-HMS are used for rainfall-runoff transformation, while hydraulic models

(HEC-RAS and USGS- Global Flood Tool) for flood routing and inundation extend.The main source of input rainfall forecast is provided by Local Meteorological Authorities, ENTRO and IGAD Climate Prediction and Applications Centre (ICPAC) in Nairobi. Most of this information is related to riverine forecast not flash flood forecast.

8.1.6. Currently, there is no body taking care of flash floods forecast at national level or event at states level, and this is a major gap in flash floods management in the region. The humanitarian activities during flood occurrences are highly affected by the lack of information from formal or authorized organization that give warning in advance. From literature review, few instance of local attempts to develop flash floodsEWS were observed, these instances are within a framework of research projects. Worldwide review of flash floods EWS showed a vast experience, the most state-of-the-art technology is the Flash Flood Guidance System (FFGS), which developed collaboratively between WMO and HRC of the SU.

8.1.7. Flash floods mitigation measures in EN before, during, and after flood events were reviewed. The emphasis was on structural measures through the implementation of some flood control structures (dams, embankment and hydraulic structures). FEWS and flood preparedness strategies were used also as one of the non-structural methods of floods management but to limited extend.The dominant trend of river management practices is only concentrated on the course of major rivers, wadis basins not always received adequate focus.New BMPs were proposed by this study for flash floods management in the EN. The paradigm for flash floods risk management in EN need to be broadened from simply post-disaster response to more comprehensive approach that also includes prevention and preparedness.

8.1.8. Guide lines for development effective flash floods EWS for the EN were proposed. Two types of flash floods EWS is suggested; Local and Regional flash floods EWS. The local flash floods EWS is a site-specific, it is based on the hydrodynamic modeling. Fortunately, all the software and models used by ENTRO to address riverine flood are applicable for the flash floods modeling. For regional flash floods EWS, the global Flash Floods Guidance System (FFGS) is proposed to be implemented in the EN basin. The global FFGS is based on the monitoring and watching of weather condition over the region using remote sense data and gives necessary warnings for imminent flood risk.

8.1.9. The recent enhancement of the FFWS for EN developed regional rainfall forecast model using WRF model, this advances in rainfall forecasting will contribute much to the flash flood forecasting and EWSin EN.

8.1.10. Development and sustainability of Flash Floods EWS requires political commitment and dedicated investments. The organization building a flash flood warning capability has a mandate by law to warn citizens of impending flash floods.

8.2. Recommendations for Future Works

The study recommended the followings:

8.2.1. Documentation of floods (riverine and flash floods) in terms of flood depth, area affected, damage to crops, damage to infrastructures, number of people affected, and overall monetary damage.

8.2.2. The use of RADAR rainfall is highly recommended, which enhances the monitoring system and provide accurate and continuous coverage for better flood EWS.

8.2.3. The use of rainfall forecast for flash floods EWS (e.g. from developed regional WRF model) will increase the lead time in flash floods sites.

8.2.4. Enhancing the hydro-met monitoring system in flash floods catchment and streams.

8.2.5. The dominant trend of floods management practices is only concentrated on the course of major rivers; adequate focus should be given to seasonal wadi and flash floods streams.

8.2.6. The existing structural flood management system and flood control facilities in the EN region should be reviewed in the present flood risk perspective keeping in view the high rates of urban growth and stress on land use patterns.

8.2.7. The land use plans should be based on intensive assessment of flood risk, and it would be a better idea to make the land use plans based on multi hazard risk assessment for sustainable use of economic resources for development.

8.2.8. The infrastructure and plans in major cities should be reviewed and upgraded to withstand flash floods risk. Making the vulnerable communities aware of flash floods risk is a major area of focus, a multi prong approach for spreading awareness.

8.2.9. The preparedness, rescue and relief contingency plans should have special emphasis on the vulnerable segment of the communities: the poor, old, women, pregnant, children and the disabled.

8.2.10. One of the most intrinsic gabs in flash floods risk management in the region is creation, maintenance and proper use of database and development of robust flash floods EWS. Data should be accessible to the EN basin countries.

8.2.11. ENTRO can approach WMO and HRC of the US for possible implementation of the FFGS in the EN region.

8.2.12. Early warning system should be incorporated as integral components of any nation's disaster risk management strategy, enabling governments and communities to take appropriate measures towards building community resilience to natural disasters.

8.2.13. Mainstreaming DRR into the developmental plans is highly recommended for easy recover, reconstruction and long term flood risk resilience.

9. REFERENCES

1. Abdo, G.M., (2015). Flash flood assessment in Sudan with focus on the Gash Wadi. Report submitted to UNESCO Cairo Office within the frame work of Urgent Capacity Development for Managing Natural Disaster Risks of Flash Floods Project, Dec., 2015.
2. Abdo, G. M., and Ahmed E. N., (2008). The Sudan experience in flood forecasting and early warning, Sudan Engineering Society Journal, 54 (50), pp. 43-56.
3. Abdulkarim H. Seid (2004). Flooding Extend and coping Mechanism; An Overview. Flood Preparedness and Early Warning Project. Eastern Nile Technical Regional Office (ENTRO) Addis Ababa.
4. Abhas K Jha; Robin Bloch and Jessica Lamond, (2012). Cities and Flooding: A guide to integrated urban flood risk management for the 21st Century. World Bank, Washinton DC, USA, January, 2012. https://www.researchgate.net/publication/272793713.
5. Andre D. L. Zanchetta and Paulin Coulibaly (2020). Recent Advances in Real-Time Pluvial Flash Flood Forecasting. Water 2020, 12, 570; doi:10.3390/w12020570.
6. Artan, GA; Gadain, H; Smith, JL; Asante, K; Bandaragoda, CJ; Verdin, JP, (2007). Adequacy of satellite derived rainfall data for streamflow modelling. Natural Hazards 43: 167-185.
7. Azama M., Kimb H S., Maenga S J. (2017). Development of flood alert application in Mushim stream watershed Korea. International Journal of Disaster Risk Reduction 21 (2017) 11–26.
8. Bashar, K. E., Abdo, G. M., and Gadain, H. M., (2011). Use of space technology in the management of wadi water resources, Sudan Engineering Society Journap0711, 57 (1) pp. 11-17.
9. Cools J., Vanderkimpen P., G. El Afandi, A. Abdelkhalek, S. Fockedey, M. El Sammany, G. Abdallah6, M. El Bihery, W. Bauwens, and M. Huygens (2012). An early warning system for flash floods in hyper-arid Egypt. Nat. Hazards Earth Syst. Sci., 12, 443–457.
10. Dinku, T.; Ceccato, P.; Grover-Kopec, E.; Lemma, M.; Connor, S.J.; Ropelewski, C.F. Validation of satellite rainfall products over East Africa's complex topography. Int. J. Remote Sens. 2007, 28, 1503–1526.
11. Elhadi, E. A., Barsi B I., Mohamed Y A., Salih A M A., (2018). Development of flood early warning system for flashy wadis: Case study of Gash wadi, Sudan. 4th International Symposium on Flash Flood in Wadi System, Casablanca, Morocco, December, 2018.
12. Elhadi E. A, Barsi, B. I, Mohamed, Y. A, Salih A.M. A. (2019). Potential of Satellite Rainfall Estimates as Inputs for Flood Forecasting: Case Study Gash River, Sudan. UofKEJ Vol. 9 Issue 2 pp. 25- 31 (August-2019).
13. Elhag A., and, Eljack I H., (2016). DAM Site Selection Using GIS Techniques and remote sensing to Minimize Flash Floods in East Nile Locality (Soba Valley) Khartoum State. International Journal of Engineering Science Invention ISSN: 2319 – 6734, ISSN: 2319 – 6726.

14. El Quosy, D. (2020). Flash Floods Road Mapping, Experience from Egypt. The Fifth International Symposium on Flash Floods in MENA Region (5th ISFF). 25-28, Feb. 2020. Kyoto University, Japan.
15. Esamaldeen A. K. A., Essayed Z., Khatab A. R., (2000). Flash Floods Risk Assessment of ShargAlneel area, Khartoum State, Sudan Using Remote Sensing, GIS and Geophysical Techniques. Al NEELAIN JOURNAL OF GEOSCIENCES (ANJG) Vol-1, Issue-1, 201.
16. Habib, E.; ElSaadani, M.; Haile, A.T. (2013). Climatology-focused evaluation of CMORPH and TMPA satellite rainfall products over the Nile Basin. J. Appl. Meteorol. Climatol. 2012, 51, 2105–2121.
17. Habib E., Haile A. T., Sazib N., Zhang Y. and Rientjes T., (2014). Effect of Bias Correction of Satellite-Rainfall Estimates on Runoff Simulations at the Source of the Upper Blue Nile, Remote Sens. 2014, 6, 6688-6708; doi:10.3390/rs6076688.
18. Haile, A.T.; Habib, E.; Rientjes, T.H.M. Evaluation of the Climate Prediction Center (CPC) morphing technique (CMORPH) rainfall product on hourly time scales over the source of the Blue Nile River. Hydrol. Process. 2013, 27, 1829–1839.
19. Hughes, D. A., (2006). Comparison of satellite rainfall data with observations from gauging station networks, Journal of Hydrology, 327, 399– 410.
20. Hall, A. J.L. (1981). WMO. Operational Hydrology Report No. 18. Geneva, Switzerland
21. Giriraj A, and Sharma B., (2013). Application of remote sensing and GIS in flood inundation mapping for spate irrigation assessment, Training manual, Wad Medani, Sudan.
22. Grimes, D. I. F. (2003). Satellite-based rainfall estimation for river flow forecasting in Africa. I: Rainfall estimates and hydrological forecasts. Hydrological Sciences–Journal–des Sciences Hydrologiques, 48(4).
23. IPCC. (2012) Summary for Policymakers. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change.Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 1-19.
24. Isam M., Yonis, M. J., Jalal H. M., (2012). The impact of urban land use on Gash flood in Kassala, Kassala university journal, volume 1 June 2012 pp (29-64).
25. Jeremy T. Lancaster, Thomas E. Spittler, and William R. Short, (2015). Alluvial fan flooding hazards: An Engineering geologic approach to preliminary assessment. Special report 227, Version 1.0. California Geological Survey California Department of Conservation Sacramento, California.
26. Joost C. B. Hoedjes, André Kooiman, Ben H. P. Maathuis, Mohammed Y. Said 1, Robert Becht, Agnes Limo, Mark Mumo, Joseph Nduhiu-Mathenge, AyubShaka and Bob Su (2014). A Conceptual Flash Flood Early Warning System for Africa, Based on Terrestrial Microwave Links and Flash Flood Guidance.

27. Kantoush, S. A., Sumi, T., Ogiso, Y., Saber, M., AbdElfatah, M. (2020). Flash Floods Modelling at the Valley of the Kings. The Fifth International Symposium on Flash Floods in MENA Region (5th ISFF). 25-28, Feb. 2020. Kyoto University, Japan.
28. Ledesma J. L. J. and Futter M. N. (2017). Gridded climate data products are an alternative to instrumental measurements as inputs to rainfall–runoff models. Hydrological Processes, 1–11.
29. Li, L., Hong Y., Wang J., Adler R. F., Policelli F. S., Habib S., Irwn D., Korme T., and Okello L., (2009). Evaluation of the real-time TRMM-based multi-satellite precipitation analysis for an operational flood prediction system in Nzoia Basin, Lake Victoria, Africa, Natural hazards, 50 (1), pp. 109-123.
30. MrigankaGhatak, Ahmed Kamal, O.P. Mishra (2012). Flood Risk Management in South Asia, Background Paper. SAARC Workshop on: Risk Management in South Asia. Islamabad, Pakistan.
31. Nguyen, T, H., (2015). Rainfall-Runoff modeling using public domain datasets: SrePok Catchment, Vietnam - Cambodia. M. Sc. Thesis submitted to the UNESCO-IHE Institute for Water Education, Delft, the Netherlands.
32. NOAA, (2010). Flash Flood Early Warning System Reference Guide. Available at: http://www.meted.ucar.edu/hazwarnsys/haz_fflood.php.
33. Redwan A M., (2020). Flood forecast and early warning system assessment for Sudan, final report. ENTRO, Addis Ababa.
34. RIVERSIDE, (2010). Flood Risk Mapping Consultancy for Pilot Areas in Ethiopia, Final Report. Eastern Nile Technical Regional Office, Addis Ababa, Ethiopia.
35. Rokaya P., (2014). Flood simulation using public domain data for a data scarce transboundary basin: the case of Gash River Basin, Horn of Africa. M. Sc. Thesis submitted to the UNESCO-IHE Institute for Water Education, Delft, the Netherlands
36. Saghayroon A. & Adam I. S., (1996). Sudan Flood Early Warning System (FEWS), El Mouhandis, vol. 2, No. 5, December 1996.
37. Samir M. Zaid, El Sayed A. Zaghloul and Farid K. Ghanem (2013). Flash flood impact analysis of Wadi Abu- Hasah on Tell El-Amarna archaeological area using GIS and Remote Sensing. Australian Journal of Basic and Applied Sciences, 7(2): 865-881.
38. Satish K. D., Adam, E. E., Arya, D. S. and Goel, N. K. (2009). Urban flood risk assessment and mitigation. Conference of Research Activities in Disaster Mitigation for Housing in Inida, Roorkee, India.
39. Skøien, Jon O., Skøien, J S., Alagic P., Alobeiaat E., Andreenko A., Bari A., D Ciobanu, N Doroshenko, V El-Ashmawy, F Givati, A Kastrati, B Kordzakhia, M Petrosyan, Z Spalevic, M Stojov, V Tuncok, K Verdiyev, A Vladiković, D Zaimi, Klodian (2018). Assessment of the capacity for flood monitoring and early warning in enlargement and Eastern/Southern Neighborhood countries of the European Union. Luxembourg; Publications Office of the European Union, 2018 https://ec.europa.eu/jrc

40. Sumi, T., Saber, M., Kantoush S.A. (2013). Japan-Egypt Hydro Network: Science and Technology Collaborative Research for Flash Flood Management. Journal of Disaster Research (2013), 8(1): 177-178.
41. Sunkpho J., (2011). Real-time flood monitoring and warning system. Songklanakarin Journal of Science and Technology.
42. Suzuki, T. (2020). JICA Efforts for the Flood Disaster Risk Reduction in the World. The Fifth International Symposium on Flash Floods in MENA Region (5th ISFF). 25-28, Feb. 2020. Kyoto University, Japan.
43. Teshome W. (2020). Eastern Nile Flood Forecasting and Early Warning System: Final Report for Ethiopia. ENTRO, Addis Ababa.
44. Theming V., Rojas R., Mauricio Z. B., &Roo A. D., (2013). Hydrological evaluation of satellite-based rainfall estimates over the Volta and Baro-Akobo Basin. Journal of Hydrology 499 (2013) 324-338.
45. Thomas Hannigan, (2002). California flood plain management task force, Final recommendations. California Department of Water Resources 1416 9th Street, 11th Floor Sacramento, California, USA.
46. UKCC (2010). Operationalization of Flood Forecasting and Early Warning System for the Nile, University of Khartoum Consultancy Corporation.
47. UN, (2006). Global Survey of Early Warning Systems. An assessment of capacities, gaps and opportunities towards building a comprehensive global early warning system for all natural hazards. Final Version A report prepared at the request of the Secretary-General of the United Nations.
48. Vanderkimpen P.; I. Rocabado, J. Cools, M. El-Sammany& A. Abdelkhalek (2010). An early warning system for flash floods in Egypt Flood Recovery (FlaFloM). Transactions on Ecology and the Environment, Vol 133, © 2010 WIT Press. Innovation and Response II 193.
49. Verkade, J. & Werner, M., (2010). FEWS Sudan user forecast manual, Deltares, the Netherlands.
50. Vernimmen, R. R. E., Hooijer1, A., Mamenun E., Aldrian, E., & Van D. (2012). Evaluation and bias correction of satellite rainfall data for drought monitoring in Indonesia. Hydrol. Earth Syst. Sci., 16, 133–146, 2012.
51. WMO-UNESCO, (1974). Glossary of the Hydrology.
52. WMO (2019), from the website http://www.wmo.int/pages/prog/hwrp/flood/ffgs/index_en.php
53. Youssef, A. M., Abdel Moneim, A. A., and Abu El-Maged S. A., (2005). Flood hazard assessment and its associated problems using geographic information systems, Sohag Governorate, Egypt. The forth international Conference on the geology of Africa.

APPENDICES:

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ANNEX E

EASTERN NILE NATIONAL SOCIAL SURVEY REPORT

FLOOD FORECASTING AND EARLY WARNING ENHANCEMENT PROJECT

Submitted by

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ETHIOPIA SOCIAL SURVEY

FLOOD FORECASTING AND EARLY WARNING ENHANCEMENT PROJECT

Submitted by

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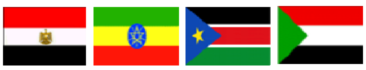
ENTRO is an organ established to implement the Eastern Nile Subsidiary Action Program within the framework of Nile Basin Initiative

Egypt, Ethiopia, South Sudan, Sudan



Executive Summary

Introduction

The Eastern Nile countries, Egypt, Ethiopia, Sudan and the South Sudan are engaged in joint investments in Eastern Nile sub-basin under the Eastern Nile Subsidiary Action Program (ENSAP). The Eastern Nile Council of Ministers (ENCOM) governs ENSAP. The four member countries and bilateral and multilateral development partners fund ENSAP.

ENTRO headquartered in Addis Ababa, Ethiopia, is the executive arm of ENSAP. It was established in 1999. ENTRO supports Eastern Nile Council of Ministers (ENCOM) and Eastern Nile Subsidiary Action Program Team (ENSAPT) in preparing cooperative water resources investment programs and projects, capacitating and strengthening institutions and providing secretariat support to its governance. Since its establishment, ENTRO has been playing significant role in advancing and enhancing cooperation among the Eastern Nile countries on water resource development and management.

Objectives of the study project

The present study project aims to ensure a robust forecasting, issuing and warning system that effectively minimize loss of life and damage by enhancing, expanding and developing a unified Flood Forecast and Early Warning (FFEW) system for EN basin. Further, to support other studies under FFEW that contribute in addressing flash flood, stakeholder analysis and flood related DSS development. The scope of work includes the following two major tasks:

Task 1: Flood Forecast System Enhancement:

- Review and analyze the gaps on the current stakeholder list at various level from data providers, forecast warning users, local communities at flood prone areas,
- Review best practice and methodologies currently available and applied in different basins and other relevant documents to be adopted
- Survey country level actors, information dissemination and action for flood early warning
- Map out current and preferred communication methods between regional, national and local levels for flood early warning and action.
- Assist and work closely with other members to specify the needs of stakeholders, communities, policy-makers, decision maker in flood disaster early warning

Task 2: Capacity building

- Deliver a training in collaboration with other team members

- Conduct and participate in consultation and validation workshops

The Method

The conceptual framework that guided the study has four components i.e, monitoring, forecasting, warning and response. A qualitative methodological approach was adopted to understand the flood forecasting and early warning practice at the national, regional, *woreda* and community levels. The study mainly focused on the dissemination and communication of warnings at all levels.

The collection of primary and secondary data was carried out. The primary data was gathered through telephone and face-to-face interviews with key informant including officials and experts involved in flood forecasting and early warning. Secondary data was obtained through reviewing of documents including NGO's reports, Disaster Risk Management and Food Security Office reports, books, internet, and other published and unpublished documents. Key informant interviews were conducted using the following three data collection instruments namely:

- Questionnaire Regarding the Early Warning Issuing Institutions;
- Questionnaire Regarding Flood Affected Communities; and
- Questionnaire for Country Level Actors in Flood Early Warning System.

An overview of the main findings

ENTRO's flood early warning in Ethiopia concentrates on three major river systems, i.e., Abbay-Blue-Main Nile, Tekeze–Setit-Atbara and Baro-Akobo-Sobat. In the Eastern Nile part of Ethiopia the well known flood prone areas are the flood plains abutting Lake Tana, Gambella plain, and Humera area (near Ethio-Sudan Boarder) of Tekeze basin and flash floods in different locations.

In the mapping of stakeholders of flood early warning system, 55 are identified and grouped under 10 main categories as national government, regional government, local government, communities, regional institutions and organizations, international bodies, non-governmental organizations, private sector, science and academic community and media.

The flood data and forecast providers identified are:

- The Eastern Nile Technical Regional Office, which prepares and communicates the flood forecast with the Ministry Water, Irrigation and Energy assuming that it will be communicated to the end users (local communities).
- The National Disaster Risk Management Commission issues the National Flood Alert and communicates to about 120 stakeholders by email including regions. Regional Disater Risk Management Commission offices will communicate to Zone and Woreda. The Woreda communicates the Kebele and local people.
- The Ministry of Water, Irrigation and Energy based meteorological data produces information for development sectors. The flood forecasting is only for riverine.

- The National Meteorology Agency gives advance warning on adverse weather conditions. The forecasting is carried out for one day, two days, three days, ten days and four months. The weather forecasts cover 34 towns.
- The non-governmental organizations including UNICEF, WFP and UN-OCHA calibrate the flood early warning obtained from the NDRMC to identify specific communities that will be affected by flood.

Vulnerability mapping

Vulnerability mapping shows the flood prone areas in Ethiopia scattered in many parts of the country along the major rivers and Lake Tana. Communities along the following rivers and Lake Tana are vulnerable to flooding.

- The Rib and Gumera rivers in South Gondar,
- Gilgel Abay river in West Gojam,
- Dirma and Megech rivers in North Gondar,
- In Gambella, Baro, Gilo,and
- Akobo and SNNPR Omo River.
- Lake Tana area

Stakeholders' gap

The flood early warning data providers

Eastern Nile Technical Regional Office

- o ENTRO's flood forecast is not communicated to the flood prone areas for the last three years.
- o ENTRO is not engaged in seasonal flood forecast with the lead time of 1-3 months.
- o ENTRO's data sharing and collaboration with other institutions is not satisfactory
- o The existing early warning system does not facilitate effective co-ordination between stakeholders.
- o ENTRO is less engaged in increased dialogue between EWS suppliers and recipients of warnings to appreciate the local culture, custom, media and geography.
- o There is no sound institutional arrangement for effective dissemination of the forecast.

Ministry of Water, Irrigation and Energy

- o The Ministry of Water, Irrigation and Energy, being doubtful of the forecast, is not communicating and verifying the flood forecast issued by ENTRO to the stakeholders for the last three years.
- o Although the National Policy and Strategy on Disaster Risk Management (NPSDRM) of Ethiopia designates the Ministry of Water, Irrigation and

Energy as a lead institution with respect to floods disaster, it did not assume such responsibility yet.

- There is no forecast for rivers without reservoirs.
- The MWIE is not involved in forecasting for flash floods.
- The MWIE is not considering indigenous early warning systems although it believes in the importance. Further, the media is not utilized for flood forecasting.

National Disaster Risk Management Commission

- The Ethiopian National Policy and Strategy on Disaster Risk Management gives the lead role to the Ministry of Water, Irrigation and Energy. However, this role is being played by the NDRMC. The National policy is not translated into action
- At Woreda and kebele levels, the early warning communication system is not well structured.
- The flood EWS, at governmental level, is not well owned and the practice is characterized as a fire fighting.
- The interest to get flood alert feedback from communities did not materialize.

National Meteorology Agency

- The lack of highly specialized manpower and technology have limited the capacity of NMA to issue seasonal flood forecast with lead times of about 1-3 months
- Lack of forecasting data has forced NMA to carry out the probability forecast with limitation.
- Data sharing and collaboration between institutions, ministries and ENTRO is not institutionalized.

Non-governmental organizations

- National flood Alert as too general. It does not indicate specific localities that would be affected by flood.
- Coordination among different institutions is not institutionalized.
- The early warning system focuses on response.

The flood forecast warning users

The flood forecast warning users include national, regional, zonal and Woreda level government offices, NGOs, UN agencies and humanitarian organization. These institutions are expected to disseminate the warnings to the flood prone communities through different channels. Among the gaps reported capacity limitation, the flood alert is too general, lack of coordination, community members' reluctance to act according to the flood alert and budget constraints.

Best practices and methodologies

Countries' experience in terms of best practices and methodologies of flood early warning communication was reviewed. The best practice from Ethiopia is about the communities in Dire Dawa Administration which reduced their vulnerability to weather-related hazards following the integration of indigenous and conventional knowledge on Early Warning Systems through a joint multi-sectoral platform.

The best practice from Assam State, India indicates that the early warning system has been viewed in the context of a river basin approach where upstream, midstream and downstream activities affect the time of concentration and volume of runoff as reflected in the shape of the hydrograph. In addition, it was noted that the involvement of the entire stakeholders under FLEWS as without their active participation FLEWS could have never been a success.

Current flood early warning communication method

Eastern Nile Technical Regional Office (ENTRO) conducts daily monitoring with three-day lead-times to produce forecasts. Rainfall and hydrological data is used to model and predict flooding with greater accuracy. Daily, weekly, and seasonal flood forecast reports are generated and disseminated to different users at different levels through the ENTRO web portal, email, and mobile phone messaging.

The National Disaster Risk Management Commission (NDRMC) communicates the Flood Alert to stakeholders by telephone and email. Further, at the time of flooding frequent communications are carried out. NDRMC communicates the issued flood alert to the Regional Commission Offices by e-mail. The flood alert will be discussed by the Regional Disaster Risk Management Committee (RDRC). The regional DRMC will communicate the flood alert to zone and Woreda offices by telephone. . The Woreda in turn communicates the kebele administration by telephone, which is responsible for the dissemination of warnings at community level.

Gaps in existing communication methodology

The following gaps in the existing flood early warning communication methodology are identified.

Eastern Nile Technical Regional Office

- The Ministry of Water, Irrigation and Energy has not communicated ENTRO's flood forecast to the stakeholders for the last three years.
- Since ENRTO directly communicates the Ministry of Water, Irrigation and Energy, the participation ofthe public and non-governmental organizations in the process of warning communication is not obtained.
- The existing early warning system does not facilitate effective co-ordination between stakeholders.
- ENTRO's consultation of stakeholders to get feedback on the flood early warning is very low.
- The existing institutional arrangement does not allow carrying out effective dissemination of the forecast.

National Disaster Risk Management Commission

- At present, the woreda disaster risk management activities are carried out along with agricultural activities by the woreda agricultural office. This has resulted in poor performance in terms of early warning communication.
- EWS is not well owned and the practice is characterizes as fire fighting.
- Some rural kebeles have no access to modern communication technology. For instance, the 16 rural kebeles in Jore woreda, Gambella region, have only two police radio communications which can serve for the early warning. The local people do not have personal radios. There were incidences of flooding in Demedolo Woreda, Nuer zone without prior notice.
- Sirens are not functional (e.g Libo Kemkem, Amhara region)
- Flooding can take place without issuing warnings to the local people (Kola Deba, Amhara region).
- No evidence of of monitoring mechanisms to check whether the warning message reach, understood and interpreted into action by the community members.

None-governmental organizations

- UNICEF, WFP and UN-OCHA noted that the National Flood Alert is too general. It does not indicate specific localities that would be affected by flood.
- Coordination among institutions is not institutionalized.
- The focus is on response rather than preparedness.

Local communities

- Some community members are reluctant to accept flood warnings
- In some areas, local people do not know what EWS means (eg. Jabitchinan, West Gojjam Zone)

Proposed flood early warning communication method and technology

Realizing the gaps in the existing communication method and technology of flood early warning, this study proposed the following.

Between users of flood early warning and data providers of warnings

- For any EWS to be effective increased dialogue between EWS suppliers and recipients of warnings will help to ensure that the former understand the needs of the latter, which includes an appreciation of local culture, custom, media and geography.
- One of the most effective ways to build rapport and understanding between governments and user communities is through mutual education.
- It must understand the needs of its users, and ensure users are involved in the EWS design as well as its implementation.

- Media is an essential part of any EWS and one of many tools for the dissemination of a warning.
- Many remote, rural communities rely on VHF radios as a primary method of communication. This type of media, in particular, necessitates a concise, coherent warning message
- Multiple forms of media need to be used, but there must be coordination with those responsible for disseminating warnings must remain abreast of developments in media and communications technology
- The increase in mobile phone usage opens new possibilities for effective dissemination of a flood warning

Current response activities to flood early warning

Flooding takes place every year in Lake Tana areas and Gambella plains. The response activities to flood early warning could be grouped into three. The first group of local people responds positively to warnings by taking the necessary preparedness actions to save their lives and property. The second group of people are reluctant and do not respond to the warnings. For instance in Amhara region, in some localities of Fogera woreda the flood incidence was noted. The third group of community members is without viable options to take the necessary preparedness action. For instance, the people living in the plains of Jore woreda, Gambella region cannot resettle in safer area because the flat land is easily inundated.

Proposal on how to improve the response to early warning

To improve the response to early warning, the following are suggested.

- Government and other stakeholders should develop the capacity of disaster risk management offices at all levels.
- Sufficient budget allocation to flood prone areas must be considered.
- Regular risk awareness creation should be given to community members.
- The flood early warnings should be timely and area specific to obtain better response.
- Due attention should be given to indigenous early warning practices.
- The community-based solutions guarantee that warning communications reach communities at risk, and that vulnerable communities are therefore prepared to counteract the risk.

Gaps in the current institutional setup at regional and national

The gaps in the current institutional setup at national and local level include concentrate on institutional arrangement, technology, infrastructure, and forecasting capability, human resources and expertise.

Proposed setup for an effective early warning system

In general, the National Policy and Strategy on Disaster Risk Management of the country has clearly designated the Ministry of Water, Irrigation and Energy as the lead institution for flood disaster risk management. The preferred institutional arrangement is to implement the policy into action. In this regard, the Ministry should assume its responsibility which would facilitate the flood early communication. The study proposed a set-up at regional and national level for an effective early warning system. The institutional setup could facilitate direct communication and shortens the communication process.

Recommendations

- NDRMC and UN-OCHA underlined that flood early warning system could be sustainable if the Ministry of Water, Irrigation, and Energy assumes lead responsibilities according the National Disaster Policy and Strategy. There is no concrete action with regard to the implementation of the lead role by sector institutions according to the policy and strategy of disaster risk management. Such issue should be resolved at higher level (Prime Minister's Office) so that sector ministries could mainstream disaster in their development plan.
- To overcome capacity limitation of NRDMC, NMA and ENTRO, the provision of training and upgrading of forecasting modeling are imperative.
- ENERO should communicate the flood forecast output to a wide range of stakeholders.
- ENTRO should regularly consult stakeholders with regard to the type of information stakeholders need.
- ENTRO should be a member of Nation Early Warning Technical Committee.
- ENTRO should sign a memorandum of understanding with, NMA and other important organizations to facilitate data sharing and collaboration.
- ENTRO flood early warning message indicates to what extent the water level is raised compared to the average. It should provide detailed information with regard to the magnitude of the flooding.
- The flood early warning system focuses on response. Since the flood prone communities are known, NDRMC should give emphasis to preventive actions.
- NDRMC should continue the restructuring process so that the disaster risk management office at woreda level could be organized independently.
- The flood forecast data providers should employ high performance technology for better forecast output, which minimizes doubtfulness on the part of forecast users. Further, this effort should be supported by indigenous flood early warning practices.
- Capacity building in terms of forecasting techniques and regular awareness creation at community level should be practiced to reduce the negative impacts of flooding.
- The regional governments and NDRMC need to consider the construction of permanent structure to protect local people from flooding in Gambella area since the flood affected people do not option to resettle in safer place.

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Acronyms

BAS	Baro-Akobo-Sobat
BCA	Basic Cooperation Agreement
BCA	Basic Cooperation Agreement
CMDRR	Community Managed Disaster Risk Reduction
DRMFSS	Disaster Risk Management and Food Security Sector
EN	Eastern Nile
ENB	Eastern Nile Basin
ENCOM	Eastern Nile Council of Ministers
ENMA	Ethiopian National Meteorological Authority
ENPM	Eastern Nile Planning Model
ENSAP	Eastern Nile Subsidiary Action Program
ENTRO	Eastern Nile Technical Regional Office
ERC	Emergency Relief Coordinator
FEWS	Flood Early Warning System
FPEW	Flood Protection and Early Warning
GHA	Greater Horn of Africa
IASC	Inter-Agency Standing Committee
IDEN	Integrated Development of the Eastern Nile
IDP	Internally displaced persons
MDGs	Millennium Development Goals
MoU	Memorandum of Understanding
MWIE	Ministry of Water, Irrigation and Energy
MWIE	Ministry of Water, Irrigation and Energy
NBI	Nile Basin Initiative
NCORE	Nile Cooperation for Result
NDRMC	National Disaster Risk Management Commission
NELSAP	Eastern Nile and the Nile Equatorial Lakes Subsidiary Action Program
NGO	None Governmental Organization

NMA	National Meteorology Agency
TOR	Terms of Reference
UN OCHA	United Nations Office for Coordination of Humanitarian Assistance
UN	United Nations
UNHAS	Humanitarian Air Service
UNICEF	United Nations Children Fund
UNISDR	United Nations International Strategy for Disaster Reduction.
WFP	World Food Program
WRF	Weather Research Forecast

Local Terms

Gote	*V*illage
Kebele	The lowest administrative unit in the government structure
Killele	Regional administration

1. INTRODUCTION

Floods are considered the most destructive of all natural disasters because they are the most common cause of the greatest number of deaths, and result in the most damage (Mileti, 1999). The increasing frequency and intensity of trans-boundary flood events in the Eastern Nile region, which is likely to continue or worsen due to climate change, reinforced the importance of regional cooperation and capacity development in flood forecasting and early warning systems.

The Eastern Nile countries, Egypt, Ethiopia, Sudan and the South Sudan are engaged in joint investments in Eastern Nile sub-basin under the Eastern Nile Subsidiary Action Program (ENSAP). The Eastern Nile Council of Ministers (ENCOM) governs ENSAP. The four member countries and bilateral and multilateral development partners fund ENSAP.

ENTRO headquartered in Addis Ababa, Ethiopia, is the executive arm of ENSAP. It was established in 1999. ENTRO supports Eastern Nile Council of Ministers (ENCOM) and Eastern Nile Subsidiary Action Program Team (ENSAPT) in preparing cooperative water resources investment programs and projects, capacitating and strengthening institutions and providing secretariat support to its governance. Since its establishment, ENTRO has been playing significant role in advancing and enhancing cooperation among the Eastern Nile countries on water resource development and management.

1.1 Rational and objectives of the consultancy work

- **1.1.1 Rational of the project**

The rationale behind the intended study project is based on the following gaps of the current FFEWS in terms of:

- coverage of all flood prone areas in the basin;
- robustness of the system and model;
- enhancing the system to up-to-date forecast standard; and
- using different models for the different flood prone areas in the basin, which is time consuming and hard to update; and
- the need for further in-depth understanding of most vulnerable communities, their socio-economic characteristics in order to design fit-for-purpose response and preparedness mechanisms (TOR and Scope of Services for Surveyor)

- **1.1.2 Objectives of the Project**

The objectives of the project are:

- To ensure a robust forecasting, issuing and warning system that effectively minimize loss of life and damage by enhancing, expanding and developing a unified Flood Forecast and Early Warning (FFEW) system for EN basin; and

- To support other studies under FFEW that contribute in addressing flash flood, stakeholder analysis and flood related DSS development (TOR and Scope of Services for Surveyor).

1.2 The Study Sub-basins

Flooding in Ethiopia, among others, occurs in the the major river systems, i.e., Abbay-Blue-Main Nile, Tekeze–Setit-Atbara and Baro-Akobo-Sobat. In Eastern Nile Part of Ethiopia the flood prone areas are the flood plains abutting Lake Tana, Gambella plain, and Humera area (near Ethio-Sudan Boarder) of Tekeze basin and flash floods in different locations.

- **1.2.1 Abay- Blue-Main Nile (Lake Tana area)**

Flooding is a recurrent threats occurring almost every year in Lake Tana area caused by the overflowing of the Rib, Megech, Gumaro and Gumara rivers and the spillover of

Lake Tana (Woldeab, 2006:22).

Figure 1.1 Map of flood prone-woredas and kebeles around Lake Tana

Fogera and Libo Kemkem woredas, Dembiya woreda and Bahir Dar special zone, all adjoining Lake Tana are the flood risk areas. In the urban areas of Bahir Dar, flood impacts have largely been the consequence of poor drainage systems in the city and local catchment runoff (SMEC, 2006). The large flat land between the Gumera and Ribb rivers is annually flooded and in extreme rainfall years the effect on humans, livestock, and infrastructure will be significant.

- **1.2.2 Baro-Akobo Basin (Gambella Plain)**

The plain area, belonging to the lowlands of Baro-Akobo Basin, is partially inundated by floodwaters every year. While most of the agrarian land use has adapted to the seasonal flux of flood waters, there are several towns affected by larger floods including the city of Gambella, and larger floods also cause hardship in rural areas. The Gambella plain lies in south-western Ethiopia and is part of the Baro-Akobo river basin (Sobat River in Sudan). Gambella city is the regional capital, about 800 km from Addis Ababa. Almost every year, over 35% of the Gambella plain is subject to flooding (SMEC, 2006). Major rivers in the areas are Baro, Akobo, and Gilo their origin is the highland high rainfall area around Gore and Masha. The ground surface elevation in along the watershed divide in the east, south-east and north-east varies from about 1700 m to values in the range of 2500–3000 m amsl. As one approaches the foot of the mountainous part of the catchment, one observes the steep decent down to the Gambella plain, where the elevation is of the order of 400-500 m amsl (Seid, 2004).

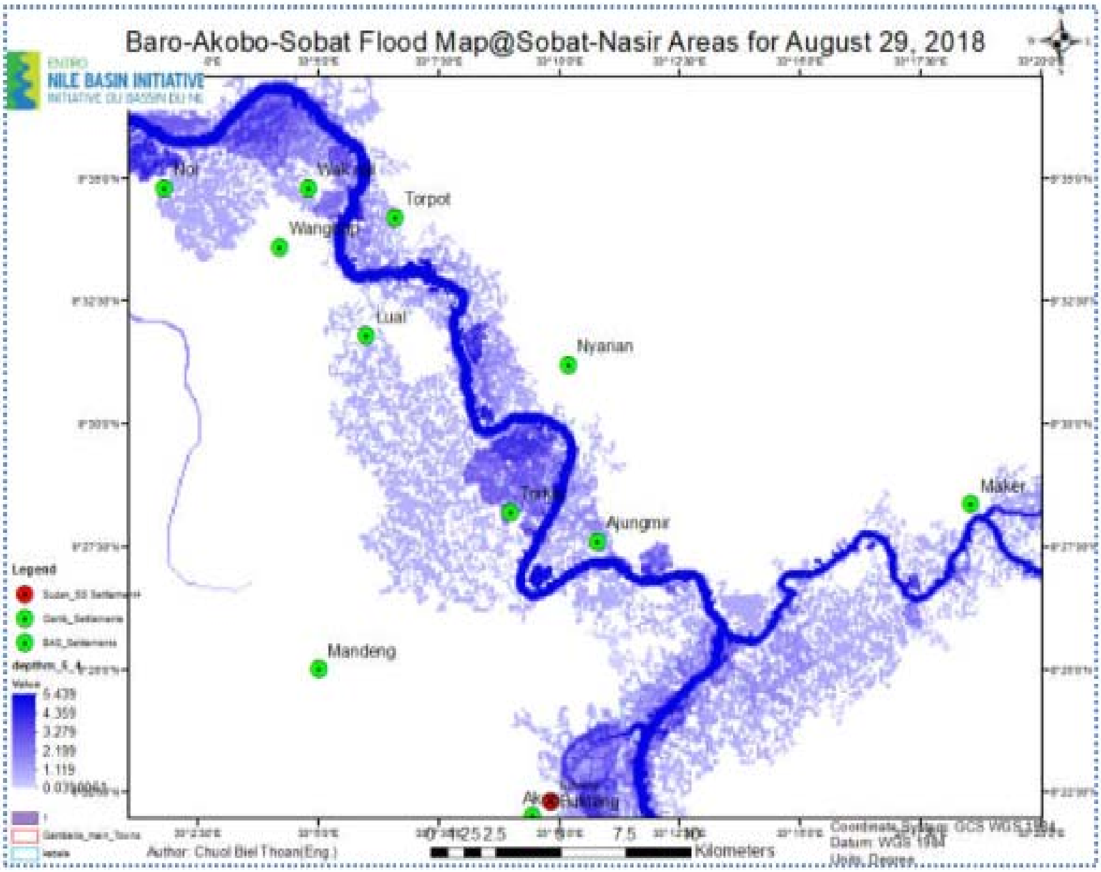

Figure 1.2: Baro-Akobo-Sobat Flood Map

- **1.2.3 Tekeze – Setit – Atbara (Humera plain)**

The flat area at Humera (near Ethio-Sudan boarder) is flooded from overflow of Tekeze River over its banks. This will occur during extreme rainfall conditions in the upper catchment of Tekeze basin.

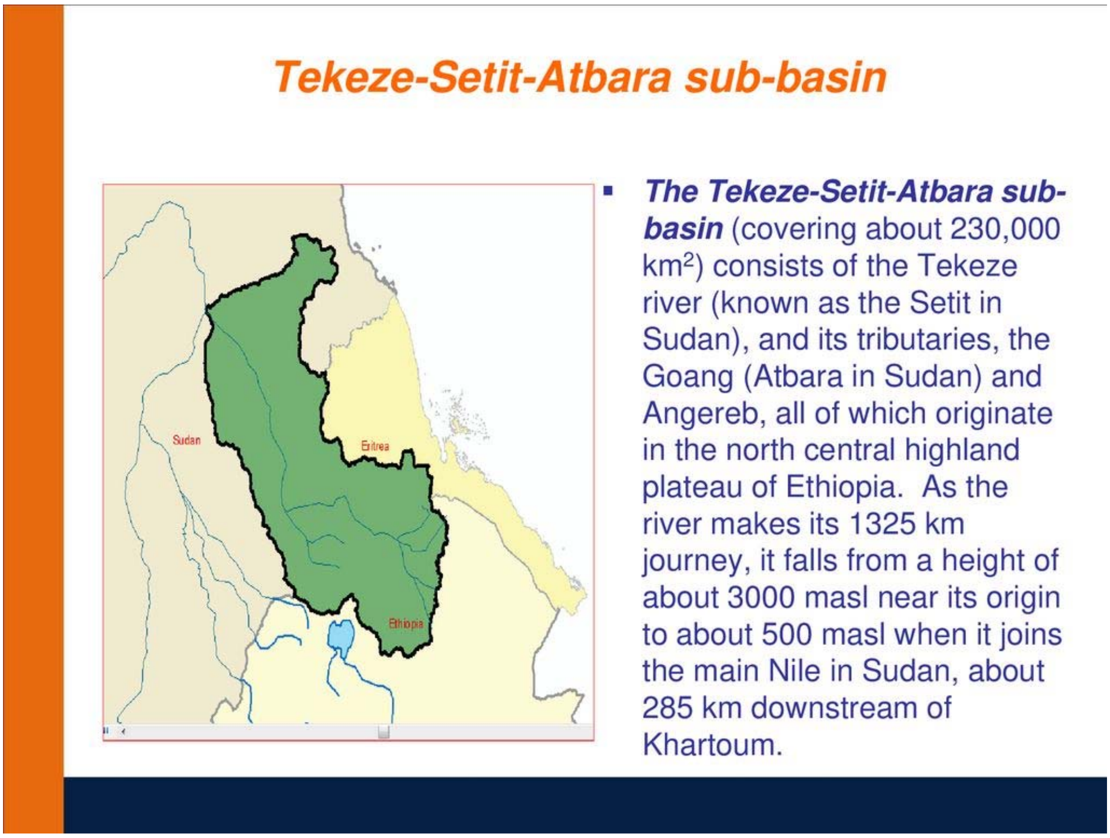

Figure 1.3 Tekeze-Setit-Atbara sub-basin

1.3 An Overview of Eastern Nile (EN) Seasonal Flood Forecast and Early Warning

Eastern Nile (EN) Seasonal Flood Forecast and Early Warning is one of ENTRO's Activities that aim to reduce human suffering caused by frequent flooding. The project emphasizes enhancing regional collaboration and national capacity in flood risk management, including flood mitigation, forecasting, early warning systems, emergency preparedness and response. The project which started in 2010 created a regional Flood Forecast and Early Warning System (FFEWS), strengthened national offices both in terms of capacity and equipment and overall reduced the risk of flood devastation for 2.2 million people in the region.

The Seasonal FFEW bring together young water resources professional from Ethiopia, Sudan and South Sudan forming a regional flood management team to jointly issue flood bulletins to their respective national water resources ministries and meteorological institutions for dissemination to local communities.

The EN Seasonal FFEW activity has been producing flood bulletins for the last seven seasons with three day lead time communicating to flood prone areas. The project utilized already available data and information from the satellite and from ground with collaboration with national and international agencies dealing with meteorological and emergency responses (ENTRO, 2018) Bulletin that shows daily real-time forecast is communicated to communities, local governments, national flood committees and humanitarian organizations.

1.4 Methodology

- **1.4.1The study approach**

The study employed a qualitative methodological approach, which involves a systematic flow of understanding of the flood forecasting and early warning practice at the national, regional, *woreda* and community levels. Focus was made on the dissemination and communication of warnings generated. Especially, how the warnings are efficient and in timely manner and in a format suited to user needs.

Both primary and secondary data were collected. The primary data was generated through telephone and face-to-face interviews with key informant including officials and experts involved in flood forecasting and early warning. Secondary data was obtained through reviewing of documents including NGO's reports, Disaster Risk Management and Food Security Office reports, books, internet, and other published and unpublished sources.

- **1.4.2 Conceptual framework of the study**

Flood early warning systems include a chain of activities: understanding and mapping flood vulnerability, monitoring rainfall and water levels, forecasting impending events, processing, and disseminating and communicating understandable warnings to decision makers and the population so that they can take appropriate and timely actions in response (UNISDR 2009).

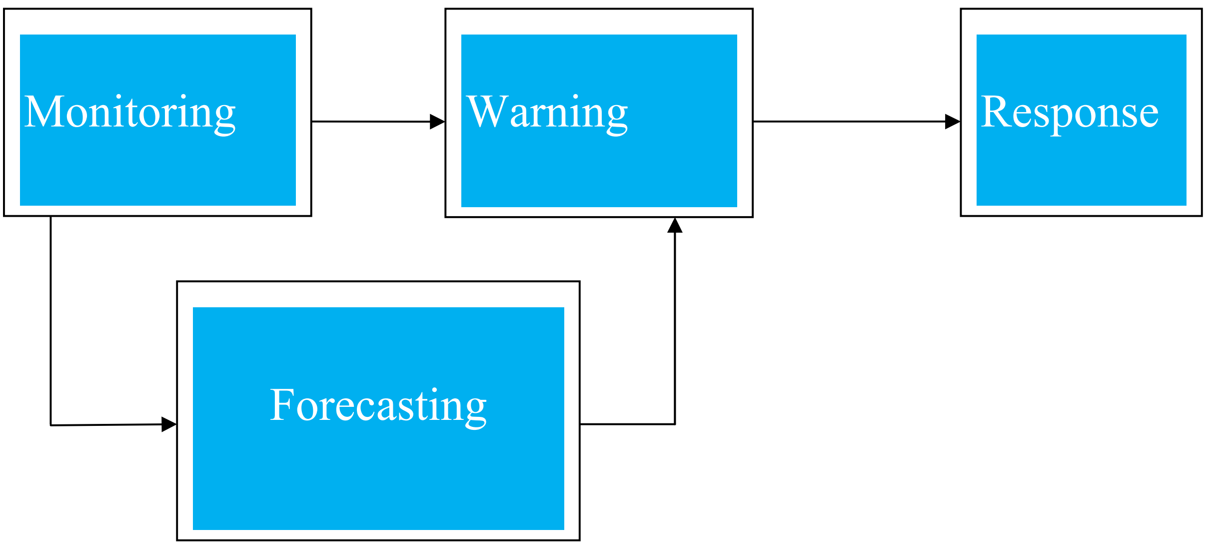

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Figure 1: 4 Conceptual Framework

(Haggett, 1998), describes the principal components of a flood forecasting and warning system as shown in the above figure (taken from Lobeyo date NA)

The principal components

Monitoring: In this stage real-time data is monitored. This includes hydrological and meteorological information, climate data, weather radar etc.

Forecasting: In the forecasting stage predictions are made of the levels and flows. Typically this involves the use of hydrological models, driven using the real-time data gathered in the detection phase and forecasts of meteorological conditions.

Warning: The warning stage is the key to the success of operational flood warning. Using information from the detection and forecasting stages, the decision to warn appropriate authorities and/or properties at risk must be taken.

Response: Response to flood warnings issued is vital to achieve the aims of operational flood warning. An appropriate response must be taken following a warning to realize the potential of the warning system.

- **1.4.3 Data collection methods**

The study used both secondary and primary data collection methods. The analysis of gaps was addressed by conducting a detailed gap assessment from regional, national and to the community levels as well as NGOs involved in early warning by reviewing existing documents and systems, interviews with key informants. Further, review of best practice examples from both industrialized and developing countries on how they issue early flood warning was carried out.

- **1.4.4 Data collection instruments**

Key informant telephone and face-to-face interviews were conducted using the following three data collection instruments.

Questionnaire Regarding the Early Warning Issuing Institutions

The questionnaire was developed to collect data with regard to flood warning issues including the type of warning (riverine/flash), warning message content and coverage, sustainability of early warning system, support need from ENTRO, coordination, collaboration, participation , consideration of indigenous knowledge and limitations

Questionnaire Regarding Flood Affected Communities

The questionnaire was designed to collect information such as the location of stakeholders/households affected by flood, frequency of flooding, level of impact, warning communication means and its effectiveness and involvement of the community members.

Questionnaire for Country Level Actors in Flood Early Warning System

The questionnaire was constructed to obtain information including which agencies provide, receive and relay flood early warning and what are their specific mandates on flood early warning, the content of warnings, communication of warning, sustainability of early warning systems, consideration indigenous early warning, participation, coordination and collaboration of institutions.

2. MAPPING OF STAKEHOLDERS IN FLOOD EARLY WARNING SYSTEM

There are many stakeholders in flood early warning system. As indicated in tables below, we can identify the stakeholders that could be categorized as regional, national, regional states and Woreda level government offices, communities, regional institutions, international bodies, non-governmental organizations, private sectors, the science and academic communities and media. These stakeholders have different involvement with regard to the four pillars of early warnings system, namely risk knowledge, monitoring and forecasting, warning communication and preparedness and response capability.

Stakeholders in flood Early Warning System

		Four pillars of EWS			
	Stakeholders under each category	Risk Knowledge	Monitoring & Forecasting	Warning Dissemination /communication	Preparedness & Response Capability
Table 2.1 National Government					
	Ministry of Water, Irrigation and Energy	X	X	X	X
				X	
	National Meteorology Agency		X	X	X
					X
	National Disaster Risk Management Commission	X	X	X	X
	Ministry of Health				X
	Ministry of Education			X	X
	Ministry of Agriculture		X	X	X
	Abay Basin Authority		X	X	X
	Baro-Akobo		X	X	X

Table 2.2 Regional Government					
	Amhara Regional Government			X	X
	Gambella Regional Government			X	X
	Amhara Region Meteorological Service Centers		X	X	
	Meteorological Service Centers				
	Regional DRMC		X	X	X
Table 2.3 Local Government					
	Zonal Administrations			X	X
	Woreda Administrations			X	X
	Kebele Administrations			X	X
	Zonal DRMC			X	X
	Woreda Agriculture Office			X	X
Table 2.4 Communities					
	Idir			X	X
	Farmers associations			X	X
	Women’s Associations			X	X
	Youth Associations			X	X
Table 2.5 Regional institutions and organizations					

	ENTRO	X	X	X	
	IGAD	X	X	X	
Table 2.6 International Bodies					
	UN OCHA		X	X	X
	UNICEF		X	X	X
	World Food Program		X	X	X
	FAO		X	X	X
	WHO		X	X	X
	IOM		X	X	X
Table 2.7 Non-governmental Organizations					
	SCI		X	X	X
	Save children international		X	X	X
	CARE		X	X	X
	World Vision Ethiopia		X	X	X
	FHE food for the hungry		X	X	X
	GOAL		X	X	X
	CONCERN		X	X	X
	Oxfam		X	X	X
	CRS		X	X	X
	Ethiopian Red Cross Society		X	X	X
	FEWS Famine Early		X	X	X
	Warning NET		X	X	X
	Red Cross		X	X	X
			X	X	X

Table 2.8 The Private Sector					
	Commercial agricultural companies		X	X	X
Table 2.1.9 The science and Academic Community					
	Agricultural Research Center IWMI ILRI	X X X	*X* *X* *X*		
Table 2.10 The Media					
	Ethiopian Broadcasting Corporation FM Radios			X X	

2.1 Data and Forecast providers

In this section, the discussion focuses on the flood early warning data providers namely Eastern Nile Technical Regional Office (ENTRO), Ministry of Water, Irrigation and Energy (MWIE), National Disaster Risk Management Commission (NDRMC) and National Meteorology Agency (NMA).

- **2.1.1 Eastern Nile Technical Regional Office**

The Integrated Development of the Eastern Nile (IDEN) was the first ENSAP project agreed by the member countries in 2002. Currently, ENTRO is implementing the 2nd 2014-2019 Strategic Plan, with the aim of facilitating Cooperation, promoting water Resources management and planning, promoting water resources development and power trade, and institution building.

The EN Flood Protection and Early Warning Project (FPEW) is one of the IDEN Projects, which aims to reduce human suffering caused by frequent flooding, while preserving the environmental benefits of floods. The project emphasis on enhancing regional collaboration and national capacity in flood risk management, including flood mitigation, forecasting, early warning systems, emergency preparedness, and response.

The FPEW project that ran until 2010 operated in Egypt, Ethiopia, and Sudan. After the completion of FPEW project ENTRO initiated with Eastern Nile countries and created a regional Flood Forecast and Early Warning (FFEW) system under the Eastern Nile Planning Model project (ENPM) and the FFEW activity continued under the current Nile Cooperation for Result project (NCORE). The FFEW, since its establishment, has been an important part of ENTRO's activity that continuously been conducted for the last six year flood season (June September). The FFEW has helped the Eastern Nile countries in reducing the loss of life and money by preparing flood forecast bulletins for the Lake Tana (Blue Nile -Ethiopia), the Blue Nile-Main Nile (Sudan) and Baro-Akobo-Sobat (BAS) sub-basins flood prone areas. The FFEW activity have strengthened national offices in terms of capacity and overall reduced the risk of flood devastation for 2.2 million people in the region (TOR and Scope of Services for Surveyor).

ENTRO prepares the flood forecast, by engaging young professionals (flood management team) from the Sudan, South Sudan and Ethiopia. The team members are experienced in flood forecasting. The Ethiopian Ministry of Water, Irrigation and Energy provides to ENTRO observed data and NMA's weather data. Based on these data, the team gives daily and weekly forecast by producing bulletin on behave of ENTRO. ENTRO communicates the forecast with the Ministry assuming that it will be communicated to the end users (local communities).

- **2.1.2 Ministry of Water, Irrigation and Energy**

The Ministry of Water, Irrigation and Energy of Ethiopia is a federal organization established to undertake the management of water resources, water supply and sanitation, large and medium scale irrigation and electricity. The ministry is a regulatory body which involves the planning, development and management of resources, preparation and implementation of guidelines, strategies, polices programs and sectoral laws and regulations. The Ministry, inter alia, administers dams and water structures constructed by federal budget.

The National Policy and Strategy on Disaster Risk Management (NPSDRM)(2013:22) of Ethiopia has designated the Ministry of Water, Irrigation and Energy "as a lead institution with respect to especially floods and other water supply, and water dams related hazards and associated disasters".

According to the NPSDRM (2013:7) "a lead sector government institution shall be assigned for every hazard and related disasters; the designated lead institution shall be responsible for the implementation of major disaster risk management activities ranging from disaster risk monitoring to response; it shall have an appropriate structure and preparedness capacity to enable it to fulfill its leading role. The lead sector government institution shall prepare and implement sector specific disaster risk management plans and programs" Further, the Policy documents that "lead sector institutions shall be assigned for every hazard at Federal, Regiona, Zonal, Woreda as well as at Addis Ababa and Dire Dawa City Administration levels and they will be responsible for undertaking activities ranging from monitoring to response. There shall be a dedicated structure in those lead institutions to be assigned for performing such tasks.

The key informant, Semunesh Golla, the Director of Hydrology and Water Quality Directorate of the MWIE, reported that the Directorate is mainly responsible for surface and ground water. Effective utilization of meteorological data obtained from different sources both international and national including NMA has been made in the management of surface and ground water, reservoir management and community-based flood early warning. Upon getting meteorological data the water sector produces information for development sectors. Issuing of flood early forecasting is the responsibility of the Directorate. The flood forecasting is only for riverine.

- **2.1.3 National Meteorology Agency**

The National Meteorological Agency (NMA) was established in accordance with proclamation No. 201/1980. NMA is designated, among others, to the following powers and duties.

- Exchange meteorological data in accordance with international agreements to which Ethiopia is a party ;
- Establish and operate communication systems, in accordance with the law for the collection and dissemination of meteorological data;
- Publish and disseminate analyzed and interpreted meteorological data and meteorological forecasts; and
- Give advance warning on adverse weather conditions; disseminate advice and educational information through the mass media; and provide, upon request meteorological services to any person.

Key informant, Aderagew Admasu, Director, Meteorological Forecast and Early Warning Directorate reported that NMA is mandated, among others, to give advance warning on adverse weather conditions. The forecasting is carried out for one day, two days, three days, ten days and four months. The weather forecasts cover 34 towns. NMA provides early warning when heavy rain is expected. The advance warning covers all the country. If heavy rain distribution is recorded, the Early Warning Directorate together other directorates of NMA could forecast the possibility of flooding. The Nile Basin and Gambella area are covered in the 34 towns, particularly in the three days weather forecast. Weather data collection centers are available in the Nile Basin and Gambella.

- **2.1.4 National Disaster Risk Management Commission**

The Government of Ethiopia a has demonstrated its commitment to the development of a comprehensive DRR approach by passing a Law that established the National Disaster Risk Management Commission (NDRMC) in 2015 and developing the National Policy and Strategy of Disaster Risk Management, to provide DRM guidance and support to line ministries, regions and districts.

The Regulation No. 363/2015 states that the NDRMC should “ensure that disaster risk management is mainstreamed into Government development policies, strategies, development plans and programs, and in the plans of the private sector as well as in the school curricula; and provide support, as may be necessary, to concerned bodies in relation to such issues”. Further, NDRMC is expected to “ensure and follow-up the inclusion of disaster risk management in the plans of the executive organs which are identified as lead sector institution in the Disaster Risk Management Policy and Strategy document”. Further the Proclamation Article 6.11 states that NDRMC should “lead and coordinate the Federal Early Warning and Emergency Coordination Center by supporting it with modern technologies; support the establishment of similar centers in lead sector institutions at Federal, Regional, Zonal and Woreda Administration levels, as required. At present, the Commission is under reorganization to address its duties and responsibilities at national level.

Flood disaster is one the areas in which NDRMC is responsible to manage. Key informant, Almaz Demessie, Director, Early Warning and Emergency Response, Directorate, reported that DRMC gets weather seasonal forecast from NMA, in which the early warning is based. Report of wet condition is important because flooding is expected. DRM Technical Committee composed of sector offices and NGOs meets every month. There is a flood task force under the DRM Technical Committee. When wet condition is forecasted, the Flood Task Force will be reactivated. Members of the task force are Health, Education, Agriculture, NMA, Water and UN organization including WFP, FAO UNOCHA. Alert is prepared and communicated to about 120 stakeholders by email including regions. Regional Commission offices communicate to Zone and Woreda. The Woreda communicates the Kebele and local people.
After the flood alert is prepared, flood contingency plan is worked out. Estimation of affected and displaced population will be carried out. Operational plan will be worked out based on priority of flood prone areas. With regard to the communication of early warning, the practice is to communicate down to the community level. However, the

communications system is not well structured. Now NDRMC is trying to restructure itself after it is established as a commission

- **2.1.5 Non-Governmental Organizations**

United Nations Children's Fund (UNICEF)[1]

UNICEF promotes the rights and wellbeing of every child, in everything we do. Together with our partners, we work in 190 countries and territories to translate that commitment into practical action, focusing special effort on reaching the most vulnerable and excluded children, to the benefit of all children, everywhere.

In all of its work, UNICEF takes a life-cycle based approach, recognizing the particular importance of early childhood development and adolescence. UNICEF programs focus on the most disadvantaged children, including those living in fragile contexts, those with disabilities, those who are affected by rapid urbanization and those affected by environmental degradation.

UNICEF was created with a distinct purpose in mind: to work with others to overcome the obstacles that poverty, violence, disease and discrimination place in a child's path. We advocate for measures to give children the best start in life, because proper care at the youngest age forms the strongest foundation for a person's future.

At the end of the Second World War, Ethiopia embarked on a program to modernize its economy and social infrastructure. International organizations were invited to support this effort and, starting in 1952, United Nations officials, including UNICEF staffers, began to frequently visit the country to deliver medical supplies and organize vaccinations of children. In 1958, UNICEF established its first office in Addis Ababa and in 1963 signed a formal Basic Cooperation Agreement (BCA) with the Government.

From inception, UNICEF was guided by the vision of a better future for all children. Through some of the country's most difficult times, and as the country achieved one milestone after another, UNICEF was there to provide policy advice, render technical support, and improve service delivery.

UNICEF is one of the stakeholders in the flood early warning system in Ethiopia. Key informant, Gebre Egziabher Lema, Humanitarian Officer, at UNICEF and member of National Flood Task Force representing his office reported that data for flood early warning comes National Meteorological Agency, Ministry of Water, Irrigation and Energy, National Disaster Risk Management Commission, Eastern Nile Technical Regional Office and UNICEF field offices. ENTRO, in particular, provides data on Gambella and Tana areas with regard to rivers levels. UNICEF attempts to triangulate the flood early warning data with the information obtained from the UNICEF field offices.

World Food Program (WFP)[2]

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[1] https://www.unicef.org/about/who/index_introduction.html downloaded on 1/21/2019

The United Nations World Food Program (WFP)is the world's largest humanitarian agency fighting hunger worldwide, delivering food assistance in emergencies and working with communities to improve nutrition and build resilience. In 2013, WFP assisted more than 80 million people in 75 countries.

WFP started its operations in Ethiopia in 1965. The guiding principle of WFP in Ethiopia is to support government programs by addressing hunger through direct food assistance where it adds value and support to the government's capacity. WFP development interventions in the country are relevant to and consistent with the national policies and programs as well as with the Millennium Development Goals (MDGs) and UNDAF priorities. WFP's main government partners are the Disaster Risk Management and Food Security sector (DRMFSS) of the Ministry of Agriculture, Ministry of Health, Ministry of Education and Ministry of Finance and Economic Development. WFP's country program of activities has consistently focused on food deficit areas, addressing land degradation, human resources development, urban HIV/AIDS, refugees and humanitarian relief. The Country Office has a well-developed vulnerability assessment mapping (VAM) unit which uses data to support emergency food needs assessment and the planning of development assistance. WFP is also managing the UN Humanitarian Air Service (UNHAS).

Key informants, Alemteshay Alemu, Vulnerability Analysis Team Leader and Abey Wogders, GIS Specialist at WFP reported that WFP is member of the National Flood Task Force. WFP triangulates the information of National Flood Alert, weather forecasts from NMA and IGAD, river and dam water levels from Ministry of Water, Irrigation and Energy with the information from field offices. FAO collects data from field level offices, uses drone technology and satellite images to compare the rainfall data to the average. Although it is not forecasting, such exercise helps to understand the magnitude and issue alert to the concerned communities.

UN OCHA[3]

OCHA is the part of the United Nations Secretariat responsible for bringing together humanitarian actors to ensure a coherent response to emergencies. OCHA also ensures there is a framework within which each actor can contribute to the overall response effort.

OCHA's mandate stems from General Assembly (GA) resolution 46/182) of December 1991, which states: "The leadership role of the Secretary-General is critical and must be strengthened to ensure better preparation for, as well as rapid and coherent response to, natural disasters and other emergencies." To this end, it also establishes the role of the Emergency Relief Coordinator (ERC), who works with the Secretary-General and the Inter-Agency Standing Committee (IASC) in leading, coordinating and facilitating

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[2]https://www.undp.org/content/dam/unct/ethiopia/docs/UN%20agencies%20profile/WFP%20profile%20design. Downloaded on 1/21/2019
[3]https://www.undp.org/content/dam/unct/ethiopia/docs/UN%20agencies%20profile/WFP%20profile%20design. Downloaded on 1/21/2019

humanitarian assistance. OCHA is the office that provides support to the ERC and the Secretary-General to meet the leadership and coordination responsibilities charted in GA resolution 46/182.

GA resolution 46/182 assigns a clear leadership and coordination role to the ERC for international humanitarian assistance to respond to the needs of affected people. This mandate extends to affected people in internally displaced persons (IDPs) situations and was reinforced by related GA resolutions (including GA resolution 70/165). This was also formally recognized in the Secretary-General's 1997 reform agenda, which assigned the ERC with responsibility for the overall coordination of assistance to IDPs. The GA expressed support for the reform agenda, and in subsequent resolutions it has emphasized 'the central role of the ERC' for coordinating the protection of and assistance to IDPs.

OCHA coordinates humanitarian action to ensure crisis-affected people receive the assistance and protection they need. It works to overcome obstacles that impede humanitarian assistance from reaching people affected by crises, and it provides leadership in mobilizing assistance and resources on behalf of the humanitarian system. OCHA is not an operational agency directly engaged in the delivery of humanitarian programs, and its added value is as an honest broker, facilitator, thought leader and global advocate, providing support to the humanitarian system. In fulfilling its coordination mandate, OCHA is guided by the humanitarian principles of humanity, neutrality, impartiality and independence.

Melaku Gebre Michal, Humanitarian Affairs Officer at UN OCHA reported that OCHA co-chairs the National Flood Task Force. In the identification of flood risk Woredas, his organization relies on NMA's rainfall forecast, National Flood Alert, river and dam water level data from the Ministry of Water, Irrigation and Energy, and field offices information concerning flooding incidences. Thus, based on this information, OCHA identifies specific localities that would be affected by flood. In this regard, OCHA supports the National Flood Task Force. Feedback of the forecast is obtained since OCHA monitors what is on the ground.

2.2 Forecast Warning Users

The flood forecast warning users include national, regional, zonal and Woreda level government offices, NGOs, UN agencies and humanitarian organization. These institutions are expected to disseminate the warnings to the flood prone communities through different channels.

- **2.2.1 National Government**

The government organizations that use the flood forecast at national level includes Ministry of Health, Ministry of Education, Ministry of Agriculture, Basin Authorities (Awash, Abay, Tekeze, Baro-Akobo, etc) and Ministry of Transport and Communications. For instance, the Ministry of Health could take the necessary health related actions in terms of response and preparedness at community level to minimize the negative impacts of flooding.

- **2.2.2 Regional, zonal and woreda governments**

The regional, zonal and woreda administrations are flood forecast users under the Ethiopian government structure. These administrations obtain technical support from the branch offices of NDRMC established at different levels. Although the structuring is not complete, at present there are independent offices at region and zone levels with the exception of woreda administration. At Woreda level, the activities of NDRCM are carried out by a Work Process (work team) organized under the Woreda Agricultural Office. Further, there are disaster risk management and preparedness committees composed of various offices at regional, zonal, woreda and kebele levels.

Key informant, Sisay Kassa, Team Leader, Disaster Prevention and Early Warning Work Process at Libo Kemkem Woreda who served for five year alone, underlined that the early warning system should be strengthened by employing professionals. At present three people are working in woreda office. Since the disaster preparedness and early warning activities are carried out along with agricultural activities, priority is given to the later. This institutional arrangement is not conducive to discharge the responsibilities of implementing the disaster early warning and preparedness activities. He underlined that the disaster risk management office should be organized independently.

Key informant, Emenesh Aseres, Team Leader, Disaster Prevention and Early Warning Work Process at Fogera Woreda reported that "flood task force used to get training before three years. All concerned people from Kebele and Woreda had a meeting once in a year. This practice was helpful to evaluate our activities and prepare ourselves for the coming flood season. At present, we simply communicate individual kebeles without having such meetings".

Birhanu, et al (2016:26) conducted a study in Libo Kemkem, Jabitehinan and Kalu Woredas located in South Gondar, West Gojjam and South Wollo Zones respectively in the Amhara National Regional State. The researchers identified that "from the zone to the kebele levels of the study areas, experts are with little knowledge of different risks and hazards. They lack comprehensive training on risk knowledge and hazards. Risk knowledge is acquired and built up on personal effort: through reading and attending trainings rather than being trained from the concerned department in higher education institutions". Further they noted that trainings which are directed towards improving experts' knowledge were uncoordinated, meager and too short. In this regard, experts from Libo Kem Kem Woreda explained that "It was only for three days in a year that they were trained by the zonal early warning Office about the concept of early warning". Experts in all three zones from the zone to the kebele levels explained that, because they do have skill and knowledge gap, when they collect early warning data from the different concerned offices; there exist data discrepancies each month".

Key informant, Agegehu Asmare, Team Leader, Misrak Dembia Woreda Disaster Early Warning and Response Work Process reported that the case of Tana affected kebeles, they have repeatedly reported to higher authorities about the damage caused by the backflow of Lake Tana. The workers responsible for checking the level of water in Lake Tana respond by saying that we will not discharge water from the lake unless the water level reaches the alarming level. Further he noted that the higher authorities are not willing to see the damage.

- **2.2.3 Non-Governmental Organizations**

The non-governmental organizations are flood forecast users. They obtain the flood forecast from NDRMC and NMA. Many of them calibrate the forecast obtained with the information collected from their field offices to address the specific flood affected communities according to their mandates.

UNICEF is one of the flood forecast users. Key informant, Gebre Egziabher Lema, Humanitarian Officer, at UNICEF and member of National Flood Task Force, noted the limitation of the National flood Alert as too general. It does not indicate specific localities that would be affected by flood. Usually, the flood task force is activated when flood is about to come. There is no ample time to conduct deep analysis to identify the impact of the expected flood. ENTRO flood early warning message indicates to what extent the water level is raised compared to the average. It does not have detailed information with regard to the magnitude of the flooding. Further, the forecast is not user friendly. UNICEF along other information attempts to identify specific localities that are going to be affected by flooding. FEW activity is a campaign work which is not a regular activity for the whole year. Early preparation is not practiced. It is a fire fighting activity. The FEWS should employ high performance technology for better forecast output, which minimizes doubtfulness on the part of forecast users. Further, this effort should be supported by indigenous flood early warning practices.

Gebre Egziabher noted that the ownership of FEWS, is not decided according to National Disaster Policy and Strategy. The policy gives the mandate to the Ministry of Water, Irrigation and Energy to handle water related hazards. In practice, NDRMC is handling such responsibility. NDRMC should give technical support to line ministries. He also suggested that the National Flood Task Force should be strengthened. Different NGOs have EWS which is based on their interest. There was an attempt to create one EWS which serves all parties, which did not materialize.

Key informants, Alemteshay Alemu, and Abey Wogders, reported that World Food Program (WFP) does not receive flood forecast from ENTRO. The flood early warning message is general to take site specific actions. It does not consider indigenous knowledge and mainly focuses on response. Coordination among different institutions is not institutionalized.

- **2.2.4 Local Communities**

The flood affected local communities located in Amhara and Gambella regions. are the social beneficiaries of the flood forecasting and early warnings. The disaster and preparedness workers at woreda level have indicated the specific communities affected by flood.

- ***2.2.4.1 Amhara Region***

Flooding is one of the natural the disasters that affect the Amhara Region. Key informant, Jemberu Desse, Director, Disaster Preparedness and Early Warning Directorate, Amhara Disaster Preparedness, Food security and Special Support Coordination Commission identified the zones and Woreda that are vulnerable to flooding in the region. The Woredas are found in West Gojam, Central Gondar, South Gondar, North Wollo and South Wollo. He indicated the flood prone woredas under Central Gondar zone, Denbia, under South Gondar zone, Fogera, Dera and Libo Kemkem, and Achefer in West Gojam zone.

The regional disaster prevention committee is composed of the President of Amhara Region, chairman and health, water, agriculture, education are members and the secretary is the Regional Commissioner for the commission for Disaster Preparedness, Food Security and Special Coordinator Commission. Further, a technical committee is setup chaired by the Director of Disaster Preparedness and Early Warning Directorate with members from NMA, Agriculture, and Water. This committee is responsible for the communication of flood alert to Zone and Woreda administrations. In addition, it is engaged in disaster preparedness by coordinating sectoral offices.

Lake Tana Area

Libo Kemkem Woreda

Libo Kemkem Woreda is one of the flood affected areas in Centeral Gondar Zone, of the Amhara Regional Government. Sisay Kassa, Team Leader, Disaster Prevention and Early Warning Work Process at the , Libo Kemkem Woreda Agricultural Office indicated the kebeles that are frequently affected by flood including Gura, Shena Tsion, Bambiko, Genda Wuha, Teza Amba, Tinaga and kab.

Fogera Woreda

Fogera Woreda is located in Central Gondar Zone, which is frequently affected by flood. Key informant, Emenesh Aseres, Team Leader, Disaster Prevention and Early Warning Work Process at the Fogera Woreda Agricultural Office reported that there are six kebeles which are fully affected by flooding. They are Nabega, Agatera, Kidest Hana, Shena, Shaga and Aquako. Partially affected are Agua Michale and Duba. The back flow of Tana could damage 600 hectares of cultivated rice. About 29,000 people could be affected by flooding in the Fogera Woreda.

Misrak Dembia Woreda

Misrak Dembia Woreda is located in Central Gondar Zone which is flood prone area. Key informant, Agegehu Asmare , Team Leader, Misrak Dembia Woreda Disaster Early Warning and Response Work Process reported that 10 kebeles are affected every year by flood in East Dembia Woreda. These kebeles are affected because of the backflow of Tana Laka and when the rivers namely Megech, Derma, Sudan Gedel and Neddit Rivers over flow their banks. Megech River affects kebles such as Addisge, Dingel, Deber Zuria, Arebi Abalibanos, Gur Amba Michale and Tana Wyne. Derma River affects Gebeban, Gur Amba, Bata, Kola Deba town, Keran, Gabzo Terara, Magnego. Sudan Gedel River affects Jangua, Neddit River affects Gur Amba, Achera, Terra Diablo, Gur Amba Michale. Tana lake affects Achera Tana Wyne and Addisge Dingel.

- ***2.2.4.2 Gambella Region***

Key informant, Lule Jone Public Relations Officer at the Gambella Disaster Prevention and food Security Agency reported that flooding affects two zones namely Nuare and Aguack. Under Nuare Zone: the Woredas affected are Etang, Lare , Jikaw , Wantua and Mapue. Under Aguack Zone: Gof and Jore Woredas are affected. The flooding comes during Kirmet season. Early warning steering committee is available at Killele, Zone, Woreda and Kebele levels. Flood alert is communicated through FM radio in five local languages. In addition, telephone calling and workers go to the flood affected areas. Lule believes that the communication is effective. Local people know that flooding will occur when there it rains all day. Many people do not own mobile phone. The message communicated is trusted.

Thowat Tiach Kuon, key informant, Water Resource Officer, the Gambella Water & Irrigation Bureau was a member of the Gambella Early Warning and Preparedness committee. He said out of 12 Woredas of Gambella Killele, 8 are affected by flooding. Gambella town is also minimally affected. The victims are mainly rural Woredas. The frequency of flooding in the region is once in a year, during kiremt season (July to first week of September). It causes dislocation of local people, crop fields are inundated and outbreak malaria.

Lare Woreda

Jone Kon**,** keyinformant**,** Coordinator of early warning in Lare Woreda, Gambellareported that **t**here are 28 kebeles in Lare Woreda. Most of them are affected by flood. The kebeles are Wushinkur, Tangha, Nif Nif, Mamok, Talbon, Watercon, Botonech, Kutin, Malo, Etanbur, Hilut, Kormancho and Kenakoch. There is a steering committee at Woreda administration composed of health, agriculture, education, women affairs offices. The Woreda gets flood early warning from Killele and zone offices. It communicates the kebele chairman to call a meeting of local people. The steering committee informs the people about the flooding. It advises people to leave the area if the flooding is going to be devastating.

2.3 Vulnerability mapping for settlement on flood prone areas

The flood prone areas in Ethiopia are scattered in many parts of the country along the major rivers. Rib and Gumera rivers in South Gondar, Gilgel Abay river in West Gojam, and Dirma and Megech rivers in North Gondar can cause flooding in surrounding areas. In Gambella, Baro, Gilo, and Akobo and SNNPR Omo River flooding cant take place. The National Flood Alert No.2 which covers the Kiremt season, i.e. June to September 2019 identified the flood risk areas in Ethiopia as follows.

Gambella Region-

Neur zone - Wantawa, lare, Akobo, Makuwey and Jikawo Woredas. Ankwak zone -Gambella Zuria, Gambella town, Dima, Jore, Goge and Abobo Woredas. Mejenger zone -Mengeshi Woreda and Itang special Woreda.

Benishangul Gumuz Region:

Assosa Woreda.

Oromia Region:

West Hararghe- Habru, Hawi Gudina and Oda Bultum Woredas. East Hararghe - Golo Oda, Goro gutu, Jarso, Gursum, Deder and Meta Woredas. West Arsi - Shalla, Arsi Negelle, Siraro, Kofele, Nensebo, Kore and Yaya Gulele Woredas. Arsi - Ziway, chole, dugda, gololcha, Robe and Seru Woredas. Bale - Agarfa, Legehida, Gasera, Gololcha, Ginnir, Seweyna, Goro, Berbere and Guradamole Woredas. Borena - Das, Dire, Arero, Miyo, Moyale, Yabello and Dubluk Woredas. West Shewa – Ejere Woreda. South West Showa – Illu and Ginchi Woredas. Guji- Adola, Urga, Bore, Anasora and Dima Woredas. East Shewa - Boset, Adama town, Adama Woreda, Adame tulu, Jido Kombolcha, Fentale and Lume Woredas. Illu Ababora – Becho Woreda.

Amhara Region:

South Gonder -Libo Kemkem, Fogera and Dera Woredas. Central Gonder- Dembia, Gonder Zuria and Alefa Woredas. West Gojjam -Bahir Dar Zuria and Dega Damot Woredas. Oromia special zone- Jile Tumuga, Artuma fursi and Dawa Harawa Woredas. North Showa -Antoskia Gemza, Ataye town, Shewa Robit, Kewet, Efrata Gidim and Ensaro Woredas. South wollo -Ambassel, Kombolcha and Kalu town Woredas.

Somali Region:

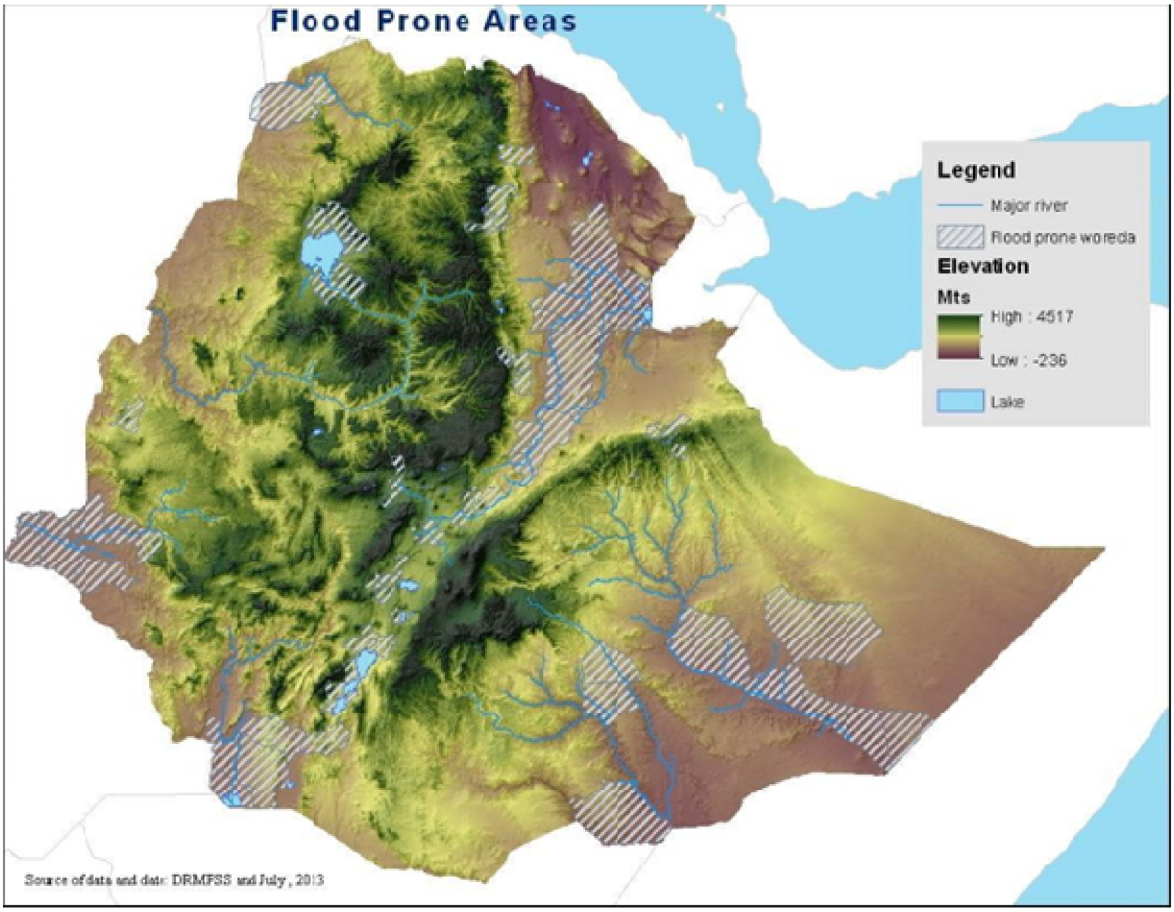
Shebele - Kelafo, Mustahil, Ferfer, Gode, Berano, DehunAdadile and East Imey Woredas. Afder - W/Imey, Chereti, Dollobay and Hargelle Elkeri Woredas. Liben - Dollo Ado Woreda. Dollo – Warder Woreda. Fafen – Jijiga, Togochale, Kebribeyah Woredas. Siti – Afder, Ayisha, Erer, Miesso and Shinile Woredas.

Afar Region:

Zone -1 - Dubti, Asayita, Mille, Chifra and Afambo Woredas. Zone 3 - Amibara, Gewane, Bure Mudayitu, Dulecha and Awash Fentale Woredas. Zone 2 - Abala, Berhale, Megale and Koneba Woredas. Zone 4 – Ewa Woreda.

Tigray Region:

W/Tigray – Humera and Tsegede Woredas. Southern Tigray - Alamata Woreda. Raya –Azebo, Enda- Mehoni and Maichew Woredas.



Map of flood prone areas in Ethiopia

SNNPR:

South /Omo- Dasenech, Nanghatom, Hamer and Selamago weredas. Hdiya – Shashego and Mirab Bedewacho. Wolayta – Humbo, Damot Waydie, Dugna Fango, Kindo Didaye, Kindo Koysha and Boloso Bombe. Halaba Special wereda – Halaba. Sidama – Loka Abaya, Hawassa Zuria, Hawassa Town; SilteDalocha, Sankura and Silte weredas. Guragie- Meskan, Mareko and Kochere.

Dire Dawa:

Dire Dawa city

Harari Region:

Harar city

Addis Ababa:

Flood prone sub cities

3. ANALYSIS OF STAKEHOLDERS' GAP IN FLOOD EARLY WARNINGS

3.1 Data and Forecast providers

In this section, the discussion focuses on the flood early warning data providers namely Eastern Nile Technical Regional Office (ENTRO), Ministry of Water, Irrigation and Energy (MWIE), National Disaster Risk Management Commission (NDRMC) and National Meteorology Agency (NMA)

- **3.1.1 Eastern Nile Technical Regional Office**

Eastern Nile Technical Regional Office (ENTRO) communicates the issued flood forecast with the Ministry of Water, Irrigation and Energy (MWIE) expecting that the flood early warning will be communicated to the end users (local communities) by the Ministry. Further, ENTRO sends the flood forecast to Amhara, Gambella regions and Abay Basin. However, ENTRO is not sure whether it reaches the end users. The current practice is that ENTRO's flood forecast is not communicated to the flood prone areas as expected. Semunesh Golla, Director of Hydrology and Water Quality Directorate, the Ministry of Water, Irrigation and Energy noted that the flood forecast of ENTRO is not communicated to the stakeholders and verified for the last three years. The Ministry is doubtful of the forecast model HEC –HMS. ENTRO, realizing the limitation, had promised to improve the modeling. She underlined that ENTRO should provide a reliable flood forecast to support the issuing of flood early warning to the target communities.

Different flood forecasting systems are employed for Lake Tana, Gambella and BAS areas. This practice needs the employment of three professionals for the respective forecasting areas, which is expensive for ENTRO; and thus, the enhancement of the forecasting system needed.

ENTRO is not engaged in seasonal flood forecast with the lead time of 1-3 months because of financial constraints. There is a project in progress that address seasonal forecast at Easter Nile Basin level.

There is lack of documentation (e.g. forecasters handbook) for systematic verification of products through the forecast chain. Forecasting professionals come from the MWIE during rainy season. After they completed their work they go back to the Ministry.

ENTRO's data sharing and collaboration with other institutions is not satisfactory. Individual relationship matters to facilitate the exchange of data. To support the issuing of the flood early warning, ENTRO would like to get actionable information from stakeholders. To this end, a sound institutional arrangement at national and regional levels that would facilitate data sharing is imperative. Although ENTRO gets weather data from National Meteorology Agency (NMA) through the Ministry, it needs to have a direct relationship with NMA. The importance of cooperation between ENTRO and NMA has been underlined in the ENRTO's Flood Preparedness and Early Warning Seasonal Report (2018:29) which states that "It is advisable to enhance and modernize the WRF numerical weather model, verify results and use of it for the flood forecast and used for the hydrologic model. To verify the model results, ENTRO should cooperate with the Ethiopian National Meteorological Agency (NMA) in order to facilitate real time precipitation data exchanges in addition to capacity building of the experts'. Thus, ENTRO may need a Memorandum of Understanding with NMA for number of reasons including data sharing and utilization of NMA's high performance computer for the forecasting.

Key informant, Azeb, water specialist at ENTRO, also indicated that flood early warning issued by ENTRO does not consider indigenous flood early warning practices. In addition, verification of the forecast is not carried out because of budget constraint. Flood early warning is not issued on flash flood because of lack of budget. Further, the warning practice does not encourage the participation ofthe public and non-governmental organizations. She also noted that the existing early warning system does not facilitate effective co-ordination between stakeholders. The emphasis of the EWSs is response rather that preventive actions. Further, that existing EWSs does not address the most important issues of local communities. In this regard, ENTRO assumes that the MWIE will address such issues.

In terms of timing, probability and areas to be affected, the flood early warning message is satisfactory. With regard to flood forecasting chain, ENTRO did not identify implicit authors or mediators regarding flood disaster in the community. There is no effort made to reduce the complexity of forecasting at the supplier end of the chain.

With regard to mobile phone usage to disseminate flood early warnings, Azeb Mersha noted that at first stage of the project ENTRO has distributed mobile phones in Lake Tana area by identifying focal persons to text forecasts message.

The existing flood EWSs is not technically sustainable since the institutional arrangement is not clear. The Ministry wants to establish its own forecast center. Conversely, ENTRO may face a problem when, in the middle of the year, asks and engage the professionals of the Ministry to work out the flood forecasting activities. Further, to carry out effective dissemination of the forecast, a sound institutional arraignment should be in place. Within ENTRO, there is infrastructure problem such as absence of high performance computer; internet connection is poor to download global data for six hours and more. Further, the power interruption is a bottleneck. The stakeholders list for flood forecast dissemination is outdated. In addition, the impact of the forecast is not known.

- **3.1.2 Ministry of Water, Irrigation and Energy**

The Ministry of Water, Irrigation and Energy (MWIE) is one of the flood early warning data providers. Although the National Policy and Strategy on Disaster Risk Management (NPSDRM) of Ethiopia designates the Ministry of Water, Irrigation and Energy as a lead institution with respect to floods disaster, it did not assume such responsibility yet. At present, the National Disaster Risk Management Commission (NDRMC) plays the lead role. The Review of Disaster Risk Reduction Practices in Ethiopia (2016:5) notes that "relatively good policies, systems, plans, or regulations are in place but seem to be ignored, or make little impact on DRR practices. For policies to make an impact they must be constantly taken into account in routine decision-making and must be institutionalized (legislated and integrated into the laws, practices, and customs of the society)" Further, the Review indicated that "coordination and cooperation among government and non-governmental organizations is not strengthened to the desired level to enable the integration of DRR into development planning. Functions and responsibilities do not seem to be formalized and accepted by all involved entities”.

The Ministry of Water, Irrigation and Energy, being doubtful of the forecast, is not communicating and verifying the flood forecast issued by ENTRO to the stakeholders for the last three years. Although the Ministry has a compelling reason not to communicate the flood early warning, it should have discussed with ENTRO to fill the gap created.

Flood forecasting for the rivers with reservoir is well practiced. There is no forecast for rivers without reservoirs. Real time flooding could be communicated, which river needs gauge. However, since there is no prediction data, forecasting is not carried out. The public needs the forecasting.

The MWIE is not involved in forecasting for flash floods because of limited capacity in forecast modeling. In the flood early warning process, the MWIE is not considering indigenous early warning systems although it believes in the importance. Further, the media is not utilized for flood forecasting.

Further, the MWIE, realizing its capacity limitation, would like to get from ENTRO capacity development; in terms of providing forecast software and training of manpower and knowledge sharing that would enhance local input verification and communication and joint professional work.

- **3.1.3 National Meteorology Agency**

The discussion with key informant, Aderagew Admasu, Director, Meteorological Forecast and Early Warning Directorate indicated the gaps of NMA. The lack of highly specialized manpower and technology have limited the capacity of NMA to issue seasonal flood forecast with lead times of about 1-3 months. Further, lack of forecasting data has forced NMA to carry out the probability forecast with limitation. Data sharing and collaboration between institutions, ministries and ENTRO is not institutionalized. The collaboration takes place when the need arises. Further, the flood early warning coordination between NMA, ENTRO and national and regional governments is not satisfactory. Aderagew expressed that there is capacity limitation in the national institutions to create functional and comprehensive meteorological and hydrological networks to generate accurate forecasts and guidance. Government or donors’ investment in leadership and soft skills to improve flood EWS is low.

Data sharing and collaboration between institutions, ministries and ENTRO is weak. The collaboration is not on regular basis. When the need arise, collaboration among institutions takes place.

NMA would like to get the following actionable support from ENTRO:

- NMA is involved in weather forecast, which is vital for flood forecast. On the other hand, ENTRO collects water level data from river gauges. NMA needs river water data from ENTRO. Thus, if the two organizations work together the flood forecasting output could be more accurate.

- WRF Hydro is important for flood forecast, which is internationally accepted. If NMA and ENTRO collaborate in modeling, better output could be achieved.
- The rich NMA's modeling experience could be useful for ENTRO.
- The radar in Tana Beles area is not operational due to absence of electricity. If ENTRO makes an effort to provide power to the radar, it could be beneficial since NMA has weather data collection station in the area. The radar could provide electromagnetic data which could be calibrated with NMA's data

- **3.1.4 National Disaster Risk Management Commission**

The Ethiopian National Policy and Strategy on Disaster Risk Management (2013:11) states that " a decentralized disaster risk management system that clearly identify and assign the roles and responsibilities of each level of government, concerned organizations at all levels, communities and individuals in accordance with disaster risk management activities shall be set up". To this end, the National Disaster Risk Management Commission (NDRMC), after it was re-established in 2105 by the Regulation No. 363/2015, is re-structuring itself. It has opened independent Regional Commissions and Zonal Offices. However, at Woreda level, disaster risk management is organized under the Woreda Agricultural Office as a Work Process lead by a Work Process Team Leader with few workers. Key informant, Almaze Demessie, Director, Early Warning and Emergency Response Directorate has underlined that "the communication system is not well structured" noting the weakness at Woreda and kebele levels. Further, Almaz indicated that flood EWS, at governmental level, is not well owned and the practice is characterized as a fire fighting process. At Woreda level, lack of skilled manpower and high turnover and limited budget allocation are some of the problems encountered.

The Ethiopian National Policy and Strategy on Disaster Risk Management gives the lead role to the Ministry of Water, Irrigation and Energy. However, this role is being played by the NDRMC. The National policy is not translated into action. Key informant, Abera Kassa, Director, Disaster Risk Reduction Directorate at NDRMC , noted thatuntil nowthere is no concrete action with regard to the implementation of the lead role by sector institutions according to the policy and strategy of disaster risk management. Such issue should be resolved at higher level so that sector ministries could mainstream disaster in their development plan. Currently, when disaster occurs, the practice is to push it to NDRMC.

Key informant, Beletu Tefera, noted that although there was an interest to get flood alert feedback from communities, which did not materialize, should be given the due attention. The Flood Alert is too general, which does not indicate a particular area that could be affected by flood. Further, she underlined the importance of incorporating indigenous early warning practice in the early warning system. At present, the emphasis of EWS is on response rather than on prevention. Although NRDMC has owned EWS the operation appears to be fire fighting. Beletu, to overcome capacity limitation of NRDMC, suggested the provision of training, upgrading of forecasting modeling and annual forecasting.

The actionable information NDRMC would like to get from ENTRO to support the issuing of the flood early warning are: ENTRO should continue to send flood forecast output to NDRMC. ENTRO should regularly consult stakeholders with regard to the type of information stakeholders need. It can benefit from such consultation to develop its forecast output. It has to be participatory. ENTRO should be a member of Nation Early Warning Technical Committee.

NDRMC is interested to support ENTRO in its regional flood early warning practices. ENTRO could use NDRMC communication system, which would enable ENTRO to understand stakeholder's interest.

3.2 Forecast Warning Users

The flood forecast warning users include regional, zonal and Woreda level government offices, NGOs, UN agencies and humanitarian organization. These institutions are expected to disseminate the warnings to the flood prone communities through different channels.

- **3.2.1 National Government**

The national government is one the flood forecast users. At federal level, the ministries such as Ministry of Health, Ministry of Education, Ministry of Agriculture and Basin Development Authority use flood forecast to minimize the negative impacts of flooding. For instance, the Ministry of Health, could take the necessary health related actions in terms of response and preparedness before and after the occurrence of flooding in a particular community.

- **3.2.2 Regional, zonal and woreda administrations**

The regional, zonal and woreda administrations are flood forecast users under the Ethiopian government structure. These administrations obtain technical support from the branch offices of NDRMC established at different levels. Although the structuring is not complete, at present there are independent offices at region and zone levels with the exception of woreda administration. At Woreda level, the activities of NDRCM are carried out by a Work Process (work team) organized under the Woreda Agricultural Office. Further, there are disaster risk management and preparedness committees composed of various offices at regional, zonal, woreda and kebele levels.

Sisay Kassa, key informant, Team Leader, Disaster Prevention and Early Warning Work Process at Libo Kemkem Woreda who served for five year alone, underlined that the early warning system should be strengthened by employing professionals. At present three people are working in woreda office. Since the disaster preparedness and early warning activities are carried out along with agricultural activities, priority is given to the later. This institutional arrangement is not conducive to discharge the responsibilities of implementing the disaster early warning and preparedness activities. He underlined that the disaster risk management office should be organized independently.

Key informant, Emenesh Aseres, Team Leader, Disaster Prevention and Early Warning Work Process at Fogera Woreda reported that "flood task force used to get training up to three years ago. All concerned people from Kebele and Woreda had a meeting once in a year. This practice was helpful to evaluate our activities and prepare ourselves for the coming flood season. At present, we simply communicate individual kebeles without having such meetings".

Birhanu, et al (2016:26) conducted a study in Libo Kemkem, Jabitehinan and Kalu Woredas located in South Gondar, West Gojjam and South Wollo Zones respectively in the Amhara National Regional State. The researchers identified that "from the zone to the kebele levels of the study areas, experts are with little knowledge of different risks and hazards. They lack comprehensive training on risk knowledge and hazards. Risk knowledge is acquired and built up on personal effort: through reading and attending trainings rather than being trained from the concerned department in higher education institutions". Further they noted that trainings which are directed towards improving experts' knowledge were uncoordinated, meager and too short. In this regard, experts from Libo Kem Kem Woreda explained that "It was only for three days in a year that they were trained by the zonal early warning Office about the concept of early warning". Experts in all three zones from the zone to the kebele levels explained that, because they do have skill and knowledge gap, when they collect early warning data from the different concerned offices; there exist data discrepancies each month".

Agegehu Asmare, key informant, Team Leader, Misrak Dembia Woreda Disaster Early Warning and Response Work Process reported that the case of Tana affected kebeles, they have repeatedly reported to higher authorities about the damage caused by the backflow of Lake Tana. The workers responsible for checking the level of water in Lake Tana respond by saying that we will not discharge water from the lake unless the water level reaches the alarming level. Further he noted that the higher authorities are not willing to see the damage.
There are many projects at wordea level. However, these projects do not include disaster early warning and response. There is no much attention to such activities.

- **3.2.3 Non-Governmental Organizations**

The non-governmental organizations are flood forecast users. They obtain the flood forecast from NDRMC and NMA. Many of them calibrate the forecast obtained with the information collected from their field offices to address the specific flood affected communities according to their mandates.

UNICEF is one of the flood forecast users. Key informant, Gebre Egziabher Lema, Humanitarian Officer, at UNICEF and member of National Flood Task Force, noted the limitation of the National flood Alert as too general. It does not indicate specific localities that would be affected by flood. Usually, the flood task force is activated when flood is about to come. There is no ample time to conduct deep analysis to identify the impact of the expected flood. ENTRO flood early warning message indicates to what extent the water level is raised compared to the average. It does not have detailed information with regard to the magnitude of the flooding. Further, the forecast is not user friendly. UNICEF along other information attempts to identify specific localities that are going to be affected by flooding. FEW activity is a campaign work which is not a regular activity for the whole year. Early preparation is not practiced. It is a fire fighting activity. The FEWS should employ high performance technology for better forecast output, which minimizes doubtfulness on the part of forecast users. Further, this effort should be supported by indigenous flood early warning practices.

Regarding the ownership of FEWS, it is not decided according to National Disaster Policy and Strategy. The policy gives the mandate to the Ministry of Water, Irrigation and Energy to handle water related hazards. In practice, NDRMC is handling such responsibility. NDRMC should give technical support to line ministries. National Flood Task Force should be strengthened. Different NGOs have EWS which is based on their interest. There was an attempt to create one EWS which serves all parties, which did not materialize.

Key informants, Alemteshay Alemu, and Abey Wogders, reported that World Food Program (WFP) does not receive flood forecast from ENTRO. The flood early warning message is general to take site specific actions. It does not consider indigenous knowledge and mainly focuses on response. Coordination among different institutions is not institutionalized.

- **3.2.4 Local Communities**

The local communities are the social beneficiaries of the flood forecasting and early warnings. The disaster and preparedness workers at woreda level, working closely with the social beneficiaries, in Lake Tana and Gambella areas have expressed their views which show gaps related to flood forecasting and early warning practices.

Kello Oku, key informant, early warning worker at Jore Woreda Early Warning and Food Security, Gambella Region, reported that although there are local people who respond to the early warning and prepare themselves by constructing canals, there are some who are reluctant and assume that they can do the protection later. Such community members were flooded in two days rain. Further, Kello noted that flooding can happen without communicating early warning. The 16 rural kebles of Jore woreda have only two police radio communications which can serve for the early warning. The 14 kebles do not have communication means. Local people do not have personal radios. The other communication means is by writing a letter.

Form Libo Kemkem woreda a key informant noted that there used to be sirens which are not function. Further, it was reported that the Rib irrigation scheme has rechanneled the rivers to Baihr Dar Gondar road. These rivers are flooding the crop fields. It was also reported that the Amhara Regional DRMC does not get flood forecast from ENTRO.

When disaster strikes, the woreda communicates the zone and killel. Without issuance of early warning flooding can occur. It the rain comes at night flooding can take place without early notice. For instance, in the flooding that took place in Kola Deba town was without notice. The public was not aware of it since it has never happened in town.

By and large, the communication system is not well organized and there are people who are reluctant after they received the flood early warnings. The construction of permanent structure to protect local people from flooding in Gambella area needs considerations since the flood affected people do not option to resettle in safer place.

A study by conducted by Birhanu, et al (2016) in West Gojjam Zone clearly indicates the knowledge gap in terms of understanding the concept of EWS among the communities.

Box 1:

Knowledge gap observed at the expert level is also common among the local community at the kebele levels .though they have identified some of the risks and willing to develop knowledge they are not supplemented with appropriate trainings from the experts. Discussants from “Abasem Zeguay” kebele, Jabitehinan Woreda of West Gojjam Zone clearly stated that they do not know what EWS mean and about the existence of early warning committee in the kebele. Neither of the discussants remembers anybody who gives them early warning education. Almost all discussants in the selected kebele levels explained that there is no attempt to build their risk knowledge and about early warning. Experts on their side stated that there is no mechanism for early warning education to the community. Even it is not incorporated in the plan of the process. They complain that the government is allocating no money for the desk, except salary. Because there is no early warning education, the communities lack deep knowledge on risks in respective Kebles except their long established indigenous knowledge system.

Berhanu et al (2016) further reported that “there is no evidence of monitoring mechanisms to check whether the warning messages reach, understood and interpreted into action by the community. Informants from West Gojjam Zone for instance stated that almost all kebeles in the zone have telephone; however information delay is very common because of network related problems”

In addition, for some Woredas, especially for Bahir Dar Zuria Woreda, which has well organized early warning committee at the kebele level, bells, phones and “tirunba” are purchased and supplied by a SNIF project. Kebele level meetings are the other methods of information dissemination and communication. However, in some kebeles of the Zone people are reluctant to attend meetings of such a kind and only the elderly and women used to attend meetings. In the case of south Wollo Zone All the warnings were not reached and agreed by all of those at risk. Government officials and communities did not understand all the warnings and the risks. The warning information was not clear and usable to all. There were no uniform and systematic dissemination and communication strategies established at all levels. However, in the selected Woreda there were established dissemination and communication strategies and early warning system modalities for timely responses of risks. As one of the informants said, “there was emergency coordination forum (NGOs, GO;) in the Woreda to disseminate and communicate early warning information to concerned parties including Current situation analysis of the area, action point and Implementation strategies, and designed response actions for disaster risk”

Birhanu, et al. (2016:26) indicated community members' low level of early warning concept since "discussants from "Abasem Zeguay" kebele, Jabitehinan Woreda of West Gojjam Zone clearly stated that they do not know what EWS mean and about the existence of early warning committee in the kebele. Neither of the discussants remembers anybody who gives them early warning education. Almost all discussants in the selected kebele levels explained that there is no attempt to build their risk knowledge and about early warning. Experts on their side stated that there is no mechanism for early warning education to the community". Further Berhanu et al. (2016:26) noted that "because there is no early warning education, the communities lack deep knowledge on risks in respective Kebeles except their long established indigenous knowledge system".

The Review of Disaster Risk Reduction Practices in Ethiopia (2016:6) revels that "there are gaps in properly approaching the community through existing traditions, culture, knowledge and local capacities and enable them choose their development options. Using local knowledge to improve DRR is yet to be developed".

4. COMMUNICATION METHODOLGOY FOR FLOOD EARLY WARNING

4.1 Best practices and Methodologies in Flood Early Warning Communication

- **4.1.1 Ethiopia**

Ethiopia is one of the flood affected countries in East Africa. Flooding occurs in various parts of the country. Dire Dawa City Administration is among the flood prone areas located in the Eastern part of the country.

The report of Ashenafi Dejene and Yetayal Amsalu (date NA) indicates that how communities in Dire Dawa Administration, Eastern Ethiopia, have reduced their vulnerability to weather-related hazards following the integration of indigenous and conventional knowledge on Early Warning Systems through a joint multi-sectoral platform. About 13,000 households living upstream and downstream Dire Dawa have developed appropriate coping mechanisms for the frequent and cyclic flooding by establishing a community-based weather forecasting capacity.

In 2013, the Community Managed Disaster Risk Reduction (CMDRR) committees were initiated and facilitated by the Partners for Resilience (PFR) program. These committees were established in the upstream divisions of Ejeaneni, Adiga Felema and Lege Bira with a total of 6,400 beneficiaries. The community-led initiatives compliment the Ethiopian government's major investments in flood control. Based on, the upstream and downstream CMDRR Committees implemented Early Warning Systems (EWS).

The Partners for Resilience (PFR) program followed the following method to establish the flood early warning system.

Step 1: Conducting community risk assessment conducted in the project site.
Step 2: Establishing community Managed Disaster Risk Reduction (CMDRR) committees.
Step 3: Strengthening the indigenous early warning systems.
Step 4: developing locally appropriate communication strategies to disseminate weather and climate information including included using sirens, hand held megaphones and mobile phones.
Step 5: establishing a joint multi-sectoral platform for sharing climate information for Early Warning. Each of the eight organizations involved in the joint platform, signed a Memorandum of Understanding (MoU) pledging to collaborate and share weather and climate information through the joint multi-sectoral platform.

Step 6: Through this partnership with PFR, seven Community Information Centers were established within the target communities to facilitate grassroots-level information sharing and cross learning on weather forecasting and alerting capacity. The centers were equipped with sirens, a hand held megaphone and mobile phones by the project.

Step 7: Partners for Resilience, through Cordaid also strengthened the CMDRR committees by facilitating their registration as legal entities. The program conducted trainings on Early Warning Systems for local community members.

The communication process:

During floods, the CMDRR committees from the Oromia region upstream notify their downstream counterpart committees in Dire Dawa city by mobile phone using designated emergency phone numbers. Then the downstream Dire Dawa committees use sirens and megaphones to relay the emergency weather and climate information and also to prompt responsive action by the most-at-risk community members. As an innovation, the local communities combined the indigenous early warning signals with the conventional Early Warning Systems primarily disseminated by government agencies, non-governmental and private-sector organizations.

- **4.1.2 Assam State, India[4]**

The best practice reported here is based on the report titled Flood Early Warning System: A warning Mechanism for Mitigating Disasters during Flood" date (N.A) is a project initiated by Assam State Disaster Management Authority in collaboration with North Eastern Space Application Center

Assam is the gate way to the northeastern part of India. Occurrence of flood has been an age-old phenomenon in the riverine areas of the region. The frequency and intensity of flood has grown over the years primarily because of the increased encroachment of flood plains. There are mainly two river systems in Assam i.e. Brahmaputra and Barak River. Flood is an annual event in the State of Assam. More than 40 percent of its land surface is susceptible to flood damage. The total flood-prone area in Brahmaputra valley is about 3.2 million ha.

The main purpose of the initiative was to develop a location specific early warning system which could help the administration in taking advance precautionary measures an issue flood alerts to the those specific areas so that necessary measures can be undertaken by the people.

Major Technical Components of the Project

1. The meteorological components comprises of the two major sub components of Weather Research Forecast (WRF) model for grid based rainfall prediction through numerical schemes and multi-parametric (CTT, CMV, Vortices etc.) synoptic weather monitoring for overall probability of rainfall in a particular basin.

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[4]The flood early warning system designed as a warning mechanism for mitigating disasters during flood in Assam State in India was selected as the best practice by the Department of Administrative Reforms & Public Grievances, Ministry of Personnel, Public Grievances and Pensions of Government of India.

2. The hydrological component comprises of a hybrid approach of lumped grey box model known a Rational model in combination with a quasi-distributed hydrological model know as the HEC-HMS in Arc-GIS platform. While the first approach provides the forecast of the peak value for a river basin, the distributed model provides the forecast for the daily hydrograph for that basin. Comparing both the forecast with the established flooding thresholds for that river, issue of flood warning is decided.
3. The third component is the post flood identification of the embankment breaches and general monitoring of embankments.

Figure 4.1 Flow chart of overall methodology of FLEWS

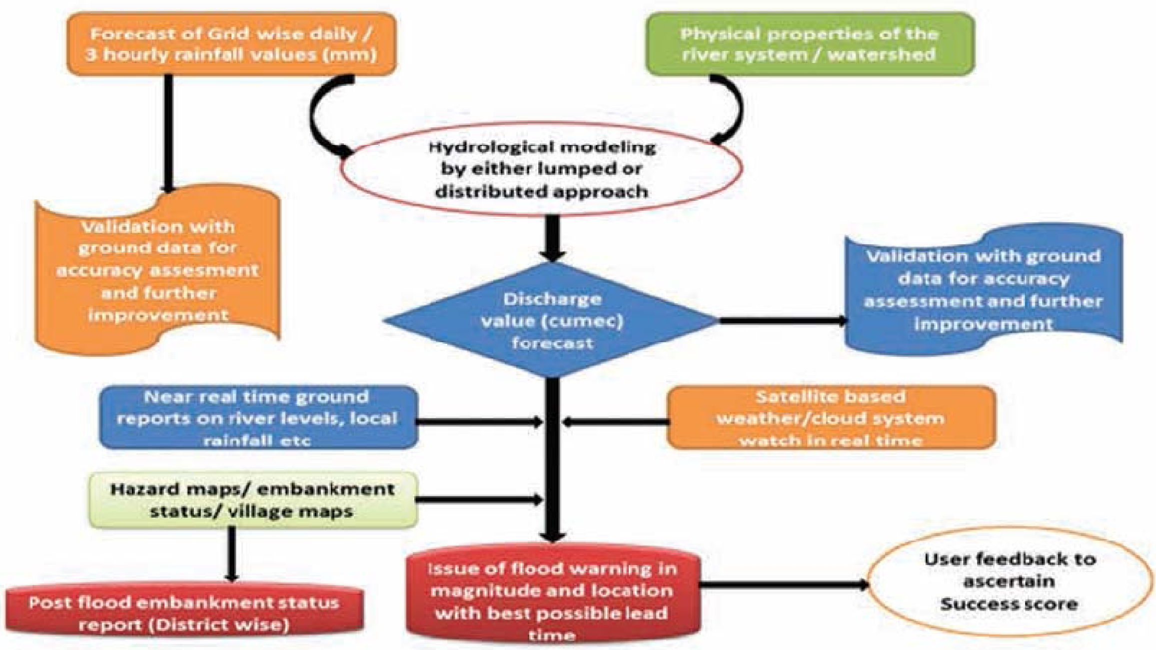

Fig.5: Flow chart of the overall methodology of FLEWS

Methodology for dissemination of flood warning alerts to districts

Once the Flood Warning Alert is received at the State HQ, the same is disseminated to the District Deputy Commissioners and the District Project Officer (Disaster Management) for alerting the concerned Circle Officers, Water Resource Department PWD (Roads) Department, through SMS, phone/mobile and personnel messenger. The flow chart for Flood Warning dissemination as indicated in the following figure shows two way communications between the North Eastern Space Application Centre (NESAC) which issues flood alters and GAON BURAS/PRI/TASK FORECES/NGOs/CBOs at GP and Village.

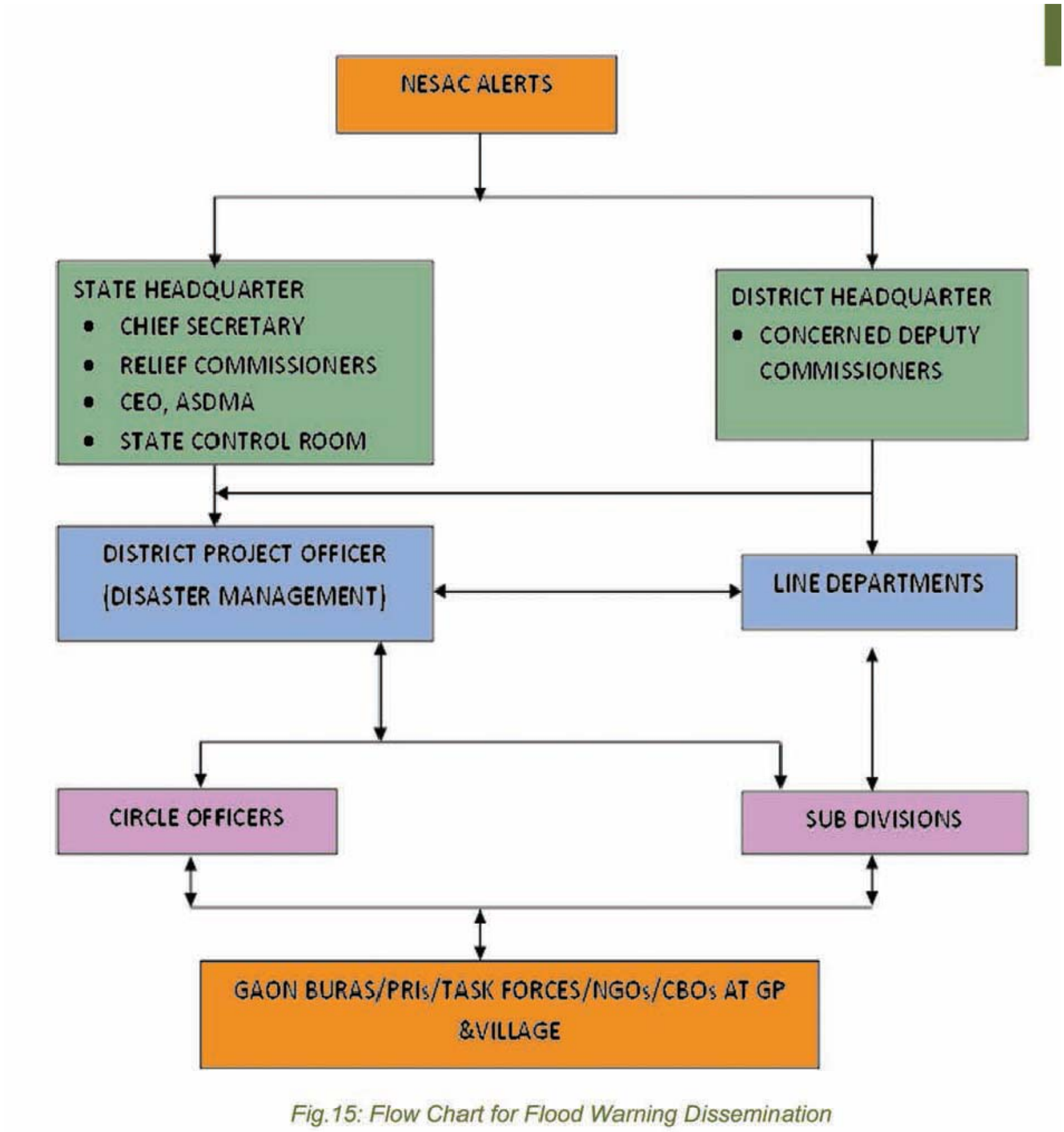

Figure 4.2: Flow chart for flood warning dissemination

Organizations/stakeholders involved

FLEWS is an integrated effort of different stakeholders viz. Indian Meteorological Department (IMD), Central Water Commission (CWC), NEEPCO, Water Resources Department, NESAC and ASDMA to achieve a common goal of effective management of flood in Assam. The Assam State Disaster Management Authority (ASDMA) takes the lead role in bringing all the stakeholders together in a common platform for developing this system. Prior to development of FLEWS each stakeholders were working independently within their own domains for flood management and it was ASDAMA that played the catalyst role in getting all on board and brought in the North East Space Application Center to develop the location specific FLEWS model. Since then each department has been contributing significantly for effective implementation of the FLEWS and thereby making it a success.

Strategies adopted for bringing about the transformation and its impact

1. The first strategy in the establishment of FLEWS is the consideration of the flood prone districts on a basin or catchment. The early warning system has been viewed in the context of a river basin approach where upstream, midstream and downstream activities affect the time of concentration and volume of runoff as reflected in the shape of the hydrograph.

2. The second strategy adopted in FLEWS is providing location specific early waning advisory bulletin. The warnings issued by NESAC provide information about the revenue circles and the probable villages that may be affected due to flood. This information is of great help to the administrative machinery for preparedness and response activity. The flood alert is also disseminated to the community through revenue circle officers and gaon buras.

3. The third strategy is the involvement of all the stakeholder under FLEWS as without their active participation FLEWS could have never been a success.

The model developed by North East Space Application Center for flood early warning has an accuracy rate of around 60 %.

4.2 Current Flood Early Warning Communication Method

- **4.2.1 Eastern Nile Technical Regional Office**

ENTRO conducts daily monitoring with three-day lead-times to produce forecasts. Rainfall and hydrological data is used to model and predict flooding with greater accuracy. Daily, weekly, and seasonal flood forecast reports are generated and disseminated to different users at different levels through the ENTRO web portal, email, and mobile phone messaging.Daily, weekly, and seasonal flood forecast reports are generated and disseminated to different users at different levels through the ENTRO web portal, email, and mobile phone messaging.

ENTRO has direct relations with the Ethiopian Ministry of Water, Irrigation and Energy. It sends the English version of flood early warning to the Ministry by e-mail to provide early warning information to local government (woreda) authorities to aid in flood preparation and response.

Further, an attempt is made to widen the dissemination of the forecast by sending the forecast to the National Disaster Risk Management Commission (NDRMC), Red Cross and other NGOs. The Flood forecast of 2018 issued by ENTRO is indicated in the following Box 2.

Box: 2

In Lake Tana floodplains, the methodologies for flood forecasting processes were used combined hydro-meteorological| flood models. The WRF rainfall forecast for the EN is issued for the 2018 flood season from third week of June to end of August, the Configured Hydrologic Modeling System (HEC-HMS) to produce the corresponding runoff forecasts, and the Hydraulic River Analysis System (HEC-RAS) model used for routing the runoff forecast on the LT floodplain areas. Then, the flood inundation maps were produced that shows the degree of inundation depths and the number of flood affected households residing on the LT floodplain. This was done using the simulation results from the hydrodynamic model and HEC-GeoRAS mapper in arc-GIS interface. In the FEWS-Sudan, integrated forecasting models were used and run, including HEC-HMS hydrological model of the Upper Blue Nile catchment (upstream of El Deim gauging station). HEC-RAS model of the Blue Nile between El Deim and Khartoum, and Linear Correlation Models between El Deim and Dongola in the Blue and Main Nile river systems. USGS-RFE and TRMM 3B42satellite based rainfall estimates for upper Blue Nile, Dinder, Rahad, Sitet and Atbara catchments were used as forcing data for the HEC-HMS hydrological model. In addition, there are three days rainfall forecasts of WRF from NOAA and inundation maps library for the Blue Nile River based on the discharge at El Deim station. In the development of BAS flood forecast model, WRF rainfall forecast is used as an input to the configured hydrologic model for BAS (Gambella floodplain and Sobat Floodplain) and the anticipated relative peak runoff during the forecast period were used as an input to hydrodynamic model component that was developed for Gambella Floodplain and the Sobat areas. Hence, verification was done with mean daily gauge readings from Gambella and Itang Stations. Alternatively, Global Flood Tool from USGS was used to model the inundation patterns for different depths of the rivers. Source:
ENRTO (2018) Flood Preparedness and Early Warning Seasonal Report

- **4.2.2 National Disaster Risk Management Commission**

The National Disaster Risk Management Commission (NDRMC) communicates the Flood Alert to stakeholders by telephone and email. Further, at the time of flooding frequent communication is carried out. For instance, in 2014 the emergency coordination center of NDRMC implemented the National Incidence Management System (NIMS) from USA. Depending on the urgency of the disaster we use every possible communication system. Recently a pilot project called Woreda Net in about 35 Woredas with computers provided the Commission with data. The information collected is helpful for situation update. The flood forecast issued by NDRMC covers all the country. The institutional arrangement for flood early warning and dissemination is indicated in the following figure.

Current flood early warning institutional arrangement and communication method

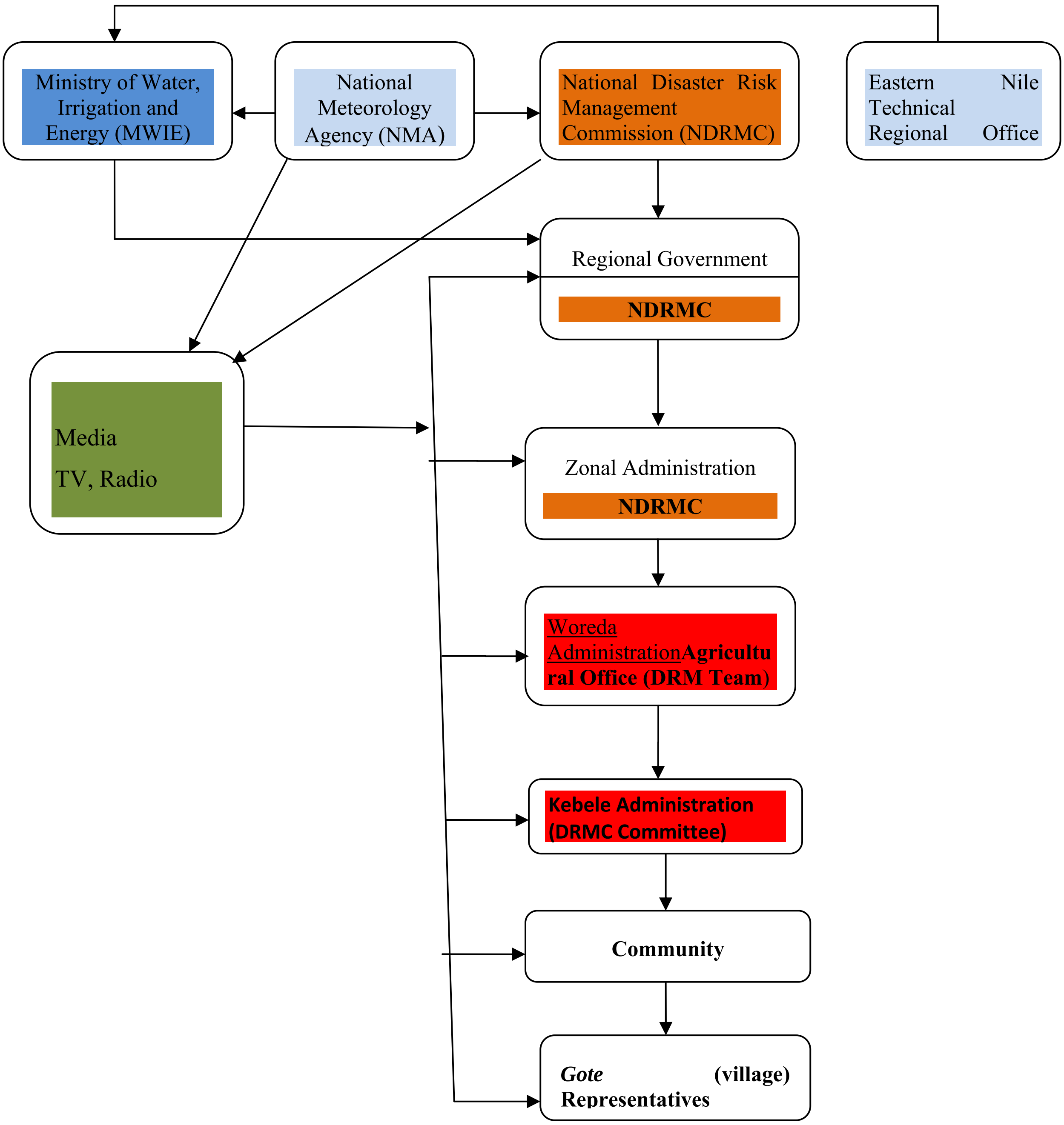

Figure 4. 3 Flood Early Warning Communication and Dissemination Chain

Flood Alert No.2

This National Flood Alert # 2 covers the Kiremt season, i.e. June to September 2019. The National Flood Alert # 1 was issued in April 2019 based on the NMA belg Weather Outlook. This updated Flood Alert is issued based on the recent NMA kiremt Weather outlook to highlight flood risk areas that are likely to receive above normal rainfall during the season and those that are prone to river and flash floods. This flood Alert aims to prompt early warning, preparedness, mitigation and response measures.

During the months of May and June 2019, 33 Woredas (in seven regions) were affected by flood forcing 42,249 families to displacement, significant number of livestock death, and property damage, i.e. crop, houses, schools and other vital infrastructure.

In SNNP region, 13 Woredas were affected by flood whereby 5,901 families were displaced and 4616 ha covered with crops was flooded. There are also reports of significant damage such as destruction of 150 houses and other key infrastructures. In addition, there were reports of flooding which affected 13 schools in the above mentioned Woredas.

In Afar, 36,000 families were reportedly displaced due to flood while significant number of livestock deaths were reported.

Similar flood incidents were reported from Amhara, Gambella, Oromia, Somali and Tigray regions.

FLOOD RISK AREAS

The 2019 Meher season flood risk areas list was developed based on the NMA 2019 Meher season weather forecast, and historical data.

Gambella Region- Neur zone - Wantawa, lare, Akobo, Makuwey and Jikawo Woredas. Ankwak zone -Gambella Zuria, Gambella town, Dima, Jore, Goge and Abobo Woredas. Mejenger zone -Mengeshi Woreda and Itang special Woreda.

Benishangul Gumuz Region: Assosa Woreda.

Oromia Region: West Hararghe- Habru, Hawi Gudina and Oda Bultum Woredas. East Hararghe -Golo Oda, Goro gutu, Jarso, Gursum, Deder and Meta Woredas. West Arsi - Shalla, Arsi Negelle, Siraro, Kofele, Nensebo, Kore and Yaya Gulele Woredas. Arsi - Ziway, chole, dugda, gololcha, Robe and Seru Woredas. Bale - Agarfa, Legehida, Gasera, Gololcha, Ginnir, Seweyna, Goro, Berbere and Guradamole Woredas. Borena - Das, Dire, Arero, Miyo, Moyale, Yabello and Dubluk Woredas. West Shewa – Ejere Woreda. South West Showa – Illu and Ginchi Woredas. Guji- Adola, Urga, Bore, Anasora and Dima Woredas. East Shewa -Boset, Adama town, Adama Woreda, Adame tulu, Jido Kombolcha, Fentale and Lume Woredas. Illu Ababora – Becho Woreda.

Amhara Region: South Gonder -Libo Kemkem, Fogera and Dera Woredas. Central Gonder- Dembia, Gonder Zuria and Alefa Woredas. West Gojjam -Bahir Dar Zuria and Dega Damot Woredas. Oromia special zone- Jile Tumuga, Artuma fursi and Dawa

Harawa Woredas. North Showa -Antoskia Gemza, Ataye town, Shewa Robit, Kewet, Efrata Gidim and Ensaro Woredas. South wollo -Ambassel, Kombolcha and Kalu town Woredas.

Somali Region: Shebele - Kelafo, Mustahil, Ferfer, Gode, Berano, DehunAdadile and East Imey Woredas. Afder - W/Imey, Chereti, Dollobay and Hargelle Elkeri Woredas. Liben - Dollo Ado Woreda. Dollo – Warder Woreda. Fafen – Jijiga, Togochale, Kebribeyah Woredas. Siti – Afder, Ayisha, Erer, Miesso and Shinile Woredas.

Afar Region: Zone -1 - Dubti, Asayita, Mille, Chifra and Afambo Woredas. Zone 3 - Amibara, Gewane, Bure Mudayitu, Dulecha and Awash Fentale Woredas. Zone 2 - Abala, Berhale, Megale and Koneba Woredas. Zone 4 – Ewa Woreda.

Tigray Region: W/Tigray – Humera and Tsegede Woredas. Southern Tigray - Alamata Woreda. Raya –Azebo, Enda- Mehoni and Maichew Woredas.

SNNPR: S/Omo- Dasenech, Nanghatom, Hamer and Selamago weredas. Hdiya – Shashego and Mirab Bedewacho. Wolayta – Humbo, Damot Waydie, Dugna Fango, Kindo Didaye, Kindo Koysha and Boloso Bombe. Halaba Special wereda – Halaba. Sidama – Loka Abaya, Hawassa Zuria, Hawassa Town; SilteDalocha, Sankura and Silte weredas. Guragie- Meskan, Mareko and Kochere.

Dire Dawa: Dire Dawa city

Harari Region: Harar city

Addis Ababa: Flood prone sub cities

NDRMC communicates the issued flood alert to the Regional Commission Offices by e-mail. The flood alert will be discussed by the Regional Disaster Risk Management Committee (RDRC). The regional DRMC will communicate the flood alert to zone and Woreda offices. The woreda disaster preparedness committee is composed of Chief Woreda Administrator, water, health, education, finance and economy, women affairs and transport. The Woreda in turn communicates the kebele administration by telephone, which is responsible for the dissemination of warnings at community level. There are agriculture extension workers at kebele that are responsible for dissemination of information. Further, there is disaster prevention and early warning committee composed of the chairman of kebele who chairs this committee, agricultural workers, heads of kebele security and social activities. These members spread the flood alert message in different ways including through got leaders, calling meetings, by word of mouth in churches and market places.

In Amhara Region, the kebele administration is sub-divided in to *Gotes* (villages) to mobilize the local people for development and other activities. The kebele calls a meeting of *Gote* representatives to inform the flood alert. The *gote* representatives will communicate the flood alert to their respective *gote* people. In addition, in some Woredas the chairman of can call a general meeting of the local people to communicate the flood alert. In some cases the agricultural extension workers can communicate the people. In some instances the people who received mobile phone can disseminate the flood alert. The informal way of communication could be from relatives or friends who live in the high lands areas. These people can inform about the rain and the volume of river water to their friends and relative who live down stream by mobile phone or any other means. There were instances in which some areas were flood without communication of flood alert such as Kola Deba town, Misrak Dembia Woreda, which was flooded by Derma River.

ENTRO has distributed four small boats to Dembia, Fogera, Libo Kemkem and Dera Woredas which are highly affected by flooding. The boats are used to conduct flooding assessment during the rainy season and they also transport people from one area to another which are difficult to cross by foot. The assessment is helpful to launch early warning. The Amhara region covers fuel and per diem during the assessment. Further, ENTRO has given 40 mobile phones to the above mentioned kebeles to communicate flood alert. The region re-charges these mobile phones during *keremt* season. The people with the mobile phones communicate with Woreda administration with regard to flooding. In addition, wooden poles which show flooding level and sirens which alert people the prevalence of flooding are installed by ENTRO. However, the wooden poles have fallen. When the flooding problem is pressing, the Woreda can directly communicate Killel or Federal authorities.

The communication is effective. The public understands the message. Relatives in the area can give calls of early warning. There is involvement of the public on the ground. No one is legally liable if he fails to communicate flood early warning. The victims usually demand various types of support after the flood damage. Before three years, there was a practice every year by calling kebele disaster committee members at Woreda level to give short training about disaster. Now due to budgetary constraint there is no training.

In Gambella region, the practice of early warning communication is similar to Amhara region. The formal government structure down to kebele is employed. The slight difference is the means of communication when the flood alert is communicated to the community. The first major communication of flood alert is to use FM radio broadcasting service in five local languages. Further, telephone calling and the early warning committee goes to the flood affected areas to inform the community members. The case of rural kebeles, with communication problem, including Jore Woreda with 16 rural kebles have only two police radio communications which can serve for the early warning. The 14 kebles do not have communication means. Local people do not have personal radios. There were incidences of flooding without prior notice which were reported by the local people to the concerned authorities, For instance, Demedolo Woreda, Nuer zone, was affected by flood.

The existing EWSs don't take into consideration indigenous early warning systems. However, it encourages the participation of the public and non-governmental organizations. The National Early Warning Technical Committee is a tool for coordination. There is data sharing and collaboration among institutions when the Flood Alert is prepared. It should be strengthened. With regard to awareness creation on the use of flood forecasting products, training is given regularly to Woreda. Region also gives training to Woreda. Every year there is a plan to train at Woreda level. As to the elements contained in the early warning message, Almaz noted that the Timing **w**hen is the hazard due to strike is included. The areas which are going to be affected are indicated. The magnitude of the hazard is predicted. Further, what should at-risk populations do to protect themselves is communicated.

4.3 Gaps in Existing Communication methodology

The following gaps in the existing flood early warning communication methodology are identified.

- ***4.3.1 Eastern Nile Technical Regional Office***
    - The Ministry of Water, Irrigation and Energy has not communicated ENTRO's flood forecast to the stakeholders for the last three years.
    - ENTRO has not verified the flood forecast.
    - ENTRO does not consider indigenous flood early warning practices.
    - Since ENRTO directly communicates the Ministry of Water, Irrigation and Energy, the participation ofthe public and non-governmental organizations in the process of warning communication is not obtained.
    - The existing early warning system does not facilitate effective co-ordination between stakeholders.
    - ENTRO's consultation of stakeholders to get feedback on the flood early warning is very low.
    - The existing institutional arrangement does not allow carrying out effective dissemination of the forecast.
    - The stakeholders list for flood forecast dissemination is outdated. In addition, the impact of the forecast is not known.

- ***4.3.2 National Disaster Risk Management Commission***

    - At present, the woreda disaster risk management activities are carried out along with agricultural ones since they are carried out by the woreda agricultural office. This has resulted in poor performance in terms of early warning communication.

- The manpower assigned at woreda level is not enough both in terms of number and skill.
- EWS is not well owned and the practice is characterizes as fire fighting.
- The NDRMC's annual short training on early warning at woreda level has discontinued.
- Some rural kebeles have no access to modern communication technology. For instance, the 16 rural kebeles in Jore woreda, Gambella region, have only two police radio communications which can serve for the early warning. The local people do not have personal radios. There were incidences of flooding in Demedolo Woreda, Nuer zone without prior notice.
- Sirens are not functional (e.g Libo Kemkem, Amhara region)
- Flooding can take place without issuing warnings to the local people (Kola Deba, Amhara region).
- No evidence of of monitoring mechanisms to check whether the warning message reach, understood and interpreted into action by the community members.

- ***4.3.3 None-governmental organizations***
  - UNICEF, WFP and UN-OCHA noted that the National Flood Alert is too general. It does not indicate specific localities that would be affected by flood.
  - Early warning Indigenous knowledge is not considered
  - Coordination among institutions is not institutionalized.
  - The focus is on response rather than preparedness.
- *4.3.4 Local communities*
  - Some community members are reluctant to accept flood warnings
  - In some areas, local people do not know what EWS means (eg. Jabitchinan, West Gojjam Zone)

4.4 Preferred/Proposed Flood Early Warning Communication Method and Technology

Realizing the above mentioned gaps in the existing communication method and technology of flood early warning, the following is proposed based on the report of (Wilton Park, 2016:pp.6-7)

Wilton Park[5] brought together many of the stakeholders involved in the flood early warning including representatives from NGOs, intergovernmental institutions, the United Kingdom (UK) Met Office, the World Meteorological Office (WMO), World Bank and meteorologists and hydrologists from a variety of backgrounds. The aim of this

[5]**Wilton Park** is an executive agency of the UK Foreign and Commonwealth Office providing a global forum for strategic discussion. It organizes over 50 events a year in the UK and overseas, bringing together leading representatives from the worlds of politics, business, academia, diplomacy, civil society and media. Events focus on issues of international security, prosperity and justice.

collaboration was to discuss the current frameworks and guidance that exist regarding flood forecasting, EWS and disaster risk reduction (DRR). Through constructive dialogue participants also examined why EWS need to be more effective for countries in the Greater Horn of Africa (GHA) and identified ways to help EWS in the GHA progress as well as the barriers to change that must be overcome if greater efficacy is to be realized.

Between users of flood early warning and data providers of warnings

- For any EWS to be effective increased dialogue between EWS suppliers and recipients of warnings will help to ensure that the former understand the needs of the latter, which includes an appreciation of local culture, custom, media and geography.
- In order to reach the User Groups at the "Last Mile" located on the margins of society at the grassroots level, the government must enact a policy or resolution that recognizes incorporation of Indigenous Knowledge (IK) and Traditional Forecasting Systems (TFSs) as well as their conveyance into the scientific forecasting methods including service delivery, advocacy, communication and outreach program
- One of the most effective ways to build rapport and understanding between NMHSs, governments and user communities is through mutual education.
- it must understand the needs of its users, and ensure users are involved in the EWS design as well as its implementation.
- Primary education in particular can be instrumental in building long-term trust and understanding of the risks of flooding in a community, and what actions they can take
- Re-education of user communities regarding both the risks of flooding and the courses of action available to them is also important.
- Visual reminders of disaster threats help to improve the longevity of communities' memories of those disasters
- User communities must also be educated in what action they can take in the event of a flooding event.

Media

- Media is an essential part of any EWS and one of many tools for the dissemination of a warning.
- Knowledge of the types of media that user communities possess (and favor) is essential for governments and NMHSs when disseminating a warning
- Many remote, rural communities in the GHA rely on VHF radios as a primary method of communication. This type of media, in particular, necessitates a concise, coherent warning message
- It is important that the media involve the communities to help disseminate warnings. Here, knowledge of community demographics is important to ensure that every group is targeted by some form of media

- For example, one community may rely heavily on radio or television, whereas others are better reached through local religious institutions or by their community elders visiting their homes in person
- Multiple forms of media need to be used, but there must be coordination with those responsible for disseminating warnings must remain abreast of developments in media and communications technology
- The increase in mobile phone usage in the GHA opens new possibilities for effective dissemination of a flood warning
- Flood early warning communication method to be effective it must understand the needs of its users, and ensure users are involved in the EWS design as well as its implementation.
- Increased dialogue between early warning suppliers and recipients of warnings will help to ensure that the former understand the needs of the latter, which includes an appreciation of local culture, custom, media and geography.
- In order to reach the User Groups at the "Last Mile" located on the margins of society at the grassroots level, the government must enact a policy or resolution that recognizes incorporation of Indigenous Knowledge (IK) and Traditional Forecasting

4.5 Existing Indigenous Flood Early Warning Practice

In the flood prone areas, indigenous flood early warnings are practiced. For instance, in Libo Kemkem woreda, Amhara region, the local people forecast flooding when the rain comes from the Debre Tabor direction. In Fogera Woreda, the local people forecast flooding when they see dark clouds massed on the horizon and strong wind blowing from north to south.

Key informant, Jemberu Desse, Director, Disaster Preparedness and Early Warning Directorate, Amhara Disaster Preparedness, Food security and Special Support Coordination Commission reported that the local people have their own indigenous forecasting system. For instance, they may watch how the rain starts and forecast how the rain will be heavy or not. Further, he suggested that it is important to encourage the community people to mobilize the flood affected people using their indigenous knowledge with regard to flooding. He also noted that NDRMC did not attempt to utilize indigenous knowledge of flood forecasting. The flood early warning practice could be strengthened if new flood forecasting software are available, provision of training, experience sharing forum, evaluation of performances regularly.

5. CURRENT RESPONSE ACTIVITIES TO FLOOD EARLY WARNING

5.1 Performance of Current Response to Flood Early Warning

- **5.1.1 Amhara Region**

Key informant, Jemberu Desse, Director, Disaster Preparedness and Early Warning Directorate, Amhara Disaster Preparedness, Food security and Special Support Coordination Commission indicated that the communication channel may not be effective since some members of the community may be reluctant to take action according to the warnings given. This is mainly because the flooding occurs every year. In this regard, concerted effort to raise their awareness should be taken.

In Libo Kemkem woreda, every year there is flooding. However, the impact is minimized since the community constructs dikes. The boat given by ENTRO is not functional since the motor is stolen. However, the Woreda borrows boat from Killel for flood assessment.

In Fogera Woreda, there are some people who are reluctant to take preventive actions assuming that flooding will not create a problem. However, the flooding could damage their crops and cattle.
In Misrak Dembia Woreda, for instance, Derma River has affected the town of Kola Deba. Earlier, a dyke was constructed to prevent the town from Derma River flooding. The river has overflowed the dyke and affected a number of households. At present the government has allocated 1.2 million birr to construct dyke. The budget is small and it was released lately after the rain has started.

- **5.1.2 Gambella Region**

In Jore Woreda, since the land is flat, flooding occurs every year. In 2005 (EC), because of the flooding people were moved to another area which was considered safe. However, the flooding has continued in the new area. Although the local people have constructed canals to minimize the flooding, the land is inundated when the water overflows the canals. At present the river Gilo has caused flooding in five kebles namely Omoge, Alaw, Kento, Kento gira and Tu. About two thousand people are affected by the flooding. Crop fields are inundated. The flood early warning has been communicated to the community in April and May, 2019. The flood early warning message contains that the regular rain has started and later volume of rain will increase and as a result overflowing of the Gilo River could take place. Thus, the community has to construct canals early. By and large, the community has accepted the message. However, the overflowing of the constructed canals is beyond the capacity of the people. There is no other place to relocate the people. The local administration has assumed the present location as safer. The current flooding has damaged the crop fields, houses, and incidence of malaria has taken place. The flood affected people are in a shelter where 318 people were living. At present, additional 300 people have joined the earlier displaced people. Thus all the 618 people are crowded in one area. The local people understand the message. The regular rain starts in April and later the volume of rain increases which contributes to the overflow of Gilo River. Since the people live in a low land, there is no safe place to relocate them. The solution according to Kello is to construct a permanent structure that channels the water.

5.2 Proposal on how to improve the response to Early Warning

An early warning system can fail even if the infrastructure is installed and functional and the warnings are issued and disseminated correctly; a warning alone mightn't be sufficient to prompt a response. Public and institutional preparedness, including institutional response capacity, have to be developed to a sufficient degree to allow for an organized, risk-mitigating reaction to warnings. Risk-mitigating reactions and the preparedness of institutions and the broader public can be difficult to achieve, especially if the time between warning and disaster is short or not used efficiently. Moreover, if the priorities of different response actions are not well delineated, warnings can give place to chaotic and interfering actions.
In sum, to improve the response to early warning, the following are suggested.

- Government and other stakeholders should develop the capacity of disaster risk management offices at all levels.
- Sufficient budget allocation to flood prone areas must be considered.
- Regular risk awareness creation should be given to community members.
- The flood early warnings should be timely and area specific to obtain better response.
- Due attention should be given to indigenous early warning practices.
- The community-based solutions guarantee that warning communications reach communities at risk, and that vulnerable communities are therefore prepared to counteract the risk.

6. INSTITUTIONAL ARRANGEMNET

6.1 Gaps in the current institutional setup at national level

The gaps in the current institutional setup at national and local level include:

- ***Institutional arrangement:*** The Ministry of Water, Irrigation and Energy is not play the lead role in water related disaster including flooding according to the Ethiopian National Policy and Strategy on Disaster Risk Management. Institutional coordination and collaboration is of paramount amount for early warning and communication activities. However, stakeholders have noted the limitation in this regard. The existing institutional arrangement does not allow carrying out of effective dissemination of the forecast and ENTRO and MWIE is case in point. Gaps in institutional and co-ordination frameworks can prevent the operation of flood early warning system and the integration of risk information into decision-making across all sectors. The National Disaster Risk Management Commission organizational structure at woreda level is mixed up with the Ministry of Agriculture. This has hindered effective early warning and communication at local level.

- ***Technology, infrastructure, and forecasting capability***: technology plays a key role for EWS, especially for its monitoring, forecasting, and warning dissemination components. Yet in the context of Ethiopia, the necessary infrastructure and capabilities are lacking. Stakeholders including ENTRO, MWIE, NMA and NDRMC have noted the limitations in this regard.
- ***Human resources and expertise:*** The effectiveness of EWS goes well beyond the efficiency and availability of early warning technology. Personnel responsible for maintaining and operating the systems also have to be competent and well trained. In Ethiopia, the public sector lacks human resources with the necessary experience and skills.
- ***Public engagement and empowerment*:** For EWS to truly serve the public and be effective, communities have to be involved in the process of designing and implementing EWS. The current practice shows that the public as simple recipient of flood early warnings. Engaging and empowering communities can be difficult due to cultural and linguistic barriers, as well as political realities. Further challenges include physical distance and lack of effective communication networks that can create difficulties delivering messages to rural settlements and nomads and/or transhumant. The content and presentation of warnings also have to be customized, depending on how communities perceive risk, what degree of detail can be understood, and how prompt actions can be effectively induced.

6.2 Proposed setup for an effective Flood Early Warning System

In general, the National Policy and Strategy on Disaster Risk Management of the country has clearly designated the Ministry of Water, Irrigation and Energy as the lead institution for flood disaster risk management. The preferred institutional arrangement is to implement the policy into action. In this regard, the Ministry should assume its responsibility which would facilitate the flood early communication.

Communication is an essential component in any EWS chain and must be improved/ consolidated at all levels if a warning is to be timely, relevant and effective. Good communication is also required if coordination between actors is to be increased. Effective flood early warning has to be communicated and disseminated to people to ensure communities are warned in advance of impending flood hazard and to facilitate national and regional coordination and information exchange.

Regional

Eastern Nile Technical Regional Office (ENTRO)

The Eastern Nile countries namely Egypt, Ethiopia and the Sudan (South Sudan joined in 2012 following its independence) launched the Eastern Nile Subsidiary Action Program (ENSAP) to initiate concrete joint investments in the Eastern Nile (EN) sub-basin.

ENTRO as technical office prepares flood forecast for Ethiopia (Tana area and Gambella), Sudan and Egypt. It prepares the flood forecast by engaging professionals (flood management team) from the water resources ministry from the member countries

ENTRO communicates the forecast with the concerned water resource ministries. Further, an attempt is made to widen the dissemination of the forecast by sending the forecast to the Ethiopian Ministry of Water, Irrigation and Energy, National Disaster Risk Management Commission (NDRMC), Red Cross and other NGOs.

The World Meteorological Organization (WMO 2011: 17-20)) suggested the following areas for considerations in setting up collaborative arrangements for international and cross-border exchange of warnings.

Weather warnings are intended to alert the public in dramatic or attention-grabbing fashion and are usually issued in plain language. For international exchange, translation into a single agreed language or coded format such as XML is necessary for practical reasons. Communication among neighboring countries enables consistent warnings about the hazards be issued to the public and concerned organizations. The efficient exchange of warnings of severe phenomena with the potential for cross-border impacts must clearly be a high priority component of any well-coordinated system for multi-national disaster preparedness and response.

The thresholds for issuing weather warnings vary from one country and one region to another, usually for reasons of climatology and vulnerability. Thresholds and intensities for which these phenomena are considered potentially harmful should be decided by mutual agreement. These initial alerts should be followed by regular updates as the timing, scale and intensity can be more accurately observed and forecast. In practice the most effective mitigating actions are usually taken from three (3) to six (6) hours before an event. Within the limits of current forecasting capabilities, realistic objectives for forecasting the onset of a severe weather event would be:

- Three (3) days for initial alerts for large-scale events; and,

• Three (3) hours for details on intensity, duration and location

Communication methods for the exchange of warning information may include:

- Global telecommunication system (GTS);
- Telephone;
- Facsimile;
- Direct link for bilateral exchange;
- Web form;
- E-mail; and/or
- Satellite system.

The essence of any warning is to give timely notice that a risk exists. It therefore follows that mechanisms for exchange of information must be as fast and reliable as possible. To achieve effectiveness and consistency, the system should be designed around the most reliable technology that is mutually available.

Maximum benefit and success of any program of cooperation in exchange of warnings will be realized if there are regular reviews of the process and if all operational staff is adequately trained. Reviews of the process should be held at least once per year and it is highly recommended that they also take place after a significant event. Through these review meetings, shortcomings and training needs could be identified and steps could be taken.

The review should also include the continual assessment of the following:

- User requirements;
- Means to meet those requirements;
- Ensuring that the users know how to make best use of the products and services provided by the NMHSs; and,
- Assessing the accuracy and usefulness of those products and services.

6.2 Proposed set-up for an effective early warning system national and regional and local

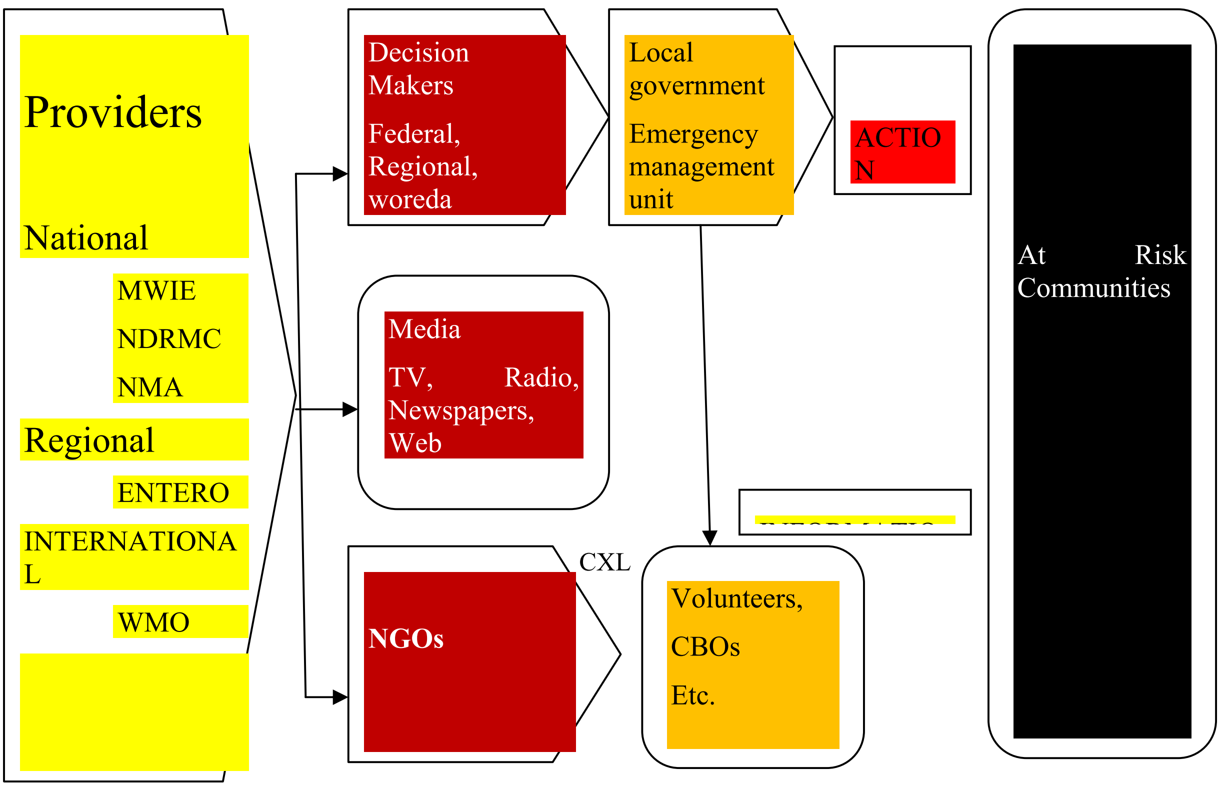

Figure 6.1 Proposed institutional setup for early warning system

The institutional setup proposed shortens the communication channel in terms of early warning and communication. It is suggested that the data providers can issue flood alert directly to decision makers, media and NGOs. The decision makers can communicate the woreda emergency management unit to take action for the community at risk. Simultaneously, the local emergency management unit can provide information to volunteers and CBOs in order to mobilize them for action along with the local emergency management unit.

7. CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

The main findings of the study include:

- The EN Seasonal FFEW activity has been producing flood bulletins for seven seasons with three day lead time communicating to the Ethiopian Ministry of Water, Irrigation and Energy by e-mail. However, ENTRO's flood forecast has not been communicated to the flood prone areas for the last three years.
- In the flood early warning system, the data and forecast providers include ENTRO, MWIE, NDRMC, NMA, UNICEF, WFP and UNOCHA.
- The Flood Alert issued by NDRMC is too general, which does not indicate a particular area that could be affected by the flood
- ENTRO's data sharing and collaboration with other institutions is not satisfactory.
- The existing early warning system does not facilitate effective co-ordination between stakeholders. Data sharing and collaboration between institutions, ministries and ENTRO is not institutionalized.
- The emphasis of the EWSs is response rather that preventive actions. Further, it does not consider indigenous flood early warning practices
- There is lack of awareness creation forum such as workshop, training or field visit.
- With regard to flood forecasting chain, implicit authors or mediators regarding flood disaster in the community are not identified.
- The existing flood EWSs is not technically sustainable since the institutional arrangement is not clear.
- The Ministry of Water, Irrigation and Energy did not assume the role of a lead institution with respect to floods disaster. The National policy on disaster risk management is not translated into action. NDRMC is playing the lead role.
- Capacity limitation prevails in the national institutions to create functional and comprehensive meteorological and hydrological networks to generate accurate forecasts and guidance. Government or donors' investment in leadership and soft skills to improve flood EWS is low.
- Disaster risk management is organized under the Woreda Agricultural Office. The communication system is not well structured at Woreda and kebele levels. At Woreda level, lack of skilled manpower and high turnover and limited budget allocation are some of the problems encountered.
- The interest to get flood alert feedback from communities did not materialize.
- There is lack comprehensive training on risk knowledge and hazards.
- The non-governmental organizations calibrate the forecast they obtain from NDRMC and NMA with the information collected from their field offices to address the specific flood affected communities according to their mandates.
- Flooding can happen without communicating early warning. For instance, in Jore woreda, Gambella Region, 14 kebles do not have communication means. Local

people do not have personal radios. The other communication means is by writing a letter.

- In some areas, people are reluctant to take action after they received the flood early warnings. No evidence of monitoring mechanisms to check whether the warning messages reach, understood and interpreted into action by the community.
- Best practices and methodologies in flood early warning from Ethiopia and India are identified.

7.2 Recommendations

- NDRMC and UN-OCHA underlined that flood early warning system could be sustainable if the Ministry of Water, Irrigation, and Energy assumes lead responsibilities according the National Disaster Policy and Strategy. There is no concrete action with regard to the implementation of the lead role by sector institutions according to the policy and strategy of disaster risk management. Such issue should be resolved at higher level (Prime Minister's Office) so that sector ministries could mainstream disaster in their development plan.
- To overcome capacity limitation of NRDMC, NMA and ENTRO, the provision of training and upgrading of forecasting modeling are imperative.
- ENERO should communicate the flood forecast output to a wide range of stakeholders.
- ENTRO should regularly consult stakeholders with regard to the type of information stakeholders need.
- ENTRO should be a member of Nation Early Warning Technical Committee.
- ENTRO should sign a memorandum of understanding with, NMA and other important organizations to facilitate data sharing and collaboration.
- ENTRO flood early warning message indicates to what extent the water level is raised compared to the average. It should provide detailed information with regard to the magnitude of the flooding.
- The flood early warning system focuses on response. Since the flood prone communities are known, NDRMC should give emphasis to preventive actions.
- NDRMC should continue the restructuring process so that the disaster risk management office at woreda level could be organized independently.
- The flood forecast data providers should employ high performance technology for better forecast output, which minimizes doubtfulness on the part of forecast users. Further, this effort should be supported by indigenous flood early warning practices.
- Capacity building in terms of forecasting techniques and regular awareness creation at community level should be practiced to reduce the negative impacts of flooding.

- The regional governments and NDRMC need to consider the construction of permanent structure to protect local people from flooding in Gambella area since the flood affected people do not option to resettle in safer place.
- The communication method at kebele administration level is not well organized. Thus, the method should consider the issues mentioned under section 4.4 Proposed Flood Early Warning Communication Method and Technology.

References

Abdulkarim H. Seid (2004) Flooding Extents and Coping Mechanisms in the Eastern Nile, (an overview)

Ashenafi Dejene and Yetayal Amsalu (date NA) Strengthening Community-based Early Warning Systems through a multi-sectoral platform

Azeb Mersha (2016) *EN Flood Preparedness and Early Warning Project EN Flood Season Monitoring Program.*

Birhanu Gedif, Wuletaw Wondmagegn, Tarekegne Ayalew, Legesse Gelaw (2016) Analysis of the existing early warning systems: The case of Amhara national regional state *International Journal of Research Advanced Scientific.*

Eastern Nile Technical Regional Office (ENTRO) (2017) Flood Preparedness and Early Warning Seasonal Report

Federal Democratic Republic of Ethiopia (2103) National Policy and Strategy on Disaster Risk Management, Addis Abba

Haggett, C. (1998*).* An integrated approach to Flood forecasting and Warning in England and Wales. *Journal of the Chartered Institution of Water and Environmental Management, Vol. 12,,* pp 425–432

Lobeyo, Angelo George A. (date N.A) Comparison of Flood Forecasting Models, ENTRO Addis Ababa/Ethiopia

Mileti, D.S (1999) Disaster by Design: A reassessment of Natural Hazards in the United States, Joseph Henry Press, Washington, DC.

Review of Disaster Risk Reduction Practices in Ethiopia: the Experience of the Interagency Working Group (2016)

Sayed, Mohamed Abdel Aty (2006)A Documentation and Analysis Report, Nile Basin Initiative, Eastern Nile Technical Regional Office (ENTRO) Flood Preparedness and Early Warning Project.

UNDP (2016) Climate Information & Early Warning Systems Communications Toolkit

United Nations Office for Disaster Risk reduction (UNISDR) (2006) Global survey of early warning systems. An assessment of capacities, gaps and opportunities towards building a comprehensive global early warning system for all natural hazards. Geneva, Switzerland.

United Nations Office for Disaster Risk reduction (UNISDR) (2006) Developing Early Warning Systems: A Checklist. EWC III Third International Conference on Early Warning From concept to action 27 – 29 March 2006, Bonn, Germany.

Wilton Park (2016) Flooding in the Greater Horn of Africa: building effective early warning systems. Flooding in the Greater Horn of Africa: building effective early warning systems Wednesday 28 – Friday 30 September 2016 / WP 1497.

Woldeab Teshome (2007) Living with Risk: Flood Disasters and Local Response around Lake Tana Area, North West Ethiopia. Addis Ababa

World Meteorological Organization (WMO) 2011 Guidelines on International and Cross-border Collaboration in the Warning Process

Documents:

Best Practices on Flood Prevention, Protection and Mitigation (2003)

Eastern Nile Technical Regional Office ENTRO (2018) Nile Seasonal Flood Forecast and Early Warning (flier). Eastern

Eastern Nile Technical Regional Office ENTRO (2019) Terms of Reference and Scope of Services –Surveyor.

National Disaster Risk Management Commission (NDRMC) (2018) Flood Alert #3

Annex

List of interviewed stakeholders

No	Interviewed person	Position/specialized field	Institution
1	Eng. Azeb Mesaye	Water specialist	ENTRO
2	Semunesh Golla	Hydrologist Director of Hydrology and Waster Quality Directorate,	Basin Development Authority, Ministry of Water, Irrigation and Energy
3	Almaz Demessie	Director, Early Warning and Emergency Response, Directorate	National Disaster Risk Management Commission
4	Surafel Mamo	Flood Modeler	ENTRO/Ministry Water, Irrigation and Energy
5	Thowat Tiach Kuon	Water Resource and Water Quality Officer	Gambella Water & Irrigation Bureau
6	Lul Jone	Publications Officer	Gambella Disaster Prevention and Food Security Agency

7	Jone Con	Coordinator, Woreda Disaster Prevention and Food Security Agency	Lare Woreda Disaster Prevention and Food Security Agency
8	Aderajew Admassu	Director, Meteorological Forecast and Early Warning Directorate	National Meteorology Agency
9	Tesgaye Ketema	Director, Development Meteorology Service Directorate	National Meteorology Agency
10	Kello Oku	Early warning worker	Jore Woreda Early Warning and Food Security
11	Agegehu Asmare	Team leader, Disaster Early Warning and Response Work Process	Misrak Dembia Woreda Agricultural Office
12	Beletu Tefera	Former chair of National Flood Task Force, retiree	National Disaster Risk Management Commission
13	Abera Kassa	Director, Disaster Risk Reduction Directorate	National Disaster Risk Management Commission
14	Sisay Kassa	Team Leader, Disaster prevention and Early Warning Work Process	Libo Kemkem Woreda Agricultural Office
15	Emnesh Asres	Team Leader, Disaster prevention and Early Warning Work Process	Fogera Woreda Agricultural Office
16	Jemberu Desse	Director, Disaster Preparedness and Early Warning Directorate	Amhara Disaster Preparedness, Food Secuirty and Special Support Coordination Commission

17	Gebre Egziabher Lema	Humanitarian Officer and member of the National Flood Task Force	UNICEF
18	Alemteshay Alemu	Vulnerability Analysis Team Leader	World Food Program
19	Abey Wogders	GIS Specialist	World Food Program
20	Melaku Gebre Micheal	Humanitarian Affairs Officer	UN OCHA

SOUTH SUDAN SOCIAL SURVEY

FLOOD FORECASTING AND EARLY WARNING ENHANCEMENT PROJECT

Submitted by

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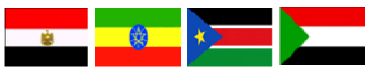
ENTRO is an organ established to implement the Eastern Nile Subsidiary Action Program within the framework of Nile Basin Initiative

Egypt, Ethiopia, South Sudan, Sudan



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EXECUTIVE SUMMARY

South Sudan is a new country that came to exists as a sovereign and an independent state on 9th July 2011. As a new country it is imperative that challenges, gaps and inconsistencies of any kind including flood forecasting and early warning systems cannot be ruled out. In this respect therefore the launching of this Eastern Nile Flood Forecasting and Early Warning Project came at right time. Following the review, mapping and survey carried out by the consultant during the study exercises, much useful information about the project which is important and beneficial to Eastern Nile countries was identified.

The rationale for establishment and launching of this project is because of the presence of the inconsistencies, gaps and challenges that exist in the sub-basin including the presence of different models which make it difficult to upgrade whenever a new one is developed. These challenges created an idea in the minds of members of Eastern Nile countries to think of how something better and useful should be done to correct the status quo. It becomes therefore necessary to develop a single model for the sub-basin which could be used in every Eastern Nile countries. To better understand the nature of these challenges a study has to be done.

The study consists of three separate components. The first was the inception phase. This was mainly done to lay down the foundation of the flood forecasting and early warning programme in the country in regard to nature and status of the flood. The second phase consists of the dynamics, processes and the impacts of the floods, and the final component consist of the specific cases of floods in each and every country of the eastern Nile countries. For the case of South Sudan the third component study concentrated to the flash floods which happened between July and November 2019.

This study which was done in South Sudan, found out that the country is a flood prone country whereby its floods happens annually. For this reason it requires some dynamic and robust flood forecast programme responses to address its impacts on annual bases. The study also identified specific flood prone areas including vulnerable communities. These areas includes, Akobo, Nassir, Malakal, Bor, Juba, Torit, Kapoeta, Aweil, Rumbek, Mangala and other smaller towns in the country. The corresponding communities in those places are the Nuer, Anyak, Dinka, Bari, Chollo, Jur Bel and many other town dwellers of various occupations which are also affected by those floods.

But unfortunately the study also found out that South Sudan has no robust and active flood forecast and early warning systems programme put in place for addressing this phenomenon. Following the mapping, survey and review exercise that was carried by the consultant, the study found out that almost ten to twelve government institutions, national Parastatal agencies and community based organizations which have a stake in flood related management.

The study also identified some challenges of these institutions which hamper their active involvement in flood forecast and early warning systems management. These challenges include among others lack of policy, legal and institutional frameworks and mechanisms, capacity gaps, among the technical and decision and policy makers, budgetary and funding constraints from government treasury and development partners respectively, communication technology and others. A proposal is also made to ENTRO to extend the capacity building programme which is going on to other stakeholders as well to ensure that the capacity of all the stake holders in the country can be strengthened and deepened.

Another important item identified and discussed during the study is the issue of communication methodology and technology in flood forecasting and early warning system which are supposed to be applied in flood early warning issues. These methods include the best practice which consists of email, radio, and television and news bulletin in most cases. The study also discusses the current methods of communication which are not really different from the best practices. The challenges of communication were also identified. This include lack of internet and power, lack of capacity, lack of the facilities, lack of policy, legal and institution framework inadequate funding and lack communication infrastructure.

It is recommended that a unit of communication should be created or established in the Ministry of Water Resources and Irrigation for receiving and sending of quick and urgent messages of flood early warning to vulnerable communities and other stakeholders. It is believed that if the communities are informed earlier, they are able to prepare themselves to address the consequences that flood would occur. One of an important element of communication is the recognition of the indigenous practices. These methods if promoted and encouraged, they can be very useful tools for flood forecasting and early warning systems in the country both in South Sudan and in the other countries.

The other important issues identified in the exercise are the institutional setup between the regional and national levels. The study recognised the role played by the regional and national institutions in flood forecast but it has been discovered that South Sudan does not have a country office for ENTRO in Juba despite the fact that it has these offices in Ethiopia and Sudan. IGAD has an early warning office in Nairobi which can support South Sudan in this particular field as South Sudan is its member but due to inadequate power and internet connectivity in the country, it becomes difficult for the staff of various institutions to access the data and information from the site.

In conclusion, the consultant would like to re-iterate that South Sudan is a flood prone country and being a new country, it is very important to note that flood forecast and early warning systems programme in this country though necessary is still non-existent. The study also recognized that the challenges to flood forecast and early warning system in the country are huge such that a cooperative approach in addressing these challenges are needed.

The consultant would like to make the recommendation that for the ENTRO and South Sudan to succeed of flood early warning management, the issue of capacity and institutional building, resources mobilization and policy development for flood forecasting should be given a priority in their planning. ENTRO and Ministry of Water Resources and Irrigation need to develop guidelines for regulating the activities of those who have gone for those flood training financed by ENTRO so that the efforts to improve the systems will be successful.

ACRONYMS

AF	Appeal Fund
CBO	Community Based Organization
CISPO	Community Initiative for Sustainable Peace Organization
CSO	Civil Society Organization
DREF	Disaster Response Emergency Fund
ENC	Eastern Nile Countries
ENFFEWSP	Eastern Nile Flood Forecast and Early Warning System Project
ENSFFEWS	Eastern Nile Seasonal Flood Forecast and Early Warning System
ENTRO	Eastern Nile Technical Regional Office
ESCAP	Economic and Social Commission for Asia and the Pacific
HYCOS	Hydrological Cycle Observation System
ICPAC	IGAD Climate Prediction Application Centre
ICRC	International Committee of Red Cross
IGAD	Inter-Governmental Authority for Development
IKS	Indigenous Knowledge Systems
IOM	International Organization for Migration
MAFS	Ministry of Agriculture and Food Security
MEF	Ministry of Environment and Forestry
MHADM	Ministry of Humanitarian Affairs and Disaster Management
MLF	Ministry of Livestock and Fisheries
MRT	Ministry of Roads and Transport
MWRI	Ministry of Water Resources and Irrigation
NBI	Nile Basin Initiative
NELSAP.CU	Nile Equatorial Lakes Subsidiary Action Programme. Coordination Unit
NGO	Non-Governmental Organization
SSCAA	South Sudan Civil Aviation Authority
SSMA	South Sudan Meteorological Authority
SSRC/RC	National Red Crescent and Red Cross Society
SSRC	South Sudan Red Cross
UNCEF	United Nations Children's Education Fund
UNMISS	United Nation Mission in South Sudan

WMO	World Meteorological Organization

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1. INTRODUCTION

1.1. Rationale and Objectives of Consultancy Work

1.1.1. Rationale of the Project

The rationale for the design, establishment and launching of Eastern Nile Flood Forecasting and Early Warning System project by Eastern Nile Technical Regional Office (ENTRO) composes of many factors, gaps and challenges. These includes but not limited to the inconsistencies that prevails in the region, the level of limited capacity of enhancing the current system to an acceptable standard, the presence of different models for different flood prone areas which make it difficult to update whenever a new version is developed and the challenge of communication and dissemination of any information and message to other key stakeholders in the EN countries is causing problems to ENTRO.

To address these challenges, there is need for establishment of a single and unified forecasting and early warning systems so that a detail and in-depth study of communities and their social, economic and cultural characteristics to ensure that a viable, robust and easy to operate response and preparedness mechanism is designed for the entire Eastern Nile countries. This is why Eastern Nile Flood Forecasting and Early Warning Systems project (ENFFEWSP) is necessary to be launched to serve the vulnerable population in the region to avoid loss of lives and properties of some citizens in the EN countries. The project will also take into consideration the recent flash floods which has never happened in recent history.

1.1.2. Objectives of the Project

- To design a robust forecasting and early warning system that effectively and efficiently minimize loss of lives and damage of properties by enhancing, and developing a unified Flood Forecast and Early Warning system for EN countries.
- To support other studies under FFEWS that contribute in addressing flash floods, stakeholder's analysis and flood related DSS development.

1.2. The Study Sub-basins

The overall study of flood forecasting and early warning systems management in the Eastern Nile countries covers three important sub-basins. These are Baro-Akobo-Sobat, Blue Nile, and Tekeze-Setite-Atbara.But in South Sudan the focus of this study is done on Baro-Akoba-Sobat but other sub-basins of Bahr el Jebel, Bahr el Ghazal and White Nile were also studied. There is also a little discussion about the western part of the country.

1.3. The Overview of (EN) Seasonal Flood Forecast and Early Warning (ENSFFEW)

The Eastern Nile Seasonal Flood Forecast and Early Warning is one of the activities carried out by Eastern Nile Technical Regional Office (ENTRO) in fulfilling its mandate of serving the Eastern Nile countries in advancing the Nile cooperation. The ENSFFEW runs from July to September even though the rainy season in South Sudan begins from May to early November. The main purpose of the seasonal forecast and early warning is to monitor rainfall and river levels with an objective of predicting floods so that the lives of about two million vulnerable communities at risk can be reduced. This year has witnessed abnormal flood situation which is described by some as the first of its kind in their lifetime.

The planned scope of the seasonal flood forecast is to cover all sub-basins of the four Eastern Nile countries of Egypt, Ethiopia, South Sudan and Sudan which lie within the Nile Basin. But practically the flood forecast and early warning is done on Lake Tana in Ethiopia,Baro-Akobo-Sobat in Ethiopia and South Sudan and in Blue Nile and Main Nile in Ethiopia and Sudan respectively. The main flood prone areas covered by the focus are the towns of Gambella and Akobo, Dolet Hills in the outskirts of Malakal town in South Sudan, Ed Deim and Khartoum in Sudan and around L.Tana area in Ethiopia.

The main issues which are covered by the seasonal flood forecasting and early warning includes but not limited to Hydrographs of the rivers which explains the levels of water as a result of rain fall in the basins or sub-basins, rainfall which explains the frequency and duration of rainfall whether it can cause flood or not, flood depths, which explains the level of water which can predict the intensity of flood, flood maps which explains the coverage of floods and information users who are the stakeholders. Some of the issues discussed during the flash floods in South Sudan include unpredictable and unknown sources of the floods

The forecast and early warning systems has produced a lot of data and information during the four or so months of flood forecasts. As a result of this, about 200,000 thousand people do receive alerts and messages of floods in Sudan and about 150,000 thousand people in Ethiopia. But it is not very clear as to how many people have received flood alerts in South Sudan. For the sudden and flash abnormal floods which happened in South Sudan has affected an estimated number of about one million people. The noticeable challenge of this forecasting is that the coverage is very low especially in South Sudan. ENTRO is therefore recommended with the support of the EN countries to widen this scope of this exercise so that a good number of EN countries citizens particularly the citizens of South Sudan can benefit from this forecast and early warning system so that they can save their lives and properties.

1.4. Methodology

The consultant used seven methods during the study to ensure that the information and data obtained from the study is accurate, reliable and of high quality. These methods include the following:-

Literature Review

This method was used to obtain data and information from international best practices and the needs of stakeholders both at the national and at the local levels. Not only success was considered alone but failures of other countries in flood management and early warning were considered. Several documents were reviewed and important and useful data and information was discovered. The emphasis here was to find out about information, communication and dissemination methods which facilitate flood forecasting and early warning processes among global, regional, national and local levels.

Application of Questionnaires

This method was used as a guide to obtain specific data and information from the key stakeholders who address key issues such as who are the responsible people? Which departments within the institutions are responsible for early warning systems managements? How do the communities receive information well in advance before flood happens? What are the preferable methods of dissemination and communication in the country in general and among the communities in particular? Were there any indigenous early warning methods in the communities or not. Was there any spectacular flood incidence in some of the elders' lifetime?

Interview Method

This method was used to obtain data and information from specific groups of people. As a result of this method; a number of people were interviewed by the consultant. These include interest groups and other key stakeholders such as policy and decision makers, local politicians' community and religious leaders, affected communities, chiefs, women leaders, and the youth. The consultant also interviewed some intellectuals both national and foreign nationals.

Observation Method

This method was used to obtain data and information about an event which happens in the presence of the consultant when there is nobody responsible to address the issues affecting people. The example of this was the flooding in Juba town during the months of July and August 2019 which blocked roads and there was no body available to answer questions such as what caused this flooding and who is supposed to address this?. This method was also used for obtaining data and information about the current and preferred methods of information dissemination and communication both at the global, national and local levels.

Dialogues with Key Stakeholders

This method was used to find out the correct information from the members of the same institution. This was because some professionals have a different understanding of what early warning means. To create a common understanding and consensus, they have to dialogue and make extensive discussions and debate about the relevant and contextual methods for South Sudan.

Focus Group Discussions

This method was applied to obtain information from interest groups. The interests of such groups are basically expectations and aspiration of what they think or expect should happen to address this recurring phenomenon. Or the benefits they would gain politically as a result of these disasters. These groups include women, local politicians, religious groups, independent researchers and media professional and members of Parliament. There was also a specific discussion with those affected by the recent abnormal floods in the north of the country in which an approximated one million people were affected by the flood

Research Questions

Research questions are those questions which came out during the course of discussions. As the discussion intensifies, it becomes apparent that some of the information requested by the consultant could not be obtained through the questions in the questionnaire. These are questions like what methods do you use as a group or as a person? Which method do you preferred and at what time do you need it to be communicated or disseminated.

2. THE MAPPING OF STAKEHOLDERS IN FLOOD EARLY WARNING SYSTEM

2.1. Data and Forecast Providers

Eastern Nile Technical Regional Office

The mandate of ENTRO is to support Eastern Nile Council of Ministers and the Eastern Nile Subsidiary Action Programme Team with a purpose of advancing and enhancing cooperation among Eastern Nile countries on Water Resources Management and Development.

In regard to flood forecasting and early warning systems management, generates information through the Eastern Nile Seasonal Flood Forecasting and Early Warning and send it to the Ministries of Water Affairs and Universities and Institutions in Eastern Nile Country that are cooperating with them across the sub-basin so that they can send the data to their data users.

In regard to flood forecasting and early warning activities, ENTRO conducts daily monitoring to produce forecasts through its seasonal flood forecasting and early warning system. It uses the rain and hydrological data to model and predicts floods. It generates data and information and communicates and disseminates it to different stakeholders at different levels across the basin countries and hopefully across the communities.

Ministry of Water Resources and Irrigation

The mandate of Ministry of Water Resources and Irrigation is to sustainable harnessing and accountable management of water resources of South Sudan that responses to water related public health needs, livelihoods and development aspirations of the people of South Sudan in an equitable manner.

In terms of flood forecasting and early warning services, it is supposed to develop plans for risk and disaster prevention measures with a clear term of reference for the required capacity on all levels of government at an annual base. But this has not happened due to lack of political will as well as lack of resources and technical staff with the necessary skills and expertise.

The Ministry through the Directorate of Hydrology and Survey is supposed to generates information and send it to the Ministry of Communication particularly to South Sudan Radio and Television network and other media houses for dissemination, Ministry of Disaster Management for humanitarian intervention, Department of Civil Defence for evacuation purposes and other important stakeholders for their various uses but this does not happen because of lack of facilities, equipment and systems of collecting and communicating information to the key stakeholders.

Ministry of Environment and Forestry

After reviewing the Environmental Policy, Environmental Bill and having some discussions with the Director General of Directorate of Planning and Sustainable Development and other officials of the Ministry, it was found that, the Ministry of Environment and Forestry has the responsibility to protect, preserve and manage the environment as well as ensure the sustainable utilization of natural resources of Republic of South Sudan. In regard to flood forecasting and early warning, it was also found out from the policy, legal documents and from the discussions with the senior officials of the ministry that the Ministry of Environment and Forestry is supposed to work jointly with the South Sudan Meteorological Authority to generate weather and rainfall data.

At the same time the MEF is supposed to complement the Ministry of Water Resources and Irrigation to generate data on flood forecasting and early warning for the country. But this does not happen because the department of flood forecast and early warning has never been established and no staffs were employed for the assignment. Because there are no institutional arrangements and technical staff for flood forecasting and early warning in the Ministry, it becomes very difficult to tell exactly the type of activities it plays in generating the data the Ministry is supposed to collect whether rain, weather or river in this particular activity.

Ministry of Roads and Transport

From the Policy, it was found that The Mandate of the Ministry of Roads and Bridges is to develop and maintain roads, airports and bridges network, and for the efficient and safe provision of road and air services in all the states of the Republic of South Sudan through the co-ordination and management of all activities of the Ministry.

In regards to flood forecasting and early warning systems, the data on rain and weather is collected by the South Sudan Meteorological Authority which is a subsidiary institution of the Ministry whose mandate is to monitor weather and rain in the country. About the mandate of monitoring the water level of the rivers in the country, this is done by the Ministry of Water Resources and Irrigation. The Ministry of Transport which is key stakeholder in water uses needs this information on daily bases for management of river transport in the country.

Ministry of Energy and Dams

In my conversation with the Director General of Planning and Projects in the Ministry of Energy and Dams about the mandates of the Ministry of Energy and Dams the following information were identified;

The mandate of the Ministry is to develop policies and laws for the generation and supply of electricity to all the people of South Suda.This can be done by building dams over the rivers and through installation of Solar panels for the rural population. But in regard to flood management, it is supposed to be responsible for flood prevention and control and at the same time it is supposed to be responsible for early warning for down streams vulnerable population. But up to this time the Ministry has never even built a single dam in the country for it to use for preventing and early warning for floods downstream. The Ministry has not even developed a policy and law for electricity supply and construction of dams. Therefore its activities of flood management and early warning are not yet been active.

South Sudan Meteorological Authority (SSMA)

I visited the Head Office of South Sudan Meteorological Authority at Juba International Airport and I interviewed the Director General of South Sudan Meteorological Authority and other forecasters, I was told that, The Mandate of South Sudan Meteorological Authority is to collect data on weather and rainfall on daily bases. After analysing the data, the information is sent to all stake holders countrywide for their various uses.

In regard to early warning and forecasting, it uses to communicate the information to the users such as national radio and television network and other media houses for communication and dissemination to the public. The SSMA also communicates the information on rain to the Ministry of Water Resources and Irrigation for storage and dissemination to the wider audience through the data base or through the Water and Information Management Systems.

Ministry of Humanitarian Affairs and Disaster Management

The Mandate of Ministry of Humanitarian Affairs and Disaster Management is to establish early warning system, emergency preparedness and response mechanism. The mission of MHADM is to formulate policies, coordination humanitarian assistance that ensure saving of lives, restoration of dignity and sustaining hope for the vulnerable group.

In regards to flood forecast and early warning systems managements, it is to achieve a paradigm shift in national disaster management strategies from conventional response and recovery to more comprehensive risk reduction culture and to promote comprehensive disaster management as an important factor in ensuring the resilience of communities to hazards.

In regard to early warning activities, it receives warning information from its key stakeholders and coordinates it with the relevant authorities in providing disaster response to the victims of flood and other disasters.

Non-Governmental Organization.

In the survey, mapping and discussion with the key people in the country about the role of nongovernmental organizations in data collection on flood forecast and early warning systems management, it was discovered that there are no national and foreign nongovernmental organizations working in the field of data collection and provider for flood forecasting and early warning messages. The mandate of data collection of early warning belongs to the government.

But on rare cases, the International Committee of the Red Cross (ICRC) and other International Organizations and UN Agencies in agreement with the government do collect data on flood forecast and early warning for their own uses especially on humanitarian basis. They do this to fill the gaps created by the challenges the government is facing in the area of data collection in order that they can save lives and properties of the people of South Sudan.

United Nations Agencies.

During the survey, mapping and discussions with the key people in the countries about the role of UN Agencies in data and information collection process, it was discovered that foreign agencies are not supposed to collect data for the country. But if they do for their specific purposes, this cannot be used for reference purposes. But when the abnormal and sudden floods happened in the country five UNA and one international organization took part in data and information collection processes. These are as follows

International Organization for Migration (IOM)

This IOM came into the data collection process during the sudden and unpredicted flood which happened during the month of July and November 2019. This agency came in because of the call of the government for humanitarian organization to support the country in addressing this disaster. It sent some flood forecast experts to assess the situation of the affected people in the flood affected counties of the country

United Nations Children Educational Fund (UNCEF)

UNICEF is one of the UN agencies which responded to the call of the President when he declared a State of emergency when the flood struck some counties in the north of the country. The main aim of UNCEF in the data information collection was the lack of data and information about the issues of children and mothers who are the main victims of the floods.

United Nations Office of Coordination of Humanitarian Affairs (UNOCHA)

This UNOCHA agency is supposed to be a data and information user in the area of flood forecasting and early warning services but it became a data and information provider because of the seriousness of the situation in the field. For this reason, it has to get involved in data and information collection from the flood affected counties in north of the country.

International Committee of Red Cross (ICRC)

This international organization is not supposed to be a data and information provider. But it played this role because of the urgency and seriousness of the situation. Without data and information, it would not be possible to render humanitarian services and assistance to the flood affected population in the counties and states of Republic of South Sudan.

International Federation of Red Cross and Red Crescent Societies (IFRCRCS)

IFRCRCS is in the same way is supposed not to be an agency of data and information provider but because of the urgency and seriousness of the situation, The specific reason that brought ICRCRCS was the need for WASH and flood mitigation conditions of the affected population. Due to absence of this data, it has to come in to assess the gravity of the situation. And this led it to be a data and information provider.

And because of the financial and logistical capacities those UN Agencies possess, they were able to collect enough emergency data and information for supporting and assisting the flood affected population in north of the country. This sudden and abnormal flood in the north of the country has created a situation where the data and information providers become both data and information providers and users at the same time.

2.2. Forecast Warning Users

National Government.

In the survey made by the consultant during the mapping and survey processes, eight national flood forecast and early warning related institutions which are using early warning information on behalf of the government were identified. These are the following:-

Ministry of Information, Communication and Postal Services.

This institution is supposed to use the information for informing the public about the incoming floods which will have some negative impact on the lives of the people. The Council of Ministers which meets once a week usual makes media briefing and if floods and early warning messages are brought to the council of Ministers by the concern authorities for discussions, their decision can be communicated to the journalist through the government Spokesperson.

Ministry of Livestock and Fisheries.

In my discussion with some officials of the ministry, they told me that their ministry is supposed to use the information to inform and warn the pastoralists and fishermen who are grazing their animals and those who are fishing in the flood prone areas about the incoming floods .The purpose is to enable them to save their lives and their animals. But this is not happening because the system of receiving and communicating the early warning messages to the pastoralists and fishermen is not established. Further to this, the pastoralists and fishermen are not mobilized and are not aware about the danger of sudden floods

Ministry of Roads and Transport.

The Ministry uses this information to inform the travellers about the possibilities of overflowing of water over some of the bridges that might have some implications on travellers. The Ministry also informs the airline companies through the South Sudan Civil Aviation Authority (SSCAA) about the danger of flooding at the airports across the country as it used to happen sometimes. And the ministry also uses the information for planning and managing river transport on daily bases.

Ministry of Humanitarian and Disaster Management.

In my discussion with some officials and after reviewing some policy documents, I learnt that the ministry use this information in collaboration and cooperation with relevant authorities in warning the vulnerable communities at risk at the various flood prone areas in the country and at the same time it uses the information for mobilizing and coordinating humanitarian relief assistances with the relief and humanitarian agencies in providing assistance to flood victims during disasters.

Ministry of Agricultural and Food Security.

In my conversation with one of the Inspectors in the Directorate of mechanization, I learnt that the Ministry is supposed to use this information for informing the farmers about the incoming floods which might destroy their crops and their livelihoods especially those who are cultivating in the flood prone areas. And for that matter the need for preparation for famine in the days to come. But this is not happening because of lack of systems and programme for early warning management.

Ministry of Water Resources and Irrigation.

This institution is supposed to uses the information and data for informing the Council of Ministers and the National Legislative Assembly for emergencies responses during times of flood. The Ministry also uses the information for informing other stakeholders in the country who want to carry humanitarian activities in country as stated by some officials from the ministry.

Ministry of Energy and Dams.

In my discussion with officials from the ministry, I was told that this institution is supposed to use the data and information for informing downstream countries in case of floods. But this arrangements are not yet made due to fact that the Ministry is not well established to carry out this function.

Department of Civil Defence (Fire Brigade in particular).

I interviewed some former and present employees of the department of Fire Bridge (Civil Defence), they told me that there is a programme for evacuation and rescue in this department during the time of floods. It is supposed to use this information for planning purposes but due to presence of some challenges these programmes are not very active and much work need to be done on this particular area. But as of now there is no activity for flood evacuation management by this department in Republic of South Sudan

State and Local Government

The State Government

In the survey made by the consultant during the mapping and survey processes, two State forecast warning users who were supposed to use this information for informing the vulnerable communities are identified. These are the following:-

The first is the Directorate of Water Affairs in all the states in general and in the flood prone areas States in particular. They are supposed to use the information to warn the counties about the coming floods. But they cannot do it because this programme and the unit to implement these processes have never been established in their respective Directorates across the states of the country.

The second is the National Technical Task Team. In my discussion with the Acting Director General of Early Warning Systems in the Ministry of Humanitarian Affairs and Disaster Management in regard to early warning systems operations in the Ministry; she told me that the Ministry of Humanitarian Affairs and Disaster Management has established a National Technical Task Team Focal Points. National Technical Focal Point who is deployed to all the states. The members of this are drawn from stakeholders of the ministry. They use the information for informing the vulnerable communities about the incoming disasters in the counties and down to Payams and Bomas where they are deployed.

The Local Government.

There is one institution in the county which is supposed to play a key role in flood forecasting and early warning system management by the local government. This is the Office of the Assistant Commissioner for Water Affairs in the Counties. It is headed by the Assistant Commissioner of Water. This office is supposed to use this information to inform the Payam and Boma Administrators about the any incoming floods. But the unit for early warning has never been established due to a number of factors and challenges.

UN and other Humanitarian Organizations

As stated above, UN Agencies and other humanitarian agencies are supposed to be the early warning data and information users. But because of the urgency and seriousness of the situation created by the abnormal and sudden flooding, they become both providers and users. Since their roles and responsibilities have been mentioned above, it is not discussed here to avoid repetition.

Non-Governmental Organizations (NGOs)

In the survey made by the consultant during the mapping and survey processes, it is found out that there are many non-governmental organizations working in the country in the field of data users. Most of them are registered with South Sudan Relief and Rehabilitation Commission, a subsidiary of MHADM. Most of them get their information from UN Water Cluster. But normally they work with MHADM to provide relief and humanitarian assistance during the time of floods or any other disaster.

South Sudan Red Cross (SSRC).

The consultant interviewed the Director of Administration of this organization and he indicated that South Sudan Red Cross is a National Society for Red Cross and Red Crescent and its partners. The mandate of this organization is to support the government in the areas of disasters such as drought, floods and diseases. This organization is supposed to get flood early warning from the Ministry of Water Resources and Irrigation but due to lack of this information, they get their information directly from the field. It was stated that SSRC operates in partnership with MHADM

Community Initiative for Sustainable Peace Organization (CIPO).

The Mandate of this local community based organization states that CISPO is to move to all parts of South Sudan and beyond to create awareness about those things that brings conflict and those that brings peace so that it is able to build sustainable peace among the communities.

In regard to early warning systems, CISPO creates awareness among the local communities about any situation such as floods, drought, disease, conflict and many others that has the potential of bringing disaster to the communities.

Local Communities

The local communities who are supposed to users the early warning information are those living or working in the flood prone areas in the country. These communities include the following:-

The first group of communities are the Nuer and Anyuak and those in the surrounding areas. These communities are found in Akobo and Nasir areas. They practice both farming and fishing along River Sobat.They are both pastoralist and farmers.

The second group of communities who are supposed to be the users of information and data are the Bari, Dinka Bor, Nuer and Chollo. These communities are living along Bahr el Jebel basin before and after the Sudd.These communities also practise farming, fishing and rearing of livestock.

The third are the town dwellers that live in the city of Wau.The most vulnerable population are those who live in Hai Khor Mudir in the West Bank of river Jur, Hai

Dinka and the Soldiers who work and live in the Military Barracks which is built near the flood prone areas of the city.

The fourth are the citizens of Juba city. The vulnerable communities are residents of Airport road, Gudele Blocks Five and Four and Juba West Kapuri area.

The fifth are the Dinka and Jur Bel and other residents. The vulnerable people are those who live in Aweil town and the outskirts of the city.

The sixth are the Toposa, Didinga, Buya and other dwellers. The vulnerable are those who live in Kapoeta and the surrounding areas.

The seventh are the Lotuko and other residents who live in the city of Torit and in the outskirts of the city and other villages in the county. The vulnerable communities are those who live in Ilgum, Gumbo and other surrounding areas.

The eight are the Chollo, Dinka, Nuer and Burun, Koma.The vulnerable population are those who live along the Nile. In terms of livelihoods, the vulnerable groups are they practise farming, fishing, agro-pastoralists who are rearing animals, and other petty traders.

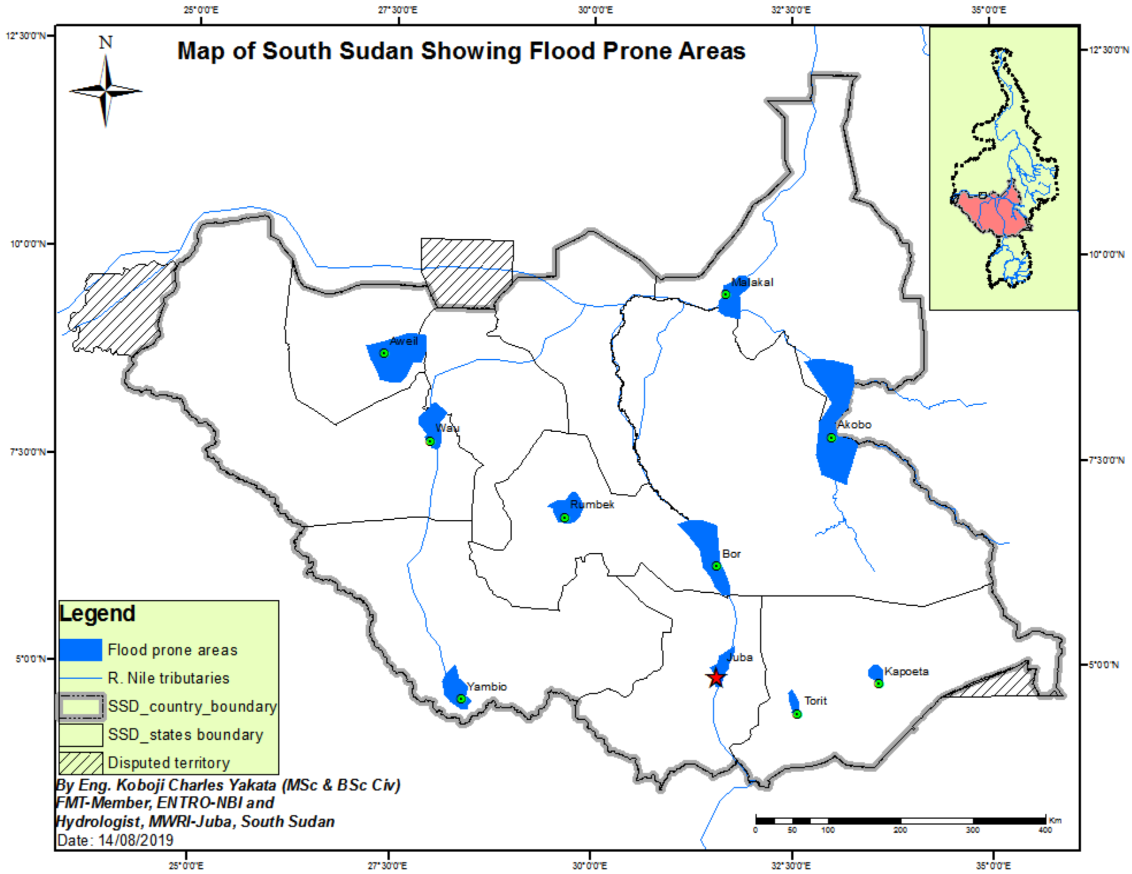

Figure 9The Map of South Sudan Flood Prone Areas and the corresponding Vulnerable Communities and their Villages.

2.3. The Vulnerability Mapping for Settlements on Flood Prone areas

There are many and various vulnerable groups of communities who live and work in the flood prone areas of the country. These groups range from towns up to villages dwellers. The report about them is arranged according to their areas as defined by the findings of the consultant. The main vulnerable areas of settlement are the following:-

Akobo: The vulnerable population who settle in flood prone areas are the Anyak and Lou Nuer in Akobo town and the surrounding areas and Jikany Nuer in Nadir town and the surrounding areas. They are affected by flash and river floods.

Wau: The flood prone areas are Khor Mudir in the West Bank of river Jur, Hai Dinka and Military Barracks. The people are mostly affected by river and flash floods.

Juba: The flood prone areas are Juba Na Bari Residential area including the airport road, Gudele Blocks Five and Block Four and Juba West Kapuri area. In Northern Juba the population affected by floods are the Bari in Mangala County of former Central Equatorial State.

Bor: The vulnerable people who settled in flood prone area is the Dinka Bor and the Nuer.They are normally affected by river and flash floods.

Aweil: The vulnerable population who settle in flood prone area and they are vulnerable are the Dinka and Jur Bel including the population at the cities.

Kapoeta: The vulnerable population who settle in the flood prone area are the Toposa, Dindiga, Buya and others.

Torit: The vulnerable people who settled in the flood prone areas are the Lotuko and other people of different nationalities who work and live in Torit Town.

Malakal: The vulnerable flood prone area, the vulnerable communities are the Shilluk, Dinka, Nuer and Burun, Koma and other small communities that may be living in those areas. The detail and the exact locations of these places can be seen from above map of flood prone areas of South Sudan.

3. THE ANALYSIS OF STAKEHOLDERS GAPS IN EARLY WARNING

3.1. Forecast Providers

Eastern Nile Technical Regional Office (ENTRO)

Eastern Nile Technical Regional Office is supposed to lead flood forecasting and early warning processes in the entire Easter Nile countries according to its mandates. ENTRO has made some significant progress in establishing flood forecasting institutional mechanism for these processes in the countries. It has established national offices in Ethiopia and Sudan but it has not done so in South Sudan.

The Flood forecast and early warning programme which is being done by ENTRO during the flood seasons does not cover the whole of South Sudan but it only covers Bara-Akobo-Sobat Sub-basin. Secondly there are some complaints that the internet in the office is not constant and there are a lot of power failures. Thirdly ENTRO also suffered from constant cuts in power supply which can disrupt information and communication flow as was described by the senior consultant

It was also discovered in the study that ENTRO is only supplier of warning information in the eastern part of River Nile. And the western part of River Nile is to be done by NELSAP. I have not got any documentation to this respect. But the most serious impact of the floods in South Sudan is happening in the western part of River Nile. I think South Sudan may need to make effort to make sure that this part of the country is attended to so that flood issues in the country are wholly addressed by one single entity.

The other issue is that the Nile Basin Initiative where ENTRO is a part is still a transitional Organization. The Cooperative CFA Framework Agreement has never been signed by all the countries. This makes it difficult to established permanent river basin organization. The absence of this organization affects the countries in establishing country wide offices for water and water related issues.

The Ministry of Water Resources and Irrigation (MWRI)

In the discussion I had with the Director General of Hydrology and Survey, he highlighted the following gaps in the Ministry in discharging flood Early Warning:-

- There is no sub-sector policy and institutional framework which defines the roles and responsibilities of the staff and units in the Directorate in general and in early warning in particular.

- The systems for collecting data from the rivers and stations are malfunctioned and they cannot provide data for flood forecasting and early warning systems during flood season.

- It has no specific unit for data collection and dissemination in the country.

- There are few specialised trained staffs in communication technology in the Ministry who can offer this services as it should do so. As a matter of fact there are no official programme of training of staff on this particular programme and assignment in the Ministry. There are some courses sponsored by development partners and other bilateral arrangements but not specifically for early warning.

The Ministry of Environment and Forestry (MEF)

The Ministry of Environment and Forestry has a major role in flood forecasting according to its policy and legal framework but unfortunately, it has no institutional arrangement in its administrative set up for flood forecast and early warning systems. In my discussion with the Senior Staff in the Ministry, I was told that there are no employees who are recruited for responsibilities of flood early warning in the Ministry. As a matter of fact there are no activities going on in the area.

Ministry Agriculture and Food Security (MAFS)

Official from the Department of mechanization which is responsible for flood control in the ministry, indicated that, The Ministry of Agriculture and Food Security is supposed to receive data on rainfall from both South Sudan Meteorological Authority and Ministry of Water Resources and Irrigation so that it can send the data to the states and down to counties but this department or unit has not been established and there are no specialised staff employed to deal with this kind of activity.

South Sudan Meteorological Authority (SSMA)

The gaps of South Sudan Meteorological Authority in flood forecast and early warning includes the following:-

- There is inadequate capacity for collecting and sending data and information on early warning systems on daily bases to its users as more and more equipment are being manufactured for complex forecasting and early warning processes.
- There is no coordination unit for cooperation with other stakeholders in flood forecasting and early warning management.

The Ministry of Humanitarian Affairs and Disaster Management

The Ministry of Humanitarian Affairs and Disaster Management has established the Directorate of Disaster Risk Management. But there are many gaps which affect the ministry. These includes the following;-

- There is no communication infrastructure technology which can be used for data and information sharing among the key stakeholders at the national levels and with the states and counties.
- There are few or no technical staff at all who could be engaged in the communication and dissemination process during the time of flood or during disaster,
- There is no flood forecasting and early warning system in the Ministry as it is struggling with a number of issues which includes lack of infrastructure for communication and engagement among various stakeholders.
- There is no coordination mechanism between national and state stakeholders in the issues of disaster in general and flood forecast and early warning in particular.

The Ministry of Livestock and Fisheries

This ministry is discovered to be a key stakeholder in early warning systems but it has no department of flood forecast and early warning systems.Becasue of this absence there are no staff who could be engage in early warning discussions and consultations. As a result there are no activities for flood early warning.

Non-Governmental Organization (NGO)

There are no nongovernmental organizations working in flood forecasting and early warning systems in the country. There was a project managed by a certain organization called Niras which was working in Eastern Equatorial and Lakes States but it is implementing the programmes of the government. There was no data about gaps available.

And for the community Initiative for Sustainable Peace Organization, it is still at infancy stage (although it is able to make awareness) but cannot carry out big tasks of awareness about flood forecast and early warning but the most challenge gap of this organization is that it lack of office space and qualified staff to run some of its programmes but is trying very hard to come up with some few people to carry out its core activities.

In other countries both at the global and regional levels, there are many independent researchers and writers on various issues which affect humanity. But in South Sudan we do not have these groups of people such that the only people who see the early warning issues are the government institutions and the development partners.

3.2. Forecast Warning Users

National Government

There is no Flood Coordination unit in the Ministry of Water Resources and Irrigation for coordinating, disseminating and communicating of flood forecasting and early warning messages to various stakeholders in the country.

The Key Stakeholders of Ministries of Environment and Forestry, Ministry of Humanitarian Affairs and Disaster Management and Ministry of Livestock and Fisheries have no communication and dissemination units to receive and use the messages.

Most of these flood forecast warning users have no programme for flood forecasting and early warning management in terms of policy, legal and institutional framework. There is need for the training of local communities for the use of appropriate technologies in flood forecasting and early warning messages communication and dissemination to other vulnerable people.

The flood forecast warning users have no programme for flood forecasting and early warning management in terms of policy and legal and institutional framework in the country.

State and Local Government

In our governing structure that is to say National, State and Local Governments, the followings are the gaps in flood forecasting and early warning systems management:

- There are no policy and legal instruments for flood forecasting and early warning systems management in the states and counties.
- There are no departments or units in the Directorate of Water Resources Management dedicated entirely for flood forecasting and early warning systems management.
- There are no technical and administrative staff trained or employed to manage floods despite the fact that floods are occurring on yearly bases with devastating impacts on people and their properties.

Non-Governmental Organization (NGO)

Most of the Non-Governmental Organizations working in South Sudan are of foreign origin and they are supported by the International Organizations and UN Agencies in the operation of their activities. They therefore have no flood forecasting and early warning management arrangements or mandates.

Secondly the area of their operations is defined by the government but not on their own arrangements but they do support the victims of flood in any part of the country if it happens

Their activities and programmes are defined and determined by their sponsors in their country of origin. For that matter their activities are flexible.

The Local Communities

As we mentioned earlier, there are many local communities some with strong social structures in their localities. But they cannot carry out flood forecasting and early warning systems management because of the following gaps:-

The idea of flood forecasting and early warning systems management is a foreign idea and they therefore have no arrangements for this process.

There social structures have never been mapped and understood and therefore it is difficult at this point to know and tell what their methods of administration these communities are using.

The location and the degree of vulnerability are yet to be mapped and understood within these project arrangements.

4. THE METHODOLOGY OF COMMUNICATION FOR EARLY WARNING

4.1. The Best Practices of Global Communication Methods in Early Warning

In the survey and mapping that was carried out by the consultant, it was discovered that the followings are the common methods for communication globally. They includes the following

- Radio and Television Broadcasting Services. Channels such as British Broadcasting Corporation (BBC) and Cable News Network (CNN) do report on issues of early warning or any issue including flood. At the National level we also have national radios and Television networks. The government is using them for all types of messages.
- Email address which is use for sending and receiving early warning messages across the globe.
- Issuing of press release on emergent flood early warning events by policy and decision makers whenever there is threats of floods.
- Telephone whether mobile and landline phones which people can use in case of floods and other disasters.
- I talked to journalists of some newspapers and they told me they can publish early warning messages. Even one newspaper called Juba Monitor gave the Ministry of Water Resources and Irrigation a complete page for publishing water and water related issues including floods and its impacts on the lives of people and their properties.

4.2. The Current Early Warning Communication Method in South Sudan

In the survey, mapping and in discussions with junior and senior members of the government, the following are the current methods of communication which can be used for early warning. Since there are is no active flood forecast in the country, the same methods that are used for other events are the same that could be used for floods. These include the following:-

- Email communication with the key stakeholders such as the focal points, ENSAPT members and any other Stakeholders working in flood forecasting and early warning systems

- Daily, weekly and monthly bulletin which are produced on periodic frequencies to explain and predict floods and its impact. The Director General of Early Warning in the MHADM told me that they are using bulleting for early warning communication with their stakeholders

- Local radios, television broadcasts bulletin and newspapers both print and online versions. The examples of these are Sudan Tribune and many others operating in South Sudan

I went to the Office of South Sudan Meteorological Authority at Juba International Airport and the Director General and one forecaster told me that they are sending the early warning message of weather and rain information to the National Radio and Television and other stakeholders using templates. I also asked the people of Hydrology and told me that they receive rain information from the SSMA through filled forms in form of templates.

The Officials of SSMA also told me that they use narratives in bullet points for sending Early Warning messages to South Sudan Radio and Television for broadcasting to the general public and to other stakeholders of the South Sudan.

Because there are gaps at the national level, there are corresponding gaps at both State and county levels which can result to communication breakdown.

4.3. Gaps in Existing Communication Methodology in South Sudan

In my conversation with Director General of Meteorology and some of the forecasters in the Directorate, Director General of Early Warning in the Ministry of Humanitarian Affairs and Disaster Management and Director General of Hydrology and Survey including his staff about gaps in existing Communication Methodology in the country, the following are the findings I received. The most serious ones include the following:-

- In the Ministry of Water Resources and Irrigation, specifically in the Directorate of Hydrology, there is no core unit in the ministry which is responsible for generating and communicating early warning data and information at the national level to all other stakeholders in the country.

- There is also no communication infrastructure or communication technology in the country which controls communication processes such as sending and receiving early warning messages.

I talked to the Acting Director General of Early Warning in The Ministry of Humanitarian Affairs and Disaster Management and she told me that the mandate of the Ministry as stated earlier is responsible for coordinating disaster early warning messages among the key stakeholders at the national level. The gap is that it does not have communication infrastructure for connecting the stakeholders both horizontally and vertically.

The official also stated that due to lack of electric power in the country, this has made it difficult to constantly use telephones and emails and other means of communication for early warning.

The Director General and forecasters of South Sudan Meteorological Authority indicated that, they use to send early warning information to South Sudan Broadcasting Corporation through the internet so that they can download and broadcast it to the nation. This makes it difficult to communicate.

Officials from the Ministry of Agriculture and Food Security which is supposed to be an early warning data user at the national level and they told me that one of the gaps which affect communication in the ministry is the breakdown of the database. Database is a key facility for communication because of its storage of information and data.

The other critical issue in early warning communication is the inadequate capacity to plan and organize data communication from one level to the other between the national and counties.

The same is true at the State and local levels. Since there are gaps at the national levels in terms of providers and users; there is the corresponding gap at the states and counties levels. There is lack of constant power for charging batteries and even maintaining and operating internets.

In general for all the Ministries at the national level which are the producers of data and information, do not have active systems of communication which connect the headquarters, states and the counties. Therefore data and information can be generated at the national offices from the regional organizations such as ENTRO but to communicate it to the state and county level becomes difficult.

The early warning users both at the national, state and local level have no coordination unit in the Ministry of Water Resources and Irrigation which can plan and organize communication systems both for national ,state and local levels.

One of the major challenges in the communication methodology is the inadequacy in capacity building action plans, programmes, resources mobilization arrangements and policy and institutional arrangement from national through the states and down to counties.

4.4. The Proposed Early Warning Communication Method and Technology

Following my discussion with the key stakeholders, the following are the proposed communication methods which can be applied for early warning messages. These include the following:-

- Creation of communication unit and equipping it with modern equipments in the Ministry of Water Resources and Irrigation for assembling all data and information from all other stakeholders and disseminate it to all users country wide.
- Designing or improving a reporting template which is available in many ministries for disseminating the characteristics of floods such as water level, speed and depth of the water, duration of the rainfall so that the stakeholders can act accordingly.
- Supply of radio sets to the chiefs or another key actor among the vulnerable communities so that he or she can tune to it especially during flood season and once he or hears this information, he can disseminate it to the communities using indigenous method. This is done in other parts of the world and has succeeded.
- Development of series of television, radio and news programmes on early warning on reasonable frequencies to inform the decision and policy makers as well as the vulnerable groups about the likelihood of floods and its impacts on the lives and properties of the people.
- Create a network of professional staffs and interested individuals in flood forecasting and early warning systems management in the country such that whenever flood message is received by one member, he or she can alert the other members to inform the other communities.

4.5. Existing Indigenous Flood Early Practices

In the survey and review exercise in regard to indigenous (knowledge) practices on early warning around the world in general and in Africa in particular, I reviewed six references and talked to some other people and reviving my own experiences about this issue, the following indigenous practices were discovered:-

Definition of indigenous (knowledge) practices as outline below:-

According to Shaw, Noralene, and Baumwoll (2008) stated that indigenous (knowledge) practice is a method and a practice produced by community with keen understanding of their local environment. These skills can take generations to have a command on these. The knowledge regarding the changes in the local environment has important characteristics. These include originating within the community, maintaining a non-formal means of dissemination, collectively owned, developed over several generations and subject to adaptation, and imbedded in a community's way of life as a means of survival.

Indigenous practices can be deduced from the behaviours of plants.

It is observed that, a good amount of well distributed rainfall is signaled by the presence of higher than normal flowering intensity of certain trees; the immaturedropping of fruits by certain tree species, the shedding of leaves of the sycamore fig during August to October and the exuding of water from the leaves*before* the onset of rains. In our community, there is also a plant which grows green during the dry season but it becomes dry when rainy season is about to come.

Indigenous practices can be deduced from the behaviours of animals.

It has been observed that certain animals both wild and domestic have some degree of predicting rain. The report cited particularly goats, sheep and cattle .That these animals when they smelled rain, they would make repeated shouts continuously which means that they want to be taken away from where they are. For cattle it has been observed that if they smell rain, they do not want to be driven to graze areas. I have confirmed these because of my own experience with our cattle before the war.

Indigenous practices can be deduced from behaviours of birds.

It has been observe in the villages that birds like kits and others, come during the dry season. But when rain is near, they disappear from the villages. Other birds begin to migrate during the approaching rainy season. One elder told me that there are some birds which make distinctive sounds when rain is about to come. I proved this to be true because these days especially this year in Juba, these types of birds are many as floods are extraordinary.

Indigenous practices can be deduced from behaviours of insects.

It has been observed that some insects especially the black ants tend to migrate from wet to dry places. Therefore when these insects are seen moving from one place to other carrying food, their young ones and even eggs; this means that after short time rain would come. The same is true for the red ants. When they move from one place to another in groups, this shows that rain is about to fall.

Indigenous practices can be deduced frombehaviours of winds and clouds.

It has been observed that when rain is about to come the clouds always look thick and it seems to covers all parts of the sky,there would be presence of heavy lightning and thunder, the temperature of the day will either rise or fall, the changes of the direction of the wind depending on where the area is located.

Indigenous practices can be deduced from behaviours of celestial bodies.

It has been observed that when colour of moon is surrounded by a circle and it looks dim, or when the colour of the sun changes from white to red on certain days or it is covered with clouds and the intensity of the light becomes weak, there is a possibility of a rain.

Indigenous practices can be deduced from the behaviours of frogs and crabs. Frogs and crabs are considered as the announcers of coming rainfall. It has been observed that they always make some distinctive sounds repeatedly at a certain time of either the day or the night especially when the rainy season delays. It has been observed that these shouts are signs of informing people that rain is about to come.

5. CURRENT RESPONSE ACTIVITIES TO FLOOD EARLY WARNING

5.1. Performance of Current Response to Flood Early Warning

In my discussion with the Director General of Meteorology and some of the Flood Forecasters, the Director of Administration of South Sudan National Society of Red Crescent and Red Cross, the former and current Staff of Department of Civil Defence (Fire Brigade) and the staff of the Ministry of Water Resources and Irrigation, about current response activities to flood early warning, the following information about how responses are to be acted upon were obtained from the discussion.

The Department of Civil Defence (Fire Brigade) is supposed to put contingency plans of how evacuation and rescue is to be carried out in response to early warning messages about flood disasters in the flood prone areas of the country. But since there is no early warning programme in the country, this means that there are responses in regard to evacuation.

The Ministry of Humanitarian Affairs and Disaster Management has established the National Technical Task Team at the national level and National Task Focal Point at the state level to monitor disaster cases country wide. In case of any outbreak of disaster, the members of task team can report the issues to the headquarters for response.

MHADM has also put some emergency preparedness programmes for coordinating relief operations with the UN and other Humanitarian organization to rush food and non-food items to those who are affected by flood or any other kind of disaster.

The Ministry of Water Resources and Irrigation is supposed to prepare a task team headed by the Directorate of Rural Water Supply to supply clean and safe drinking water to those who are affected by floods so that cholera or any other water borne diseases can be prevented and controlled. But this does not happen because of lack of resources.

The National Society of Red Crescent and Red Cross told me that, since there is no early warning message from the Ministry of Water Resources and Irrigation and Meteorological Authority, the Administration of this organization has established two disaster responses programmes. One is called Disaster Emergency Fun (DREF). This programme is in every state except where there are conflicts. Whenever flood happens, they make an immediate assessment to establish the level of the damage. As a result an immediate intervention to rescue the victims is made.

The second is called Appeal Fund (AF). This is big and it takes long time to respond. The reason is because there are factors that are connected with this programme. These includes the magnitude and levels of fear about the disaster .He said they do not apply this in the times of floods but on the issue of diseases such as Ebola, coronavirus and among many others.

The National Non-Governmental Organizations, Foreign Non-Governmental Organizations have some plans for responses when flood disaster happens. Their responses to early warning programmes are coordinated by the Ministry of Humanitarian Affairs and Disaster Management and United Nations Office of Coordinating Humanitarian Affairs (UNOCHA). What they do normally is to supplying humanitarian and relief assistance to victims in form of food, medicine, shelters and cloths when they hear the news of any disaster which has affected people in any part of the country.

The local communities have their traditional way of responding to the early warning. They normally prepare to store their food in their houses to be used when flood happens. They also did local drainages systems to drive away water that enter their houses whenever flood happens.

5.2. The Proposal on how to improve the response to early warning

There are many plans which can be put in place for the improvement of response to early warning in the Eastern Nile Countries. These include the following:-

- Increase awareness creation among the local communities in countries about the importance of flood forecasting early warning systems in saving lives and properties.
- Increase the time of training on emergency responses mechanisms and framework so that the level of intervention can be easier and effective especially for the

national staff in the Ministry of Water Resources and Irrigation and its key stakeholders.

- Involve the civil society and community based organization in the flood forecast and early warning processes especially in planning and implementation of projects, programmes and action plans such that whenever early warning message is received, the degree of community response involvement can be higher.
- Commission more studies into deeper and wider understanding of the nature and status of response to flood early warning systems so that knowledge and skills of response can be deepened, improve and sharpened among the key stake holders.
- Develop a strong strategy for mobilization of more resources for flood forecasting and early warning responses activities so that countries are on the same page in this process.
- There is need for the training of local communities and other vulnerable communities and groups facilitating in comprehensive early warning responses.

But we also need to underscore that the challenges of flood forecast in the country are huge and though ENTRO may need to support the country to identify the most important priorities and national process to this effect can be initiated.

6. INSTITUTIONAL ARRANGEMENT

6.1. Gaps in the Current Institutional Setup at Regional and National Level

From the interview with the Director Generals of South Sudan Meteorological Authority, Director General of Directorate of Hydrology and Survey in the Ministry of Water Resources and Irrigation and Director General of Directorate of Early Warning System in the Ministry of Humanitarian Affairs and Disaster Management including my own experience as a Technical Advisory Committee member for NBI about current institutional set up at Regional and National levels, the following are the findings:-

- There are indeed many gaps in institutional setup at Regional and National Level in the Republic of South Sudan. As a matter of fact there are supposed to be five regional institutions which are supposed to have national and local offices for flood early warning system in the country. These include the following.
    - ENTRO has not established flood forecasting and early warning country office in South Sudan as it did in Ethiopia and Sudan. For this reason it is very difficult for South Sudan to get data and information on time from this regional centre.Because there is no country office for ENTRO, italso becomes difficult for the Country to plan and established country activities country wide.
    - I was informed that the Nile Equatorial Lakes is responsible for the other three sub-basins of Bahr el Jebel, Bahr al Ghazal and white in terms of flood forecasting. But its local or country office for this particular activity is missing. For this reason the country could not establish local offices at the state and county levels.
    - Nile Secretariat has a national office called National Desk Office. This office is responsible for organizing national activities including flood early right from national down to the communities. But this office is not established at the county and local levels due to many factors.
    - Inter-Governmental Authority for Development has an office for early warning in Nairobi called IGAD Climate Prediction and Application Centre (ICPAC). This regional Institution has a national office in South Sudan but it has no unit for early warning systems in the country. And because this is not here, it becomes difficult for the country to establish some offices in the states and counties.
    - The World Metrological Organization has a Regional Office for Eastern and Southern Africa in Nairobi. The Regional Office has country Office in Juba where the Country Director for Meteorology is the focal point. He told me that they have some offices in two states but the offices in the other states have been closed down because of the conflicts. In the same way they are supposed to have some offices in counties but this is not possible at this moment because of the conflicts in the country.

6.2. The Proposed setup for an effective Early Warning Systems Level.

In my discussion with the members of Ministry of Water Resources and Irrigation and the Focal Points of various Regional Institutions, the following are what they thought should be done.

- ENTRO may need to establish country office for flood forecasting and early warning systems management as it did in Ethiopia and Sudan. Once this is done, the country office may be able to create small units in the states department of water affairs and up to the counties so that issues of flood can reach everybody at every level.

- ENTRO through the ENSAPT Leaders may need to propose to Eastern Nile Council of Ministers the developing of a trans-boundary policy and legal framework for data sharing and exchange between the EN countries.

- NELSAP may also need to establish a country office or small unit through which its activities can be taken to the lowest communities at the states and at the counties. This is because the arrangements to do have been in discussion since South Sudan became a member.

- IGAD may need to establish early warning unit in the country office so that the office in the country can plan country activities from states to the counties.

- The Nile Secretariat may support the National Office in resources mobilization such that the country may be able to established units at the states and counties to ensure that the messages of flood forecasting and early warning are extended to the local communities.

- The most important thing is that there is need to established a coordination office for early warning systems management at the national level preferably at the Ministry of Water Resources and Irrigation .Once this office is fully functioning, it can then plan nationwide programs and action plans for flood forecasting and early warning system in the country.

- The government should try to create a temporary institution even in the form of focal point or group which can be tasked with the organizing national and regional communication and networking with regional organizations.

7. CONCLUSION AND RECOMMENDATION

7.1. Conclusion.

Following the extensive analysis and discussion of the findings of the survey and mapping, the following conclusion has been reached about the nature and status of flood forecasting and early warning in South Sudan.

- South Sudan is a flood prone country which experiences some devastating floods on annual bases with some significant loss of lives and destruction of properties.
- It has also been noted that the challenges of flood forecasting and early warning systems in the country are huge. This requires collaborative and cooperative approach both by the government and other development partners for the successful management of early warning system in the country.
- It has been recognised that there are inadequate policy, legal and institutional framework related for flood forecast and early warning systems in the country which hampers early warning and flood forecasting programmes and action plans difficult to implement.
- Capacity limitation in the country is widespread both at the technical and decision and policy makers level. Therefore training of technical, decision and policy makers seems to be the viable method of improving flood forecasting and early warning system in the country.
- The budgetary and financial constraint in the government and in the development partners remains a challenge to this programme.
- Flood forecasting and early warning systems requires relevant and vibrant communication and dissemination infrastructure both at the national and local levels to ensure better exchange and sharing of data and information across the country.
- Flood early warning systems management requires well connected infrastructure that deliver information to the threatened communities in the shortest time possible to alert the vulnerable population so that they can avoid huge loss of lives and properties.
- This project is very important to be encouraged and promoted so that the challenges, inconsistence and capacity limitations which hamper flood forecasting and early warning in the EN countries can be addressed.
- Most of the main stakeholders in the country are not fully informed about flood forecasting and early warning processes. Awareness creation and sensitization of this activity should may need to be encouraged and improved.
- The recent flood in the country has been the most destructive and most extensive in history. Even many elderly people who were consulted said that such as a flood has never happened during their lifetime. This flood is different and is special. There is need to have a special treatment for its impacts and causes

7.2. Recommendation

After making this conclusive remark about the nature and status of flood forecasting and early warning systems in the country, and in consultation with ENSAPT leaders, I would like to make these recommendations.

- ENTRO need to expand the coverage of the Eastern Nile Seasonal Flood Forecast and Early Warning Systems to other parts of Eastern Equatorial State in particular and to the entire parts of South Sudan in general to ensure a comprehensive and complete flood early warning in the country.
- ENTRO with the support of the country may need to create awareness among the local communities particularly the vulnerable population and among the decision and policy makers. The issue of awareness creation has been the popular demand of the people of South Sudan from ENTRO.
- ENTRO and the Ministry of Ministry of Water Resources and Irrigation of South Sudan may need to build the capacities of the decision makers and continue with middle and junior cadres to ensure that there is efficient and effective flood forecasting processes in the country.
- ENTRO may need to facilitate the establishment of the country office of flood forecasting and early warning system in South Sudan as it did in Ethiopia and Sudan so that some of local issues can be dealt with at the local level without reaching ENTRO in Addis Ababa.
- It is therefore necessary that ENTRO may include building of capacity of communication officers and other journalist in the areas of flood forecasting and early warning to ensure completeness of this programme.
- The occurrence of the recent floods in South Sudan has created fear and anxiety in the minds and hearts of South Sudanese leaders and communities especially in the flood affected areas or counties. For that matter, there is need for further studies to be done in regard to the sudden and abnormal flooding that happened in South Sudan outside the normal flood seasons.
- ENTRO may also need to a special focus and improve its communication with future consultancies in regard to South Sudan. This country is different from the rest. Many things are missing and requiring information with a limited period of time can lead to counterproductive.

References

ENTRO May (2015): The Nile Story, Briefing Note 7, Reducing flood devastation in the Nile

ESCAP (2015): Flood Forecasting and Early Warning in Trans-boundary Basins: A Tool Kit, November.

www.ifrc.org **(2019):**Emergency Plan of Action, South Sudan:Floods,22 September 2019

Faisal,F.(2014):Report, Extending Best Practices in Early Warning Systems for Building Community Resilience.

Government of South Sudan(2012): Ministry of Animal Resources and Fisheries, Policy Framework and Strategy,

Government of South Sudan (2007): Ministry of Water Resources and Irrigation, Southern Sudan Water Policy.

Government of South Sudan (2011): The Ministry of Water Resources and Irrigation WASH strategic Framework 2011

Government of South Sudan (2012): Ministry of Environment and Forestry, South Sudan Environmental Policy.

Government of South Sudan (2013): Ministry of Water Resources and Irrigation, South Sudan Water Bill.

Government of South Sudan (2018): Ministry of Humanitarian Affairs and Disaster Management Strategic Plan.

Government of South Sudan (2015): Ministry of Environment and Forestry, South Sudan Environmental Bill

Hassan .O,K. (2016):African Indigenous Knowledge Systems and Natural Disaster Management in North West Province, South Africa

ICRC (2012): Community early warning systems: guiding principles. International Federation of Red Cross and Red Crescent Societies, Geneva

International Network for Multi-hazard Early Warning Systems (22 to 23 May 2017): A Checklist, Outcome of the first Multi-hazard Early Warning Conference– Cancun, Mexico

ISRBC (2009)}: The Sava River Basin Analysis Report

Ketran,B, R. : Indigenous Knowledge, Early Warning System and Disaster Management: A Case Study of Khetran Community in Balochistan, Pakistan.

Megali, C. (2013): Mapping of Stakeholders and Initiatives for Early Warning Systems in Myamar.

Paul J.P, Guidelines for reducing flood Losses, UN Meteorological Organization,

Robert Š: Trogrlić Indigenous knowledge and early warning systems in the Lower Shire Valley in Malawi.

Shamika N.S: Flood forecasting and early warning system in Trans-boundary Basin.

Sharad, K, J, P. (2017):A Brief Review of Flood Forecasting Techniques and Their Applications**.**

UNDP (2018): Five Approaches to build Functional Early Warning Systems, Serbia,

WMO (2006): Strategy and Action plan for enhancement of cooperation between National metrological and Hydrological services for improved flood forecasting.

SUDAN SOCIAL SURVEY

FLOOD FORECASTING AND EARLY WARNING ENHANCEMENT PROJECT

Submitted by

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ENTRO
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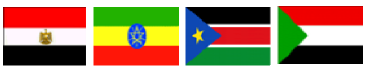
ENTRO is an organ established to implement the Eastern Nile Subsidiary Action Program within the framework of Nile Basin Initiative

Egypt, Ethiopia, South Sudan, Sudan



EXECUTIVE SUMMARY

The rationale and objectives of this consultancy work is to conduct country level survey for in-depth understanding of stakeholders, vulnerable communities in flood prone areas in the basin. This will contribute toenhanced ENTRO FEWS and to ensure continued forecast communication and dissemination is easily accessible to rural communities and also support other studies under FFEW that contribute in addressing flash flood.This surveyidentified vulnerable household levels that are most affected by floods including urban areas; it also identified coping mechanisms employed by the households during floods and strengthen positive coping strategies and identify needs of stakeholders;the scope of the work was stakeholder mapping, vulnerability mapping and household survey that addresses community based flood warning system.

The methodology for stakeholders mappingused in this survey was focused onindividual interviews,aimed at finding their specificmandate related to floods and gaps on it.Methodology for vulnerability survey was of two types, first is survey based on GIS maps overlay and buffering the river to find the location of villages on flood prone areas. Second was assessment of urban and rural vulnerability to floods using an indicator-based approach through sampling from Households and using face-to-face interviews, group discussion and questionnaires.

The results indicate that at regional level ENTRO was found to be the core forecast providers and disseminatorfor EWs to most of organizations, but ENTRO FFEWs does not cover Atbara River, Dinder and Rahad and it does not also addressflash flood in the Blue Nile basin and Gash river. The ENTRO FEWS suffers from an inadequate of observation data system, adequate data sharing, and lack of updated information and modern communication systems.

There are several users of ENTRO FFEWs products such as Civil Defence, Sudanese Red Crescent Society, Humanitarian Aid Commission,Ministry of Agriculture and Forestry,Ministry of Livestock and Fisheries, Ministry of Roads and Transport, Ministry of Environment, Natural Resources and Urban Development, and Ministry of Information

and Communication, inaddition, communities at risk and vulnerability settlement on flood prone areas.

The survey found 2,900 villages living in flood prone areas, these population and pastoral villages are distributed among the basins of the Blue Nile, Dinder, Al-Rahad, Al-gash and Tekeze -Atbara- Setit inside Sudan. Thehouseholds live in floodplains that are more susceptible to high flood impacts as well as highlyvulnerable to economic, physical/ infrastructural and attitudinal dimensions. These communities have the ability to avoid floods if they warn at least 3 days before the flood occurred, and this is evident from the floods of 2018 and 2019. The study also found out that the frequency of flash floods that occurred in the past ten years was more than riverine flood.

As a recommendation, Ministry of Water Resources, Irrigation and Electricity/Eastern Nile countries, need to upgrade existing manual records stations to make them automatic and ENTRO need to established/enhance models system in trans-boundary river basins. It also need more capacity building tousers,responders and communitiesthus regular feedbacksfrom stakeholders to ENTRO is important to improve ENTRO FFEWs.

Ministry of Water Resources, Irrigation and Electricity needs tobuild confidence between local government units and community, and launch awareness campaigns and design risk communication strategies to enhance the flood risk perceptions of the communities and engage the local institutions with the communities to implement disaster risk reduction plan effectively.

ACRONYMS

BAS:	Baro Akobo Sobat
BN:	Blue Nile Sub-basin
CMORPH:	CPC MORPHing
DRM:	Disaster Risk Management
EMMP:	Eastern Nile Flood Mitigation and Management Program
ENPM:	Eastern Nile Planning Model project
ENTRO:	Eastern Nile Technical Regional Office
EWHIC:	Early Warning and Humanitarian Emergency Information Center
EWS:	Early Warning System
FEWS:	Flood Early Warning System
FFWC:	Flood Forecasting and Warning Centre (Bangladesh)
FPEW:	Flood Preparedness and Early Warning
HAC:	Humnatiarian Aid Commission (Sudan)
HEC-HMS:	Hydrologic Engineering Center Hydrologic Modeling System, US Army Corps of Engineers
HEC-RAS:	Hydrologic Engineering Center River Analysis System, US Army Corps of Engineers
ICPAC:	IGAD Climate Prediction and Applications Centre
IDEN:	Integrated Development of the Eastern Nile
ISDR:	International Strategy for Disaster Reduction
IVR:	Interactive Voice Response
MAF:	Ministry of Agriculture and Forestry
MENRU:	Ministry of Environment, Natural Resources and Urban Development
MLF:	Ministry of Livestock and Fisheries
MoIC:	Ministry of Information and Communication
MoIWRE:	Ministry of Water Resources; Irrigation and Electricity
MRC:	Mekong River Commission
MRT:	Ministry of Roads and Transport
NCCD:	National Council for Civil Defense
NCORE:	Nile Cooperation for Result project
NFC:	National Forecasting Centre
NGOs:	Non Governmental Organizations
NOAA:	National Oceanic and Atmospheric Administration
RFE:	Rainfall Estimates
RFMMC:	Regional Flood Management and Mitigation Center
SRCS:	Sudanese Red Crescent Society
TRMM:	Tropical Rainfall Measuring Mission
TSA:	Tekeze-Setite-Atbara Sub-basin
UNISDR:	United Nations Office for Disaster Risk Reduction
USGS:	United States Geological Survey
WRF:	Weather Research and Forecasting

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1. INTRODUCTION

The EN Flood Protection and Early Warning Project (FPEW) has been one of the earliest successful IDEN Projects. The Project aims to reduce human suffering caused by frequent flooding, while preserving the environmental benefits of floods. The project emphasis on enhancing regional collaboration and national capacity in flood risk management, including flood mitigation, forecasting, early warning systems, emergency preparedness, and response. The FPEW project that ran until 2010 operated in Egypt, Ethiopia, and Sudan.

After the completion of FPEW project ENTRO initiated with Eastern Nile countries and created a regional Flood Forecast and Early Warning (FFEW) system under the Eastern Nile Planning Model project (ENPM) and the FFEW activity continued under the current Nile Cooperation for Result project (NCORE).

Currently, ENTRO is implementing its second, 2014-2019, Strategic Plan. The Strategic Plan, which is oriented in four strategic directions (i.e. Facilitating Cooperation, Promoting Water Resources Management and Planning, promoting Water Resources Development and Power Trade, and Institution Building), strives to position ENTRO for effective pursuance of its focus on Investment.

1.1 Rationales of the Consultancy work and the Project

The rationale of this consultancy work is at country level surveyor to conduct areport for further in-depth understanding of stakeholders.Vulnerable communities and flood prone areas in the basin, tocontribute in enhancedFFEW systemand toensure continued relevance of this vital program, forecast communication and dissemination need to be more easily accessible to rural communities and other important stakeholders.

The current FFEWS has gaps on coverage of all flood prone areas in the basin, robustness of the system and model, limited capacity in enhancing the system to up-to-date forecast standard. The current FFEW system use different models for the different flood prone areas in the basin, which makes it, time consuming and hard to update whenever there is a new version of model is available. Thus, there is a need to have a single robust unified flood forecasting and early warning system for the entire EN basin that include some parts of the basin were no prior work is done like flood prone areas of Tekeze-SetiteAtbara (TSA)sub-basin.

1.2 Objectives of the Project

The objective of this project is:

- To ensure a robust forecasting, issuing and warning system that effectively minimize loss of life and damage by enhancing, expanding and developing a unified Flood Forecast and Early Warning (FFEW) system for EN basin.
- To support other studies under FFEW that contribute in addressing flash flood, stakeholder analysis and flood related DSS development.
- To assess the vulnerability of households for flood prone areas and stakeholder with need for warning level and danger level that address community based flood warning system design

1.3 The Study Sub-basins

The Eastern Nile Basin can be dived into four major sub basins, the Abbay-Blue Nile Sub-basin (B.N.) including Lake TanaSub-basin, the Tekeze-Setite-Atbara (TSA) Sub-basin, the Baro-Akobo-Sobat (BAS)-White Nile Sub-basin and the Main Nile Sub-basin (Table 1).

Table 2: Total Area of the Sub-basins

Sub-basin	**Area (Square kilometers)**	**Mean Annual Inflow (billion cubic meters)**	**Proportion of Nile inflow at Aswan Dam (%)**
Abbay-Blue Nile Sub-basin including Lake Tana Sub-basin	313.657	51	57
Tekeze-Setite-Atbara Sub-basin	219.570	12	14
Baro-Akobo-Sobat-White Nile	425.511	26	29
Main Nile Sub-basin	654.600		

The Abbay-Blue Nile (B.N.) Sub-basin

The Blue Nile (or Abbay as it is known in Ethiopia), with an area of over 310,000 km^2, Originate in the highlands of the Ethiopian plateau. It begins its long journey to the Main Nilefrom Laka Tana and through a deep gorge dropping from about 4000 masl to 400 masl on its journey to Khartoum.

The Blue Nile (Abbay) contributes most of the Eastern Nile waters. The Blue Nile with several major tributaries such as the Didessa, Dabus, Guder, Anger, and Beles yield about 54 Bm^3 total when the river flows into Sudan to augment the 3.5 Bm^3 that leaves Lake Tana at the headwaters of the Blue Nile. The climate of the Abay-Blue Nile basin varies from humid to semiarid. Most precipitation occurs in the wet season (June through September), and the remaining precipitation occurs in the dry season (October through January or February) and in the midseason (February or March through May). Mean annual evaporation ranges from about1, 500mm (Fiche station (2,300 masl)) in the highlands of the sub-basin to more than 6,800mmaround Khartoum, the mouth of the sub-basin. Flooding is a serious problem at the mouth of thebasin such as Khartoum as well as in the upper course of the sub-basin.

The Tekeze-Setit-Atbara (TSA) Sub-basin

The TSA sub-basin (covering about 230,000 km^2) consists of the Tekeze river (known as theSetit in Sudan), and its tributaries, the Goang (Atbara in Sudan) and Angereb, all of whichoriginate in the north central highland plateau of Ethiopia. As the river makes its 1325 kmjourney, it falls from a height of about 3000 masl near its origin to about 500 masl when it joinsthe main Nile in Sudan, about 285 km downstream of Khartoum.

Water availability in the Tekeze-Setit-Atbara is erratic. The rainfall varies from 1000 mmnear the source of the river to about 40 mm near its junction with the Main Nile. The flows arehighly variable (compared to the Blue Nile and Baro-Akobo-Sobat sub-basins) especially in thecrucial low flow months. The main system of the sub basin at El-Girba station (about 156,000 km^2) observed to have mean annualinflow of 11.45 Bm^3 (1980-2000).

The Baro-Akobo-Sobat (BAS) and White Nile Sub-basin

The BAS Sub Basin,(covering about 180,000 km^2) consists of the Baro river (and its tributaries such as the Birbir) and the Akobo river (with its main tributary, the Pibor). After the confluence of the Baro and Akobo, the river is called Sobat in Sudan. The river makes its way from an altitude of over 3000 masl in the Ethiopian hills to about 400 masl when the Sobatcrosses into Sudan on the way to its junction with the outflow from the Sudd wetlands thatbuffer the outflows from the Nile Equatorial Region. The resulting White Nile (with its basincovering about 280,000 km^2) flows north to Khartoum where it joins the Blue Nile.

Water availability in the BAS:TheBaro-Sobat-White Nile sub-basin within Ethiopia is wellwatered.However, spatial variation of the mean annual rainfall is considerable due to the greatrange in elevation across the basin. Average annual precipitation ranges between 600 mm in thelowlands (less than 500 masl) and 3,000 mm in the highlands (over 2,000 masl). Averagerainfall of about 100 mm occurs from May to October. The highest rainfall occurs in June-September (ENTRO, 2006c).

1.4 An overview of Eastern Nile (EN) Seasonal Flood Forecast and Early Warning

The FFEW, since its establishment, has been an important part of ENTRO's activity that continuously been conducted for the last six year flood season (June – September). The FFEW has helped the Eastern Nile countries in reducing the loss of life and money by preparing flood forecast bulletins for the Lake Tana (Blue Nile -Ethiopia), the Blue Nile-Main Nile (Sudan) and Baro-Akobo-Sobat(BAS) sub-basins flood prone areas. The FFEW activity have strengthened national offices in terms of capacity and overall reduced the risk of flood devastation for 2.2million people in the region.

1.5 Methodology

The methodology of the stakeholder mapping, vulnerability mapping and household survey has been designed based on the scope of work, objectives, criteria and deliverables of the Study.

Stakeholder consultations conducted with key agencies related to FFEW including government, non-government, and civilsociety,regional and international organizations. The checklist questioner was used to guide the interviews with organizations provided.

The methodology includes:

Key stakeholders interview

The Key stakeholders' interview conducted among the selected relevant stakeholders. The interviews captured the qualitative progress of flood early warning system products and intervention including sustainability of the understanding project activities and the tasks of the consultancy as stipulated in TOR.

Discussion meetings

Discussion meetings was held with the National flood forecast and early warning center's staffs and primary data producers, who are feed the real-time data to the regional Flood Forecast and Early Warning (EWS), to gather the implementation mechanism of data communication and dissemination need to be more easily accessible to rural communities and other important stakeholders.

Groupdiscussion on significant evidence

The focus group discussions was conducted with the targeted communities and relevant stakeholders, which captured the information in regards to the existing flood-forecasting early warning system; forecast communication and dissemination need to be more easily accessible to them and other important stakeholders. Thus, aiding further in-depth understanding of most vulnerable communities, their socio-economic characteristics understood for fit-for-purpose response and preparedness mechanisms.

Individualinterviews (Face to Face)

The consultant divided the stakeholders, into two groups based on their function, androleas following:

- Data providers,those have a high-level data, and could explain the phenomena of floods. This group includes experts from:

  - Regional and National concerned Ministries (information of flood forecast producers);
  - Academic sector
  - United Nation organizations with non-governmental organizations and communities-based agencies.
  - Independent experts in flood risk management.
- Data Users: a group of users whom can provide exploratory data about the events of floods occurred in the study area and their impacts. This group includes users from:
  - Regional and National concerned Ministries (information of flood forecast users);
  - Agriculture sector
  - Community leaders
  - Local communities and others

Vulnerability mapping

- A survey has been made of the buffering the river at a distance of 2, 5 and 15 from the riverbank by the GIS using data obtained from the offices of the Ministry of Infrastructure and Urban Planning and the Population Statistics Authority.
- Study sample was selected from Household population of 2900 villages, so primary data was took from selected sample (n=50), done on August-September, 2019 extreme flood, through conducted face-to-face interviews, group discussion and questionnaires, open discussion, with household representatives during the evacuation period.

2. MAPPING OF STAKEHOLDERS IN FLOOD EARLY WARNING SYSTEM

Flood Early warning systems require contributions from a wide range of actors and institutions, including localcommunities, national governments, regional organizations, NGOs, the private sector, and the science community(UN 2006; IPCC 2012).

Twenty-four institutions involved in different aspects of disaster risk reduction in Sudan were consult about the status and effectiveness of existing flood forecast and early warning systems (Policies and institutions) and their proposal in future, the informant interviews in the respective organizations, focus on those more actives in fields of data providers and dater user's organizations.

Interviews conducted mainly with

- Regional partner representatives
- Government officials (Ministries)
- NGOs' representatives and community leaders

2.1 Data and Forecast providers

Eastern Nile Technical Regional Office (ENTRO)

ENTRO in addition to weekly, monthly and seasonalalyissued reports also conducts daily monitoring with three-day lead-times to produce forecasts of rainfall and hydrological data used to model and predict flooding with greater accuracy. The information generated is sent to ministries of water resources and universities collaborating with ENTROin Ethiopia, South Sudan and Sudan.

- In Ethiopia, the forecasts used by the Ministry of Water, Irrigation and Energy to provide early warning information to local government (woreda) authorities to aid in flood preparation and response.
- In Sudan, the information forwarded to the national flood committee, which uses it to enrich its own analysis and alerts. In addition, Sudan's National flood center / Nile Water Directorate receive a daily bulletin during the flood period, which they have increasingly used to avert destruction from flood events.

- ENTRO developed flood early warning models for South Sudan, which are also now included in its bulletins. The system continually evolving, and feedback on how it is working is integrated by ENTRO to ensure the system becomes increasingly effective.
- Local communities, relief organizations, use warnings and alerts and governments, 350,000 people across the region receive early warning messages during flood season and daily alerts in flood prone areas, 1.7 million more people across the region benefit indirectly from these alerts and messages, and are better able to reduce their risk of flood devastation.

Ministries of Water Resources; Irrigation and Electricity (MoWRIE)

- MoWRIE works simultaneously as data user of ENTRO's FFEW models products and data provider to national stakeholders.
- The ministry provides policy support, coordination, and technical assistance related to flood disaster risk management in Sudan.
- The ministry shared (works) on the four components of early warning systems
  - Risk knowledge (know the vulnerable of flood prone areas along river Nile).
  - Risk monitoring (has 29 stations. Hydrometric Network most read manually by an observer uses low frequency radio and cell phones to permit remote site staff to communicate by voice to report manually observed data to Khartoum).
  - Communication/dissemination (e.g. disseminate FEW via Broadcast);
  - Response is limited to partially closing JabelAulia Dam located atWhite Nile, 40 kilometer upstream to Khartoum, and Rosaries Dam located at Blue Nile, 620 Kilometer upstream Khartoum.Sowhen flood crosses the danger limit (discharge at Eddiem Station more than 610 million cubic meters per day), ministry take action by partially close Rosaries Dam to regulate Blue Nile flow. The same case applied for Jabel Aulia Dam to control flood peak by adjusting the inflow and outflow at Khartoum around 700 million cubic meters per day, flood hazard problems addressed at the design stage of dams that only to break the peak of floods and not store water at time of flood. The conclusion from above is close Rosaries Dam to protect downstream from the high wave of floods.

- The response taken by MOIWRE also reduce the irrigation canals discharges (e.g., close Gazira and Managil canals) to protects farms and livestock and fisheries at flood plain areas (e.g. to give time for evacuate animals).

Sudan Meteorological Authority (SMA)

- Sudan Meteorological Authority (SMA) is the provision of Meteorological information and services for the safety of life, protection of property and conservation of the natural environment.
- SMA conduct short range forecast of weather warning on daily bases up to five days lead-time.
- SMA does not warn for floods or flash floods, but it alerts for heavy precipitation and indicateit might lead to flooding.

IGAD Climate Prediction and Applications Centre (ICPAC)

- ICPAC is a specialized Institution of IGAD with the strategic objective to contribute towards enhancing the livelihoods of the people of the Greater Horn of Africa region to mitigate climate-related risks and disasters.
- ICPAC's activities focus mainly on climate information, prediction and early warning applications in support of environmental management, disaster risk reduction for sustainable development in the region.
- ICPAC plays an important role in providing the IGAD sub-region with weather and climate advisories and more importantly, timely early warnings on possible extreme weather and climate events.
- ICPACcontribution is through countries share the document of Seasonal Climate Outlook Forum, which brought together climate information providers and users from key socio-economic sectors, governmental and non-governmental organizations, decision-makers, climate scientists, and civil society stakeholders among others.
- ICPAC does not analyse the potential impacts of the hazards, it indicates seasonal rainfall outlook and on daily alerts for heavy precipitation and indicates whether it might lead to flooding.

- ICPAC disseminates information and early alerts to the public via Webpage and Portal.
- SMA and HAC used the products of ICPAC to enhance quality of their own analysis and alerts and forecast.

2.2 Forecast Warning Users

Humanitarian Aid Commission (HAC)

- The Flood Task Force, led by Government's Humanitarian Aid Commission (HAC), is coordinating and facilitating flood preparedness and response efforts.
- The Task Force has been working to identify response gaps and ensure they addressed in a timely manner and remained active until the end of such rainy season.
- Early Warning Center for Multi-Hazard in HAC has Flood Watch bulletin through this Bulletin give more explanation and clarification of image downloads from ICPAC–IRI to the areas of the flood risk situation in the upcoming 3 days, spatially for those including heavy rainfall, also include the levels of river Nile and tributaries copied from ENTRO bulletin.
- The Early Warning Center for Multi-Hazard not produces EW but make use of it easy.
- The Early Warning Center for Multi-Hazard, disseminate the bulletin to the HAC centers at states and localities level also to the NGOs.

National Council for Civil Defense (NCCD):

- NCCD dealing with alltypeofdisasters risks in Sudan.
- Civil Defense (CD) more active memberof NCCD in field of logistic response.
- NCCD for first time discussing the flood forecast day by dayin 2019flood, the information provided by MOIWR and SMA members (of NCCD) after meeting the CD take action directly to guard vulnerable places on river bank, and send the message to CD stations at states to take action.
- CD with HAC and SRC are members of NCCD, their mandate response/evacuation people foremergency cases.

Sudanese Red CrescentSociety (SRCS):

- The SRCS is a member of various emergency working groups (e.g. Task Force) at the state level.
- The SRCS headquarters is coordinating the response at the national level; implementation in Khartoum is largely taking place through Khartoum State branch and its extensive network of volunteers.
- SRCS to do its duty (response) receivedthe forecast information from MOIWR and SMA, and take appropriate action also forward the information to its branches at states where risk expected, for to take action.

Federal Governance Ministries(Flood-sensitive economic sectors)

Flood-sensitive economic sectors thoseare received from MOWRIE monthly, seasonal hydrological outlooks reports for planning, as well as short- and medium-range forecasts and warnings for daily operations. However, hear the interviewee's replies focus on daily operations.

Ministry of Agriculture and Forestry (MAF)

- The main mandate of the Ministry of Agriculture and Forestry is increase food security, improve agricultural production and productivity and formulate agricultural development policies and to advise the government on such policies relating to its administration and the management of the agricultural sector and forest of the Sudan's economy.,
- Specific Flood related mandate is to protect and monitor productivity of the scheme irrigation and rain-fed farms at depression and floodplains land areas adjacent to rivers and streams that are subject to recurring inundation.
- Upon receiving flood early warning information from or issued by MoWRIE, the action taken as following :
- The actions taken by farmers include:
  - Quick move and transfer of machineries and pesticides to high lands
  - Open stockades door for animals to escape
  - Move equipment to high lands and/or dry places

- Put power supply off in the flooded areas
- Lock sewage irrigation, fuel depots and pesticides stores

Ministry of Livestock and Fisheries (MLF)

- The Mandate of the Ministry of Livestock and Fisheries is anchored on Government functions include:
  - Animal Health
  - Fisheries and Aquaculture Research
  - Livestock and Veterinary Research
  - Veterinary and Fisheries training
  - Fisheries and Livestock Extension
  - Livestock Identification and Traceability
  - Dairy Industry Development
  - Fisheries and Management Development
  - Livestock Development
- Specific Flood related mandate is to protect and increase product and productivity of the animals and fish.
- The actions taken upon MOWRIEreleased FEW massages the ministry ordersthe farmers/pastoralists move their animals and cattle to high places, other people plugging sewage feeding fishponds.

Ministry of Roads andTransport (MRT).

- The mission of MRT, is to have a sustainable, efficient, safe and internationally comparable quality of road infrastructure in general and National Highways infrastructure in particular to achieve enhanced connectivity, quick mobility to a level which accelerates socio-economic development.
- Specific Flood related mandate isto provide effective flood alleviation and mitigation solutions (drainage).
- The actions taken by Ministryof Roads and Transport, once received the massage from MOWRI, it to be ready for closing drainages discharge water back from river and prepare pump for uplift water to the river in case water from rainfall comes sidelong.

Ministry of Environment, Natural Resources and Urban Development (MENRU)

- The MENRU mandate is, achieving balanced development while preserving the natural environment biodiversity in accordance with the purposes of the nation's international and regional obligations in the country, in order to bequeath future generations a clean environment.
- Specific Flood related mandate is conducting Hydro-meteorological hazard process and disseminating information about it, more especially for urban areas.
- The actions taken by Ministry upon receive the massage of FEW from MoWRIE it start to prepare and identify safety roads and safety places for evacuation if such flood occurred.

Ministry of Information and Communication (MoIC)

- The ministry's work focuses on developing communication policies and strategies. The ministry coordinates the public service advertisements of the government.
- Specific Flood related mandate iseach type of media (print, FM radio, and television) receives a package of public service advertisements from the government.
- The action taken by this Ministry, MoWRIE send daily flood statement situation to the broadcast, Flood/disaster issues addressed through the advertisements.

Communities at risk

- Communities at risk including community-based organizations and civil society action groups
- Communities at risk received the information of flood early warning from MOWRIE and SMA, the action taken by communities saving lives and protecting livelihood assets by moving to upland
- Six communities were used as pilot riverine flood prone areas namely:

- Um Benein village located on the western bank of the Blue Nile within Singa locality with an estimated population of 10,000 persons, most of them from Kenana tribe;
- El Sabonabi village is located on the western bank of the Blue Nile within Singalocality. The village established since 1700 it is a big village compared with that selected villages by more than 1.5 times in term of population. The total population of about 15,000 persons (750 families), 45% of the population is male and 55% were females predominantly from the Mahas, Galiyin, Bargo, Hawsa and Kawahla tribes;
- Tuti island villagelaid in the heart of Khartoum state at the junction of the Blue and White Niles, at latitude 13 o 15’ N. and longitude 30^{o} E. Its total area is about 8 square kilometers and altitude is 1,260 feet above sea level. The total number of houses in the island is 1,820, 1% built of concrete, 96.3% of red bricks and 2.7% of mud. The total population is about 20000.
- Wawisi village is located east of the River Nile, about 100 km north of Khartoum, within of Sharq Al Nil locality, Khartoum state. The total population is about 6,000 (about 800 families) mainly from Mahas tribe.
- Wad Ramly consist of five villages is located east of the River Nile, about 102kms north of Khartoum, within of Sharq Al Nil locality, Khartoum state. The total population is about 40,000 (about 14000 families) mainly from different tribes.
- Sidon city belong to Sidon administrative unit, Lamar locality, River Nile State.It is located 60 Km from Lamar, at the eastern bank of Atbara River.Number of inhabitants is 700 families.
- Alabka village belong to Sidon administrative unit, Damar locality, River Nile State. It is located 60 Km from Damar, at the western bank of Atbara River. Number of inhabitant households is 460 families. The cultivated land is about 950 acre.It is considered as flood affected area.

2.3 Vulnerability mapping for settlement on flood prone areas

The major flood prone zones not covered by the current ENTRO FFEWs in Sudan are:

- Riverine flood areas along Atbara River and Setit, Dinder and Rahad Basins

- Flash flood areas on the Blue Nile River from Sudan borders with Ethiopia to junction at Khartoum, including Khartoum town.
- Main settlement areas at Blue Nile are Hasehisa city, Wad Medan city, Singa City and Roseires city. Areas along main Nile include Shandi city and Atbara town.
- Others for mostly torrential and flash flood is gash river and settlement area Kassala city. (Plate 1)

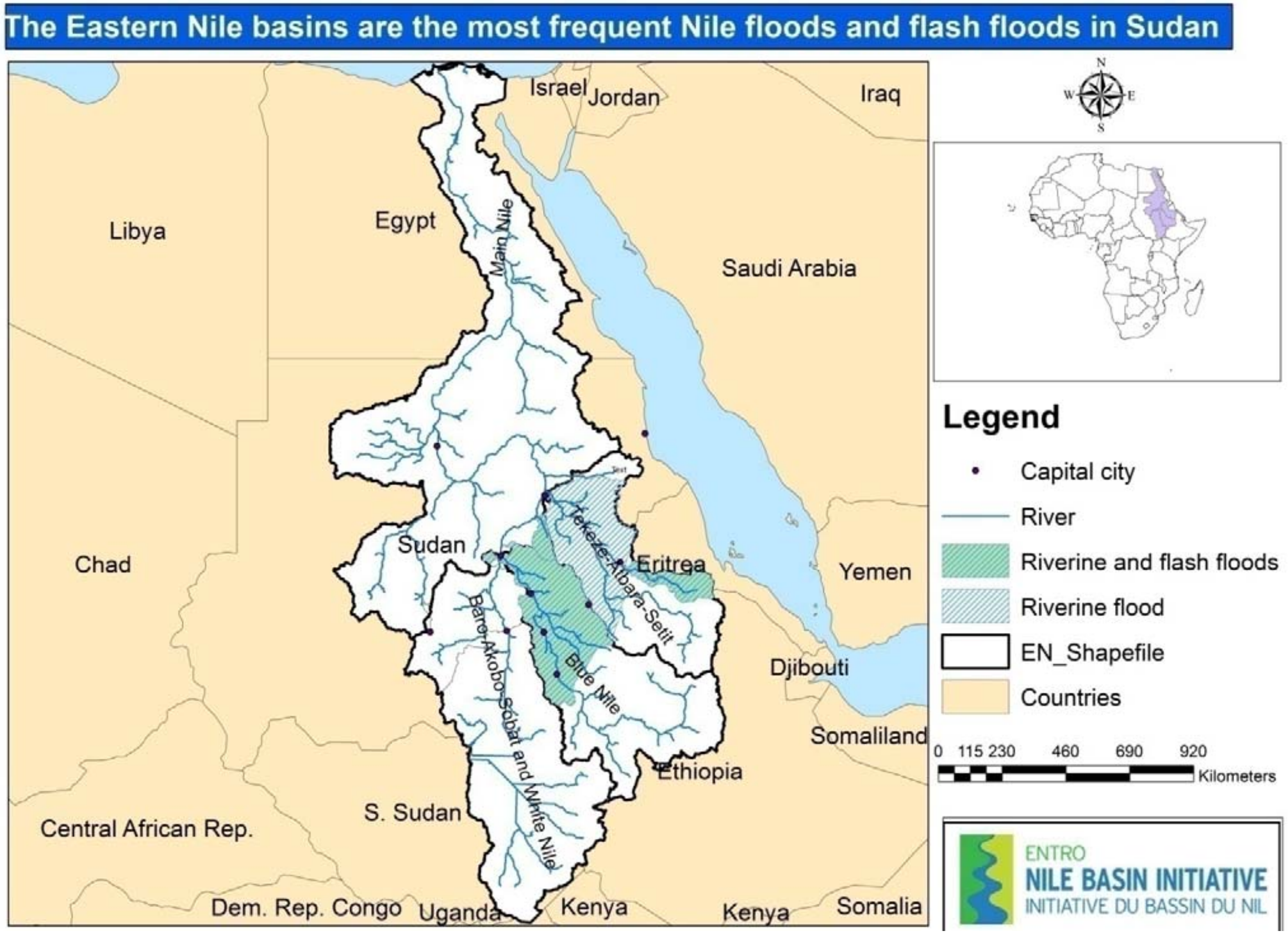

Plate 1:Catchments of riverine and flash flood in Sudan

3. ANALYSIS OF STAKEHOLDERS' GAP IN FLOOD EARLY WARNINGS

3.1 Forecast movement and use

The interviews and questioners consulted 24 organizations involved in different aspects of flood disaster reduction in Sudan, as part of this survey, including government organizations, non-government organizations (NGOs).

Table 2 describe forecast information movement and use (information from whom it is received and who is the end user).

Organizations received the forecast information either from main provider (producer, or secondary provider (forecast disseminator) and users (responder).

Summary of the finding of study in Table 2:

- Three types of forecast early warning issued either riverine or rainfall forecast indicating likelihood of causing flash flood or both riverine and rainfall.
- ENTRO was found the core of forecast FEW for both (river and rainfall) providerand disseminator to most of organizationsdirect and indirect.
- MoWRIE is second order provider (used flood early warning information from ENTRO), disseminate to national stakeholders.
- SMA is not hydrological information provider it is a rainfall information provider,disseminate to national stakeholders.
- HAC is not hydrological and not rainfall provider (used the information from ENTRO, MoWRIE and SMA),and further disseminated to NGOs, for make iteasy to use.
- The other organizations are users (e.g. HAC, CD, SRCS, MAF, UNDP ...act.)

Table 3 Providers and users of forecasting and early warning information

SN	Organization	information from whom it is received and who is the end user			
		Type of	Main FEW	secondary	user
	Government organizations				
1	Ministry of Water Resources;Irrigation and Electricity	river and rainfall	ENTRO	Yes	Yes
2	Ministry of Interior/CD	river and rainfall	MOERIE		Yes
3	Ministry of Humanitarian Affairs/HAC& SRC	river and rainfall	ENTRO/ICPAC	MOWR	Yes
4	Ministry of Agriculture and Forests	river and rainfall	MOWRIE/SMA		Yes
5	Ministry of Livestock and Fisheries	river and rainfall	MOWRIE/SMA		Yes
6	Ministry of Roads and Transport	river and rainfall	MOWRIE/SMA		Yes
7	Ministry of Environment, Natural Resources and Urban	river and rainfall	MOWRIE/SMA		Yes
8	Ministry of Information and Communication	river and rainfall	MOWRIE/SMA		
9	Sudan Meteorological Authority (SMA)	Rainfall	Yes		
State-owned organizations enterprises/corporations					
10	Khartoum state	river and rainfall	MOWRIE/SMA		Yes
11	Sinnar State	river and rainfall	MOWRIE/SMA		Yes
Intergovernmental partnership					
12	ENTRO	river and rainfall	Yes		
13	ICPAC	Rainfall	Yes		
National and International NGOs					
14	Sudanese Red Crescent (SRC)	river and rainfall	MOWRIE/SMA		Yes

15	Youth organization	river and rainfall	MOWRIE/SMA		
16	FAO	river and rainfall	MOWRIE/SMA		Yes
17	UNDP	river and rainfall	MOWRIE/SMA		Yes
18	UNICEF	river and rainfall	MOWRIE/SMA		Yes
Community representatives					
19	UmAshira; Tuti; Wawoossivillages	river and rainfall	MOWRIE/SMA		Yes
20	Saboonabi&Banain Villages	river and rainfall	MOWRIE/SMA		Yes
21	Azhur Ext.&Ammara villages	river and rainfall	MOWRIE/SMA		Yes
22	Sedon& El Abka villages	river and rainfall	MOWRIE/SMA		Yes
Academics and individual experts					
23	University of Khartoum	river and rainfall	ENTRO		Yes
24	Rabaat University	river and rainfall	MOWRIE/SMA		Yes

3.2 Data and Forecast provider's gaps

Eastern Nile Technical Regional Office (ENTRO)

ENTRO have developed a hydrologic model (using HEC-HMS) for the entire Blue Nile basin, including the portions of the basin in Ethiopia, and a hydraulic model (using HEC-RAS) for the Blue Nile from border to Khartoum. With assistance from ENTRO, Sudan was restoring and upgrading its previously implemented hydrologic forecast system, which was provide a new user interface and integrate the hydrologic and hydraulic models. The models are running simultaneously in National flood forecast center and regionally at ENTRO office, every morning during flood period. ENTRO also publishes a flood bulletin covering Ethiopia, South Sudan and Sudan, which includes rainfall indicators of potential flash flooding conditions based on daily rain forecast.

The interviewees mentioned that there some gaps in ENTRO FEWs as following:

- ENTRO FEWs does not cover Atbra River, Dinder and Rahad also areas of flash flood and torrential in the basin which inhabited by about more than 5 million residents (Urban, Semi-urban and Rural) with flood risk in the downstream river extend from *Eddeim* stations at Sudan border with Ethiopia to Atbara town at main Nile.
- Use of Stage-discharge data at Eddeim station; the stage data has effect on the shape of the hydrograph due to storage and/or backwater of Roseires dam.
- ENTRO’s flood forecast has only forecast products one cycle (e.g. accumulated precipitation for 24 h, should be breaking into at least 3 hours depending on the criticality of situation).
- ENTRO Flood early warning does not issue flood risk, hazard and vulnerability mapping derived from rainfall extremes.(The flood risk map developed by ENTRO maximum risk probability is 100-year return period flow magnitudes at Eddiem station, such that the peak of the hydrographs matched the peak of river flow magnitude of the flood frequency events), but this extreme stream flow is not combined with rainfall intensity duration curve andoverland flow.Forexample,for a12-hour duration 100-year rainfall intensity (Plate 2) if the two cases happen in the

same time results for both extreme precipitation and extreme stream flow not issued by existing ENTRO FEWS, moreover ENTRO FEWS not addressing extreme events beyond 100-year return period.

- Outputs of forecasting system or hydrological model does not covered all inundation areas for Example River Atbara, Dinder and Rahad, and Flood Hazard Maps not available in all areas of risk at Blue Nile (Plate 3) only the red circles. The existing one not update since 2012.
- Return periods of the floods for which the flood hazard maps were developed is only for 100-years.
- ENTRO is not engaged in seasonal flood forecast with the lead-time of 1-3 months.
- The flood forecast of ENTRO's flood forecast communicated to MWRIE (decision maker) is too late during the day (e.g. after 12pm).
- Language utilized in warning bulletins is in English and highly technical and poorly understood by local communities.
- ENTRO's data sharing and collaboration with other institutions is not satisfactory. The gaps in flood forecasting in trans-boundary river basins include low capacity in flood monitoring systems, limited data exchange and technical cooperation and inadequate institutional and capacity development.
- Lack of early warning indicators: Products of ENTRO's FEWS require practitioner's assessment indicators that are regionally agreed and locally referenced to measure success and failure of early warning systems and thus improve the basis for collecting and analyzing risk data.

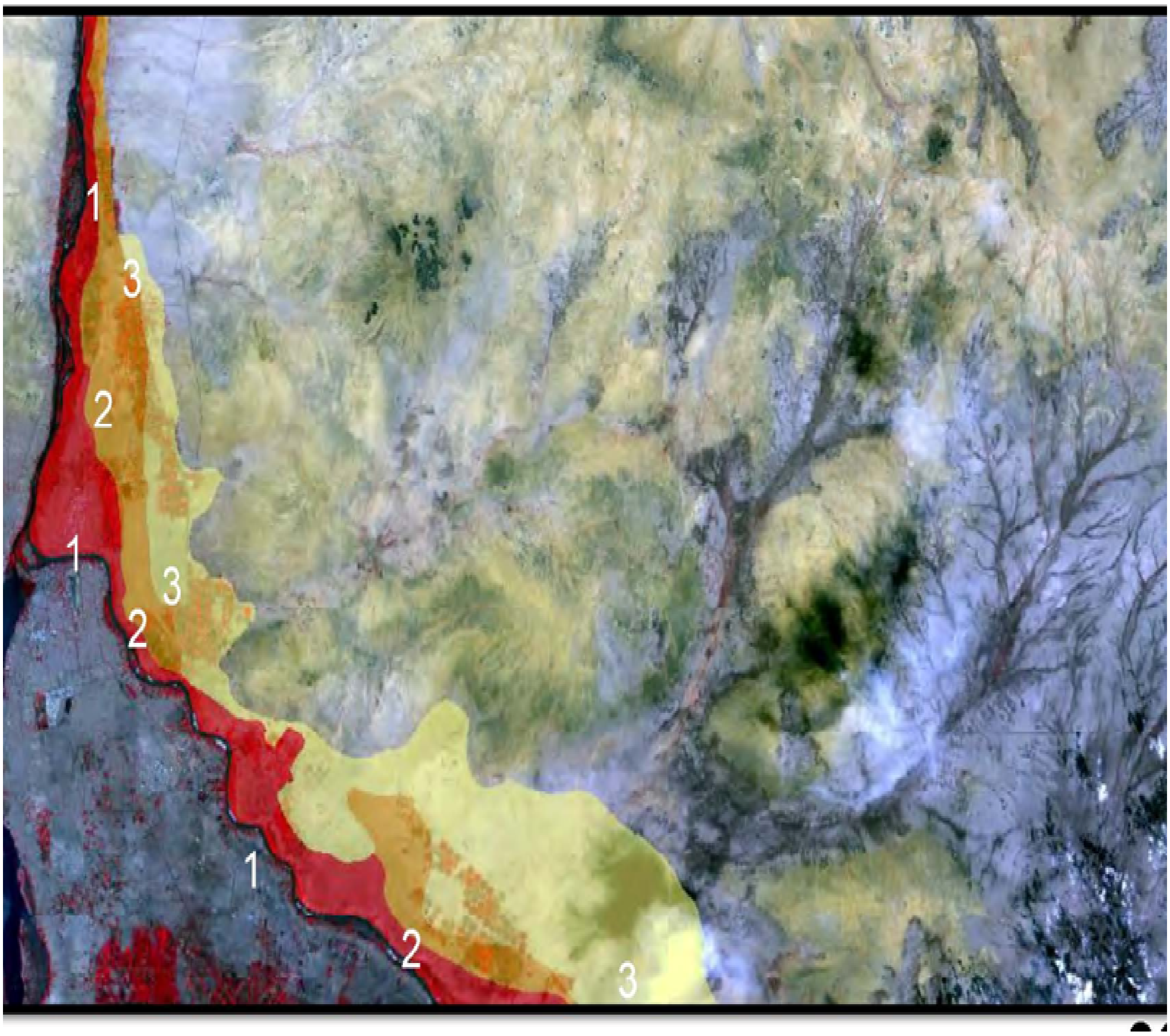

Plate 2: Flood zone levels and the related to risk (ASTER 13/8/2013)

Key:

1 -Level of high risk, mainly from the river Nile

2 - Level of high risk, mainly from the Valleys and

3 - Level rarely it affected by the Valleys.

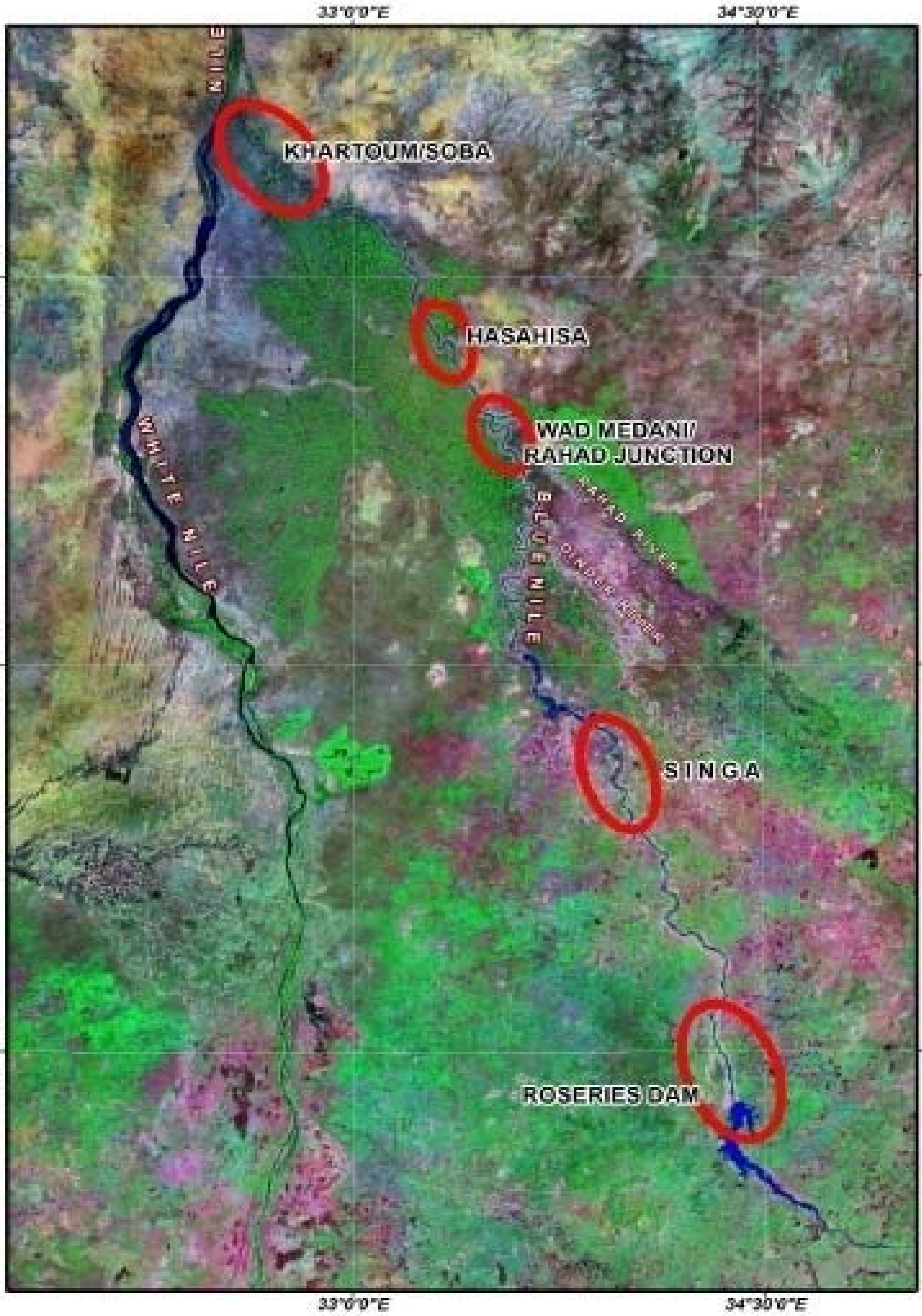

Plate 3: Pilot flood prone areas studied by FPEW I

Ministries of Water Resources; Irrigation and Electricity (MoWRIE)

Most important gaps are:

- Inadequate of observation, monitoring and forecasting systems, based on needs and capacities of MWRIE, establishing appropriate observation systems in highly vulnerable/risky areas, developing multi-hazard impact-based forecasting models, upgrading forecasting procedures to ensure effective use of local and regional products, and systematizing forecast verification, recording, and publication are priority areas.
- Data collection and transferring are manual.Both the data collected and data recorded are manual (e.g., Person in the upstream manually read the data with an instrument and provides the data to the Ministry of Water Resource; Irrigation and Electricity).
- Real-time data are not available from river and rainfall gauges (automatic stations), however there is inadequate capacity for modeling-based forecasting.
- Limitation of data available and past experiences warnings to the most of target community (flash floods and torrential)
- Inadequatefrequencyoutputs of forecasting system or hydrological model (one per day)
- MoWRIE relies on ENTRO EW uses the forecasts that received from ENTRO to enrich and fill the gap of rainfall forecastedto three days ahead which not covered by the Ministry.

Sudan Meteorological Authority (SMA)

- Lack of cooperation and data sharing activities between institutions and regional
- Inadequate coverage and sustainability of observing systems for monitoring of hydro-meteorological hazards and hydro-meteorological-observation units installed in the river basin.
- Lack of systems for many hazards, such as dust and sandstorms, severe storms, flash floods and storm surges, particularly for people at-risk and vulnerable.
- Lack of upgrading of information, communication, and IT systems as applicable to SMAneeds and requirements of resource and capacity for maintenance.

- Need for enhancement of central database for collection, processing, and archiving of historical climate data, forecasts, projections, and guidelines.

3.2.4 IGAD Climate Prediction and Applications Centre (ICPAC)

- There were a level of uncertainty within the observed data and seasonal outlook that demonstrated (e.g. flood 2019 dry in blue catchment).
- Climate outlook it's not good indicators for rainfall distribution for both temporal and spatial.

3.3 Forecast Warning Users gaps

Humanitarian Aid Commission (HAC)

- The Early Warning Center for Multi-Hazard bulletin depends onENTRO, MoWRIE, SMA and ICPAC information.
- The information in the bulletin written in way that more specific to HAC partners
- Low level of coordinate and fully utilizing received EW/forecasts of ENTRO EW

National Council for Civil Defense (NCCD)

- Weakness of coordination between early warnings related institutions in the areas of DRR and users.
- Absence of attention to exchange of experience and sharing of techniques
- Low spirit of cooperationbetween members

Sudanese Red Crescent Society (SRCS)

- No sustainable staff depends on Volunteer.
- Inadequate coordination and collaboration with other institutions

Ministries (Flood-sensitive economic sectors)

Ministry of Agriculture and Forestry

- No local hydrologic model with more spatial detail concern farms on flood prone areas.
- No flood hazards maps in detail for most area of agriculture and forestry.

Ministry of Livestock and Fisheries

- Inadequate lead-time to provide information of flood risk and warning to the pastoralists at remote areas
- Lack of trust on early warning information by end-user pastoralistcommunities.

Ministry of Roads and Transport (MRT)

- Warnings given only to communities on/near embankments
- MRT not authorized to give information to the media
- Unofficial mobile communication is used to communicate with communities

Ministry of Environment, Natural Resources and Urban Development

- No flood risk map at areasof urban development
- Low controls and regulations to grant licenses to companies working in the field of environment and urban development

Ministry of Information and Communication (MoIC)

- Weakness in to cover all Sudan with information, and providing citizens with information
- Weakness provide information for researchers interested in Sudanese affairs and field of media in particular

Communities at risk

The eight pilot communitiesassessedthrough the interviews agree upon common state (regarding the flood risk map they have since 2010) as following:

- Absence of regular monitoring, maintenance and scientific research (risk map since 2010 no update), in other words river surveyed was limited to specific pilot reaches of the Blue Nile.
- Floodplain areas were characterized used a 90-meter DEM which low elevation resolution, now there is resolution up to 10-meter DEM which is very high accuracy to generate an inundation extent grid, 2D models, the flood extent, depth, and velocity can be visualized directly in the model output
- The river is subjected to continuous changes in channel geometry due to its high sediment load, need of modern river cross-sectionsurvey.(The points above

factors governed the model accuracy, high accuracy give more confidence in early warning, subsequently more action/response by communities)

- Lack of support from government to ENTRO project for long-term master plan (Strategic planning)with respect to communities needs(This mean no government's program for periodic surveying of river channels to capture morphologic changes and update the terrain model accordingly, for the communities' pilot areas).
- Inadequate training initiatives, especially the volunteers, as appropriate, to enhance local capacities to mitigate and cope with seasonal floods
- No enough time to implement an evacuation if needed
- No reliable forecast or measurements, clear threshold for warning and alert; sometimes alerts comes from different channels this make some confusion

3.4 Household Survey of Flood Prone Areas

Generally, the land adjacent to a Nile river, the lower ground around riverbanks more likely to experience floods. With the very steep topography of east of Khartoum region it is likely that flowing water moves from higher places to lower places which experience flash floods sometimes as result of human intervention (e.g. build a roads across a valley).

Vulnerability mapping for flood prone areas

The major flood prone zones not covered by ENTRO FFEWs in Sudan are:

- Riverine flood areas along Atbara River and Setit.
- Flash flood areas on the Blue Nile River Dinder and Rahad Basins from Sudan borders with Ethiopia to junction at Khartoum, including Khartoum City.
- Main settlement areas at Blue Nile are Hasehisa city, Wad Medan city, Singa City and Ed Damazin city.
- Areas along main Nile include from khartoumto Shandi city and Atbara town.

Others for mostly torrential and flash flood are gash river and settlement area Kassala city,Plate 1and States most vulnerable to floods and torrential disasters,Plate 5.

Household surveys

General spooking about residential land,people live near major rivers and small rivers due to the availability of water, agricultural lands and fodder for animals, so found2900 villages living in flood prone areas, is an important factor for vulnerable area to flood,2 to 5 km distance from rivers bank were categorized as high risk areas, 5 to15 km as medium risk areas and areas located at over 15 km to the river channels were described as low risk areas this guidance from statistical flood return period of 25, 50 and 100 year of pilot areas, Plate 6. Because this area not only subjected to riverine, flood but also flash flood.

Geographic Vulnerability of villages in sub-basins (GIS-based map)

Geographic vulnerability caused due to the specific location of a household where hazard strikes first, giving minimum time to react and move away to save life and assets. one of the indicators namely distance from the river 2, 5 and 15 kilometer more or less it look like 25, 50 and 100 year return period. Distance analysis shows that total of 4262 villages withintwo sub-basin in Sudan, 791villages (19%) laid in high risk level category, 801 households (19%) laid in moderate level category, 2900 villages (31%) laid in low level category and the remaining 1354 (31%) laid in very low risk level category, Table 3 and Plate 4.

Table 4 Number of villages located within 15 Kilometers extends to the riverbanks

Level of Risk	Distance from bank in each side in km(flood risk zones)	Number of villages		Total
		Abbay-Blue Nile Sub-basin including Dinder and Rahad	Tekeze-Setit-Atbara Sub-basin including Kassala	
High	0 - 2	485	306	**791**
Moderate	2 - 5	416	386	**802**
Low	5 - 15	700	607	**1,307**
Total		**1,601**	**1,299**	**2,900**

Sample of Study area (Wad Ramly five villages, 2019 flood)

Study Area Selection

The reason why *Wad Ramli* villages chosen as a place to study,is because they were devastated by floods in 2019, and this has not happened before in history, also combined riverine and flash flood with torrents, moreover*Wad Ramli* villages laid within the high-risk zone of floods (e.g. 2 kilometer from riverbank). Many of the houses in terminal residential neighborhoods in Khartoum built from brick, cement block and mud, these building materials are not strong enough to withstand an extreme flash flood and more of the surveyed houses severely damaged by the 2018 flood (Table 3). In 2019 flood, the water level of the Nile gradually increased over a period of two weeks. People not anticipated a higher level for longer duration of the flood than usual. Several houses were inundate for two weeks in *Wad Ramly* as result riverine flood in 2019 (Figure 2) however the event of death was less compared by flood 2018 because they received flood-warning massage from MOWR at time. In response, some people decided short-term preventive measures to reduce damage they moved to safe places.

Study sample from HouseholdSelection

The community from Wad Ramly was chosen forin-depth study based on a face-to-face interviews, group discussion and questionnaireswere conducted for households, and identified based on proximity to floodhazard sources, frequent severe flooding, and past heavy flood damages, 14,000 households lived in the Wad Ramly villagestook 50 households as a sample. Using 17 questionnaires concerning five main dimensional vulnerabilities donein the field, in August - September 2019.Thisstudy tries to quantify dimensional vulnerability usingsocial, economic, physical/infrastructural, institutional, andattitudinal dimensions.

This multidimensional vulnerabilityassessment would greatly help in identifying a relevantcourse of action for disaster risk reduction in exposedcommunities.

Formulation of a Multidimensional Vulnerability Index

The index-based approach ofthis study developed for assessing five dimensions ofvulnerabilitysocial, economic, physical/infrastructural,institutional, and attitudinal vulnerability.Four indicators each was used for social, economic, physical/infrastructural andattitudinal vulnerability,five indicators for institutional vulnerability;the original primary datasets were standardized usingrespective weights for the computation of the compositeindex.Thisstudy also uses a subjective weighting technique to allocatevalues to classes of phenomena for each indicator andformulates indices based on Eq. 1. (Annex 3).

Results and Discussionof studysample

Indices for each dimension calculated using the methodology described in the previous section. Statistical tests performed to understand the level of difference in each dimension.

Social Vulnerability

The socialsurvey shows that households in *Wad Ramly* villages community,most of them wereextended families (68%),About 14% of households includedmembers who were suffering from a chronic illness or aphysical/mental disability, or were pregnant.Long pastexperiences of householdsattributed toreduce floods disaster in Wad Ramly community, and because mostfamilies in village had relatively dealing with each other's like one family during the floods disaster, however with respect to social vulnerability, around 8% of the surveyed householdsclassified as highly vulnerable. Table A2-1,thesocial vulnerability index of households variedfrom 0.05 to 1, average 0.4 in*Wad Ramly*community, Table A3-6.

Economic Vulnerability

The dependency ratio (dependents to total household size)was relatively high in the *Wad Ramly*community(30%) in the range of 75-100% members of family depended on Household head, most of the households living in the floodproneareas were low income,working as famers, due to fact that people inherited agricultural lands from their ancestors, agricultural lands became narrow and did not fulfill the individual’s need, so some of them working as governmentemployees, traders, or daily wage earners, or they migrated temporarily to the locations of the gold mines,making those households highly vulnerable.Significantly, 30% ofthe households had no other asset (land/house outsideflood-prone area), making them economically challenged. Table A3-2,the economic vulnerability index of households variedfrom 0.1 to 1average 0.45 in *Wad Ramly*community, Table A3-6.

Physical/Infrastructural Vulnerability

Almost all of the surveyed households lived in highlyvulnerable floodplains, and some had even built houses betweenlevees (trench) and embankments (68%). These houses were builtillegally (nature of villages in Sudan you can build without return to urban planning regulations and laws local name *Ashwaei*) when the floods comes last time not find drainage to Nile, closed by building. Generally, most of the houses were*Galosse* (constructed from mud, 48%), and built almost 20 years ago (44%), Table A3-3.Only a few households were living in adobe housesGreat beam (Brick, Cement) (20%). The physical vulnerability index of households variedfrom 0.05 to 1 with average 0.4, Table A3-6.

Institutional Vulnerability

Institutional vulnerability included reach and efficiency ofearly warning systems, risk information communication, and emergencyplanning by institutions.More than a quarterof thehouseholds (28%) in the study areas did not receive anykind of warning in the initial of 2019 flood.This inefficiency can be attributed to the lack existence of locality management authority, and no local agency (SRCS) was officially delegated with this responsibility.Around 20% and 15% (Table A3-4) of the households were unaware of the location ofemergency shelters and evacuation routes during floods started, respectively.

Around 30% of the households did not have access toemergency plans, increasing their vulnerability.10% of the household members had never attended anykind of awareness program to cope withflooding. Households asserted that local administrationshad not helped them prepare for flood hazards andmitigation.The institutional vulnerability index of households variedfrom 0.04 to 1 and average 0.34, Table A3-6.

Attitudinal Vulnerability

Around 14% of the households had poor approached localinstitutions to seek help or advice regarding flood preparedness.Respondents indicated that they distrusted thelocal institutions, perhaps because the government, according to its strategies, wants to deport them to high places, or may be lack of communicationbetween exposed households and local institutions.Around 14% in of the households did not believe in communitycooperation when floods strike,respondents were of the opinionthat everyone looks after himself or herself, and no one paysmuch attention to the people around them in disaster settings.

The attitudinal vulnerability index value of householdsvaried from 0.05 to 1, average 0.4 Table A3-5, Table A3-6.

Multidimensional Vulnerability

The results in the previous sections highlight the fivedimensions of vulnerability and emphasize the major factors that affect these dimensions.

Different dynamicsinfluence of the flood vulnerability in the*Wad Ramly*community, are riverine floods, flash flood and torrent, a markeddifference in flood hazard sources (e.g.,flash flood and torrent was more destructive).

Figure 1 reveals interesting insights into each dimensionof vulnerability, through average index values. Figure 1,show no-big variations observed in social, economic, and physical/infrastructural vulnerability among the very high vulnerability scale.Overall, the average multidimensional vulnerability is 0.4 (Table A3-6), was more or less the same for all five dimensionvulnerability. These findings show that there is a need to launch awareness campaigns and design riskcommunication strategies to enhance the flood risk perceptionsof the communities and engage the local institutionswith the communities to implement disaster riskreduction plan effectively.

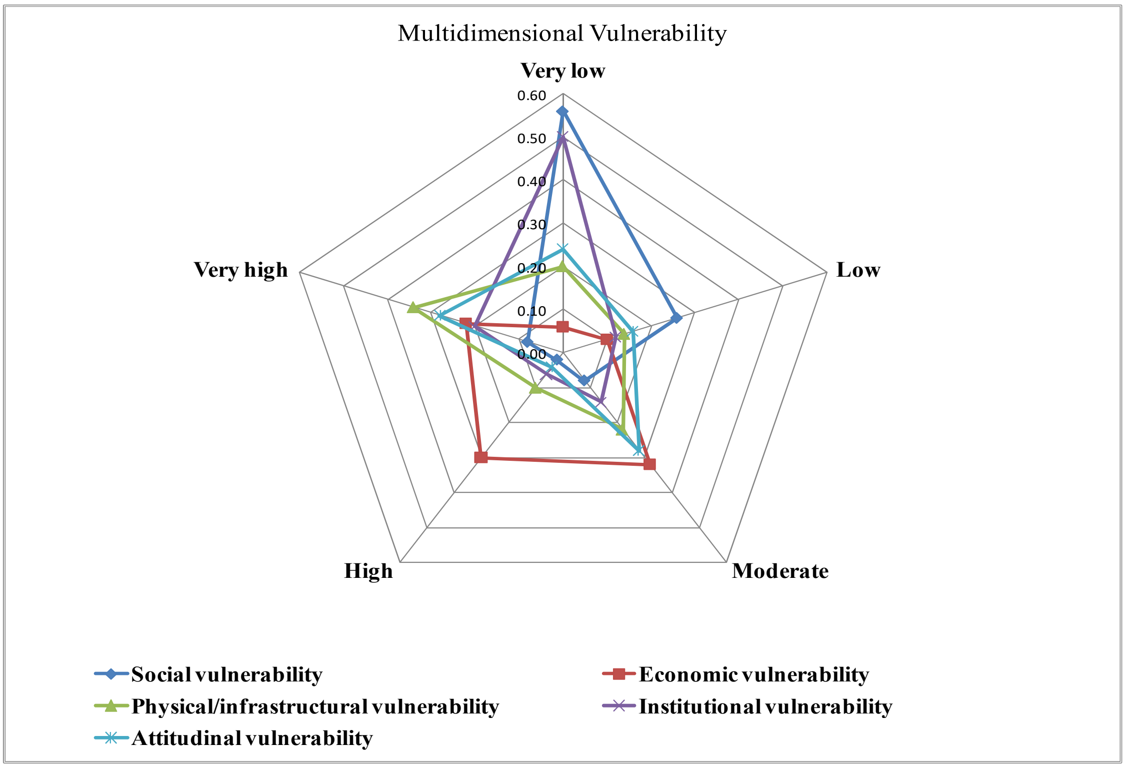

Figure 10 Multidimensional vulnerability to Floods prone area in Wad Ramly community

3.5 Communities, which have experienced floods

Specifically the study was considered some villages as pilot riverine flood prone areas, the basis for selection was the communities frequently suffer impact of the flood, communities who are residing on or near to floodplains, people living in a community lacking provision for flood protection in both rural and urban, people more affected by and less able to cope with floods.

- Um Benein village located on the western bank of the Blue Nile within Singa locality with an estimated population of 10,000 persons, most of them from Kenana tribe;
- El Sabonabi village is located on the western bank of the Blue Nile within Singa locality. The village established since 1700 it is a big village compared with that selected villages by more than 1.5 times in term of population. The total population of about 15,000 persons (750 families), 45% of the population is male and 55% were females predominantly from the Mahas, Galiyin, Bargo, Hawsa and Kawahla tribes;
- Tuti island village laid in the heart of Khartoum state at the junction of the Blue and White Niles, at latitude 13 o 15’ N. and longitude 30o E. Its total area is about 8 square kilometers and altitude is 1,260 feet above sea level. The total number of houses in the island is 1,820, 1% built of concrete, 96.3% of red bricks and 2.7% of mud. The total population is about 20000.
- Wawisi village is located east of the River Nile, about 100 km north of Khartoum, within of Sharq Al Nil locality, Khartoum state. The total population is about 6,000 (about 800 families) mainly from Mahas tribe.
- Wad Ramly consist of five villages is located east of the River Nile, about 102kms north of Khartoum, within of Sharq Al Nil locality, Khartoum state. The total population is about 40,000 (about 14000 families) mainly from different tribes.
- Sidon city belong to Sidon administrative unit, Damar locality, River Nile State. It is located 60 Km from Damar, at the eastern bank of Atbara River. Number of inhabitants is 700 families.

- Alabka village belong to Sidon administrative unit, Damar locality, River Nile State. It is located 60 Km from Damer, at the western bank of Atbara River. Number of inhabitant households is 460 families. The cultivated land is about 950 acre. its considered as flood affected area.

3.6 Infrastructure and properties on flood prone areas

The interviewees stated that flash floods had devastating consequences and had effects on the economy, the built environment, properties, infrastructure and the people. During 2018 floods, especially flash floods destroyed roads, bridges, farms and houses.

As examples:

- National road northern state
- Kosti- Al obeid
- Sinnar - Madani
- Wad Banda-Kordfan north
- Al fao -Al mafaza

In Khartoum, 2013 flash floods at eastern Nile locality, the interviewees mentioned that, many factors that causes high flash flood risk. Some factors are natural while other factors are due urban growth allows for buildings or infrastructure to be constructed that actually obstruct natural drainage channels, that can be seen from satellite images perspective the flood-prone areas are formed by the three-major valley Deltas in the locality, namely, Green valley, Soba valley and Haseeb valley, Plate 7. Most of the valleys end-up to Deltas (Flood prone area), no water courses reach the Nile.

The second factor causing by human intervention like lack of proper land use planning; 80% of the urban and agricultural schemes are within the flood-prone zone; and road construction intersecting valleys without proper drainage system very narrow culverts.

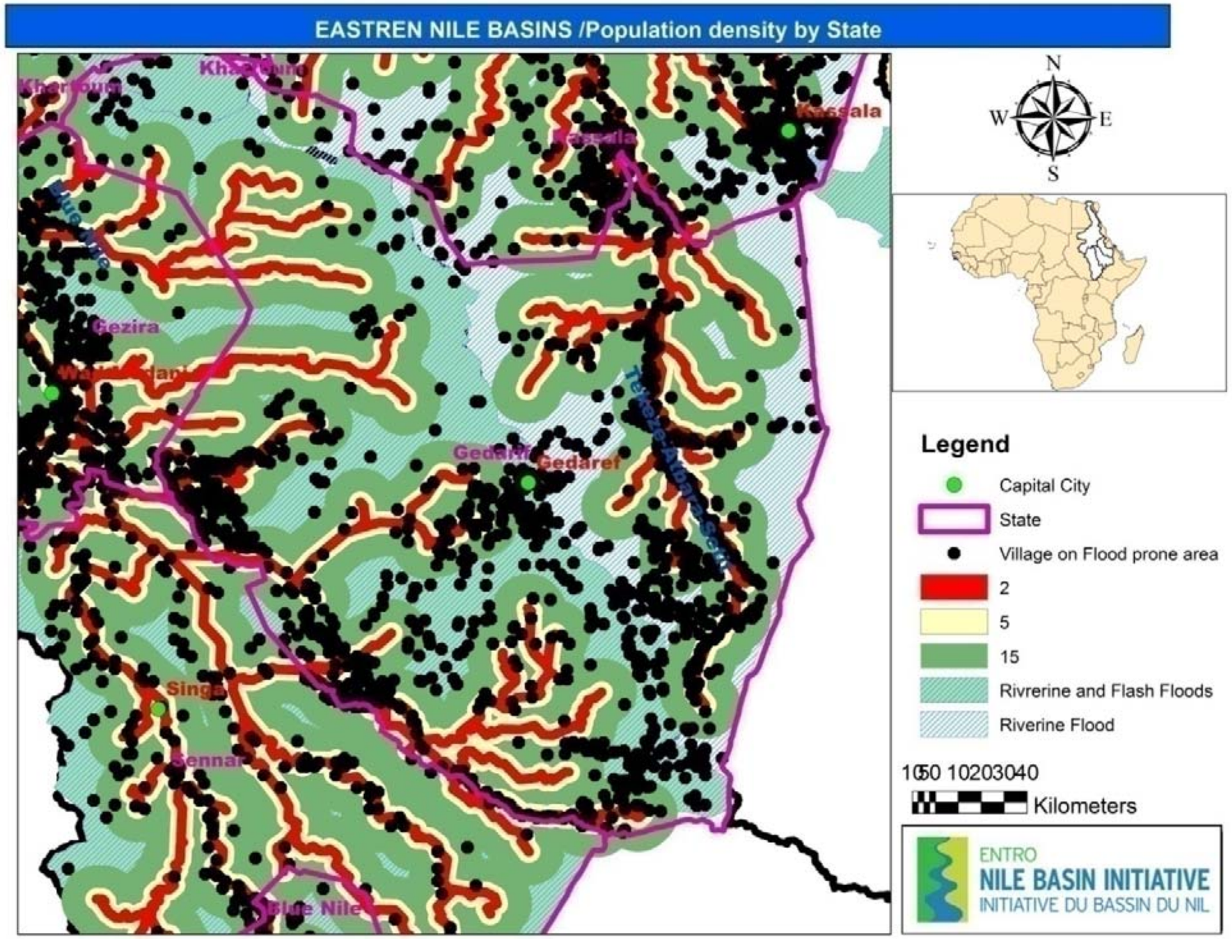

Plate 4: Population density by State on flood prone areas

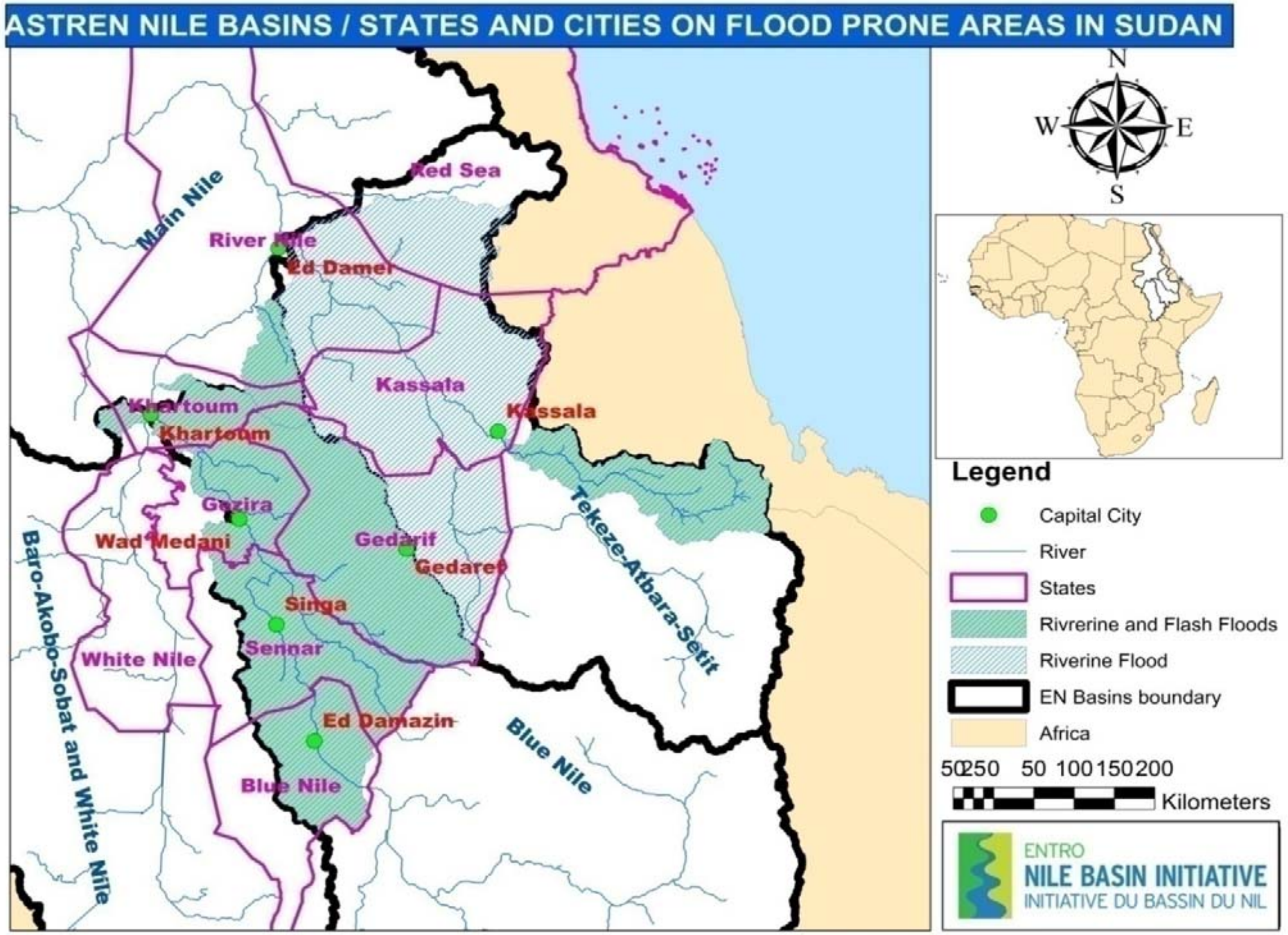

Plate 5 : States most vulnerable to floods and torrential disasters

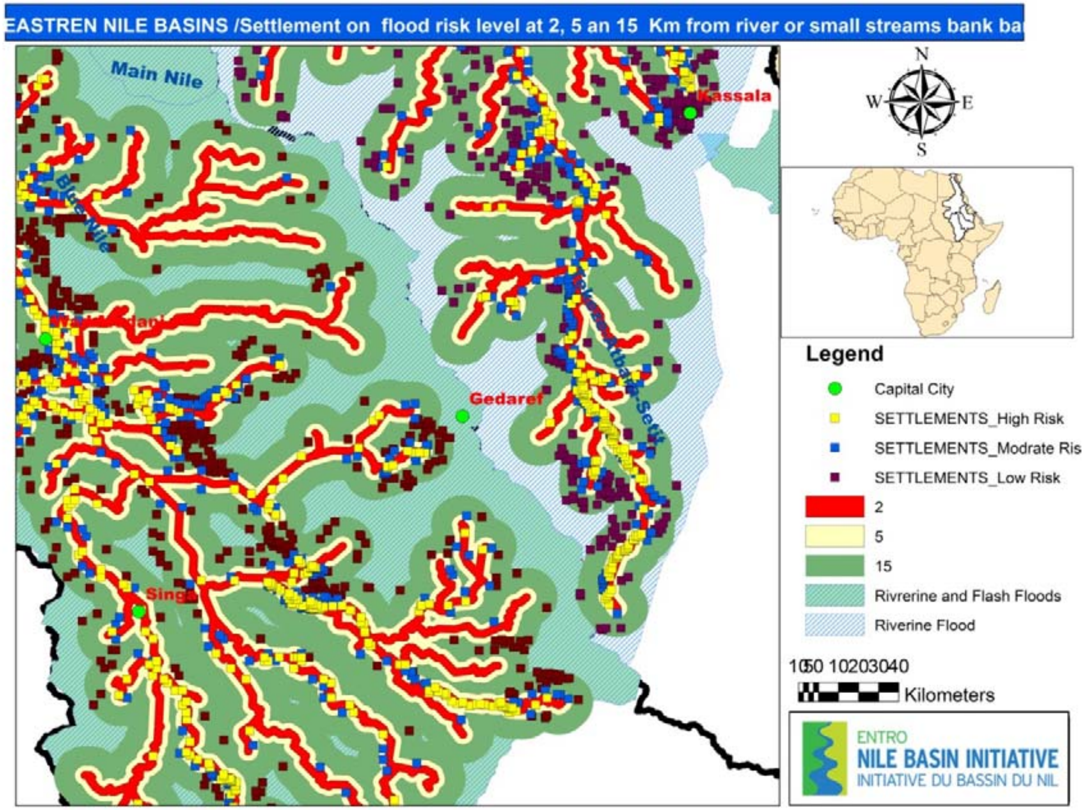

Plate 6: Proximity of settlements to rivers and drainage

Table 5 : The impact of the 2018 and 2019 extreme floods

State	Year	People		Houses damage		Services	Shops and stores	Agriculture sector(Acre)	Animal death	
		death	injured	Total	partial				cattle	Poultry

Khartoum	2018	30	24	62	81	3	1		10	
	2019	16	19	34	96	46				
Gazira	2018	8	3	156	271	37				
	2019	19	33	1709	2276	55	4	900	495	
Sinnar	2018	3		699	2265		1		273	
	2019	6	29	4000	3972	6	1		12	
White Nile	2018	4	5	1162	502	56				
	2019	5	5	6302	7845	109	10	114170		
Gadaref	2018	3	1	5583	4207	13		200040	5	
	2019	1	1	1196	1774	87	14	71000	36	
Kassla	2018	5	1	1500	2087	9				
	2019	14		2702	2675	1			175	
Red Sea	2018	11	11	474	1796	23	249	456	276	21000
	2019	3	1	575	2114	10	137	8	1877	
River Nile	2018	14	2	60	474	8	2			
	2019	14	7	3496	1896	55	4	900		

Source: CD, secondary data, household survey, 2018 and2019

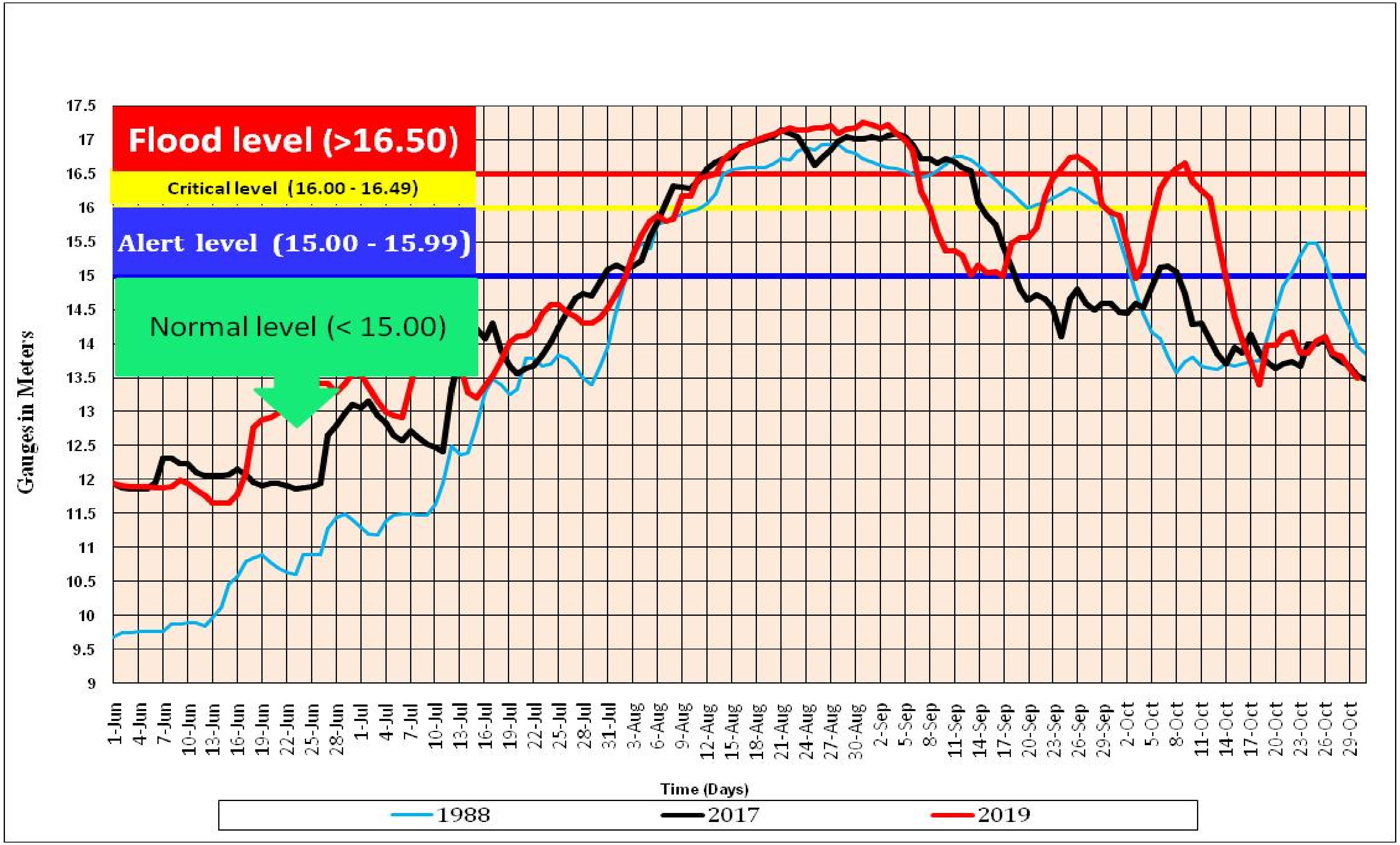

Figure 11: Water level at Khartoum station

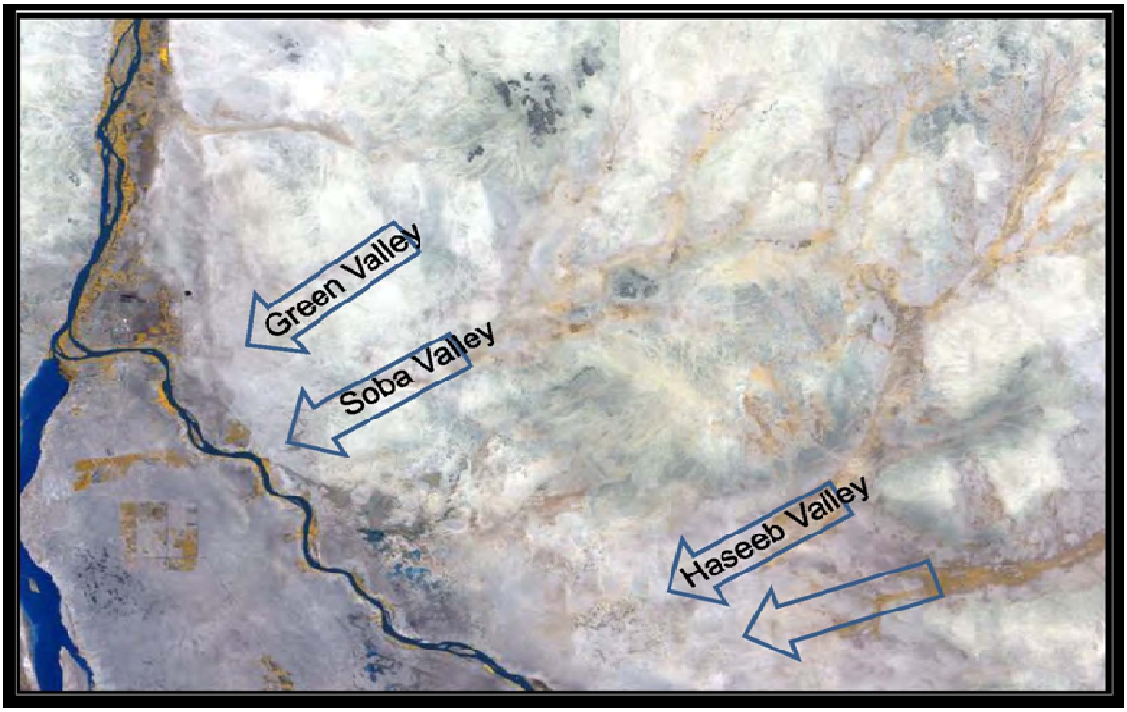

Plate 7: Valleys where floods in eastern Khartoum

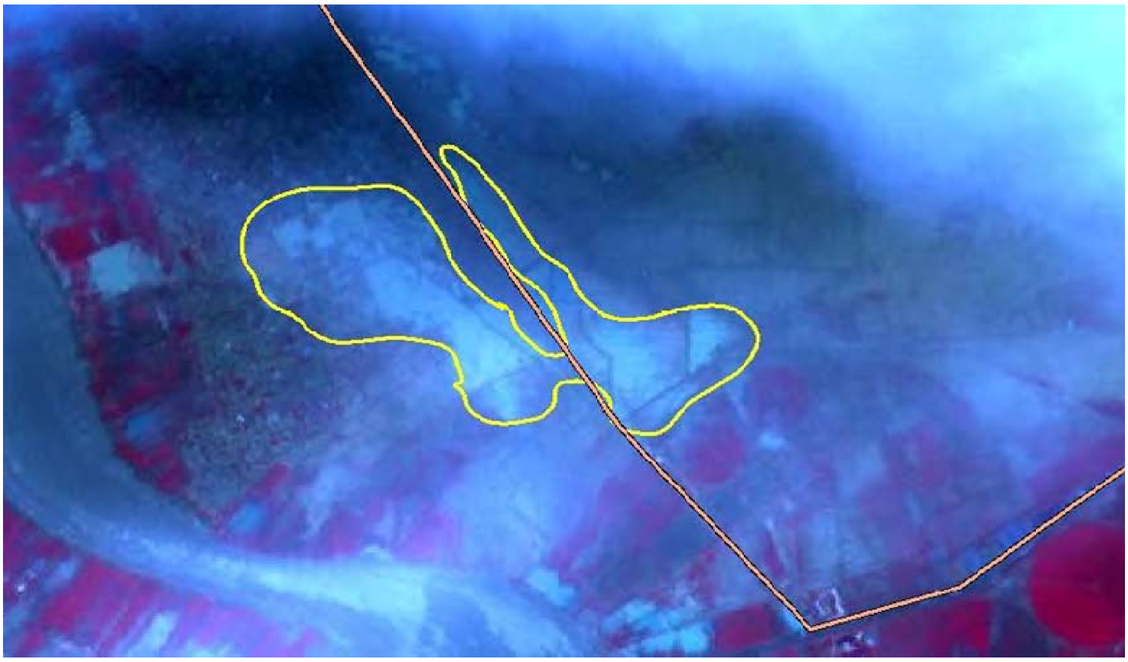

Plate 8: Flash floods populated areas in eastern Khartoum(yellow line)

3.7 Frequency of flood occurrence

After reviewing all interviewee's replies about flash floods events, it was found that in Sudan flash flood events was more periodic occurred in recent years than before Table 5.

Some of these events happened when the season was at its peak (during August), at night period of the day, which cause significant impacts at the local communities and agricultures sector, it leaves economic impacts. The occurrence of these events has left many damages in private and public properties besides the death of many people.

Table 6: Type of flood events and its time in Sudan

N	Year	Riverine	Year	Flash	Most affected cities
1	1988	√	1988	√	Khartoum, Damazin and Madani
2	1998	√	2000	√	Khartoum, Singa, Kassala
3	2006	√	2006	√	Madani, Singa, Damazin
4	2011	√	2013	√	Khartoum, Singa and Kassala
5	2012	√	2012	√	Sinnar, Singa and El girba
6	2016	√	2018	√	Khartoum, Sinnar, Singa and Kassala
7	2019	√	2019	√	Khartoum, Sinnar, Singa and Kassala

3. 8 Needs of stakeholders from flood warning

Lead time

Lead-time provided by flood warning has to be sufficiently long to allow response action to take place. Forecasts with short lead-time are useful for saving lives, but not adequate for making decisions to reduce flood risks to livelihood systems. Community level surveys in Sudan (Table 6) revealed that at least 7 days lead time is required to save livelihood assets from flood disaster, however long lead time the less accurate.

Table 7: Forecast lead-time required for community-level decisions

Target group	**Decision**	**Lead time requirement**	**Current estimated time from historical analysis (short-lead time)**	
			Riverine flood Plate 1	**Flash food mentioned in Para 2.1**
Households	Excavating drainage canals for torrential and flash floods; and evacuation people on threatened flood prone zones.	7-14 days	From Eddiem to Ed Damazin 1 day ------------------------- From Ed Damazin to Singa 1.5 day ------------------------- From Singa to Madani 1day ------------------------- From Madani to Khartom 2 days ------------------------- From Khartoum to Ed Damer 2 days	Dinder and Rahad up to Singa and Madani 5-7 hours .... Flash flood around Khartoum 2-3 hours .... Kassala 3-5 hours
Farmers	delayed sowing cotton at Gezira Scheme, Sorghum at Gedarefand Selling or move poultry	10-15 days		
Pastoralists	Move cattle, goats, and camels from drainage and flood prone areas	1-2 days		

Warning level and danger level

Flood threshold levels, such as warning level and flood level, are important references for the issue of flood warning. Flood warning thresholds define the meteorological and river, conditions at which decisions taken to issue flood warnings. Flood level thresholds are the values at which flooding occurs. Normally, a flood-warning threshold is set to achieve an acceptable lead-time before the flood level threshold reached (Figure 2). If proper flood warning threshold levels identified for the areas of interest, an automatic alert system based on real-time monitoring could also developed. Rainfall thresholds could provide additional lead-time, and could be useful in mobilizing personnel to increase the frequency of monitoring.

Threshold for riverine flood key stations

The flood-forecasting departmentof the MOIWR has defined the warning level as the flood flow that just passes over the riverbank (Critical), but does not affect the nearby settlements. It is the level of flow at bank full stage of a river. The Danger level is that level of flow at which the floodwater rises above the mainstream channel and enters the settlements affecting people and their properties (flooding).

Because of this work, the warning levels and danger levels have identified by analyzing the flood inundation scenario for a range of flow boundary conditions at forecasting stations for each river. Table 7, presents the threshold water levels with reference to Mean Sea Level (MSL) and stations gauge height and runoffs corresponding to warning level and danger level.

Critical level for rainfall to cause runoff and flash flood

The flood vulnerability variables were determined by; rainfall duration and intensity, drainage density and shape, slope type of soil and land cover.

Floods related to extremes in rainfall (from tropical storms, thunderstorms, aerographic rainfall, etc.). A combination of precipitation characteristics (e.g., the amount of rainfall, intensity, duration and spatial distribution) influences the flood events.

Flash floods due to the upward rains and cumulative clouds that fall at night in the Gedaref region, Dinder and Al-Rahad received a lot of attention from the communities and was considered a feature of the parts of the basins located in the border strip of Sudan from the Red Sea in the north heading south passing through the borders of Eritrea and Ethiopia with Sudan to the city of Malakalin Southern Sudan, the reason for interest is because it is an agricultural and pastoral area. Also, the frequency of flash flood losses has increased in recent years due to the population increase in cities and the lack of proper urban planning (knowledge of contour maps) in major cities such as Khartoum. The rainfall cannot immediately infiltrate as ground water or runoff. It converges to the catchment area. The heavy rainfall raises the amount of discharge from rivers and causes overflowing, according to the flood record by SMA, this case often occur inside Sudan, Table 8.

Table 8: Threshold runoff, warning level and danger level

River	Station	R. to MSL	Threshold Runoff (m^3/day)			
			Normal	Alert	Critical	Flooding
B.Nile	Eddeim	481.20	< 350	350 - 519	520-608	> 608
			Threshold Water Level (m)			
			Normal	Alert	Critical	Flooding
B.Nile	Madani	380.09	10.91 -18.41	18.41-19.41	19.41-19.91	> 19.91
B.Nile	Khartoum	363.00	10.00 -15.00	15.00 -16.00	16.00-16.50	> 16.50
M.Nile	Shandi	342.40	10.60 -16.10	16.10 -17.10	17.10-17.60	> 17.60
Atbara	Atbara	332.82	9.68 -14.18	14.18 -15.18	15.18-15.78	> 15.78
M.Nile	Marwi	231.30	10.00 -12.00	12.00 -15.50	12.50-13.00	> 13.00
M.Nile	Dongola	212.03	8.97-13.47	13.47 -14.72	14.72-15.22	> 15.22

Table 9 : Rainfall classification by Sudan Meteorology Authority (SMA)

<table>
<tr><th rowspan="3">Catchment in Sudan</th><th rowspan="3">River</th><th colspan="5">Rainfall intensity range and description</th></tr>
<tr><th>0-10 mm/day</th><th>10 - 25 mm/day</th><th>26 - 50 mm/day</th><th>50 - 100 mm/day</th><th>>100 mm/day</th></tr>
<tr><th>Very light</th><th>Light</th><th>Moderate</th><th>Heavy</th><th>Very heavy</th></tr>
<tr><td>Blue Nile from Eddeim up to Wad Madani.</td><td>B.Nile</td><td></td><td>Starting causing runoff in valley</td><td>Generate runoff in valley to river</td><td>runoff in valley to river and torrential</td><td>runoff in valley to river and torrential and flash flood</td></tr>
<tr><td>Blue Nile from Wad Madani to Khartoum</td><td>B.Nile</td><td></td><td></td><td>runoff in valley to river and torrential</td><td colspan="2">Runoff in valley to river and torrential and flash flood</td></tr>
<tr><td>Dinder and Rahad</td><td>Dinder and Rahad</td><td></td><td>Starting causing runoff in valley</td><td>Generate runoff in valley to river</td><td>runoff in valley to river and torrential</td><td>runoff in valley to river and torrential and flash flood</td></tr>
<tr><td>Setit and Takazi up to El Girba Dam and gash</td><td>River Atbara And gash</td><td></td><td>Starting causing runoff in valley</td><td>Generate runoff in valley to river</td><td>runoff in valley to river and torrential</td><td>runoff in valley to river and torrential and flash flood</td></tr>
<tr><td>River Atbara to Atbara Town</td><td>River Atbara</td><td></td><td></td><td>Starting causing runoff in valley</td><td>Generate runoff in valley to river</td><td>runoff in valley to river and torrential</td></tr>
</table>

4. COMMUNICATION METHODOLOGY FOR FLOOD EARLY WARNING

Warning communication refers to users' understanding of the received message, prompting users to take appropriate actions.

Dissemination is the physical delivery of flood forecast and warning information.

Every warning system is made of two main components:

- Communication infrastructure hardware that must be reliable and robust, especially during the natural disasters; and
- Appropriate and effective interactions among the main actors of the early warning process such as the scientific community, stakeholder, decision makers, the public and media.

Many communication tools available for warning dissemination such as short massage(SMS), Email, Radio, TV, and web service,Newspaper,Flags, Sirens, Phone, speakerphone and door knocking. etc.

4.1 Best practices and Methodologies in Flood EW Communication Globally

The chain of communication about the risk of flooding, from key providers to the users

ICPAC Flood forecasting

- ICPAC has established a Live-Web map service for flood forecasting known as "Flood-FINDER".
- The Flood-FINDER system is a modeling chain that includes meteorological, hydrological and hydraulic models that accurately linked to enable the production of warnings and forecast flooding scenarios up to three weeks in advance.
- Together with modeling is an automated flood forecasting using MIKE-Hydro and GEOSFM models covering all the major river basins in the GHA region.
- With these flood-forecasting capabilities, an online flood risk map with 90-meter resolution and a 25-year return period has been established for the region.

Bangladesh Flood Forecasting and Warning Centre (FFWC)

- FFWC issues five-day deterministic flood forecasts and ten-day probabilistic flood forecast.

- Satellite altimetry-based flood forecasting technology, providing lead times of up to eight days
- Flash flood forecasts, based on rainfall intensity–duration thresholds
- Flood forecast information made available on the webpage of the FFWC, also disseminated viaSMS andtoll-free24-hour Interactive Voice Response (IVR).
- Discharge forecasts at boundary locations use Mike 11 hydraulic model to generate water-level forecasts.
- The FFWC generates flood bulletin and flood situation summary on a daily basis during the monsoon.
- The FFWC carries out monitoring, forecasting, dissemination and communication of flood early warning.
- The response and preparedness capacity framed through standing orders on Disaster (SOD) at the national, district (sub-national) and local government levels.
- Different NGOs have done risk assessments at community level.

4.2 Current Flood Early Warning Communication Method

- ENTRO conducts EWs Daily, and weekly flood forecast bulletin and reports written in English generated and disseminated to different users at different levels via ENTRO website, portal, email, and watts. (Figure 3)
- MoWRE combined regional and nationalflood earlywarningsin one statement(in Arabic),and disseminated it on daily bases officially to relevant stakeholders such as federal ministries, media, response agencies and communities viatelephone,email and fax, also shared via the social media watts, twitter and face-book.
- ENTRO's FEWs, and thus making communities flood resilient is a development better, there is so far, formal communication and dissemination channel of flood information fromENTRO to the government and the communities, (Figure4).
- SMA bulletin EW communicated by Arabic language and disseminated twice a day by phone, Radio/TV, Newspaper, watts and website.
- HAC/center bulletin EW communicated by English language and disseminated no regular bywatts and website.

- ICPACbulletins EW communicated by English language and disseminated by wattsup and website,portal and dashboard.

4.3 Gaps in Existing Communication methodology

- At both national and regional,lack follow-up of thereare no systems for gathering and responding to feedback from the local or district level to regional level or even national levelto improve the dissemination and communication system.
- Lowapplication of Information and Communications Technology in ENTRO FEWs websites and dashboard, gapin layers ofHydro Met monitoring system data source and forecasted risk mapping information inwebsites and dashboard, these media has low uploaded of observed and forecast data, hazard and risk information, and warnings in visual form, through info-graphic, data tables, geospatial layers, maps.
- At national level lack on reliability of communication channels, the communication channel mainly depend on internet access this can seriously delay dissemination (e.g. at 11:00 o'clock there is limitations to intent access).
- At regional level, insufficient frequency of warning (e.g. depends on the nature, intensity, and duration of the threat but ENTRO only one per day).
- At both national and regional, lack of communication skills, (e.g. water level at Eddeim station is 13.40 m, this need more elaboration (duration, magnitude, probability likelihood of the hazard happening, potential impacts and advisories).

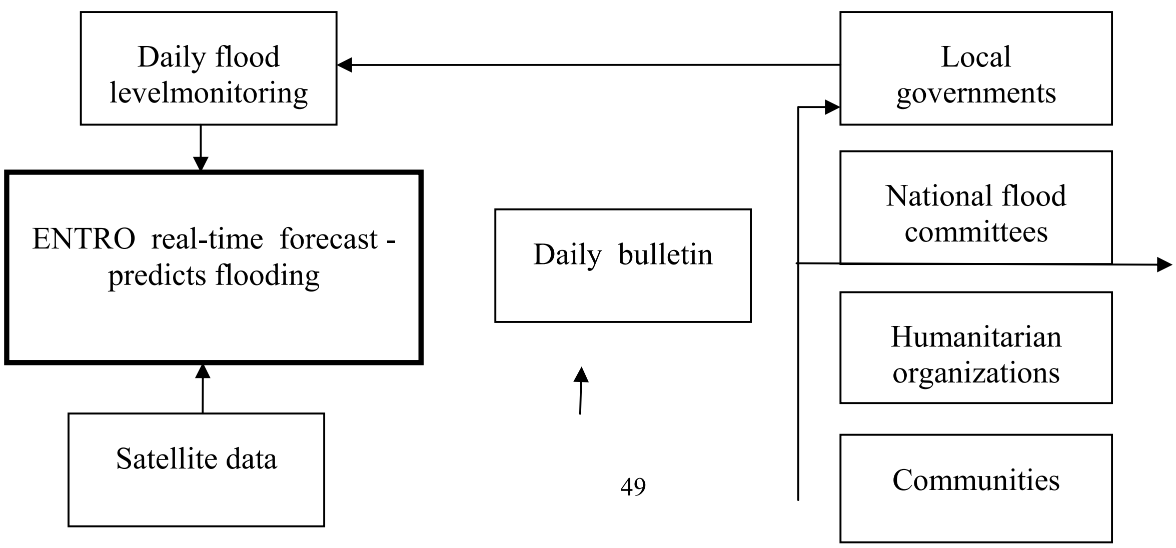

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Figure 12: ENTRO forecasting disseminate of data and information

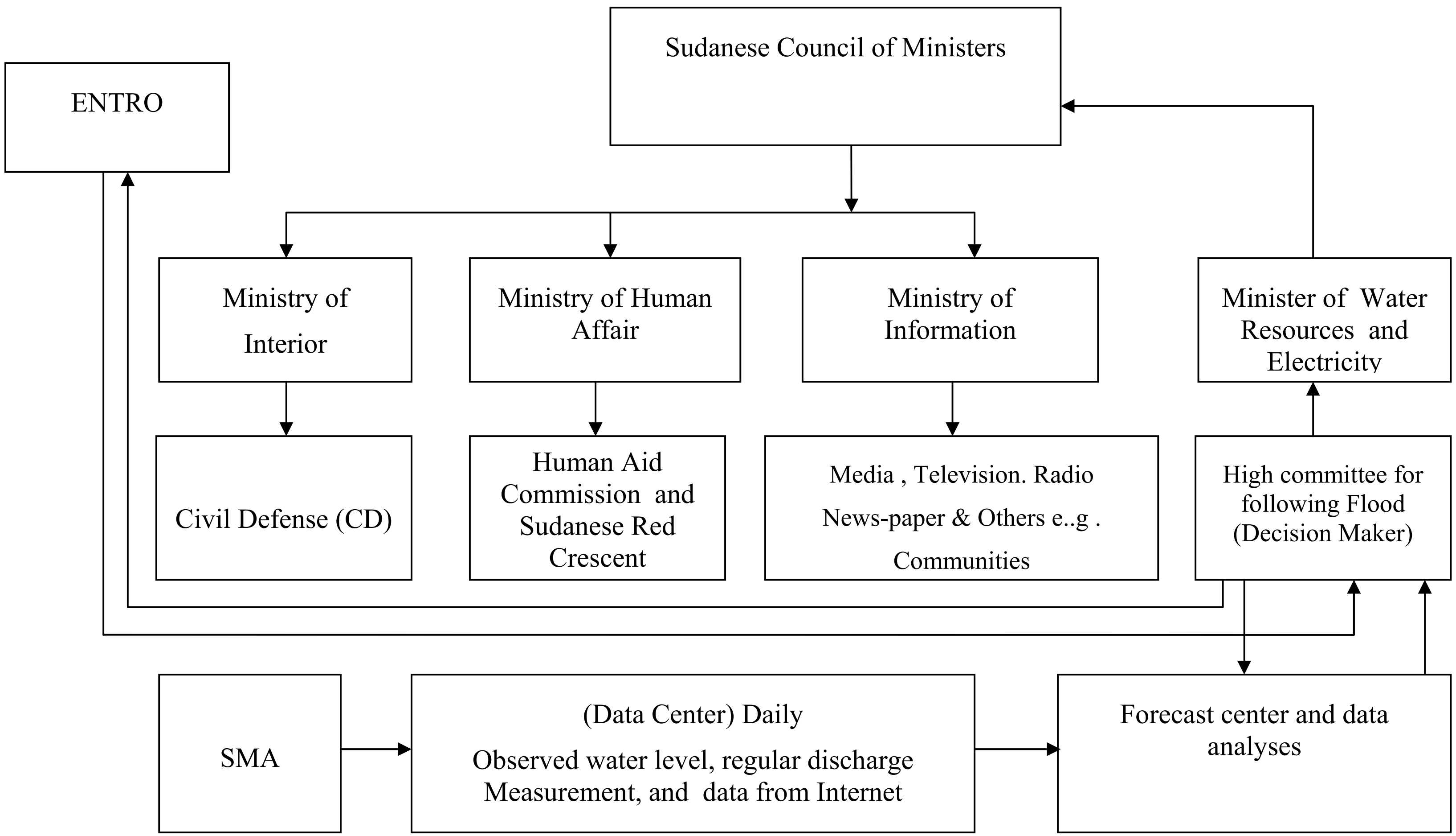


Figure 13: Governmental structures charged within flood management and disseminate of data and information

Table 10: Access to early warnings in Pilot community areas (Total 40 person e.g. 10 per pilot)

category	question	Overall sample	Pilot flood community areas (State)			
			Tuti Island andWawsi at Khartoum State.	Sidon and AlAbaka at River Nile State.	Elsabounabi Umbaneenvillages SinnarState	Seven villages Azuhur Extension Blue Nile
Access to communications technology	Do you have access to a phone You can use?	29 (73%)	9	7	7	6
	Do you have access to a radio?	28(70%)	10	6	5	7
	Do you have access to a TV ?	23(58%)	10	6	3	4
	Do you have access to theinternet?	14(35%)	7	2	3	2
	Do you have access to the gauge reading?	10(25%)	3	2	2	3

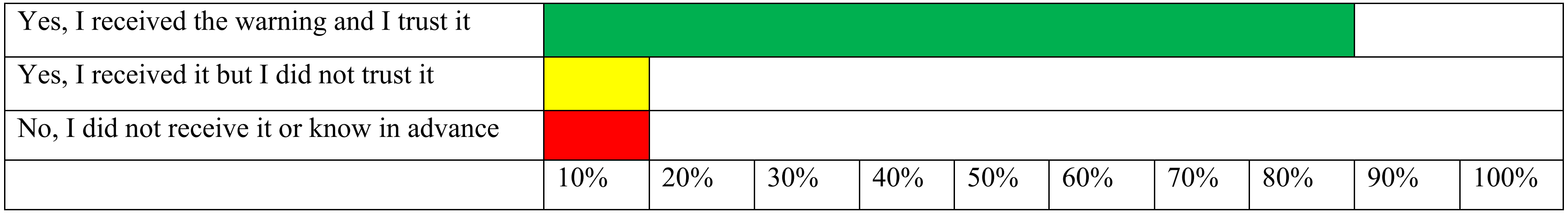


Figure 14: Timeliness of warnings in pilot flood communities floods area (overall sample)

4.4 Proposed Flood Early Warning Communication Method and Technology

From the interviews, it seems that communication tools available for warning dissemination are short massage (SMS), Email, Radio, TV, and web service, Newspaper.

- Though some are not receive these messages or information because they do not have a phone, radio, TV or internet access (Table 9) and (Figure 5).For those poor communities flood areas risk,early warning can be receive bycommunity leaders (*Emam Elmasgid*) and disseminate the information through a speakerphone.
- At national level where there flood plain settlement areas, (e.g. Wad Ramly village) just Northern Khartoum, the first information reach communities suppose come from the river bank observer (like gauge reader) but volunteer from local area, already trained on notice the color marked staff which indicate rate of river rising (how much the river rising during the day after threshold of flood level).
- In Khartoum or others towns flood marks and other forms of visualization can be used to communicate past water levels of historical floods andpublic by locate flood marks on the side of bridges.
- At regional level, enhance Websites and dashboard content: These media allow sharing of observed and forecast data, hazard and risk information, and warnings in visual form, through info-graphic, data tables, geospatial layers, maps, etc.
- Effective websites and geo-dashboard usually includesof three layers :
    - First layer, data source, will composeof automatic stage gauges and rainfall station with others climatology sensors (Automated Hydro Metstations or manual). including the data downloaded from satellite, connected to a ENTRO center and the sensors will be design to collect data from the river reaches and sub-basin catchments, e.g. its stage, velocity, rainfall quantity an duration, humidity, water quality and temperature.
    - Second layer, service layer for fusion, as well as for transforming and sharing the data provided by the previous layer. In addition, analyses the quality of these data in terms of their accuracy.

- Finally, the third layer, the visualization layer consists of the (Automated Hydro Met stations) monitoring system and forecasted risk mapping dashboard which draws on the bases of historical and real-time data provided by the service layer to create a simple and unique dashboard with performance indicators that are essential to assist decision-making of several types of official agencies.

- Warning dissemination could take advantage of new information and communications technologies (ICT) is used, which includes Internet and mobile services. Use of ICT for warning dissemination is, however, context specific, with consideration of available communication infrastructure, social culture, literacy, etc.
- For ENTRO's FEW, dissemination to be more effective through proposallinkages with National Council for Civil Defense (NCCD) structures charged within floods dissemination and communication information and response mechanism illustrated in (Figure6).

Central Body responsible for collection assimilation and dissemination of information in terms of issuing alerts when disaster is likely to occur, or when it has actually taken place, (this body exist and take action during 2019 flood).

Once information received of an imminent disaster or a disaster having occurred, Central Body generates alert massage/disaster warning to the concerned authorities.

Warning of impending, imminent or actual disaster situations may reach Central Body from various sources in a number of ways. Central Body confirms the exact position in this regard from the model officers of official sources/agencies before issuing Alert massages.

Upon receipt of weather warnings or reports of actual disasters, Central Body activates "call up actions".

Each disaster situation has different parameters in terms of severity, early warning and time available for response. Therefore, different stages for different events shall standardize for issuance of Alert massages.

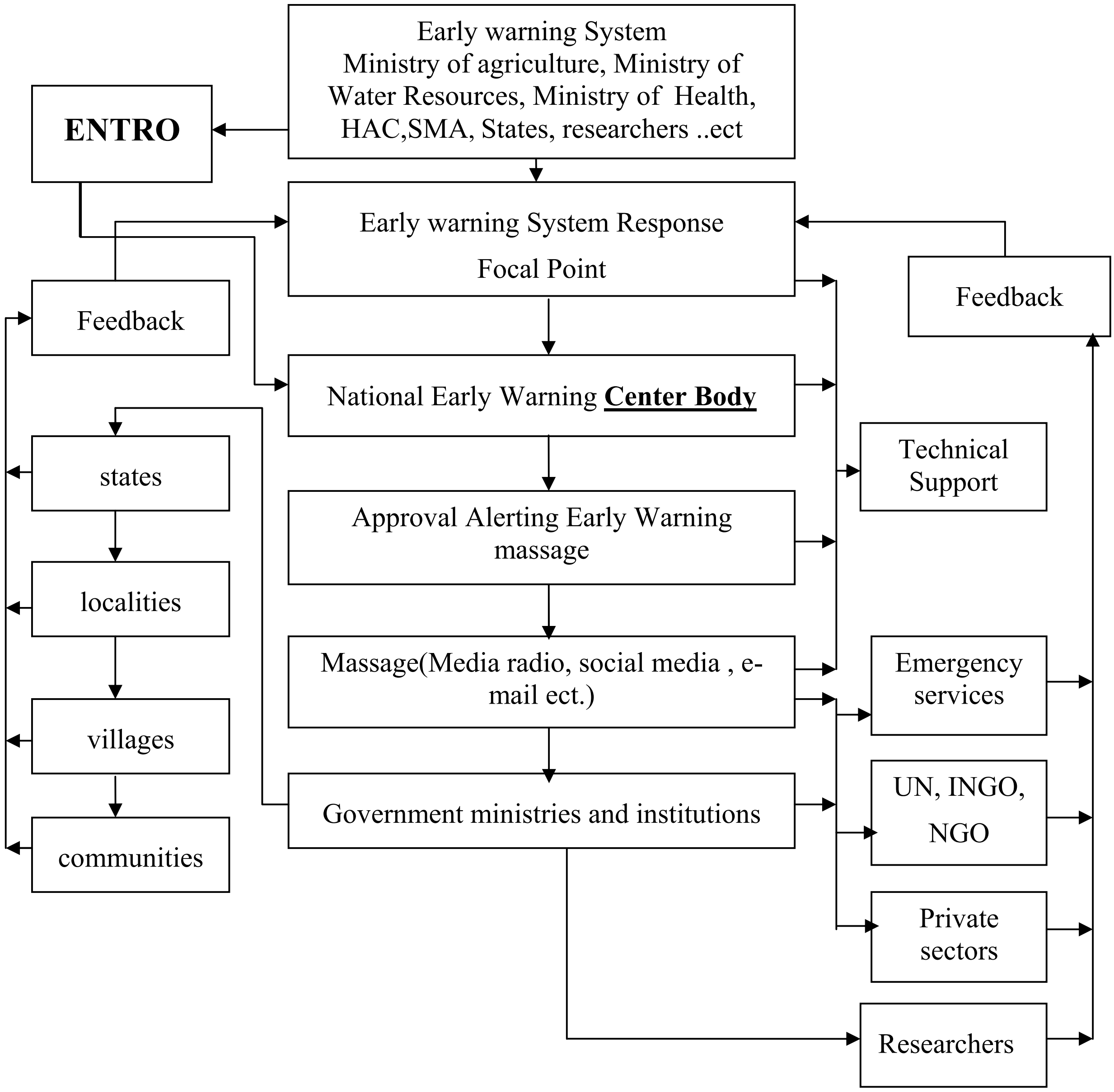


Figure 15: Proposal for ENTRO to linkages with NCCD structures charged within floods dissemination and communication information and response mechanism.

In Sudan practices related to indigenous early warning for both flash and riverinefloods are:

Flash flood

- Heavy formation of clouds in the Northeast with Thunder (locally called Morbat Al Egil) during night (lielia) and during morning (Dahawia) =>forecasting heavy rain.

- Low clouds moving rapidly from south-west to northeast =>forecasting flashflood.

Riverine floods

- River water color turningmuddy, creation of foam in the waters=>forecasting flood.

The water in the river before the floods is very dirty and carrying timbers and trees sometimes carrying animals and the these show up its only a matter of time before the river flood this happen at River Atbara locally called (Crazy river).

- Peoplecompare the label on trunks of trees labeled by pastyear floodand they can predict the new one (flood) when onset,where can extend on floodplain.
- The traditional system being common to most communities "watch and warn" managed differently by adding more preparedness aspects.

Watch Component:

- Large groups of frogs seen outside the mainstream of the river
- Change in the color of the river water suggests the arrival of large quantities of water
- Movement of insects like ants and mice with their young from one place to another.

  Such traditional indicators vary from one community to another depending on the traditional inherited experiences in each community.

Warn Component:

The traditional warning in the communities varies from one area to another such as:

- Traditional drums
- Horn
- Human voice (*roray*)

Depending what these sounding traditionally at the community level, the first sounding of, mean may indicate that communities should prepare, while a second one meant that they should evacuate.

5. CURRENT RESPONSE ACTIVITIES TO FLOOD EARLY WARNING

5.1Performance of Current Response to Flood Early Warning

From the interviews at the flood area, people seem to trust and give credence to the messages or information they receive directly from the ENTRO/MOWRE or any official warning (e.g. broadcast warnings, websites),

- The statement send broadcast and direct provided to CD, HAC and SRCS as well as communities at risk (pilot areas). Once the warning reached CD and communities at risk they take action, for examples in 2019 flood CD evacuated people at flood risk areas (North Khartoum) as soon as it got the information.
- The above performance did not fully cover the Nile and its tributaries, (e.g. Atbara River, Dinder and Rahad are out of the system of EWs,needto develop of inundation maps to support their rapid response of major flooding events).

5.2 Current strategies of coping with flood risks and adaptation mechanisms

Before flooding vulnerable people individually and collectively, develop their own means, resources and strategies to cope with flooding. To prevent or minimize the potential impacts from natural disaster occurrence in the future, the interviewees (Wad Ramly) were asked what preparations and plans their households were considering to counter the impacts of floods. Most of interviewee's respondents indicated that they rehabilitated flood diversion trenches around their houses. This was based on their perception that the impacts were only from flash flood from rainfall that life would return to normal after such disasters and they forget riverine flood. This finding indicates that some households in the community lacked confidence to depend on local government units for defensive strategies and actions to move them to high places, Table 10.

At individual household level people use of sandbags and tree logs; raised pit latrines and doorsteps; provision of water outlet pipes above plinth level; construction of embankments around wall, protection walls and elevation of house foundations

Immediate short-term strategies

During and after the 2019 flood, affected households received assistance from the government and friendship countries as well as NGOs like UNICEF, WHO, IOM, UNHCR and the WFP which played an important role in assisting most of the surveyed households. This assistance was mostly in the form of food and material aid. In addition, the government provided temporary shelters and tents in Wad Ramly villages, which used by most of the respondents.

In 2019 flood at Wad Ramly, while the people were staying in temporary shelters and tents, the government distributed new site residential lands in high places to people affected by the flood instead of their old site places located in the flood plain of the river.

Table 11: Planning of new places for the resettlement in 2019 flood

No	State	Number of villages to move	Number of villages moved
1	Blue Nile	8	0
2	Red Sea	1	0
3	Gadaref	67	0
4	River Nile	30	0

Long term strategies

Following the high floods of 1998, a decision taken by Sudan Federal government to resettle 190 flood prone villages that were located along the Nile and its tributaries.

The responsibility of implementing the plan left to the affected states. In each state, the Ministry of Physical Planning is the administrative body that plans the new settlements and demarcates areas for essential public services. Once plots allocated, it assumed, Ministries from the relevant sectors would construct essential service infrastructure. (Health, water, schools etc.). So far, the focus has been on settlement planning and there has not been an accompanying financial package to support costs of home construction and/or service provision. Some of the concerned communities have moved and started a new life in the designated areas but the vast majority did not leave their original areas.

Adaptation Measures/Strategies and Coping Mechanisms of Households and Community

An important question posed in this study was; “What adaptation measures/strategies were being implemented by the households, the community in general, and the local government units to address the impacts of flood risk disasters?” Household survey results (Table A2- 9) showed that majority of the respondents (70%) indicated having adaptation measures to address vulnerability, risk reduction, and coping mechanisms for flood disasters.

The top four adaptation measures/strategies implemented by many of the respondents included the following: Transfer of households to evacuation area temporarily (30%); restructuring of housing units to fit the new condition (20%), improvement of the dike system or canal near residence (20%), other respondents prepared their household needs and safety precautions (20%), changed their livelihood and sources of income (4%), and changed their land use to fit their new conditions (1%), (Table A2-10).

This finding indicates that some households in the community lacked confidence to rely on cooperative solutions or to depend on local government units for defensive strategies and actions. Another interesting finding was that the households’ most preferred option of temporary relocation seemed to base on their perception that the impacts were only short-lived and that life would return to normal after such disasters.

In addition mentioned in chapter 3 in social indicator in this chapter also the households answer that in the rural floodplains, local residents have usually helped or worked together in order to mitigate flood damage to individuals and the local community. Local residents have helped each other to upgrade or build houses, flood-related means, dykes, roads or bridges this is one of good practice coping mechanism.

5.3 Proposal on how to improve the response to Early Warning

- Need of capacityfor awareness on the use of ENTRO flood forecasting products, few stakeholders know how to use inundation map and forecast on digital numbers.
- The Flood Early Warning System needs be extend to cover all the flood hazards (Main Nile, Atbara River, Dinder and Rahad) which will allow humanitarian

agencies, individuals exposed to hazard of flood risk to take action to avoid or reduce their risk for effective response.

- In order to strengthen the capacity of the community to response it is necessary to deal with Flood Task Force led by Government's Humanitarian Aid Commission (HAC), which coordinating and facilitating flood preparedness and response efforts.
- The Task Force requires more response equipments such as hand mikes and medicines, life jackets, boats etc. Regular tests, training and drills undertaken to ascertain the readiness of the warning systems and response mechanisms.
- Evacuation routes and shelter zones jointly identified by the Task Force and communities with help of MENRU, and subsequently equipped with first aid facilities, water and sanitation, relief materials and communication facilities needed during the flood disaster.

6. INSTITUTIONAL ARRANGEMENTS FOR EWS

Since 2010, the implementation of FPEW phase (I), important institutional changes have created new roles and responsibilities for flood early warning in Sudan. The Ministry of Water Resources and Irrigation would have oversight on flood forecasting and early warning system through the national flood center and ENTRO, Figure 7.

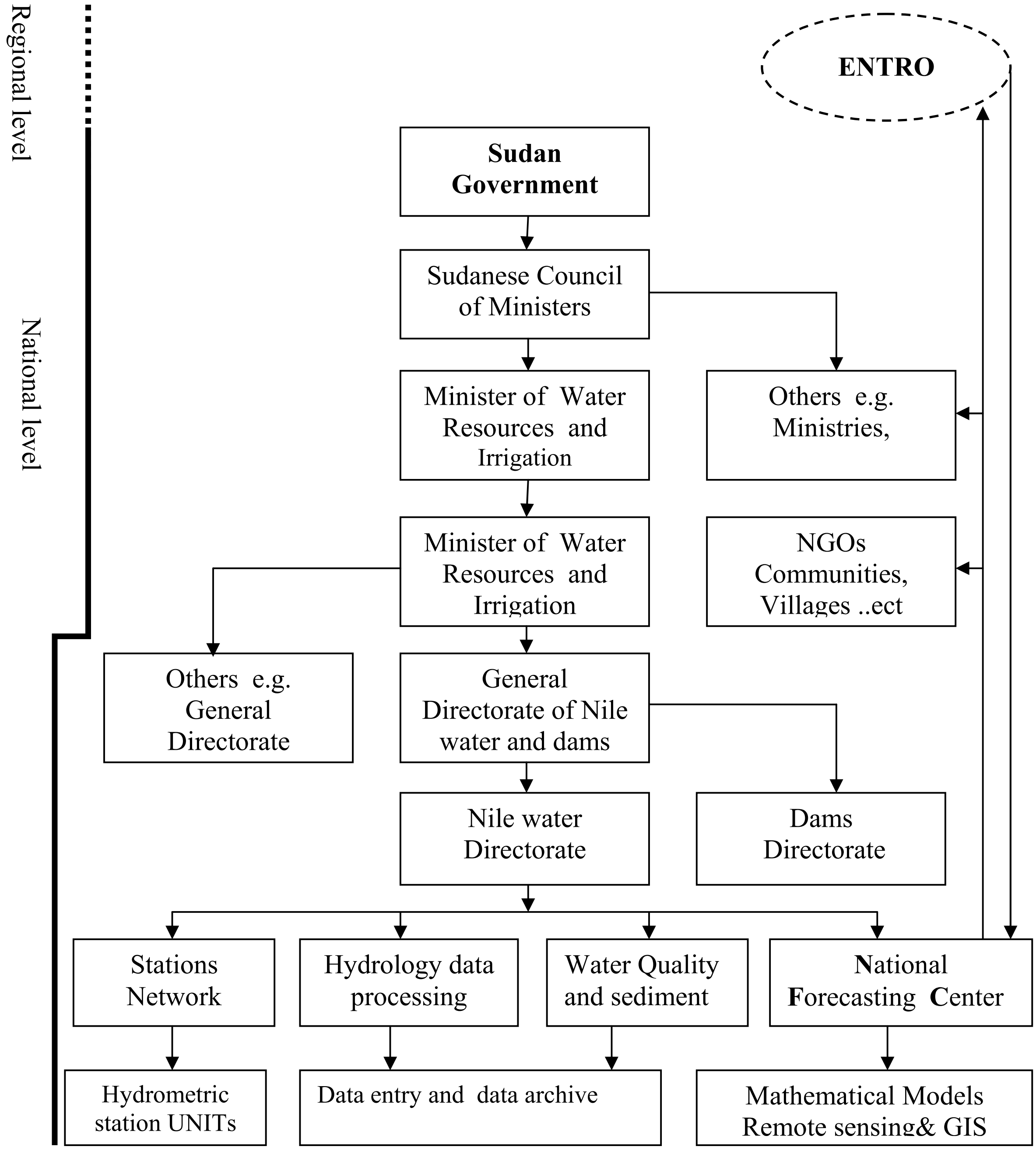


Figure 16: EWS governance arrangements

Institutions and their roles

The findings indicated that multiple institutions are involved in disaster risk reduction in Sudan but their roles, inter-relationships, coordination mechanisms, and accountability arrangements are overlapped or most organizations have multiple roles Table 11.

Table 11, provides most roles and functions of different organizations in disaster risk management in Sudan, Most of the activities in disaster risk management are being undertaken by multiple organizations with overlapping roles and responsibilities; 10 of the 13 organizations were involved in coordination; 10 in providing technical support, and 10 in implementation, while only six were involved in formulating policy and strategy frameworks. The policy and strategy related activities mainly carried out by central level government organizations, and implementation by local NGOs and community-based organizations, supported by INGOs and national NGOs.

In fact the overlap of roles in the activities through institutions is not typical it is depend on the mandate of the institutions, e.g. research with regard to flood in ministry of water is different with research in ministry of health.

There is an ongoing regional effort through the ENTRO to improve FEWS and national efforts by National disaster risk reduction committee to strengths disaster risk reduction in Sudan, and propose institutional arrangements for effective implementation. However, at present, there is no comprehensive or systematic documentation specifically for flood early warning systems at the different levels (community, district, and national) that describes institutional roles, structures, systems, and practices, or overall architecture.

6.1 Gaps in the current institutional setup at Regional and National Level

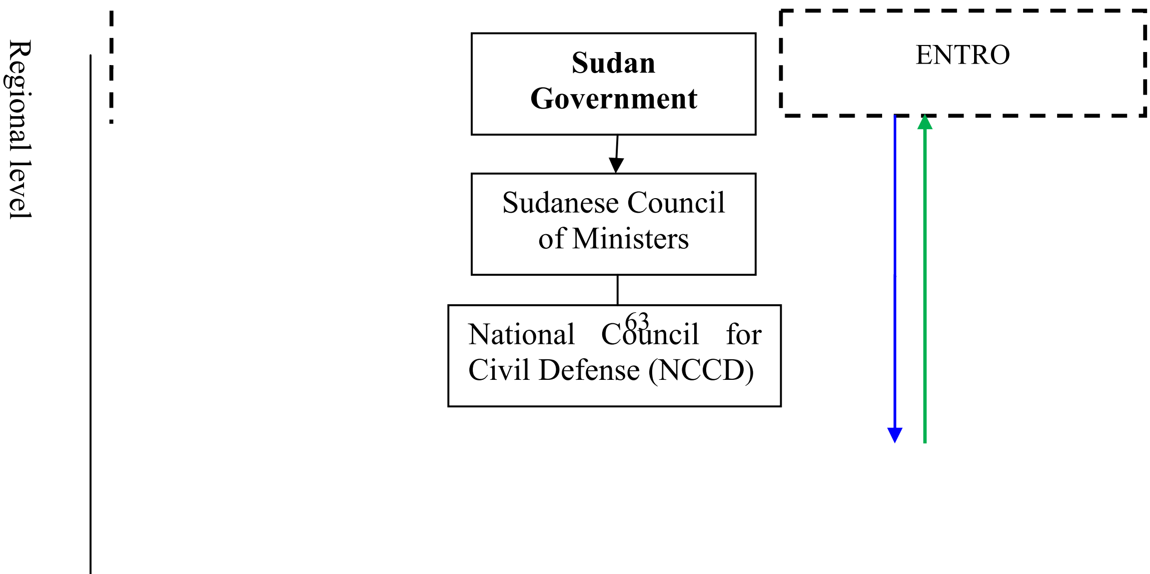
- Top-down institutional arrangements (Figure 4) generally refer to a decision-making process that starts at the constitutional-choice level (national) and goes through the collective-choice level (regional/national) to the operational level (local) the gap is one-way no feedback from FEW responses.
- So need of bottom up or lateral (collaborative) is vital, local stakeholders and communities, with a focus on intervention, problem identification, strategy formulation and implementation, may lead Bottom-up arrangements.
- At the communities, level there is a gap in terms of capacity to respond to warning information if they receive it.

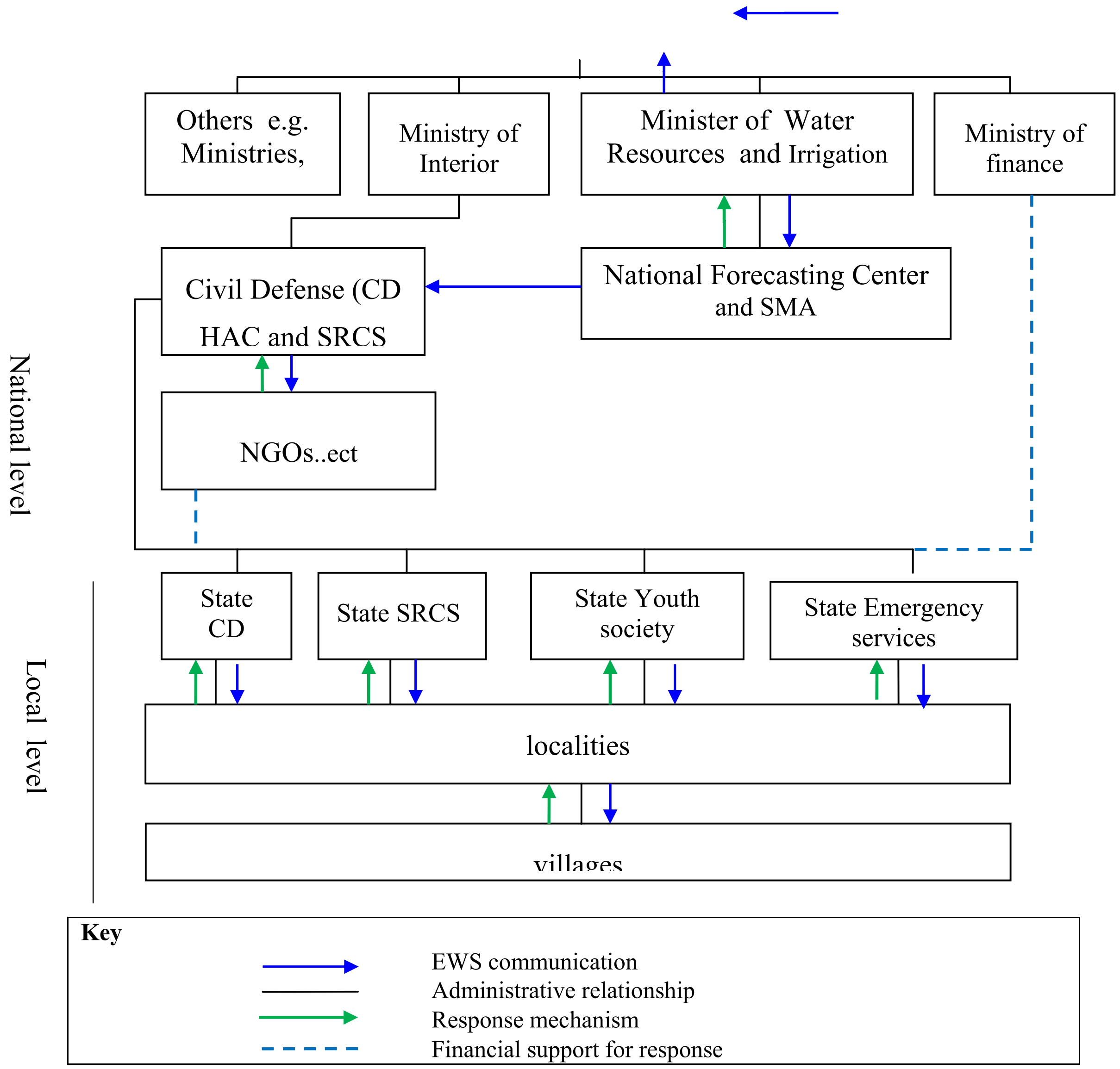
6.2 Proposed setup for an effective Flood Early Warning System Level

The new proposal structure distributes power and resources to sub-national and local levels (urban and rural municipalities), offering an opportunity to improve all components of floods EWS in Sudan. This section reviews the roles and responsibilities of, and coordination between, the government and NGOs, and offers suggestions regarding how EWS can improve under the new proposal structure. Roles and responsibilities assessed at the national, states and local levels – in the Blue, Main and Gash river basins – including the role of NGOs in developing community-based EWS. (Figure 11) and (Figure 8).

Table 12: Roles and functions of different organizations in disaster risk management

<table>
<tr><th>Policy</th><th>Coordination</th><th>Research</th><th>Technical support</th><th>Implementation</th></tr>
<tr><td colspan="5">Ministry of Irrigation; Water Resources and Electricity</td></tr>
<tr><td colspan="2">Ministry of Interior</td><td></td><td colspan="2">Ministry of Interior</td></tr>
<tr><td colspan="3">Ministry of Humanitarian Affairs</td><td></td><td>M. Humanitarian Affairs</td></tr>
<tr><td></td><td></td><td colspan="3">Ministry of Agriculture and Forests</td></tr>
<tr><td colspan="4">Ministry of Health</td><td></td></tr>
<tr><td></td><td></td><td colspan="3">Ministry of Social Affairs</td></tr>
<tr><td colspan="5">Ministry of Finance</td></tr>
<tr><td colspan="2">Ministry of Environment</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="2">Universities</td><td></td></tr>
<tr><td colspan="5">Intergovernmental partnership and nongovernmental organizations</td></tr>
<tr><td></td><td>NGOs</td><td></td><td colspan="2">NGOs</td></tr>
<tr><td colspan="5">ENTRO</td></tr>
<tr><td></td><td colspan="2">UNDP</td><td></td><td>UNDP</td></tr>
<tr><td></td><td colspan="4">Save the Children</td></tr>
</table>





7. CONCLUSION AND RECOMMENDATIONS

Figure 17: Proposed setup for an effective Flood Early Warning System Level

In order to enhance ENTRO FEWS,stakeholderswere mapped through individual interviews approach to find out forecast providers and users, analyse stakeholders mandate, gaps,response activities and communication methods for flood early warning.

- ENTRO,was found to be mainly involved in forecast provision in Sudan, however it doesnot cover Atbra River, Dinder and Rahad, it is also not addressing the issues of flash flood in the basins,with more than 5 million inhabitants.
- ENTROFFEW products, makesMOWRIE flood forecast warning development better, nevertheless there some barriers to accessing ENTRO's warning forecasting information due to low internet access and insufficient information on its websites/dashboard, in additionto its EW frequency of warning and lack of communication skills on ENTRO models products.
- ENTRO, during of FEWP phase (I) through the community action plan, the communities learnt from it and develop their own preparedness andare so far ready torespond. Still there is a challenge for those not covered by ENTRO's FEWs as they lack thecapacity.
- MOWRIE, mandateis improveriver-monitoring system, also release of warning and ensuring that warning massage reached everyone in the community and shared across multiple actors, however there is no institutionalized feedback mechanisms to evaluate whether warning massage accessed, understood or used.
- MOWRIE, multiple institutions are involved in disaster risk reduction in Sudan but their roles, inter-relationships, coordination mechanisms, and accountability arrangements are overlapped, or most organizations have multiple roles.
- It is apparent from flood prone areas map and settlement map. There are 2900 villages within 15 km radius of the riverbank that are directly exposed to floods.
- Sample of household study shows that vulnerability to urban and rural flooding or any other hazard must not treated as a single entity, but rather as a composition of social, economic, physical/infrastructural, institutional, and attitudinal factors, and proposesa multidimensional model to measure vulnerability.

- Sample of household survey shows the fact that these households live in floodplains makes them more susceptible to high flood impacts. Moreover, these households highvulnerable to economic dimension and veryhigh vulnerable to physical/ infrastructural and attitudinal dimensions.

- Community level surveys in Sudan revealed that at least 7 days lead time is required to save livelihood assets from flood disaster, however long lead time the less accurate.
- Popular mechanisms employed by households to mitigate the impact of floodswere:
- Seeking relief materials from the Government and other agencies, constructing flood diversion trenches to protect villages form torrents and moving the effected households fromflood prone areas to safer upland.
- Adaptation measures and coping mechanisms of Households and Community, households in the community lacked confidence to rely on cooperative solutions or to depend on local government units and preferred option of temporary relocation than permanent.

7.2 Recommendations

- MOWRIE/EN countries, need to upgrading existing manual record stations to make them automatic stations (hydro met) and increasing the spatial density of stations, to feed into national centers, as well as appropriate stations feed to regional center that can provided a good data base and consequently improve flood forecasting and early warning systems.
- ENTRO is encouraged to established/enhance such models system to be like Toolkit of FFEW in trans-boundary river basins or a system or modelling chain that includes meteorological, hydrological and hydraulic models that are accurately linked to enable the production of warnings and forecast, using appropriate modelscovering all the major river basins in the EN region. This will enables to use flood-forecasting online flood hazard risk map with 90-meter resolution and a 25 up to 300-year return period to be establish for the region.
- MOWRIE/ENTRO, need to provide regular, tailored training and capacity building for users, responders and community members on ENTRO FFEWs products and what to do when they receive warning information and send feedback to the centers.
- ENTRO needs to improve warning dissemination and take advantage of new information and communications technologies (ICT), which includes Internet and

mobile services may be solve problems of unexpected communication channel breakdown e.g. low internet access.

- MOWRE, needs to strengthen the capacity of the community to response is necessary deal with Flood Task Force led by Government's Humanitarian Aid Commission (HAC), which coordinating and facilitating flood preparedness and response efforts which include NGO.
- MOWRIE/ENTRO, need of bottom up approach. It needs to intensify visits to flood-affected people and adopt their ideas to solve the flood problem and cooperate with the relevant authorities to reach a plan to reduce flood damage. Feedback from bottom is important is vital, local stakeholders and communities, with a focus on intervention, problem identification, strategy formulation and implementation, may lead bottom-up arrangements.
- To make the flood awareness more official and responsible its better ENTRO FFEWs products, can disseminationthrough Committee for Flood Control (decision maker) of Ministry of Irrigation and Water Resources (MoIWR),which has direct link to the National Council for Civil Defense (NCCD), This integrated flood forecasting system and dissemination system of MoIWR and NCCD also has many links to the stakeholders and communities levels.
- Need to launch awareness campaigns and design risk communication strategies to enhance the flood risk perceptions of the communities and engage the local institutions with the communities to implement disaster risk reduction plan effectively.
- Need of build confidence between local government units and households in the community for such solutions of defensive strategies and actions concerning floods early warning (households and community need to be involved in such process and development).

References

Abdalla, A.K. (2003). "Evaluation of the Sudanese experience in rainfall seasonal Forecast". Workshop on the use of meteorological data in disaster control. Sudan Meteorological Authority. Khartoum, Sudan.

Abdel Ati Hassan (2005); A Baseline Social Survey Report – Sudan. Khartoum and Addis Ababa: MoIWR/Sudan and Eastern Nile Technical Regional Office/ENTRO, Ethiopia.

Abdel Ati Hassan (2009), Enhancing Voluntary Resettlement in SUDAN, A Report for Flood Preparedness and Early Warning Project (FPEW-I) Nile Basin Initiative (NBI)

Civil Defense report"Flash flood impact", **2018 floods**.

Consultancy Service's report"Flood early Warning Survey in Sudan", Project April NBI- FPEW, 2010.

Consultancy Service's report "Peak Season Community Surveillance in Sudan", Project NBI- FPEW, July 2010.

Deltares, (2015), Final Report: Mobile Services for Flood Early Warning in Bangladesh.

EC, 2003. EU Best Practices Document on Flood Prevention, Protection and Mitigation. Available online at: http://ec.europa.eu/environment/water/flood_risk/pdf/flooding_best practice.pdf.

ANNEXURES

Annex 1-1:List of persons and institutions met

	Name	Email	Telephone	Job / Institution
1	Dr. Balla Ahmed Abdelrhman Shaheen	ballashaheen1@yahoo.com	+249 91 269 3455	General Director of Nile Water and Dams Affairs (Nile TAC member) / MoIWR
2	Dr. Salih Hamad	Shhomer@gmail.com	+249 91 269 1468	Head of the Technical Organ for Water Resources/ MoIWR
3	Eng. Abdelrhman Sagairon	a.saghayroon@gmail.com	+249 123 494 480	Director for Nile Water/MoIWR
4	Eng. Ahmed El Tayeb Ahmed	aeltayeba58@yahoo.com	+249 123 348 972	Director for Dams /MoIWR
5	Dr.Ahmed Abdelkarim	ahmed.akarim2010@gmail.com	+249 91 292 8619	Director-General for Sudan Metrology Authority (SMA)
6	Gasim Musa	gasim1_78@yahoo.com	+249 12 140 1745	Sudan Metrology Authority (SMA)
7	Major General. Abubakar Sayed Ahmed	cdga@nccd.gov.sd	+249 91 220 5001	Secretary General of the Secretariat of Civil Defense/NCCD
8	Pilot officer. Hosham	cdeias2016@yahoo.com	+249 91 814 0652	Civil Defense/CD
9	First lieutenant. Hassam	yousrimoh3@gmail.com	+249 12 276 9013	Civil Defense/CD
10	Prof. Kamaluddin Bashar	basharke@gmail.com	+249 99 1919194	Dean of the Faculty of Engineering, Islamic University of Omdurman
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12	Yaser Hashem	sewsusu@gmail.com		Head of Early Warning center/HAC
13	Hafsa Ahmed	hafsareal@gmail.com	+249 91 2895077	Early Warning center/HAC
14	Ghada Nasreldeen	nasreldeen@un.org	+249 187 123 110	UN/Sudan
15	Hanan Mutwakil	hanan.mutwakil@undp.org	+249 187 123 110	UNDP/Sudan
16	Ms/Sawsan Khair Elsied	Sawsanatkh2yahoo.com	+249 91 255 9438	Director-General/MLF
17	Osama Abdalla	oaraby@gmail.com	+249 12 702 0301	Communities representative

Notice: A few managers mentioned above during interviews, I deal with level below them or available person in the place.

Annex 1-2:Key stakeholders contacted

	Name	Telephone	Institute
1	Al zamzmy Othman	0916818869	Wad Ramly
2	Mobark Mohammed		Wad Ramly
3	Awad Abdel Monem	0911213607	Wad Ramly
4	Khalid Mohammed Abdelgalil	0918199841	Wad Ramly
5	Altaype Mohammed Madani	0128439770	Wad Ramly
6	Ala Eldin Abdelhab Mohammed	012430020	SRCS
7	Abo Bakar Othman Mohammed	0912232525	SRCS
8	Majda Abdela Mohammed	0923400988	SRCS
9	Amna Owad Gaber	0922568946	SRCS
10	Major General. Abu-Bakr Saied Ahmed	091 220 5001	NCCD
11	Pilot officer. Hosham	091 814 0652	CD
12	First lieutenant. Hassam	012 276 9013	CD
13	Dr. Ahmed Suliman	0912243464	U of K
14	Fattma Yousuf	0122769013	Ministry of physical planning
15	Nagla Ginawi	0912220143	Ministry of Agriculture
16	Bader Adam	0912390965	NCCD
17	Mohammed Ahmed	0922253773	NCCD

Annex 2:Check list questions

Interview questions platform for expert group

Name			
Sex:		Qualifications	
Years of Experience		Job Title	
Organisation		Group	expert

Q1.	How many flood events have you encountered? And at what times? Were these events occurring ?
Q2.	What are the flood-prone areas in the Sudan? and what is the reason?
Q3.	What are the main valleys in the Sudan causing flash flood?
Q4.	Where are these valleys passing through?(i.e. residential, agricultural, economic areas). What will be doing to prevent flood water from coming to residential areas? What problems did you encounter in your bid to ensure that floods do not overwhelm households? How do you think these situations could be improved?
Q5.	These valleys constitute a major factor in flood occurrence in the local, through your experience, how do you explain that?
Q6.	Floods mainly leave casualties or damages; can you talk about these damages?
Q7.	When floods occur, preventive measures have to be taken to reduce the floods risk, what are these measures?

Q8.	What measures or tools does Ministry of water resource and irrigation adopt to mitigate flood risk?
Q9.	What measures do the people adopt at property level? Do they over rely on regional measures?
Q10.	Is there a periodic review for these measures and improvement as appropriate need? What authorities are involved in this? Are there any joined up activities between different authorities and agencies?
Q11.	Ministry of Water Resources and Irrigation plan to deal with the flood risk (that may be annually reviewed) is an important component, of disaster risk management plan, how does (should) Ministry of Water Resources and Irrigation coordinate with concerned parties (within contingency plan) to reduce flood risk, such as civil defence, Ministry of Humanitarian Affairs, Sudanese Red Crescent …etc.?
Q12.	How does Ministry of Water Resources and Irrigation and/or civil defense are assess (should assess) the damages due to flooding? What are the processes followed?
Q13.	Is there specific policies relating to floods in your organisation? What is the Flood Early Warning System (FEWS) from your point view? How soon should the early warning be received for it to be meaningful? And what are the factors important for effecting FEWS?
Q14.	What are the main components of the FEWS?
Q15.	How would a FEWS be an effective system and helps mitigating floods impacts?
Q16.	FEWS that be established in Minstry of Water Resource and Irrigation, rigional

	at ENTRO, to whom it should be directed? Local communities, local government(MOWRE) , different stakeholders …etc. How do they perform their function; how many warnings have they issued or transmitted in the recent past? What is the content of their warning? Is it enough and understandable? Do they issue both riverine as well as flash flood or only riverine? Which actionable information would they like to get from ENTRO to support the issuing of the (flood) early warning? What support are they comfortable giving to ENTRO to support the regional early warning?
Q17.	How could locals be aware of the actions that they have to do in case of flood?
Q18.	How do these systems (FEWS) deal with the nature of flash floods, such as suddenness, unpredictable?
Q19.	What are the current modelling methods (in Sudan) related to floods?
Q20.	What are the current early warning systems related to floods?
Q21.	What is the level of communication and interaction between your orgaisation/institute and other agencies to achieve your goals?

Interview questions platform for users group

Name		Group	Users
Education		Sex: a) M b) F	
Occupation		Age	
Village/ region		Years of experience	
		Monthly Income (Average)	

Q1.	How long have you been living (*here the name of region*-----------)?
Q2.	How many flood events have you encountered? And at what times? Were these events occurring when in specific place?
Q3.	What are the flood-prone areas in the region? And what is the reason?
Q4.	How the flooding, according to your perspective, affected the pepole and economic activities of the area?
Q5.	What are the impacts of floods in the region (infrastructure, public and private properties …etc.)?
Q6.	Have there been any casualties in the past due to the floods? When? How many was the number of deaths in each event?
Q7.	When did you think the casualties were the highest and why?
Q8.	What type of early warning system is in place in this locality? How does it function? Who owns it? How does it sustain? Any committees to manage it? Are there clear roles and responsibilities of the committee for flood contral (MoWRIE)?

Q9.	Is there a cooperation and coordination between regional, government institutions, local community and community-based organisations to reduce flood risk? What is the nature of this cooperation and coordination?
Q10.	Are the local citizens aware of the actions to follow in case of flooding? What independent measures do they adopt?
Q11.	From whom do they seek more information? Are you happy with this information and what adjustments are needed?
Q12.	Are there any community awareness and training programmes on early warning on flooding?
Q13.	Who in your opinion should train you or make more awareness? How many times did you attend such trainings? Have you participated in any meetings related to flood management? How many times have you attended such meetings? Who (department/office) organized the meetings?
Q14.	What is the best way to inform you about a flood according to your opinion?, e.g. Radio-Television- Through mobile Phone. Why do you think that it is effective?

Annex 3: Household Vulnerability Index Analysis

The subjective weighting technique to allocate values to classes of phenomena for each indicator and formulates indices based on Eq. 1.

CI = (W1+W2+W3+…Wn)/n = $\sum_{i=1}^{n} w_i / n$-------------------------- (1)

Where, CI is the composite index, W1 to Wn are respective transformed values assigned to indicators, and n is the number of indicators used for computing the composite index.

Following this general principle, the Social Vulnerability Index (SI), Economic Vulnerability Index (EI), Physical/ Infrastructural Vulnerability Index (PI), Institutional Vulnerability Index (II), and Attitudinal Vulnerability Index (AI) were calculated.

The Multidimensional Vulnerability Index (MVI) for each householdin the study area calculated using Eq. 2.

$$\text{Social Vulnerability Index (SI)} = \sum_{i=1}^{4} \frac{SW_i}{n} \qquad (n = 4)$$

$$\text{Economic Vulnerability Index (EI)} = \sum_{i=1}^{4} \frac{SW_i}{n} (n = 4)$$

$$\text{Physical/ Infrastructural Vulnerability Index (PI)} = \sum_{i=1}^{4} \frac{SW_i}{n} (n = 4)$$

$$\text{Institutional Vulnerability Index (II)} = \sum_{i=1}^{4} \frac{SW_i}{n} \qquad (n = 4)$$

$$\text{Attitudinal Vulnerability Index (AI)} = \sum_{i=1}^{4} \frac{SW_i}{n} \qquad (n = 4)$$

$$\text{Multidimensional Vulnerability Index (MVI)} = \frac{SI + EI + PI + II + AI}{5} \qquad (2)$$

The original values of the indicators have transformed to 0–1 based on the vulnerability level, for computing the indices. The values closer to

Zero signifies low vulnerability, whereas values closer to one denote high vulnerability. Each variable further divided into classes depending on its characteristics:

For example, nature of response divided into two classes (yes or no response), three classes, four classes, and five classes, as required. With literature support, these classes framed to demonstrate the degree of variation, as much as possible, in that particular variable. In dual classes, the values were zero and one. The indicators with three classes assigned the values 0.33, 0.67, and 1; for four classes, the values were 0.25, 0.50, 0.75, and 1; and for five classes, the values were 0.2, 0.4, 0.6, 0.8, and 1. Thus, the composite index for each component fell between zero and one. Table A3-1 lists the indicators used for the different dimensions, the classes and values, and the empirical studies that have used these indicator

Table A3-1 Social vulnerability indicators and transformed values for dimensions of vulnerability.

S.No	Indicators	Classes	Transformed values	Frequency	Percentage(%	Explanation
1	Family type	Extended	0.33	34	68	The extended family type will have morestrength in number, and have moreaccess to societal resources
		Middle	0.67	11	22	
		Single	1	5	10	
2	Household that includes family members with chronic illness/pregnancy or disability	0	0	43	86	Household with special needs will belimited in its mobility in case ofemergency.
		1	0.33	7	14	
		2	0.67	0	0	
		> 2	1	0	0	
3	Household living incommunity (in years)	>40	0.2	29	58	Household residing for shorter time maynot be aware of evacuation routes andemergency protocols.
		30-40	0.4	10	20	
		20-30	0.6	6	12	
		10-20	0.8	4	8	
		<10	1	1	2	
4	Household having past experiences with floods	Yes	0	42	84	People with previous encounters withfloods can foresee issues and problemsthat could faced.
		No	1	8	16	

Table A3-2 Economic vulnerability indicators and transformed values for dimensions of vulnerability.

S.No.	Indicators	Classes	Transformed values	Frequency	Percentage (%)	Explanation
1	Dependency ratio(dependents to totalhousehold size)	< 0.25	0.2	4	8	Infants, children, and the elderly will bemore vulnerable than young personsand adults, because of limited mobilityand dependency
		0.25-0.5	0.4	6	12	
		0.5-0.75	0.6	16	32	
		0.75-1	0.8	15	30	
		>1	1	5	10	
2	Livelihood options of thehousehold	0	1	15	30	Multiple sources of livelihood will Decrease vulnerability.
		1	0.67	30	60	
		>1	0.33	5	10	
3	Average monthly household's income (SDG)	<1,500	1	20	40	Lower income results in higher vulnerability
		1,500- 4,999	0.8	15	30	
		5,000-9,999	0.6	7	14	
		10,000-19,999	0.4	5	10	
		>20,0000	0.2	3	6	
4	Household residing in rentedhouses	Yes	1	10	20	Tenants on rent cannot repair, fortify their buildings against floods
		No	0	40	80	

Table A3-3 Physical/infrastructural vulnerability indicators and transformed values for dimensions of vulnerability.

S.No	Indicators	Classes	Transformed values	Frequency	Percentage (%)	Explanation
1	Location of the house	Between trench andriverbank	1	34	68	Low elevation and proximity to floodhazard source will increasevulnerability
		Floodplain	0.67	10	20	
		Upland	0.33	6	12	
2	Building type	*Galosse (*constructed from mud*)*	1	24	48	Type of materials used for constructionwould affect structure. *Galosse and Agad layby*localterminologies fordescribing strength of buildingmaterials used
		Agad layby (mud, brick)	0.67	16	32	
		Great beam (Brick,Cement)	0.33	10	20	
3	Building age (in years)	<10	0.2	5	10	Old houses will be structurally weaker and make household more vulnerable
		10-20	0.4	13	26	
		20-30	0.6	22	44	
		30-40	0.8	5	10	
		>40	1	5	10	
4	Household means of communication	Yes	0	40	80	Household with no access to means ofcommunication will be morevulnerable
		no	1	10	20	

Table A3-4 Institutional vulnerability indicators and transformed values for dimensions of vulnerability.

S.No	Indicators	Classes	Transformed values	Frequency	Percentage (%)	Explanation
1	Warning about last floods received by the household	Yes	0	36	72	Household that did not receive warningin last flood, indicates institution'sinefficiency
		No	1	14	28	
2	Household's level of understanding national warning system	Very high	0.2	12	24	Household that does not understand national warning system, represents enable of institution to convey properearly warning.
		High	0.4	18	36	
		Moderate	0.6	10	20	
		Low	0.8	5	10	
		Very low	1	5	10	
3	Household's awareness regarding emergencyshelter	Yes	0	40	80	Lack of awareness of household showsincapacity of institutions
		No	1	10	20	
4	Availability and circulation of emergency plans.	Yes	0	35	70	No circulation ofemergency plans by institutions mayincrease household vulnerability
		No	1	15	30	
5	Household's knowledge ofemergency protocols regarding floods	Very poor	1	5	10	Household not understanding local authority's emergency procedures will be more vulnerable
		Poor	0.75	10	20	
		Average	0.5	25	50	
		Good	0.25	10	20	

Table A3-5 Attitudinal vulnerability indicators and transformed values for dimensions of vulnerability.

S.No	Indicators	Classes	Transformed values	Frequency	Percentage (%)	Explanation
1	Community cooperation indisaster response	Very poor	1	2	4	Cooperation strength represents community attitudes and social networking towards helping each other and coping with floods
		Poor	0.8	5	10	
		Average	0.6	23	46	
		Good	0.4	10	20	
		Very good	0.2	10	20	
2	Household believing in possibility of future occurrence of floods	Low	1	35	70	Household not believing in flood likelihood might be more vulnerable
		Moderate	0.67	10	20	
		High	0.33	5	10	
3	Household feeling afraid offlood	Not afraid	1	10	20	Household not feeling afraid of flood willnot seek preparedness measuresagainst future flooding, and might bemore vulnerable
		Neutral	0.67	25	50	
		Afraid	0.33	15	30	
4	Community having land use/zoning laws and household following them.	Yes	0	40	80	Household not following urban planningregulations will be more vulnerable
		No	1	10	20	

Table A3- 6 Multidimensional vulnerability to floods prone areas in Wad *Ramly community*, (HHs = Households; n = 50)

Dimension vulnerability		Vulnerability increase from Very low to very high					Descriptive statistics	
	Class	Very low	Low	Moderate	High	Very high	Total	

	Range	<0.25	0.25-0.49	0.50- 0.74	0.75-0.99	> 1		
Social	No. of HHS	28	13	4	1	4	50	Min = 0.05 Max = 1.00 Mean = 0.4
	%	56	26	8	2	8	100	
Economic	No. of HHS	12	4	13	8	13	50	Min = 0.10 Max = 1.00 Mean = 0.45
	%	24	8	26	16	26	100	
Physical/ infrastructural	No. of HHS	11	7	12	1	19	50	Min = 0.05 Max = 1.00 Mean = 0.4
	%	22	14	24	2	38	100	
Institutional	No. of HHS	24	6	7	3	10	50	Min = 0.04 Max = 1.00 Mean = 0.34
	%	48	12	14	6	20	100	
Attitudinal	No. of HHS	13	8	15	1	14	50	Min = 0.05 Max = 1.00 Mean = 0.4
	%	26	16	30	2	28	100	
Total		8	18	10	3	12	50	

Table A3-9 Adaptation measures/strategies implemented by households to minimize the impacts of flood risk, Wad Ramly, 2019

Household with Adaptation Measures	Frequency	Percentage (%)
Yes	35	70
No	15	30
Total	50	100

Table A3-10: Adaptation Measure/Strategy

Adaptation Measure/Strategy	Frequency	Percentage (%)
Relocate residence to a safe place permanently	2	4
Transfer to an evacuation area temporarily	15	30
Restructure housing unit	10	20
Improve dike system or canal near residence	10	20
Change land use to fit new condition	1	2
Change livelihood and sources of income	2	4
Prepare household needs and safety precautions	10	20
Total	50	100