MOTT MACDONALD

Assessment for the Bor Flood Control Initiative

Scoping study

14 October 2019

Final Report

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Embassy of the Kingdom of the Netherlands
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Executive summary

The population of the town of Bor, the Capital of Jonglei State in South Sudan, suffers from recurrent floods from different sources. The authorities of Bor Municipality and Jonglei State turned to the Embassy of the Kingdom of the Netherlands in South Sudan for help. Around the globe, the Dutch are known for their water management. The Embassy responded positively and arranged for a scoping mission to investigate the likely causes and extent of flooding and to develop recommendations for potential future support in the form of a Bor Flood Control Initiative. The current report is the result of this scoping mission, implemented by a small team of consultants from Euroconsult Mott MacDonald.

Three main sources of floods or water nuisance were identified. High water discharges of Bahr el Jebel, the section of the White Nile running past Bor, result in river water levels to rise above the level of the adjacent land, potentially leading to inundation. A dyke along the river, developed around 2014-2015, keeps water out. But man-made cuts in the dyke, to release excess rainwater from town, reduce functioning of the dyke, leading to inundations. The second source of 'flooding' or nuisance by standing waters in town, stems from local rainfall in combination with a largely impermeable soil surface. This situation is aggravated by the third source of flooding, being the inflow into town of excess rainwater from inland areas to the southeast. This inflow has likely increased after development of the UNMISS camp in Khor Hong, the natural drainage pathway in a long-stretched depression leading from the southeast towards its discharge point into the Nile, north of Bor. The UNMISS camp is situated in the middle of Khor Hong, effectively blocking the natural drainage pattern.

Climate change is expected to lead to increased peaks in rainfall throughout the upper reaches of the White Nile basin (i.e. the Equatorial Lakes region), which is expected to result in higher peak flows in Bahr el Jebel. Flood risks will increase accordingly, calling for protection measures. The standard measure would be to reinforce and raise the dyke, but lessons learnt from the Dutch flood control programme *Room for the River* suggest that alternative options should also be investigated. This could for example entail diverting part of the peak flow to parallel channels in the floodplain. A participatory plan process, following best practices of Strategic Environmental and Social Assessment, is recommended to develop a sustainable solution.

Climate change is also expected to lead to higher peaks in local and inland rainfall, increasing the pressure on the town from within and from the southeast. Drainage capacity in the town is insufficient to deal with local and inland rainfall already and this will aggravate in the future. Two main solutions are proposed: to design and develop an urban drainage system to avoid standing water and related water-borne health risks in town; and redesign of Khor Hong to act as an interceptor drain to divert excess inland rainfall to the Nile, reducing inflow into town. This water can also be harvested in reservoirs along the length of Khor Hong, to help overcome water shortages in the dry season. The latter is expected to become longer as a result of climate change.

The authorities of Bor Municipality and Jonglei State have already started emergency works on the dyke and the drainage system in town, but they lack reliable and detailed-enough information on terrain elevations. In a flat area like Bor, just like the Netherlands, a high-resolution Digital Terrain Model (DTM) is a prerequisite to develop a well-functioning drainage system. A DTM helps to understand the natural drainage patterns, which need to be incorporated in a sustainable drainage plan. A first activity of a future Bor Flood Control Initiative should therefore be to obtain a high-resolution, high-accuracy DTM. The data for this needs to be collected from the air (by a small drone or small aircraft) in the dry season. The DTM would also provide urban planners with much needed information for sustainable town planning.

Bor Municipality and Jonglei State display very high ownership and commitment towards a flood control initiative, combined with a desire to set an example of sustainable spatial planning and flood control for South Sudan. It is recommended to follow up soon, with maximum capacity building within the initiative.

1 Introduction

The Embassy of the Kingdom of the Netherlands in South Sudan (EKN) is planning to continue its support in the water sector in South Sudan, including a flood control initiative to directly supplement the activities of ongoing projects. The overall aim is to ensure meaningful and secure livelihoods and better living conditions for vulnerable populations in Bor[1], Jonglei State.

This report is the result of a scoping mission in support of assessment for a flood control initiative in Bor town, the seat of Jonglei State Government in South Sudan. The scoping mission looked at the causes and extent of the current flooding problem in Bor and the current local efforts to mitigate flood risks; explored possible future flood control measures for Bor; recommends the most effective, cost efficient and context relevant viable options for flood control in Bor; and finally, recommends key considerations for developing an appropriate flood control initiative for Bor town.

1.1 Background

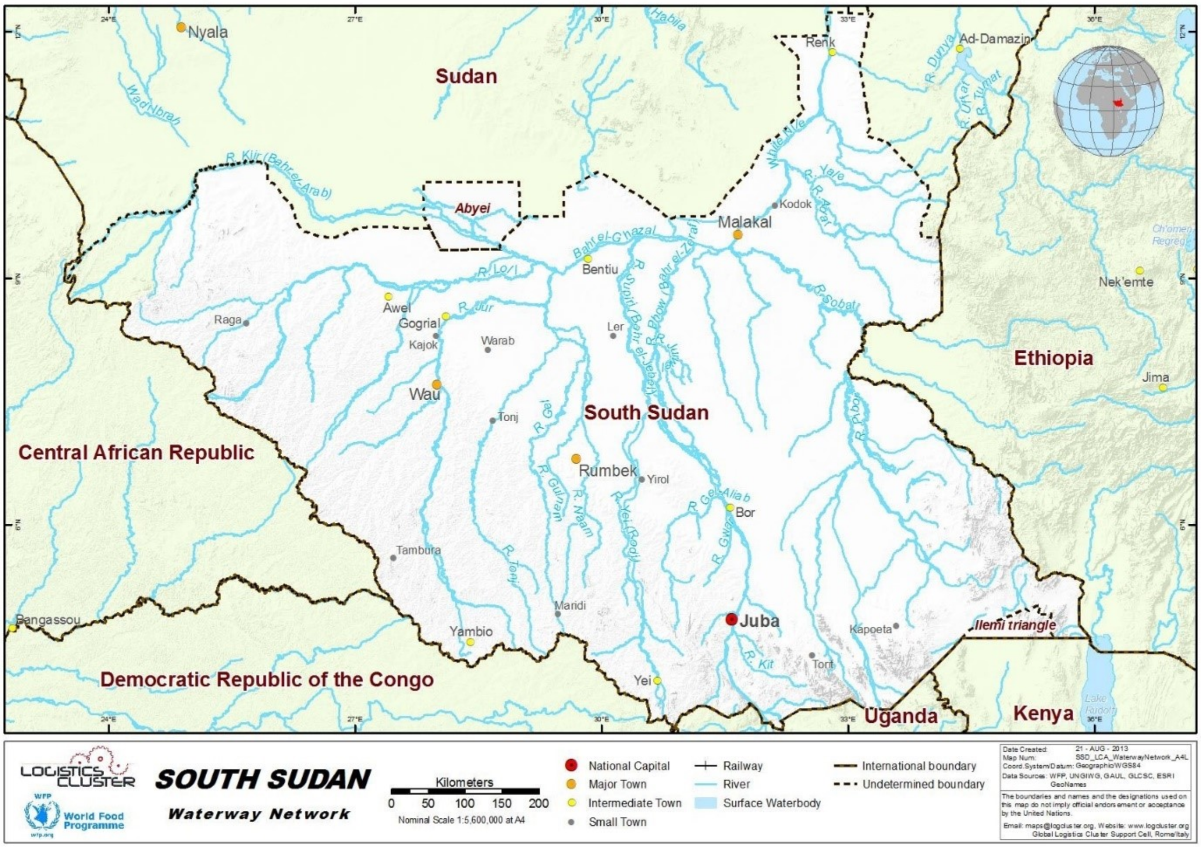
South Sudan is considered extra vulnerable to effects of climate change. Temperatures in the country have been warming 0.53 Celsius per decade in the last 30 years leading to erratic and unreliable rainfall patterns. As such floods and droughts have been recorded in parts of the country in recent years. Bor, the capital of South Sudan's Jonglei State is located on the Eastern bank of the Bahr el-Jebel (upper part of the main river of the White Nile in South Sudan, Map 1) about 180 km north of the nation's capital city – Juba. The town has an estimated population of about 120,000 people and is located adjacent to the Sudd Swamp – one of the largest tropical wetlands in the world, which floods annually covering an area between 10 km^2 to 30,000 km^2 depending on the amount of rainfall in the upper catchment of the White Nile River. The wetland is also home to variety of unique flora and Fauna while at the same time serving as a source of livelihood for of the people in the area. Due to its location, Bor is one the areas in the country that is highly vulnerable to the effects of climate change, with high exposure to floods. The rampant flooding has curtailed the potential of local populations to support themselves and live in safe environments. Combination of a weak institutional framework and capacity to respond to the effects of climate change as well as poverty and low education levels are among the key challenges. Contributing factors to the adverse effects of climate change in the country include environmental degradation as a result of overstocking of cattle; poor farming methods; deforestation; poor land use planning; and weak climate change adaptation strategies and enforcement mechanisms, among others.

Cattle keeping, fishing and sedentary agriculture are some of the main sources of livelihoods. These livelihoods options have always been vulnerable to the effects of climate change. The vulnerability has been worsened by successive political instabilities in South Sudan, the latest of which is the civil conflict that started in December 2013 with Bor town exchanging hands several times between Government and opposition forces. Nationally the conflict has displaced 1.76 million people internally and another 2.47 million as refugees in neighbouring countries. However, since 2015, Bor has been gradually recovering from its past and is now referred to as Phoenix town by some due to its ability to rejuvenate from ruin. With the relative stability, displaced populations are gradually returning, and livelihoods are recovering. These returnees however need to be supported so that they can rebuild their lives and live in safe environments free from the hazards of climate change.

Over the past decades, successive administrations in South Sudan made a series of attempts pertaining to floods control in the central part of Bahr el-Jebel (from Mangalla in Jubek State to Poktap in Jonglei State), where Bor Town is situated; but these have been inadequate to prevent inundation of the flat low-lying areas. Reports indicated that high inflows from the upper catchment areas coinciding with local rainfall frequently lead to flooding that leaves extensive areas inundated. Populations have responded through their local capacity and established different types of dykes to protect their

[1] In local language, Bor means 'flooded land'.

homesteads, land and properties – such as Homestead dykes (Photo 2), Location dykes to protect village centres and towns, Village dykes to protect farms and Overall dykes (Photo 1) to protect groups of villages and corridors of wet season pasturelands.



Map 1: South Sudan waterway network (WFP, 2013)

Photo 1: Overall dyke along the Nile in north-west of town, with damage by livestock trampling

Photo 2: Homestead dyke in Bor town

For various reasons, maintenance of the overall dykes has ceased to be carried out leading to extensive inundation almost every year. In the past, NGOs and UN Systems have implemented projects to repair the dykes. Over 2002-3, CARE/FAO/WFP/GIZ and the communities rehabilitated certain stretches of the dykes, however without lasting impact and without contributing to improved maintenance capacity at State, County and Municipal levels. The lack of a clear plan to improve flood control infrastructure and overall water management; and of people implementing capacity has been detrimental in the sense that the town of Bor is still being overwhelmed on an annual basis by flood waters, with the cause being heavy rains and high river inflows. Indeed, reports manifest that even health facilities and other public utilities are being flooded and rendered useless every year, leading to interruption of public services delivery. Observations by the mission team confirm this for August 2019.

As part of the South Sudan Multi Annual Country Strategy (MACS) of the Government of the Netherlands, the Embassy in Juba wishes to contribute to addressing the effects of climate change through among others flood control and climate change adaptation for farmers and vulnerable populations. This will be carried out in the “Hubs of Stability” of South Sudan. Bor, being one of the Hubs, has big potential to evolve into a thriving town with various livelihoods options such as fishing, agriculture, cattle production and river transport. However, this potential has been repeatedly hindered by a number of shortcomings. Key amongst them is the annual flooding of the town.

Over the years, there has been considerable Dutch presence in Jonglei State since the 1980s, including by Euroconsult and its predecessor Ilaco in and around Bor. Now there are several ongoing projects such as addressing root causes (ARC) of immigration, community policing and peace building, agribusiness development and youth employment through private sector development, etc. The proposed flood control activity is expected to directly supplement the activities of the ongoing projects and ensure meaningful and secure livelihoods and better living conditions for the vulnerable populations.

1.2 Objectives of the scoping mission

The overall objective of the scoping mission, of which this is the main report, was to establish the causes and the extend of the current flooding problem in Bor and recommend practical, cost effective and context relevant solutions to this challenge. This scoping mission was initiated as a first step with the potential of leading to development of a comprehensive flood control activity for Bor Town. This report therefore provides information on the need for subsequent assessments and activities that would inform formulation of a potential activity in the near future. The scope of this scoping mission was hence summarised in four objectives:

- Identify the causes and extent of the current flooding problem in Bor Town;
- Explore possible flood control options for the town;
- Recommend the most effective, cost efficient and context relevant option for flood control in the town;
- Recommend key considerations for developing a flood control activity for Bor town.

1.3 Structure of this report

The methodology of this report is described in Chapter 2. This consisted of two main steps: a desk study which includes a hydrological assessment (Chapter 3) and prepared for the field mission. The results of the latter are provided in Chapter 4. Based on the desk study and the field mission, recommendations for a future Bor Flood Control Initiative are formulated in Chapter 5. This chapter summarises the recommendations from the desk study and the field mission; lists a series of key considerations for context relevant flood control solutions; and provides the main elements of an intervention logic for a Bor Flood Control Initiative in the form of proposed objectives and programme components. The appendices of this report contain the support letter from South Sudan's Ministry of Water Resources and Irrigation (Appendix A); brief meeting notes of all meetings held during the field mission to South Sudan (Appendix B); and an overview of typical unit costs of civil engineering equipment and materials, from a Juba-based contractor (Appendix C).

2 Methodology

The scoping mission consisted of a remote desk study and a subsequent fact-finding mission to Bor, the headquarters of Jonglei State in the Republic of South Sudan. The on-site fact-finding mission included extensive field visits, interviews with flood-affected population members, and meetings with National, State, and Municipal authorities and professionals. All information sources pulled together provided adequate understanding of the situation.

Desk study: We undertook a review of relevant secondary information available online or at national and regional level, to inform the study. Previous interventions in Jonglei through the Pengko Pilot Project of the 1980s; elaborate documentation on the Jonglei Canal; the hydrology of the Nile (Bahr el-Jebel and the Sudd Wetlands); and past attempts pertaining to flood control in the area, were important components of this study.

National authority: Before travelling to Bor, a visit was paid to the Under Secretary (US) of the Ministry of Water Resources and Irrigation of South Sudan in Juba. The US confirmed his full support and provided the team with a support letter.

Local authority: State and Municipal authority interviews were held, to be informed on initiatives already undertaken by the Municipality and the State authorities. In these meetings, participants also studied available information including spatial plans and GIS maps.

Community interviews: On site, the field team, consisting of the Team Leader (from the Netherlands, supported by our interpreter), the Land and Water Development Expert (from South Sudan), the Mayor of Bor and technical directors from Jonglei State Ministry of Physical Infrastructure, interviewed flood prone populations along the banks of the Bahr el-Jebel in Bor town as well as those living more inland, in low lying neighbourhoods suffering from standing water and lack of stormwater drainage and in relatively dry neighbourhoods through which drainage canals could be developed to relief upstream wet neighbourhoods. These short and informal interviews proved critical in developing the team's understanding of historical and current experiences of the population, and of how they have been able to deal with the situation in the past and at current. The field team also asked the population about their own recommendation to address this flooding. While in the field, the progress of emergency stormwater drainage works, carried out under the auspices of the Mayor and the Ministry of Physical Infrastructure, was inspected and the population was asked about their opinion on the effectiveness of these works.

The general programme for the mission was set out as in the sections below.

2.1 Meetings and Reporting

- Kick-off meeting at EKN Juba, at which we:
  - Re-presented our plan for the scoping mission.
  - Agreed on the methodology and the data collection tools.
  - Agreed on key stakeholders to meet and visit
  - Agreed on key data, reports, plans
- Consultation with National Ministry of Water Resources and Irrigation, to obtain a support letter for the assignment and to see what data is available.
- Preparation of Aid Memoire in the form of a comprehensive PowerPoint presentation, which was presented at two occasions:
  - At a dedicated extended Jonglei State Cabinet Meeting (with participation of the Governor, the Deputy Governor, the Cabinet of Ministers and its Advisors, several Members of Parliament, the Vice Chancellor of the Dr John Garang Memorial University of Science and Technology, the Mayor of Bor Municipality, Directors of the Jonglei Ministry of Physical Infrastructure, etc;
  - At a debriefing meeting to the Embassy of the Kingdom of the Netherlands in Juba.

- The PowerPoint presentation reports the findings of the field mission and responds to the key objectives of the mission. In the debriefing meeting it was agreed that the comprehensive presentation served the entire purpose of an Aide Memoire. Subsequently, no separate written Aide Memoire was required, and the consultant was requested to continue preparation of the main report instead.
- The final report (the current document) was submitted to the Embassy for comments and subsequent finalisation.

2.2 Remote desk study

The desk review consisted of the following elements:

1. Literature review and collection of available data from previous projects / surveys / studies (e.g. hydrological data, topographic and soil maps, etc.) and data available from satellites (e.g. land use, flooding extent, topography, etc.).
2. Interview of Dutch former rural development coordinator for Bor / Jonglei, Dr Sjoerd Zaanen (Tong Mabior)
3. Preliminary hydrology study
4. Planning of the field mission
5. Development of scope for fact-finding

2.2.1 Literature review and collection of available data

There is quite some relevant literature available in which the Mongalla flow records are studied as Mongalla defines the inflow into the Sudd wetlands. Several publications were read to obtain a basic understanding of the area and its hydrological challenges, in preparation for the field mission. It is also known that a two-dimensional (2D) hydrodynamic assessment of the Nile swamps in southern Sudan has been carried out using DHI MIKE 21 software, based on a ground referenced and corrected Shuttle Radar Topography Mission (SRTM) digital elevation model. The team members tried to access this model but did not succeed. Other relevant primary (e.g. flow records) and remote sensing data were collected and reported in the hydrology study (Chapter 3 of this report). It needs to be noted however that no additional detailed analysis of primary data could be done at this stage. Recommendations are included in this report on what other data might be needed for a future flood control initiative and or what kind of analysis needs to be done.

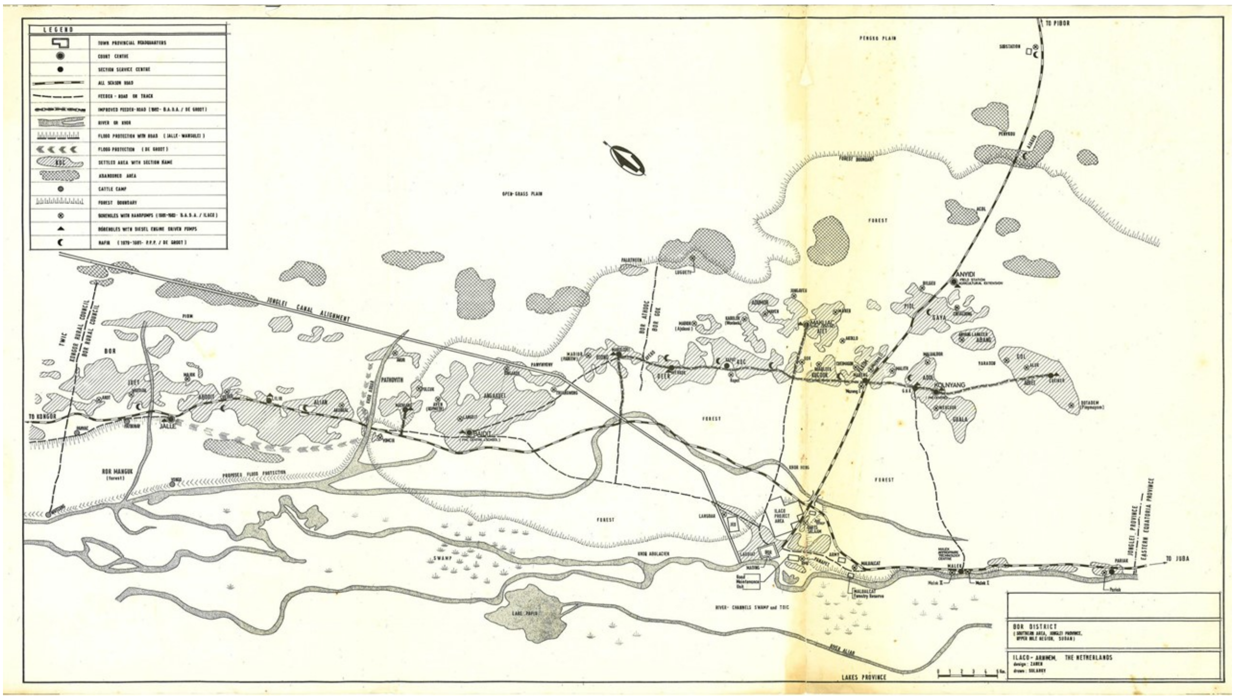
2.2.2 Interview with Tong Mabior

The team met with Dr Sjoerd Zanen, the Dutch anthropologist who lived and worked in and around Bor in the late 1970's / early 1980's. Locally he was given the name of Tong Mabior (White Spear). Dr Zanen recently wrote a book[2] on his experiences and provided the Team Leader with a comprehensive background on the environmental and social situation in the area. He also provided the team with a copy of a map from around 1980, on which the proposed trajectory of the Jonglei Canal (which would start at Bor) and the site of the pilot area for agricultural mechanisation and irrigation are depicted, as well as, importantly, the trajectories of main Khors (longitudinal depressions in the landscape, which act as main discharge channels for inland sheet flow) (Map 2).

2.2.3 Planning of field mission

Logistical planning of the mission comprised detailed preparation of itineraries and security, and was supported by Mott MacDonald (MM) Head Quarters and the national office of MM in Juba.

[2] Sjoerd Zanen, 2018. *Tong Mabior, In het gebied van de Boven-Nijl – tussen verleden en toekomst*. Occasional Publication 33, African Studies Centre Leiden, the Netherlands. ISBN: 978-90-5448-170-6



Map 2: Proposed Jonglei Canal trajectory, starting at Bor, around 1980 (source: Ilaco , Arnhem, the Netherlands)

The field mission in Bor was planned jointly with the local authorities. Lord Mayor Dr Mach Martin Majier Gai was instrumental in preparing a detailed programme including meetings with State and Municipal Authorities and extensive field visits. In order to debrief the authorities on the findings and recommendations from the mission, the field mission was concluded with a special debriefing meeting of the extended Cabinet of Jonglei State, attended by Members of Parliament, the Vice Chancellor of Dr John Garang Memorial University of Science and Technology, the Mayor of Bor, and others.

2.2.4 Development of scope for fact-finding

In preparation for the mission, questionnaires and discussion guidelines were prepared. Based on the excellent preparation by the local authorities, in particular the Mayor of Bor Municipality and the Director General and the Director of Survey of Jonglei State Ministry of Physical Infrastructure, the need for formal questionnaires and interviews became less relevant. Instead, the team held several in-depth technical discussions with relevant ministries/institutions; and most importantly, spent considerable time in the field, studying the situation on the ground and holding informal interviews with the local population. In addition, a formal visit was paid to the UNMISS camp to be informed about their water management on-site, and the debriefing with the extended Cabinet meeting was arranged. The technical scope comprised external, internal, and inland based flood risks; in other words, the Nile and its dyke embankment, urban drainage, and sheet flow coming in from the southeast and its discharge through Khor Hong, where UNMISS camp is located.

2.3 Visit to Bor

The visit to Bor yielded a series of formal and technical meetings, as well as extensive field visits to affected areas. Both the meetings and site visits were geared towards obtaining the best possible understanding of the causes of flood risks and potential remedies. Moreover, the need for integrated spatial planning became increasingly clear, leading to addressing this as another crucial topic in meetings and field observations.

3 Hydrology desk study

This chapter presents a brief assessment of the hydrology of the upper White Nile catchment, upstream of Bor, in order to understand the main factors influencing the external flood risks from the river as well as internal flood risk from local rainfall. Available quantitative data were used from literature and international (online) sources. Quantitative data were not available for the contribution of sheet flow from inland rainfall. This phenomenon is addressed qualitatively in this report, and mainly in Chapter 4, covering the field visits and in Chapter 5, recommendations.

3.1 Introduction

Located on the east bank of the upper White Nile main stem (the Bahr el Jebel) at the southern extent of the Sudd, South Sudan's vast central wetlands, the city of Bor was the headquarter of the former Bor District during the British Administration; of Jonglei Province up to mid 1970s; of Jonglei State afterwards; and now of the new Jonglei State (the then Bor District). Since 2016 the town of Bor has been upgraded to a Municipality. With a population of over 120,000 people and its strategic location 180 km north of South Sudan’s capital city, Juba, it could experience a quick growth, acting as an economic hub with several livelihood options such as fishing, agriculture, cattle production and river transport. With a relative stability after the recent civil war, displaced populations are gradually returning, and livelihoods are recovering. However, Bor is highly vulnerable to floods, and returnees need to be supported so that they can rebuild their lives and live in safe environments free from the hazards of climate change. However, Bor is highly vulnerable to floods.

Reports indicate that high inflows from the upper White Nile catchment coinciding with local rainfall frequently leads to flooding that leaves extensive areas inundated. The population and authorities, with limited support from some development partners, have responded through local solutions and established different types of dykes to protect themselves. Poor maintenance of these dykes and the lack of a defined flood control plan means that Bor is still being flooded on an annual basis.

3.2 Flood history

Evidence of flooding in Bor is scarce and mainly anecdotal, with no systematic records or hydrometric information. Johnson[3] (1992) through interviews and local administrative reports reconstructed the flood history of South Sudan, including the following flood episodes affecting Bor:

- December 1909 due to heavy rain and high Nile;
- 1916-19, 18 months of floods from Pibor to Nile. Highest in living memory, with whole districts submerged from Bor to Malakal;
- 1927, high river, Bor pastures flooded, grass scarce and late rains ruining Bor/Aliab crops;
- 1929, very high river in September affecting Bor, followed by very heavy rains in October;
- 1932, Bor District submerged;
- June 1933, high river with Bor toic under water;
- 1943, high river owing to changing sudd conditions near Bor;

[3] Johnson, D. H. (1992). Reconstructing a history of local floods in the Upper Nile Region of the Sudan. The International Journal of African Historical Studies, 25(3), 607-649.

- Jun-Nov 1944, worst flood in Bor District since 1930s;
- 1970, very high floods;
- 1975, sharp high flood.

After the civil conflict and with the onset of digital sources, reports of flooding have increased:

- September 2013[4]. More than 5,000 families have been displaced by severe flooding in Bor, the state capital of Jonglei in South Sudan. The floods were caused by the White Nile River.
- September 2017[5]. An overflowing Nile River and heavy rains flooded the South Sudanese town of Bor this week, sweeping away homes, leaving families without food or shelter.
- May 2018[6]. More than 2,000 internally displaced people living in the protection site next to the United Nations base in Bor, in Jonglei region of South Sudan, have had their homes destroyed by flooding caused by heavy rains. The rains first flooded access roads in the protection site making them impassable but continued showers have left the sea of makeshift canvas shelters submerged in water.
- June – August 2019.The most recent floods were a reason for Netherlands' Ambassador Janet Alberda to visit Bor for a field visit with Mayor Dr. Mach Majier and the Governor of Jonglei State, Maker Thiong Maal. During this visit, the Ambassador announced the scoping mission of which this report is the result.

Conversely, remote sensing data from the Global Surface Water Explorer[7], which combines Landsat imagery covering the last 35 years and offering the location and temporal distribution of water surfaces at the global scale, would not point towards a significant flood exposure in Bor. Figure 1 shows on the right the maximum extent of water between 1984 and 2018, where the map on the left captures both the intra and inter-annual variability and changes, with occurrence being a measurement of the water presence frequency (expressed as a percentage of the available observations over time actually identified as water). However, the ability of satellite images to capture open water in swamps (possibly including shallow standing water on land or temporary sheet flow) is questionable. So, these findings had to be verified on site.

[4] http://floodlist.com/africa/floods-jonglei-sudan
[5] https://www.voanews.com/africa/floods-wash-away-homes-south-sudans-bor
[6] https://peacekeeping.un.org/en/floods-devastate-homes-un-protection-of-civilians-site-bor
[7] https://global-surface-water.appspot.com/#data

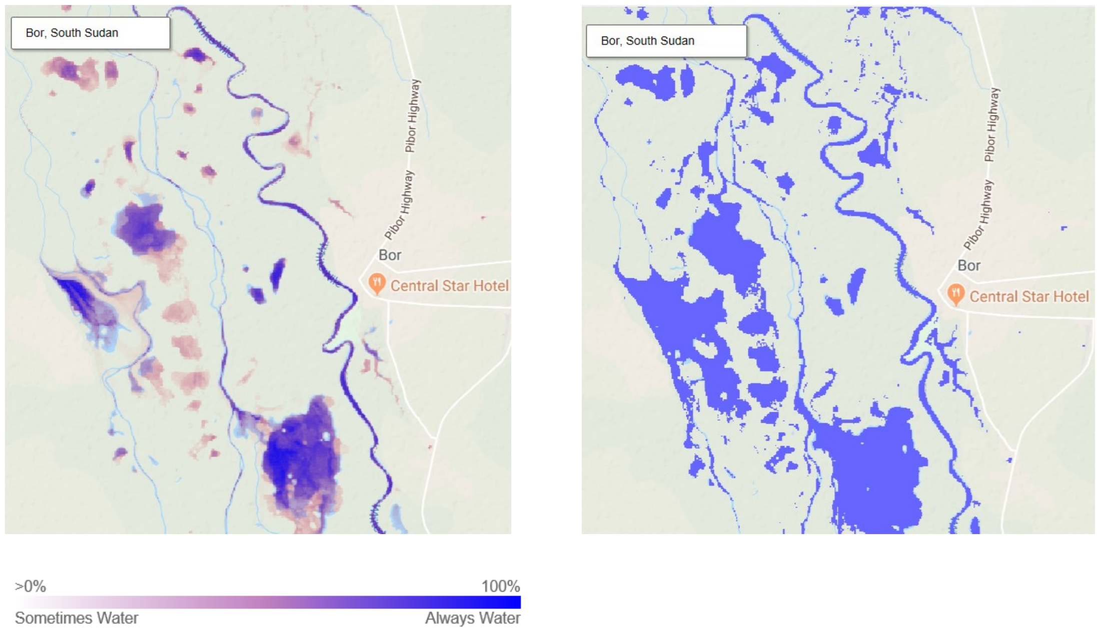


Figure 1: Surface water occurrence (left) and maximum water extent (right) in Bor

3.3 Available data

3.3.1 Topography-based natural drainage of internal rainfall and inland sheet flow

The topography of the White Nile floodplain and the area surrounding Bor has been obtained based on the Shuttle Radar Topography Mission (SRTM)[8] Digital Elevation Model with a horizontal resolution of 1 arc-second (around 30m). This joint project of NASA, the German and Italian space agencies, and the National Geospatial-Intelligence Agency, used an imaging radar obtained in February 2000 to map the surface of Earth numerous times from different perspectives. The combination of these radar data was processed to produce a global topographic map created by bouncing radar signals off Earth's surface and back to the shuttle.

The permanent and ephemeral streams potentially affecting the settlement, in addition to the White Nile, have been delineated based on this DEM and are presented in Map 3, where they are overlaid on the settlement plan according to the existing 'Urban Master Plan' of Bor. During the field visit and related discussions it became clear, however, that this plan primarily looks at settlement and related allocation of plots. Whereas it does provide for some space for public areas other than roads, it does not incorporate reservations for parks, public service distribution networks, et cetera. Moreover, many areas reserved for public open spaces are currently occupied by illegal settles / squatters. The municipality intends to clear these areas in the near future.

Five main sub-catchments can be distinguished within the 'urban perimeter', considering Khor Hong the South/Eastern natural boundary thereof. It needs to be noted that the UNMISS camp and adjacent POC camp, both situated within Khor Hong, are not indicated in the 'Master Plan' settlements. Moreover, the most Eastern and Southern neighbourhoods have not been

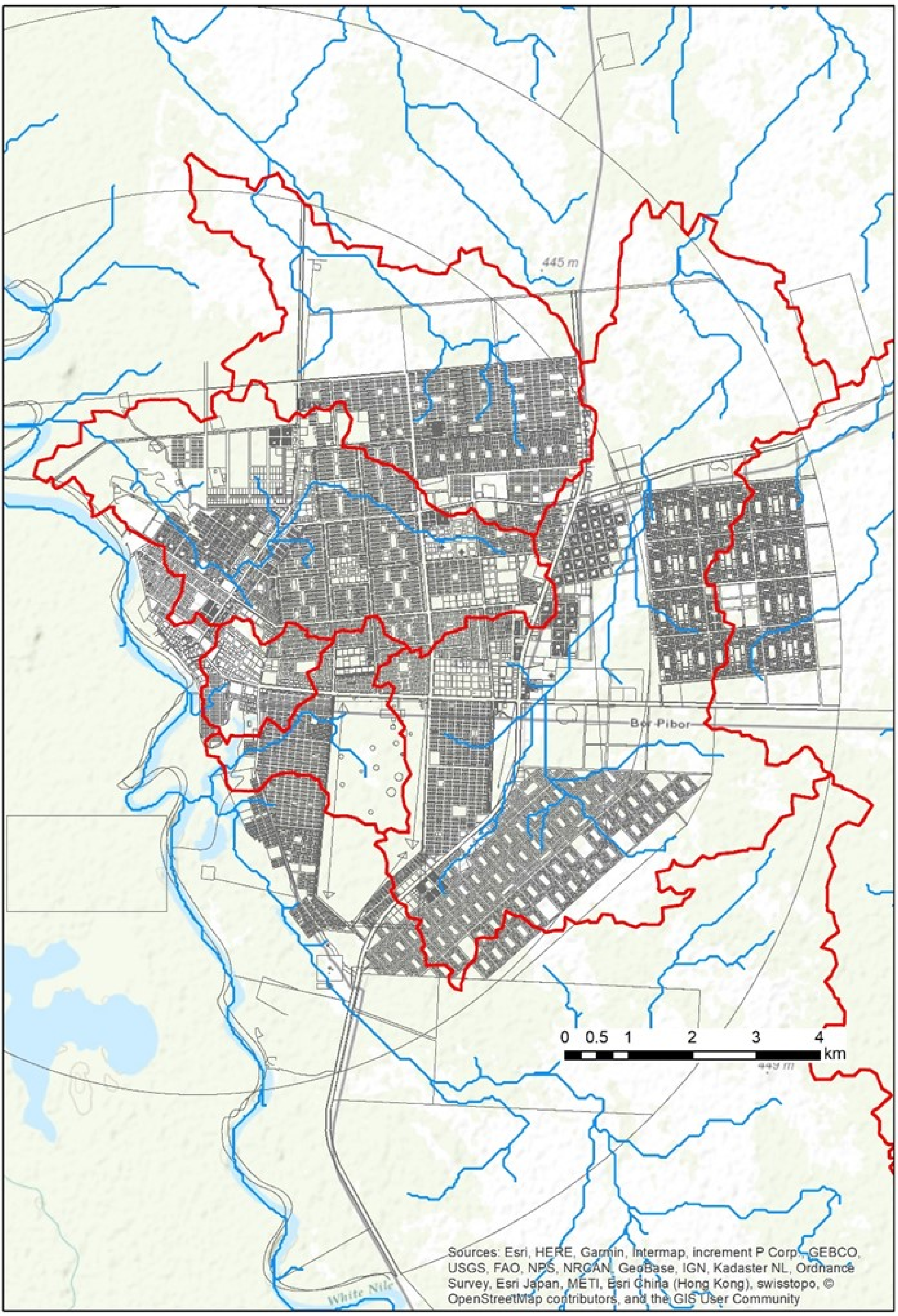
[8] https://www2.jpl.nasa.gov/srtm/

developed yet, and not all of the land in the other neighbourhoods has been surveyed and/or handed out.

Three of the sub-catchments would naturally slope (and therefore discharge) to the West, directly into the Nile. The other two slope and discharge in a Northerly direction. The lack of infiltration and absence of an effective drainage systems in town (as was confirmed in the field), poses a risk during the rainy season.

The not-demarcated sub-catchment further South of Bor, also drains West into the Nile. It first however has to cross the elevated main road to Juba. Culverts underneath this road might not be large enough for peak flows, which might lead to excess waters entering the adjacent sub-catchments to the North and East as sheet flow, aggravating the situation there.

It needs to be noted here the topographical / elevation data used for this exercise are based on coarse, low-resolution SRTM (circa 30 m resolution). For higher accuracy and better design of a surface drainage system, a higher resolution is required. This could be obtained by e.g. LiDAR technology using a small aircraft or drone-based recordings.



Map 3: Natural drainage network of Bor, based on SRTM, overlaid on 'Urban Master Plan' Bor

3.3.2 External flood risk from the Nile

A description of the flooding mechanism along the Nile in South Sudan is provided by Sutcliffe (1974)[9]. The river meanders in one or more channels from one side of the restraining trough to the other, dividing the floodplain into a series of isolated basins or islands. These basins lie below the levels of the alluvial banks of the river, through which a number of small channels carry spill. At the downstream end of each basin, where the river meets the high ground, a large channel carries spill back into the river. Further north, where the basins are not confined, the system of channels becomes more complicated, but the pattern can be visualized as a series of basins receiving spill and discharging some spill back to the river.

Below Mongalla, the channel capacities are less than the flood flows and the alluvial channels themselves are above the floodplain. Thus, excess flows leave the river through spill channels and inundate wide areas on either side of the river. This inundation is limited by higher ground only in the south of the swamps. Flooding is then controlled by the relative levels of river and river bank. Surveys showed that the alluvial bank is extremely even in height and falls steadily with respect to water level from south to north. Therefore, flooding through spill channels and over the bank increases downstream, and spreads upstream as the river rises. At the lower end of the reach, near Bor, spill through channels is continuous and the bank is submerged at an inflow of about 65 x 106 m3 per day (around 750m3/s)

Figure 2 and Figure 3 respectively show elevations and a cross section of the Nile floodplain at Bor. The majority of the town is located at high ground, but some neighbourhoods are susceptible to flooding when the Nile spills the right bank.

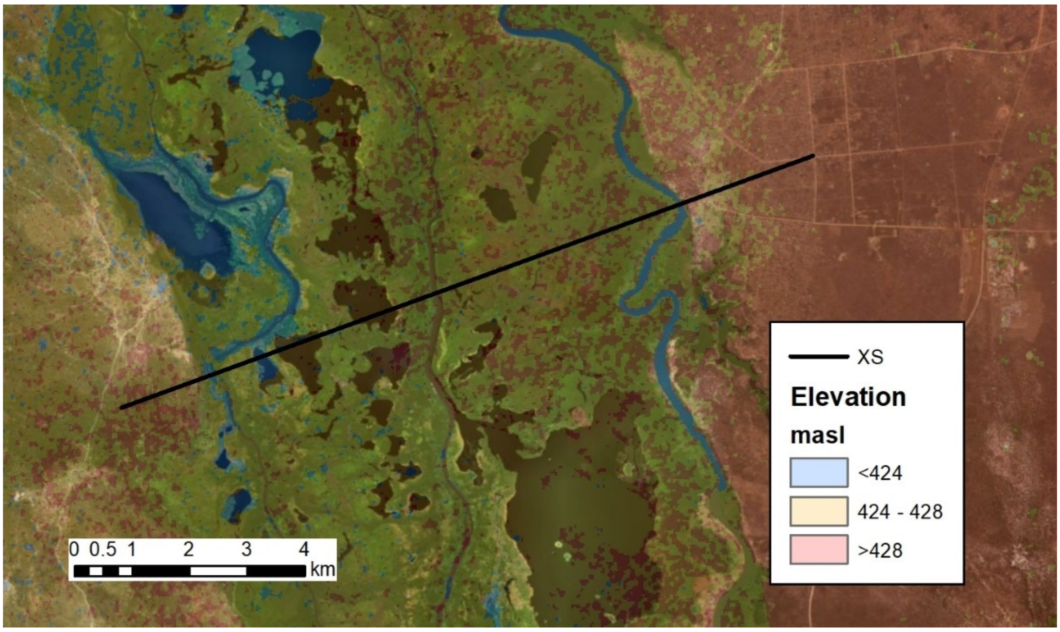


Figure 2: Floodplain topography in the vicinity of Bor

One should note the significant width of the floodplain (~12km) which contrasts with the relatively small bankfull capacity according to Sutcliffe (1974). However, longitudinal river slope is quite mild, and the floodplain is made up of depressions, islands and multiple interconnected branches with thick vegetation, which reduces the effective capacity of the river as a whole.

[9] Sutcliffe, J. V. (1974). A hydrological study of the southern Sudd region of the Upper Nile. Hydrological Sciences Journal, 19(2), 237-255.

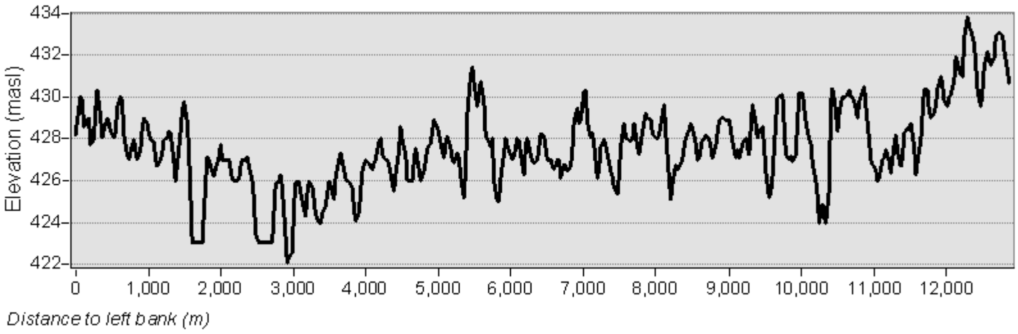


Figure 3: Cross section along the line 'XS' in figure above (source of data: SRTM)

3.3.3 Rainfall

As indicated by Sutcliffe (1974) rainfall is affected by elevation over South Sudan as a whole. Because rainfall is usually convective, it is extremely variable in time and place and average figures can be misleading. However, the mean rainfall decreases steadily from south to north, from 1200 mm at Nimule south of Juba to 850 mm near Bor. The seasonal variation is marked with the double equatorial peak evident with a dry season lasting for five months at Bor (Figure 4). As the average rainfall decreases, the variability of annual totals increases from 17 per cent at Juba to 26 per cent at Bor.

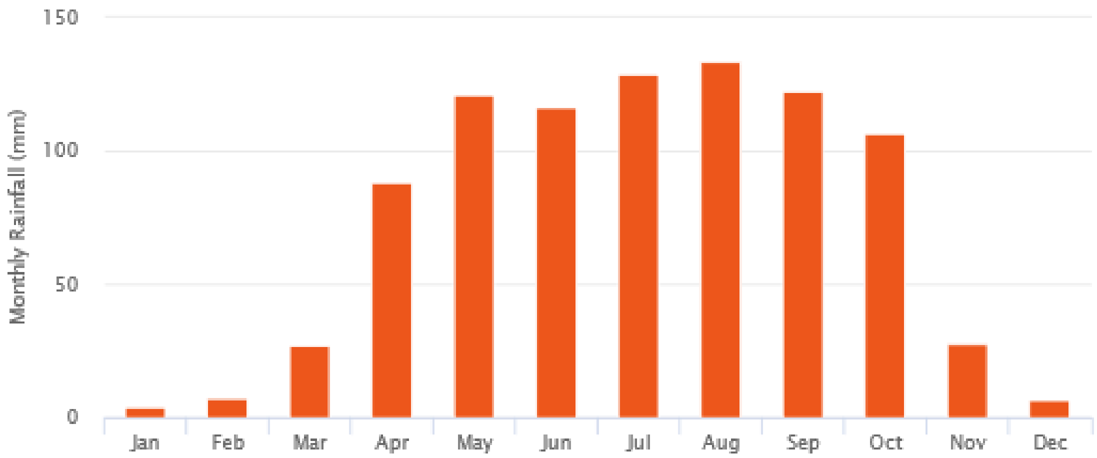


Figure 4: Mean monthly rainfall distribution at Bor (source: River Nile Water Resources Atlas)

A similar rainfall pattern, though with slightly different numbers (possible due to a different range of years over which averages have been taken), is provided in Table 1[10], alongside temperature data.

[10] Source: *Climate-Data.org* (altitude: 430m)[8], taken from Wikipedia https://en.wikipedia.org/wiki/Bor,_South_Sudan on 04/09/2019

Table 1: Climate data for Bor, South Sudan

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C	36	36.6	36.6	34.9	33	31.8	30.3	30.5	31.5	33.1	34.4	35.1	33.7
Daily mean °C	27.9	28.6	29.6	28.6	27.4	26.6	25.5	25.5	26.2	27.2	27.6	27.3	27.3
Average low °C	19.9	20.6	22.6	22.4	21.8	21.5	20.8	20.6	21	21.3	20.9	19.5	21.1
Average precipitation mm	2	5	32	80	119	112	126	150	124	105	32	4	891

There is no publicly available gauged daily rainfall data in the vicinity of Bor. The closest WMO station is located in Juba, but the series is rather incomplete. Given this, the following two daily rainfall datasets have been consulted for more detailed analysis:

- Climate Hazard Group InfraRed Precipitation with Station[11] (CHIRPS version 2.0) 1981-2019. It is a quasi-global rainfall dataset spanning between 50°N and 50°S. It incorporates 0.05° (approximately 5km) resolution satellite imagery with in-situ station data to create gridded rainfall time-series for trend analysis.
- CPC Global Unified Gauge-Based Analysis of Daily Precipitation[12] developed at NOAA Climate Prediction Center based on thousands of rain gauges across the world, with the aim of creating a suite of unified precipitation products with consistent quantity and improved quality by combining all information sources available and by taking advantage of the optimal interpolation objective analysis technique. It covers the period from 1979 to date with 0.5° spatial resolution.

Available series at Bor are shown in Figure 5 and Figure 6. CPC rainfall shows a period of out or range maxima between 1999 and 2008, which should be considered with caution. Table 2 presents the annual series of maximum daily rainfall derived from both datasets. It is important to highlight the annual maxima in 2013, 2017 and 2018 do not coincide in time with the reported floods at Bor, which would again point towards a Nile origin of these flood episodes.

[11] Funk, C., Peterson, P., Landsfeld, M., Pedreros, D., Verdin, J., Shukla, S., ... & Michaelsen, J. (2015). The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes. Scientific data, 2, 150066.

[12] Chen, M., P. Xie, and Co-authors (2008), CPC Unified Gauge-based Analysis of Global Daily Precipiation, Western Pacific Geophysics Meeting, Cairns, Australia, 29 July - 1 August, 2008.

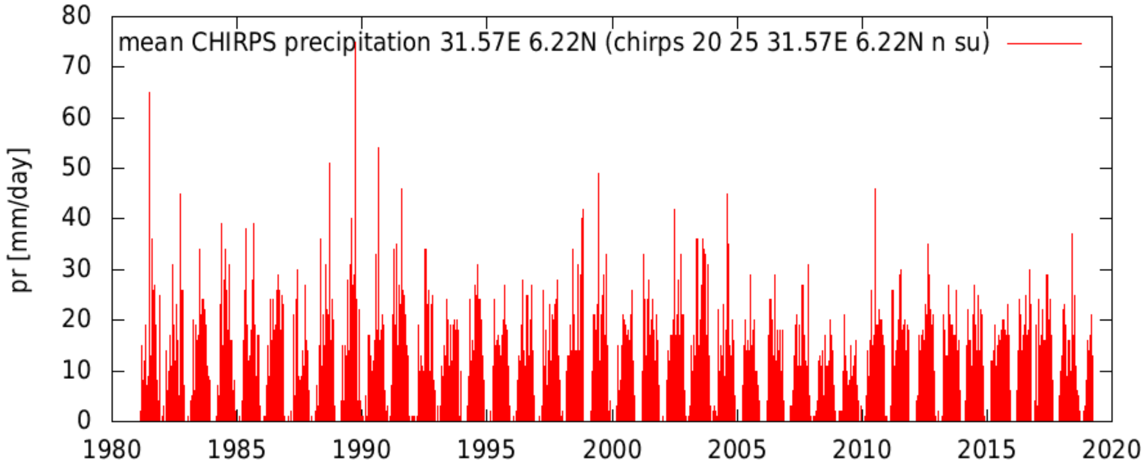


Figure 5: CHIRPS daily precipitation series at Bor (source: KNMI, the Netherlands)

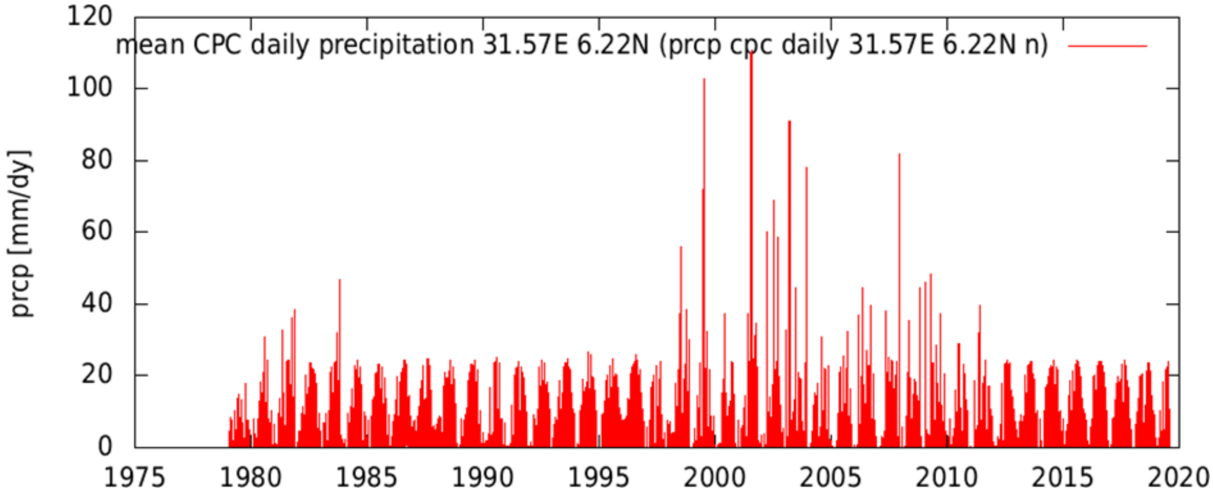


Figure 6: CPC daily precipitation series at Bor (source: KNMI, the Netherlands)

Table 2: Estimated daily rainfall maxima at Bor (Source: CHIRPS and CPC)

Year	CHIRPS rainfall Annual maximum	Date	CPC rainfall Annual maximum	Date
1979			18	14-Oct
1980			31	07-Aug
1981	65	25-Jun	39	10-Nov
1982	45	02-Oct	24	23-Jul
1983	34	25-Jun	47	24-Oct
1984	39	14-May	24	27-Jul
1985	39	07-Sep	23	13-Jul
1986	29	31-Aug	24	23-Aug
1987	30	06-Jun	25	20-Aug
1988	51	18-Sep	24	08-Aug

	CHIRPS rainfall		CPC rainfall	
1989	75	23-Sep	24	01-Sep
1990	54	28-Aug	25	04-Aug
1991	46	08-Aug	24	19-Jul
1992	34	14-Jul	24	13-Jul
1993	24	17-May	25	26-Aug
1994	31	13-Aug	27	19-Jul
1995	27	06-Sep	25	13-Aug
1996	28	06-Jun	26	10-Aug
1997	28	21-Oct	24	20-Aug
1998	42	11-Nov	56	11-Jul
1999	49	21-Jun	103	20-Jul
2000	26	21-Oct	37	07-Jun
2001	33	04-Apr	111	02-Aug
2002	42	28-Jun	69	08-Jul
2003	36	26-May	91	17-Mar
2004	45	01-Aug	31	06-Aug
2005	29	09-Jul	33	08-Sep
2006	29	08-Jul	45	01-May
2007	31	07-Nov	82	08-Dec
2008	20	24-Sep	44	21-Oct
2009	21	11-Apr	48	28-Apr
2010	46	04-Jul	29	02-Jul
2011	30	29-Jul	40	21-May
2012	35	14-Aug	25	12-Aug
2013	27	13-Jun	24	29-Aug
2014	27	06-Jul	24	05-Aug
2015	23	29-Oct	24	29-Jul
2016	30	14-Sep	24	25-Aug
2017	29	27-May	24	16-Aug
2018	37	01-Jun	24	04-Sep

Source : CHIRPS and CPC

3.3.4 Flows

The Mongalla station located upstream of Bor and between the town and Juba offers the only relevant flow series on the White Nile near the area of study. Figure 7 shows the available monthly flows series which spans from 1912 to 1982 and has been retrieved from the Global River Discharge (RivDIS) database[13]. One recognises the presence of the severe floods occurring in 1917 as well as the significant increase in flows after 1961 due to a rise in the outflows from Lake Albert upstream, and the decline which occurred afterwards. The flows at Mongalla have not been measured after 1983, but an indication of the flows since that date can be inferred from the Lake Victoria level or outflow series, showing that the decline has continued fairly steadily, interrupted by rises in 1978-1980 and 1998 and by seasonal variations. Despite the marked effect of the lake level on the baseflow component of the Mongalla flows, there is no

[13] Vorosmarty, C. J., B. M. Fekete, and B. A. Tucker. 1998. Global River Discharge, 1807-1991, V[ersion]. 1.1(RivDIS). ORNL DAAC, Oak Ridge, Tennessee, USA. http://dx.doi.org/10.3334/ORNLDAAC/199

evidence from the flows before and after 1961 of a corresponding increase in the seasonal torrent flows (see Figure 8).

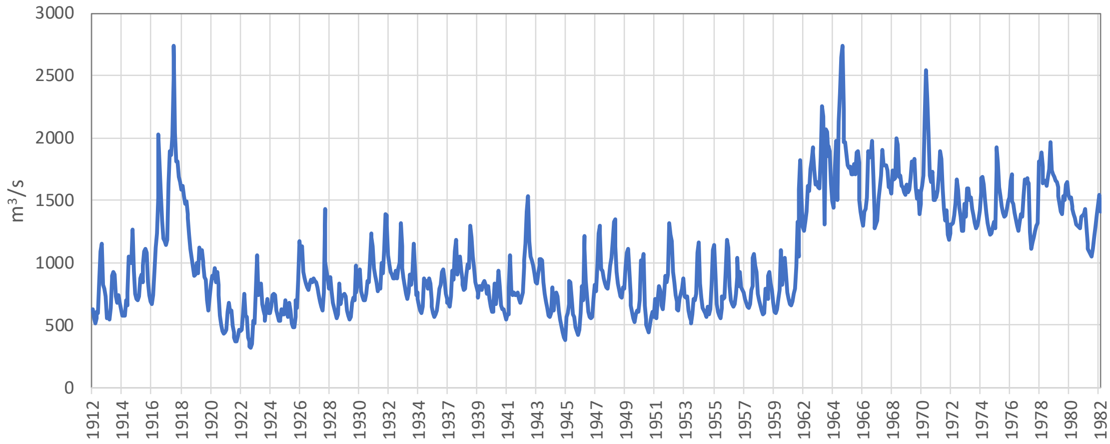


Figure 7: Monthly flows of Nile at Mongalla (Source: RivDIS v1.1)

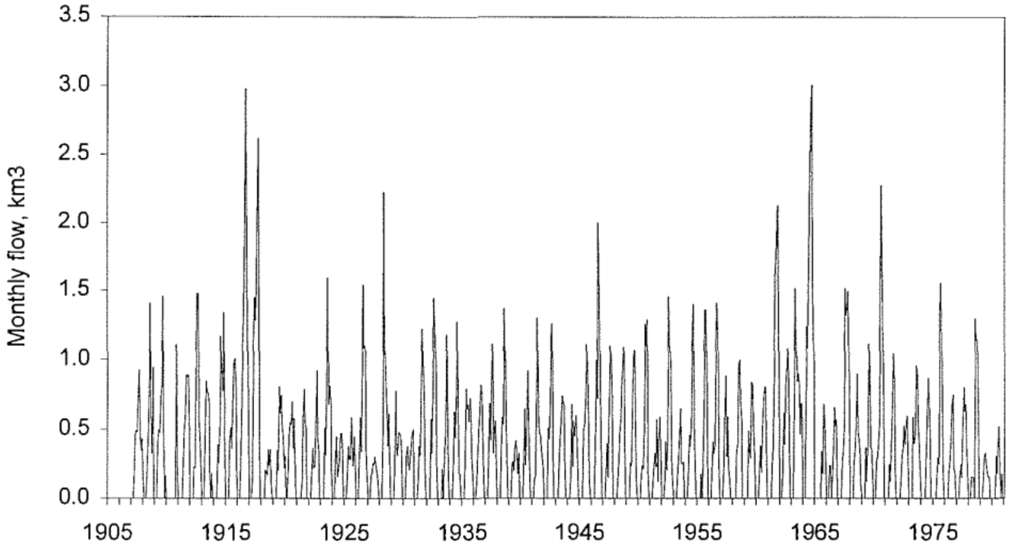


Figure 8: Estimated torrent flows between Lake Albert and Mongalla (Source: Sutcliffe & Parks (1987): Figure 5.5)

The seasonal range of river flow at Mongalla is largely related to the climate and lake storage upstream, which is later modified by the torrential lateral inflows across South Sudan. The East African upstream drainage basin of the White Nile includes the depression centred on Lake Victoria, from which the Victoria Nile flows through Lake Kioga to Lake Albert, entering the western arm of the Rift Valley system at the Murchison Falls. Flow contribution from Lake Albert is fairly steady, varying from year to year according to the levels of the East African lakes, which depend on the balance between rainfall and evaporation over a fairly long period. Conversely, discharges from the torrents between Lake Albert and Mongalla are seasonal and highly variable, with storms followed rapidly by a rise of gauge and discharge at Mongalla. The torrent flow carries a greater quantity of material in suspension than the water from the lakes. Thus, for six months of the year the river flow at Mongalla is fairly steady and clear, while for the rest of the year it is larger and more variable, and also carries more material[14].

The quality of the flow record must have varied with the frequency of gauging but in general has been reasonable. However, comparisons with upstream records showed that flows in 1963-1964, during the rise in lake levels and a rapid change of rating, would not be reliable[15]. A comparison of the rating curves at Mongalla over the period of record reveals that from 1905 to 1963 there had been a steady rise of about 0.5m in the river level corresponding to a given flow. This trend was disrupted by the increase in flows in 1963. After gauging was resumed in 1967, the earlier rise had been reversed and by 1980 the level was about 1.0m below 1962 levels.

The available data can be used to infer the flood flows associated to different return periods by means of Extreme Value Analysis. Figure 9 shows the outcome of this analysis, which has been performed by fitting different probability distribution functions to the series of annual maxima. The best fit according to the Kolmogorov-Smirnov and X^2 statistical tests corresponds to Pearson III. Related design flood flows are set out in Table 3.

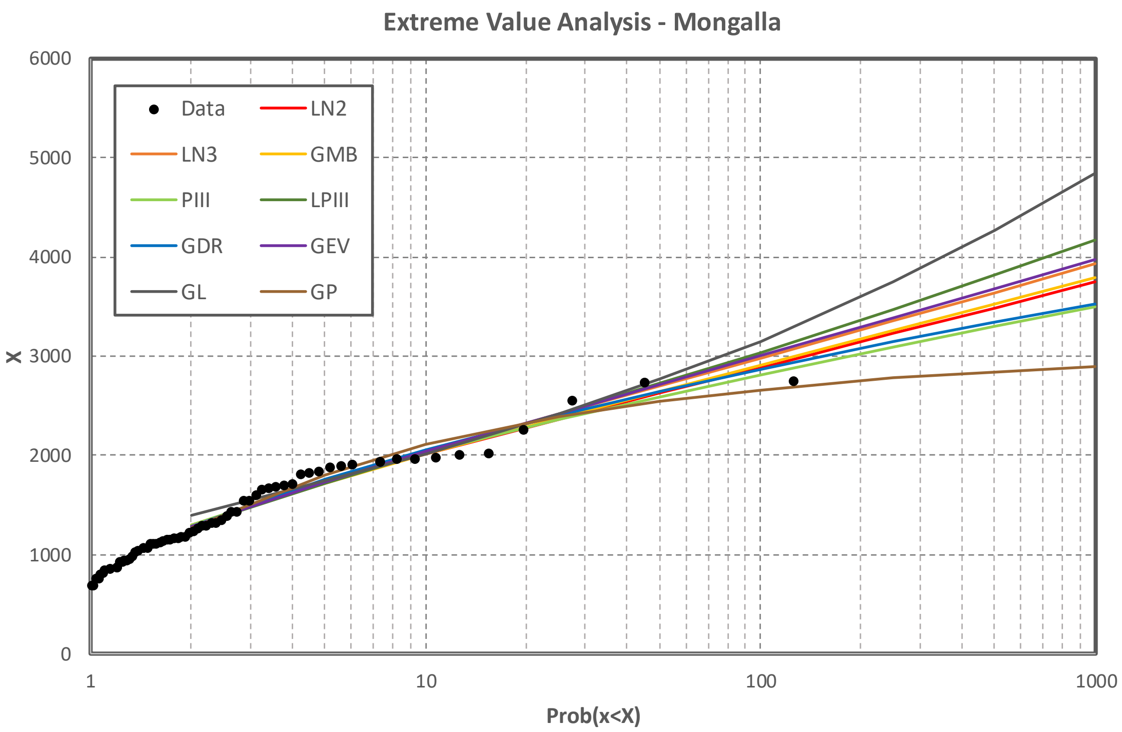


Figure 9: Extreme value analysis of mean monthly flows at Mongalla (Source: Mott MacDonald analysis)

[14] Sutcliffe, J. V., & Parks, Y. P. (1987). Hydrological modelling of the Sudd and Jonglei Canal. Hydrological Sciences Journal, 32(2), 143-159.

[15] Sutcliffe, J. V., & Parks, Y. P. (1999). The hydrology of the Nile.

Table 3: Mean monthly flows (Source: Mott MacDonald analysis)

T (years)	Mean monthly flow (m3/s)
2	1,302
5	1,751
10	2,028
25	2,357
50	2,589
100	2,810
250	3,090
500	3,295

To note that these flows correspond to mean monthly values and not to peak flows which are likely to occur at a daily time scale due to the contribution of torrent lateral flow during convective events.

3.4 Probable cause of river flooding

Due to the absence of relevant secondary streams crossing Bor, the White Nile is clearly the main source of external (river-based) flood rise. Floods on the White Nile occur due to a combination of high outflows from Lake Albert with lateral inflows from torrents. The mild slope of the river along the Sudd and the presence of dense vegetation in the floodplain also contribute to slow the current and increase water levels to a point when overbank flow starts. This would be coherent with the recorded flood history.

A simplified hydraulic analysis has been conducted for the cross section shown in Figure 2 and Figure 3, assuming normal regime with an energy slope equal to that of the bed level (0.005%) and a Manning number of 0.03 and 0.06 for the channel and floodplain respectively. The 2-yr return period flow would remain in channel with a water level of approx. 430.3 meter above sea level (masl), but the 5-yr return flow would spill over the right bank, thus highlighting that Bor would be at flood risk for relatively high likelihood events. Water level for a 500-yr return period flood would be approx. 431.1 masl, impacting significant areas of the town.

3.5 Expected climate change impact on river flooding

Two aspects can contribute to changes in flooding frequency and magnitude in the future. Due to the large attenuation provided by Lake Victoria and Lake Albert in the headwaters of the White Nile, changes in annual rainfall as a result of climate change could modify lake levels and results in higher or lower downstream releases. This phenomenon was clearly observed during 1962-64.

In order to rapidly understand the full range of potential climate change in respect of annual in the White Nile headwaters, research undertaken by the Climatic Research Unit of the University of East Anglia[16], which summarises the latest Couple Modelling Intercomparison Project Phase 5 (CMIP5) Global Circulation Models (GCMs), has been considered. These GCMs have been used to inform the conclusions of the latest IPCC Assessment Report 5th. Projections of national average rainfall change for Uganda, where both Lake Victoria and Lake Albert are located, are provided for specific levels of global warming, as well as for predicted temperature rise. The overall purpose of these projections is to provide a guide to the spread of results from different groups of climate models, in essence the full range available. This is a common way to assess uncertainty in climate projections. The scatter plots developed capture key climate change projections from the CMIP3 and 5, the Hadley Centre QUMP experiments (17-member perturbed-physics ensemble), and the uncertainty within this range of projections. As shown in Figure 10, while temperature rise is certain, there is significant uncertainty for Uganda in relation to precipitation changes, but with higher chances of a moderate increase. This tendency has augmented in the most updated AR5 (brown circles in the graphs), with more than half of models predicting an increase in annual rainfall.

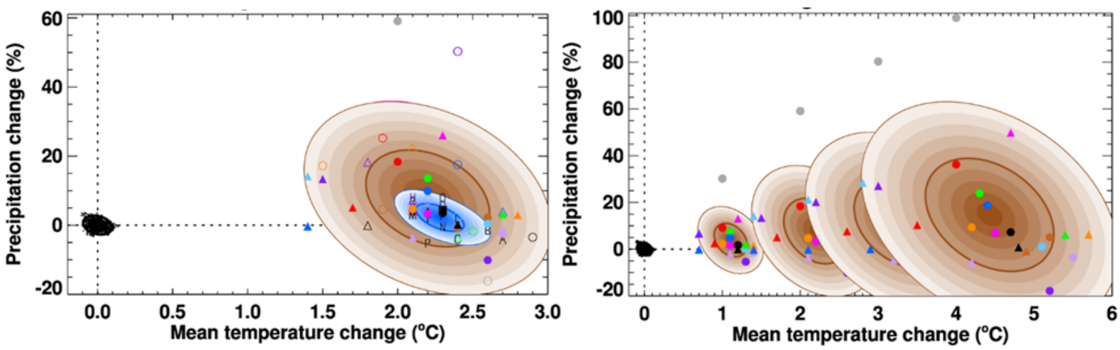


Figure 10: CMIP5 projections for Uganda, representative of White Nile headwaters. AR4 and AR5 scenarios (left) and specific global warming levels (right) (Source: CRU, University of East Anglia)

Key: Brown ellipses represent projections for AR5 scenarios and CMIP5 GCMs outputs, pink ellipses represent projections for AR4 scenarios and CMIP3 GCMs outputs, blue ellipses represent results from QUMP climatic models, and the small black dots (and associated ellipses) provide an estimate of the natural variability inherent in to the current climatic conditions.

Likewise, modification in the intense rainfall trends in the intermediate catchments across South Sudan can modify the occurrence of flooding. The Expert Team on Climate Change Detection and Indices computed several relevant indices for a number of GCMs of the CMIP5. Rx1day, maximum 1-day precipitation in a year, series for the square where Bor is located have been retrieved from the Canadian Centre for Climate Modelling and Analysis extreme indices archive (see Figure 11). Related changes in rainfall intensities are presented in Table 4. They correspond to the following two emissions scenarios:

RCP4.5 was developed by the GCAM modelling team at the Pacific Northwest National Laboratory's Joint Global Change Research Institute (JGCRI) in the United States. It is a stabilization scenario in which total radiative forcing is steadied shortly after 2100, without overshooting the long-run radiative forcing target level. CO_2 concentration would not exceed 650ppm. World population would peak at 9 billion in the last part of the century and decline thereafter. It can be considered as a moderate mitigation scenario. However, it is also consistent with a baseline scenario that assumes a global development focused on

[16] Osborn, T. J., Wallace, C. J., Harris, I. C. and Melvin, T. M. (2016) 'Pattern scaling using ClimGen: monthly-resolution future climate scenarios including changes in the variability of precipitation', Climatic Change, 134(3), 353–369

technological improvements and a shift to service industries, not directly aiming to reduce greenhouse gas emissions as a goal in itself.

RCP8.5 was developed using the MESSAGE model and the Integrated Assessment Framework by the International Institute for Applied Systems Analysis, Austria. It is characterized by increasing greenhouse gas emissions over time, representative of the high range of non-climate policy scenarios. CO2 concentration at the end of the century would reach 1,370ppm and the use of fossil fuels would continue to dominate, with a particular rise of coal. World population would grow up to 12 billion. However global GDP would follow a similar pattern, with persistent lower incomes in developing countries.

They can be regarded as leading to potential moderate and most adverse climate change impacts, thus likely bracketing the actual effect.

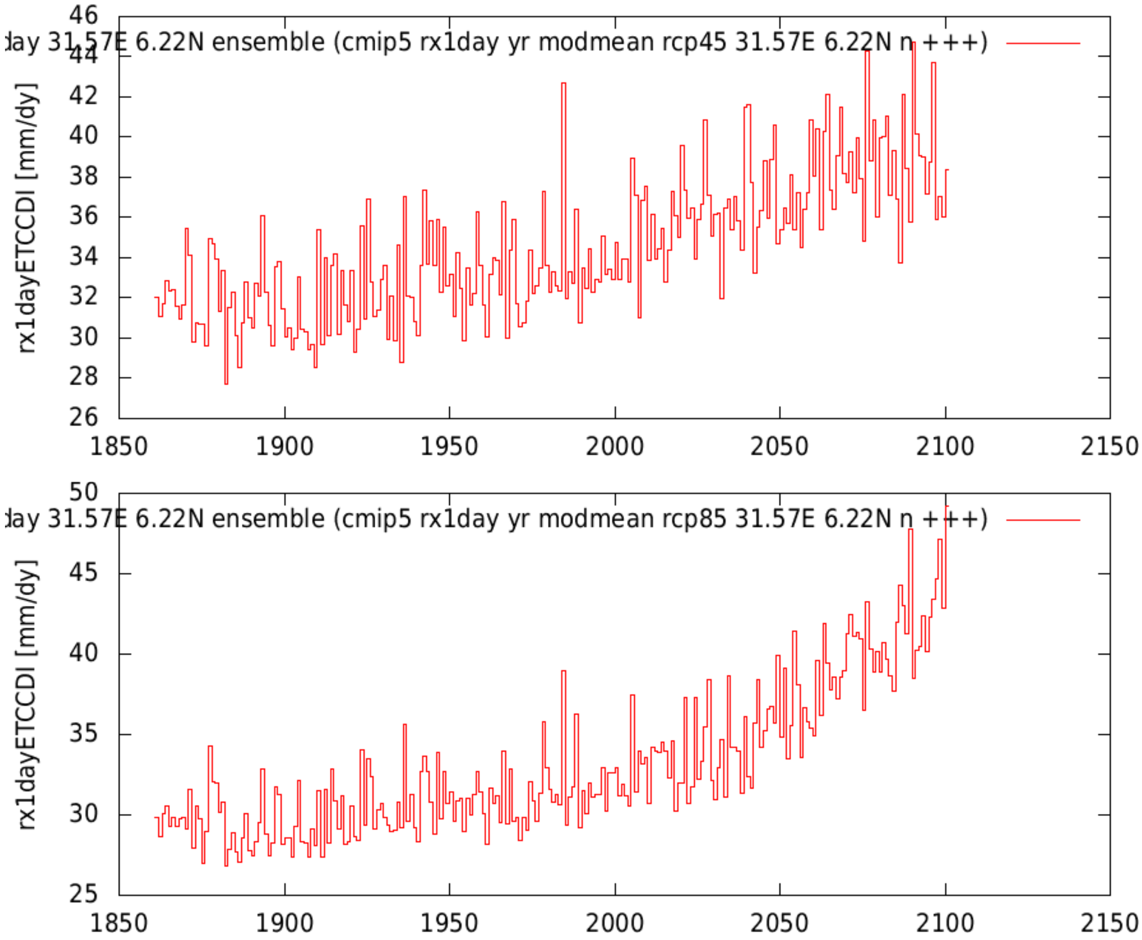


Figure 11: CMIP5 change in maximum annual daily rainfall in the study area. RCP4.5 (top) and RCP8.5 (bottom) (Source: Canadian Centre for Climate Modelling and Analysis extreme indices)

Table 4: Estimated changes in rainfall maxima in comparison with 1981-2010

Time horizon	Emission scenario	Increase (%)
2050s	RCP4.5	10
	RCP8.5	16
2080s	RCP4.5	14
	RCP8.5	30

As can be seen, a significant rise in extreme rainfall would be expected. This, together with a likely moderate increase in total rainfall in the White Nile upper catchment, would imply that flood risk at Bor would worsen, with more frequent and larger flooding events.

3.6 Recommendations from hydrology desk study for future study

This preliminary desk-based hydrological study has highlighted the lack of reliable and detailed information to formulate an effective flood risk management plan. Before effective and efficient flood protection measures can be designed, a better understanding of the current and future flood exposure should be gained. This should comprise at least of the following:

- Bathymetry survey of White Nile primary and secondary channels;
- Topography survey of banks, existing dykes, floodplains, and adjacent inland plains to complement remote sensing topographic information;
- Derivation of monthly flow series at Bor by combination of and routing of outflows from Lake Albert with the contribution of the intermediate catchment. Rainfall-runoff modelling would be needed to determine the latter, with the model being calibrated at Mongalla gauge;
- Determination of flood daily flows for different return periods from lateral torrents between Lake Albert and Bor. An effort should be made to gather the best available daily rainfall data and a full hydrological analysis needed to transform those into design flows. These could then be superimposed over the monthly flow series to define final flood hydrographs. Consideration should be made of the seasonality of extreme rainfall;
- Assess existence / availability of current hydrological and hydraulic models for the area. If available, assess quality and fitness for purpose for analysis of flood risks at Bor;
- Preparation of flood hazard maps for different return periods by means of hydraulic modelling. Fully 2D or 1D-2D analysis would be needed to properly capture the complex flows across the Sudd;
- Development of a full climate change impact assessment to establish the most likely evolution of flood risk in the future, so that potential flood protection measures can incorporate this into their design, incorporating the regional projections for the Horn of Africa, developed by the IGAD Climate Prediction and Application Centre in their Climate Change Risk Atlas (online information concurs with the information presented in this report; details may be obtained for further in-depth study), or more updated forecast from the CMIP6[17] project if available;

[17] Round 6 of the Coupled Model Intercomparison Project of the World Climate Research Programme, see https://www.wcrp-climate.org/wgcm-cmip/wgcm-cmip6

- Development of a morphodynamical study to identify possible changes in erosion/accretion patterns as well as channel displacements in order not to compromise the feasibility of potential flood protection measures.

4 Field mission

4.1 Programme of meetings and field visits

A series of meetings and field visits were held between 22 and 28 August, combined with reporting in the evenings. The very first meeting, with the Under-Secretary of the Ministry of Water Resources and Irrigation of the Government of South Sudan, resulted in a support letter, included in Appendix A. Programme details with short notes of key meetings are included in Appendix B. The sections below provide an overview of key findings in relation to:

- Internal and inland flood risk from local rainfall;
- External flood risk from the Nile;
- Spatial data and maps;
- Available civil engineering machinery in Bor;
- Unit costs for some civil engineering items (from a Juba-based commercial operator).

This chapter ends with a brief overview of recommendations from the field mission for future study in the framework of an integrated flood control initiative.

4.2 Findings of field visits on internal and inland flood risks from local rainfall

4.2.1 Observations regarding local drainage in town

The team spent considerable time in the field and was able to observe many examples of failing urban stormwater drainage. The local technocrats of the Ministry of Physical Infrastructure (MoPI) explained that after the dry season, soils become impermeable after the first rains, when cracks are quickly filled up and clay particles effectively seal off the surface layer. Rain can no longer infiltrate and runs off overland to local depressions. Originally, linear depressions known locally as *khors* used to collect and discharge excess rainwater from certain areas to the Nile. Areas without khors would collect water locally and transform into permanent or semi-permanent standing water bodies. Many original khors, but also drains that were developed previously, are nowadays obstructed by households. In the current so-called Urban Master Plan, no room has been reserved for an urban drainage network, and land parcels have been planned and given out without any public space between them. Moreover, maintenance of prior drainage channels has been absent in recent years, all in all resulting in near-absence of any drainage capacity whatsoever. Photos in this section give an impression of the situation on the ground.

Photo 3: Vehicle and cattle having problems navigating poorly drained muddy road

Photo 4: Inundated road with permanent water body on left and flooded land on right

Photo 5: Inundated area around groundwater supply point, leading to health risks

Being faced with recurrent flooding of their properties, inhabitants of Bor have developed several ways of coping, and keeping water out of their plots and properties as in Photo 6.

Photo 6: Examples of private initiatives to keep water out: bunds and sandbags

Standing water (as in Photo 7) provides the breeding ground for several water borne diseases, such as malaria and schistosomiasis (Bilharzia). The population of Bor spends considerable money on health care related to water borne diseases, including to fight cholera (Photo 8). The Ministry of Health of Jonglei State recommends limiting the duration of standing water in town to no longer than three consecutive days.

Photo 7: Permanent water bodies (recognisable by presence of aquatic vegetation) form a breeding place for water borne diseases, e.g. malaria or schistosomiasis (Bilharzia)

Photo 8: Local pharmacy with awareness poster on water borne cholera

Remnants of the pilot irrigation scheme in Bor, developed by Ilaco in the late 1970s / early 1980s, are still visible on satellite images, but also in the field. The large irrigation canal no longer carries irrigation water but can be reused in the drainage plan for the town. The booster pump that used to lift water to a higher-level section of the canal is no longer in use. This higher section was not dug out but constructed by means of two levees in between which an elevated channel was formed on top of the original soil bed, in order to irrigate nearby fields using gravity flow. Notably the first plot on the higher section of the irrigation canal has been transformed into agriculture, obstructing for the moment the potential for rehabilitation of this waterway (Photo 9). The remainder of the channel is still somehow intact and could be reused if the obstruction were removed. The booster pump itself would probably need replacement if required.

Interestingly, Dr Sjoerd Zanen (Tong Mabior) informed the team that the irrigation system was also used to pump water to a standing water body in Khor Hong, to provide water to Murle cattle holders from the east in the dry season and by doing so, releasing the pressure on the limited access points along the Bahr el-Jebel itself, avoiding potential conflicts with local cattle holders over scarce land and water resources. Restoration of this option could be considered, as well as the use of the irrigation channel infrastructure to actively flush the drainage system in order to prevent stagnant water in drains in the wet season and (at the start of) the dry season.

Photo 9: Former booster pump of the pilot irrigation system by Ilaco

Special attention was given to the site of UNMISS. Located just out of town, the area suffers from direct rainfall similarly to the rest of the town. Interestingly, the site is situated in the trajectory of Khor Hong, which means that it would in theory also suffer from high levels of sheet flow / discharge through the khor. The latter is avoided by the thick and high bund around the compound, which in hydrological terms functions effectively as a dyke, keeping out any water coming from its surroundings. The bund has been constructed with materials dug out locally, forming a new ditch along the entire bund, on the outside of the compound. The ditch is not connected to the natural drainage system of the Khor. As may be concluded from the light (high and dry) and dark (low and wet) colours on the satellite image in Photo 10, the compounds effectively block the natural drainage capacity of Khor Hong, which may very well aggravate amounts of sheet flow from the southeast into nearby neighbourhoods in the southern part of Bor. Note the (semi) permanent water body near the road. This was formerly supplemented by the irrigation canal, to help relief water shortages in the dry season.

Photo 10: Satellite view of UNMISS and POC camp situated in Khor Hong (source: Google Earth Pro, 2019)

UNMISS site management recognised the need for a proper drainage system to keep the campsite dry. To this end, a drainage plan was developed (Figure 12) and later updated (Figure 13).

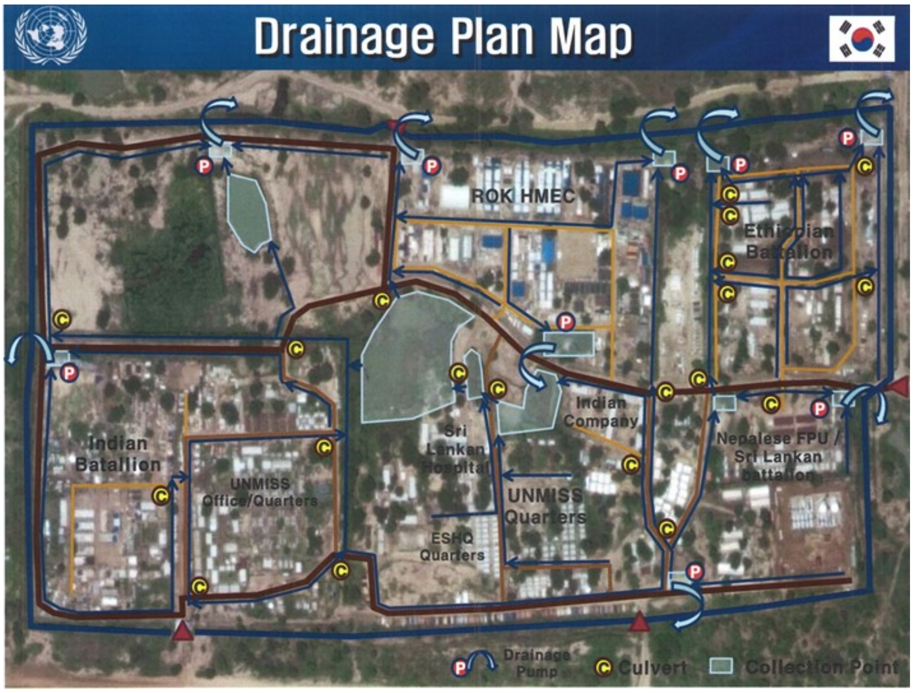


Figure 12: Drainage plan map of UNMISS compound (source: UNMISS)

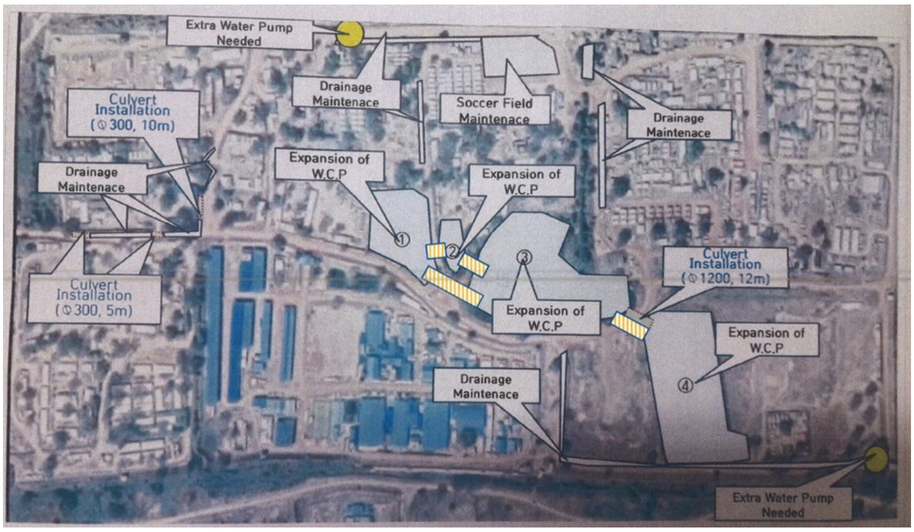


Figure 13: Drainage plan UNMISS update (source: UNMISS)

In the rainy season of 2019, Bor municipality and Jonglei State MoPI implemented emergency drainage work throughout town, to drain the most affected, reachable areas. Starting from one of the most important outlets to the Nile, rehabilitation of existing drainage channels and excavation of new drains was done progressively. By September 1st, the ad-hoc network coverage was as indicated by red lines in Figure 14. The authorities deployed the only excavator available in town (Photo 11; equipment of UNMISS is not available for work other than for UNMISS itself). Fuel costs are covered by contributions from South Sudanese diaspora, through active lobbying by the Mayor of Bor.

The emergency works are not informed by any topographical information other than Google Earth and field observations. A Digital Elevation Model (DEM) or more specifically a Digital Terrain Model (DTM, an uninterrupted spatial data layer of ground level)[18] would be needed to design a proper drainage network. And whereas at current drains are being dug on private property, a high-resolution DEM/DTM would also inform the development of an integrated spatial plan for the entire urban area, in which sufficient space is allocated to public functions, ranging from drainage to water supply to parks etc., bearing in mind land suitability.

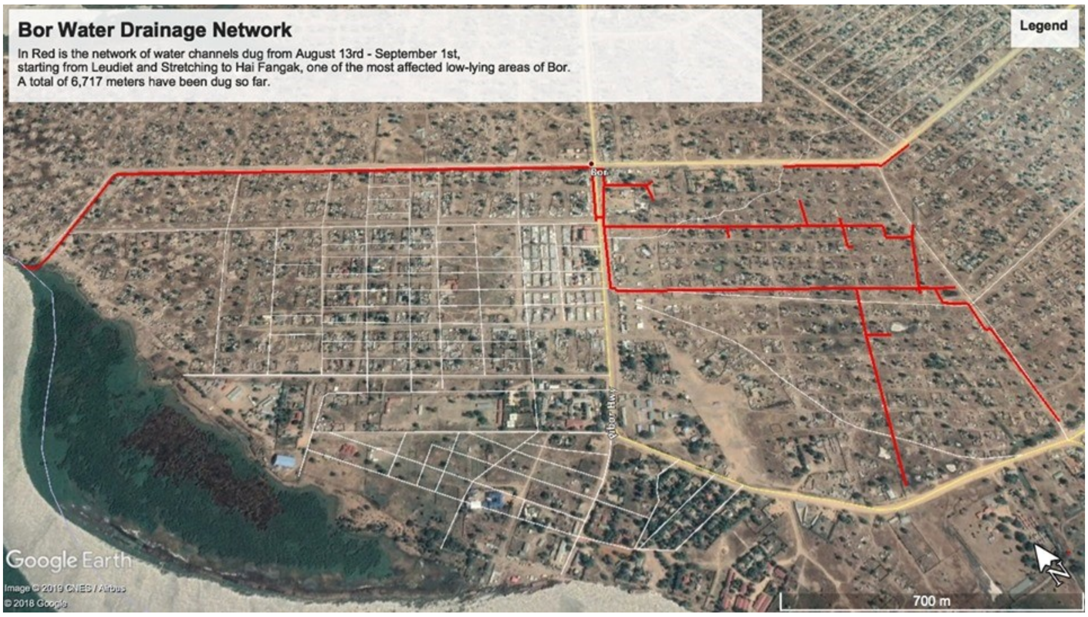


Figure 14: Bor emergency drainage network coverage by 1 September 2019 (source: Mayor of Bor and Google Earth Pro)

[18] https://en.wikipedia.org/wiki/Digital_elevation_model

Photo 11: Excavator at work in Bor, digging emergency drains

4.3 Findings on external flood risks from Nile

Bor is situated on the right (east) bank of Bahr el-Jebel, which is the common name for this section of the White Nile. The main channel of the river runs directly along Bor. The floodplain is very wide; at the southern end of the Sudd wetland (Photo 12). At high river discharges, water levels in the main channel rise to an extent that adjacent areas in Bor are flooded. The extent of the area at risk is not entirely clear, lacking a detailed DEM. As has been explained in Chapter 3 on hydrology, climate change will lead to peak rainfall events upstream increasing by up to 16 % by 2050 and up to 30% by 2080. This will result in higher peak discharges and water levels, aggravating river-based flood risks. Bor is somewhat protected by a low dyke, which has not been subjected to thorough engineering design and construction. The dyke is not very strong or high. The earthen body is not protected by grass in large sections (Photo 13) and easily damaged by cattle or other disturbances (Photo 14).

Photo 12: Satellite image of Bor and adjacent floodplain (source: Google Earth Pro, 2019)

Moreover, villagers sometimes break-through sections of the dyke in order to allow excess water collecting behind the dyke to drain off to the river (Photo 15). Obviously, this breaks the protection that the dyke offers against rising Nile waters. In response to high river flows in 2019, the authorities had to plug several of these (illegal) cuts in the dyke (locations are indicated in Figure 15). In the new flood control plan for Bor, solutions need to be included to protect from Nile floods whilst allowing for discharge of drainage water from the urban area.

The standard approach to river flood control is to build higher and stronger dykes. The Dutch have a very strong tradition in doing just that. However, after very high river discharges and water levels in the main rivers in the second half of the 1990s, a decision was made to stop fighting against nature by building ever higher and stronger dykes, but rather to work with nature. More space was provided for the river to flood dedicated areas in the floodplain, and people and properties were relocated to more secure, dry areas. A national large infrastructure programme was designed by the name of *Room for the River*. In subsequent years, the programme was implemented in very close partnership with all relevant stakeholders, following principles of Strategic Environmental Assessment (SEA), including a participatory plan process. As a result, Room for the River was the first large infrastructure programme in the Netherlands to be implemented within the original timeframe and within the original budget.

Whereas it is not possible at this stage to say anything authoritative about the technical and socio-economic feasibility of different options for river-based flood control in Bor and vicinity, a solution to cope with rising river discharges of the Nile near Bor *might* also be found in *Room for the River*-like measures in the floodplain. Testimonies by the locals, also supported by hydrological literature in the area, point to the fact that there are blockages by aquatic weeds, which lead to restriction of the river channels' discharge capacity. It would be worthwhile to conduct an SEA to study multiple alternative solutions to flood control in the area and to avoid investigating only one option that may not be the most sustainable in the long run.

Photo 13: Earthen dyke, northern Bor

Photo 14: Earthen dyke, northern Bor, damaged by cattle

Photo 15: Man-made breach in Nile dyke to allow discharge of urban (rain) water

Figure 15: Satellite image of Nile dyke, Bor, with red dots indicating plugged breaches in dyke (source: Mayor of Bor, using Google Earth Pro)

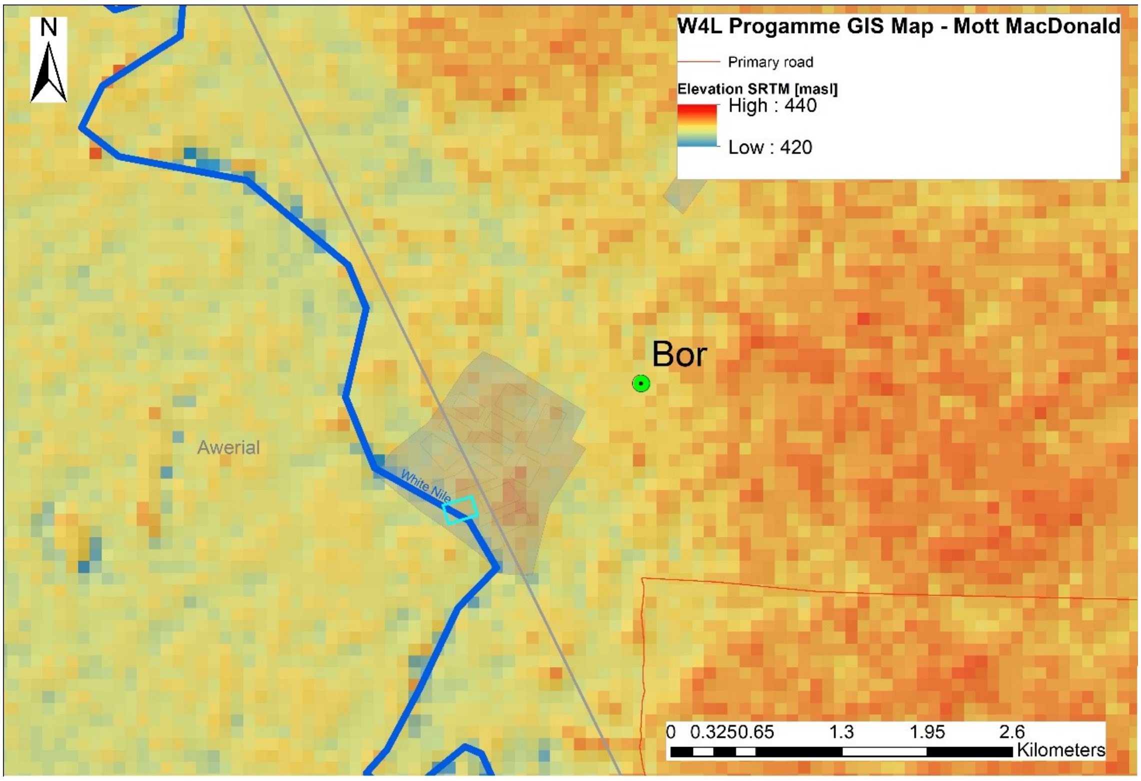
4.4 Spatial data and maps

Spatial planning, such as for flood control or urban development, requires spatial information or spatial data. This is data that describes certain features or characteristics of certain locations on earth. Quantitative spatial data such as altitude or slope, when stored digitally in a Geographic Information System (GIS), can be used to develop maps. In addition, the information can be used to develop models, such as river discharge and flood control models. The aerial or satellite photographs, as used throughout this report, are also a form of spatial information. Their value becomes apparent in the overlays of information about e.g. roads or drains.

This section presents a number of maps that were available at MoPI of Jonglei State (in hardcopy format, not in GIS), an example of a DEM (Map 4), as well as a few photos to illustrate the importance of maps in (urban) spatial planning and in understanding the landscape while in the field.

The value of good (reliable and accurate) spatial information should not be under-estimated. Good decisions can only be made if good information is utilised in the decision-making process. Lack of good information can lead to wrong decisions or to no decision at all. Both are often more costly than the cost of obtaining the missing information.

At current, the authorities of Bor Municipality and Jonglei State lack reliable and accurate information on the shape of the terrain. Elevation and slope are key parameters that define natural drainage networks to discharge excess rainwater or sheetflow. Likewise, elevation data inform the assessment of flood risks from the river. It is strongly recommended to fill this data gap as one of the first elements of a Bor Flood Control Initiative.



Map 4: Low-resolution Digital Elevation Model (DEM) of Bor and environs, based on SRTM (source: Water for Lakes programme, Mott MacDonald)

Different technologies can be applied to obtain elevation data. The most down to earth (literally) method is by manual surveying. This has several important constraints: it is very time consuming; requires special equipment and skilled operators (surveyors), and most importantly, it can only be applied in longitudinal sections (lines) at a time, which will never lead to a blanket coverage of the entire area. At the other extreme, satellites can be used. The most common example thereof is the Shuttle Radar Topography Mission (SRTM) dataset[19] of NASA, made

[19] https://www2.jpl.nasa.gov/srtm/

available free of charge online in a 30 m resolution. This dataset has been used for the preliminary delineation of sub-catchments (drainage basins) and main natural drainage systems in this study (Map 3). The 30 m resolution and related low accuracy however is not sufficient for the rather flat area of Bor, where even laser-based levelling technology in the 1980s pilot study by Ilaco proved to be not accurate enough to deal with the very small differences in ground level throughout the area. A higher resolution and accuracy are required to develop a sound drainage plan and to obtain a better understanding of actual flood risks at high river water levels. Several technologies exist to obtain such data, including photogrammetry[20] and LiDAR[21], which can utilise satellite, airplanes, or drones to get increasingly high-resolution data that subsequently are processed into a Digital Elevation Model (DEM). A DEM can take the shape of a Digital Surface Model (DSM, representing the highest points such as trees or rooftops) or a Digital Terrain Model (DTM, representing ground level). An overview of options is provided in Table 5.

Table 5: Technological options to obtain DEM

Technology	Resolution	Accuracy (theoretical)	Cost level	Remarks
Surveying	Limited to lines	Few mm to cm	Low – very high	In order to obtain a reasonable resolution for urban planning, very many lines would need to be surveyed. Requires access to many private plots. Less suitable.
Drone with photogrammetry and/or LiDAR cameras (a small size (<1 m wing span) fixed wing drone, flying at low altitude)	Very high (few cm)	Few cm	High (order of magnitude: a few hundred thousand Euros)	Very suitable technology to obtain DEM (DSM or DTM), using software to analyse multiple images and account for buildings and trees. In-house capacity at Mott MacDonald. No access to private properties required.
Plane with photogrammetry and/or LiDAR cameras	High - very high (few cm)	Few cm	High (order of magnitude: a few hundred thousand Euros)	Very suitable technology to obtain DEM (DSM or DTM), using software to help human experts analyse multiple images and account for buildings and trees. Quicker initial data capturing than with drone. No in-house capacity at Mott MacDonald. No access to private properties required.
Satellite	Low - high	0.1 m and up	Low. Free of charge (SRTM) or paid for (commercial higher resolution options)	Less suitable due to lower resolution, low accuracy, and lack of DTM option due to trees and buildings. Only suitable in uncovered

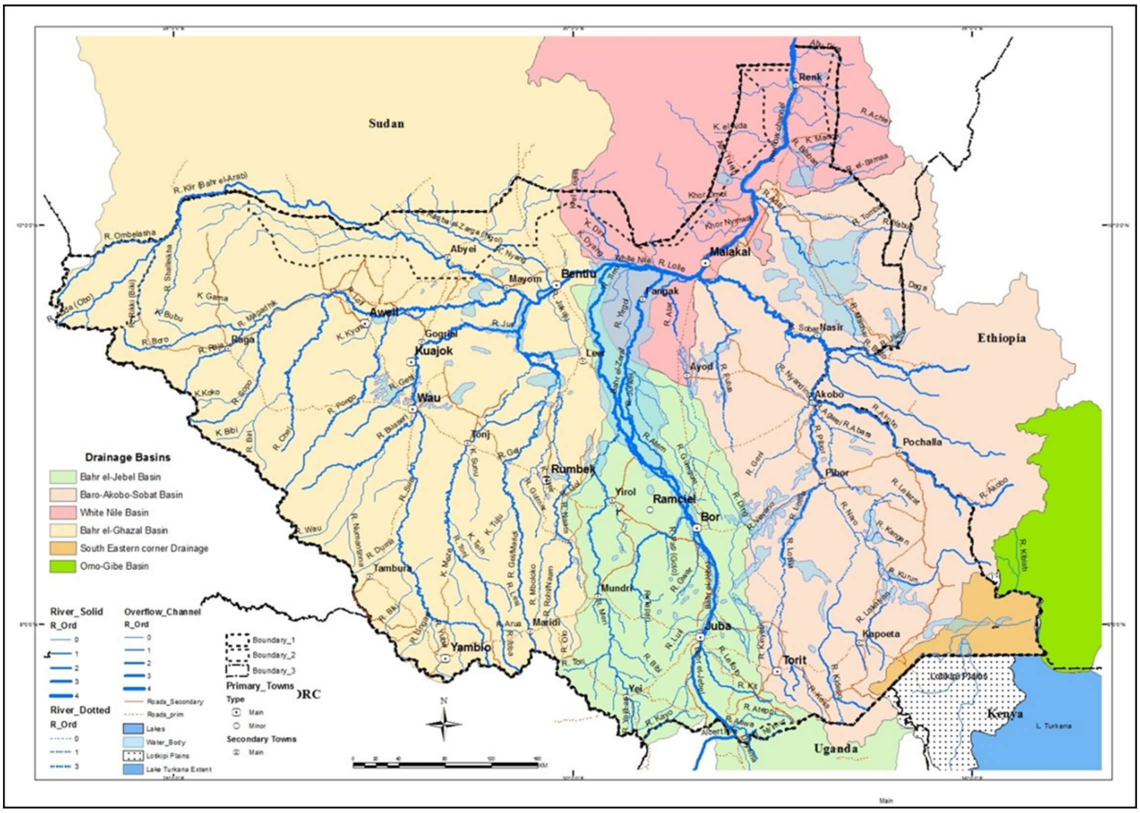
[20] https://en.wikipedia.org/wiki/Photogrammetry
[21] LiDAR is an acronym of light detection and ranging, see also https://en.wikipedia.org/wiki/Lidar

Technology	Resolution	Accuracy (theoretical)	Cost level	Remarks
				areas. Access to private properties is not required.

LiDAR offers the best technology to develop a reliable high-resolution, high-accuracy DEM / DTM. A detailed comparison needs to be made in terms of costs versus resolution between the options of utilising drones or a small aircraft. Importantly, deploying either a drone or a small aircraft with photogrammetry or LiDAR equipment requires prior Government approval and active support to facilitate temporary import and use of either option.

If the Sudan Survey Authority can be persuaded to share the GIS files that contain the data that were used to develop the contour lines in Map 7, this information could be used as additional data source to triangulate the results from the drone or aircraft based DEM. On its own the existing dataset would still be informative, but it would not come anywhere near the information density and quality of LiDAR data from a locally deployed drone or aircraft. The metadata of the existing dataset from the Sudan Survey Authority are unknown, making it impossible to assess its reliability and accuracy.

The following maps and photos illustrate the importance of mapping and spatial information in understanding the landscape and subsequently, spatial planning.



Map 5: Main catchments (drainage basins) and drainage network of South Sudan (source: Isaac Liabwel, in Groundwater Assessment for ENTRO, Aug. 2019)

Photo 16: Maps - key information instruments for spatial planning

Photo 17: Maps and spatial imagery help reading the landscape, together

Map 6: Topography of Bor Town and Environs (source: Sudan Survey Authority, 2009)

Map 7: Topography or Bor and Environs, with contour lines (source: Sudan Survey Authority, 2009)

4.5 Available civil engineering equipment in Bor

Availability of large civil engineering machinery in South Sudan is limited. The Ministry of Physical Infrastructure of Jonglei State avails of some basic civil works equipment, such as the excavator that is currently being used to open up emergency drains in 2019. Several large machines however need repair and major maintenance. A quotation has been requested from the Caterpillar representative in Juba. It seems most pragmatic and sustainable to assume that only the equipment that is currently available, will be utilised in any upcoming works under a Bor Flood Control Activity. Options for upgrades and additional spare parts can be investigated in the main Activity.

4.6 Unit costs of civil engineering works

The emergency drainage works and dyke repairs are currently being implemented entirely by municipal and state staff, whereas fuel costs for the excavator (some 200 litres of fuel per day) are paid for from funds availed by the South Sudanese diaspora (Photo 18). It is therefore not straightforward to obtain unit costs e.g. per km of drains dug. In order to obtain indications of manpower and funds required, the authorities would need to monitor inputs and outputs during the emergency works this season.

Photo 18: A team member of the excavator team, from the South Sudan Police Services, transporting fuel to the excavator in the field

For an overview of unit costs for rent of equipment and prices of basic civil works materials that could inform costing during the main activity, a price list from a major construction company based in Juba is included in Appendix C.

4.7 Recommendations from field mission for future study

Based on the field visits and meetings held between 22 and 28 August, the following recommendations were developed to support spatial planning, integrating flood safety for the inhabitants of Bor and their properties and livelihoods.

- Obtain GIS files (Shapefiles) that were used to develop the Topographic Maps of Bor and its Environs from the Sudan National Survey Authority.

- Obtain high-resolution elevation data, e.g. using drone or aircraft-based LiDAR;
- Develop GIS with detailed Digital Elevation Model (DEM) / Digital Terrain Model (DTM);
- Develop and conduct participatory spatial planning processes for external (Nile-focused) and internal (local and inland rainfall drainage focused) flood control, utilising lessons learned from Dutch Room for the River programme and best practices from Strategic Environmental and Social Assessment processes;
- Develop short-term and long-term approach to reduce flooding and to mitigate impacts of floods and dry season water needs under current and future climatic conditions;
- Integrate traditional, context relevant, cost-effective and efficient water harvesting / storage technologies, such as *haffirs* and enhanced natural depressions, in the design of the Khor Hong sheet flow diversion channel. This will improve water availability for cattle for (mainly) incoming cattle holders from the East (Murle people) in the dry season, by storing part of the excess sheet flow from the southeast. This needs to be combined with prevention or minimisation of water-borne diseases such as Bilharzia and Guinea worms, by fencing off the waterbodies, keeping distance between residential areas and standing waters and if feasible, by promoting refreshment of such stored surface water by means of river-based oscillation or active pumping / flushing;Plan for optimal deployment of locally available equipment and work force in order to achieve maximum skills transfer (sustainability) and highest value for money;
- Include repair, upgrade, and operation & maintenance costs for locally available equipment, for optimal value for money and to enhance sustainability and capability to maintain drainage systems and flood protection works within the authorities (costs of repair and maintenance of current equipment are presented in Appendix D);
- Collaborate with Dr John Garang Memorial University of Science and Technology for optimal value for money and maximum transfer of knowledge (sustainability).

5 Recommendations

5.1 Summary of recommendations from hydrology study and field mission

5.1.1 Recommendations from hydrology study

The preliminary desk-based hydrological study has highlighted the lack of reliable and detailed information to formulate an effective flood risk management plan. Before effective and efficient flood protection measures can be designed, a better understanding of the current and future flood exposure should be gained. This should comprise at least of the following:

- Bathymetry survey of White Nile primary and secondary channels;
- Topography survey of banks, existing dykes, floodplains, and adjacent inland plains to complement remote sensing topographic information;
- Derivation of monthly flow series at Bor by combination of and routing of outflows from Lake Albert with the contribution of the intermediate catchment. Rainfall-runoff modelling would be needed to determine the latter, with the model being calibrated at Mongalla gauge;
- Determination of flood daily flows for different return periods from lateral torrents between Lake Albert and Bor. An effort should be made to gather the best available daily rainfall data and a full hydrological analysis needed to transform those into design flows. These could then be superimposed over the monthly flow series to define final flood hydrographs. Consideration should be made of the seasonality of extreme rainfall;
- Assess existence / availability of current hydrological and hydraulic models for the area. If available, assess quality and fitness for purpose for analysis of flood risks at Bor;
- Preparation of flood hazard maps for different return periods by means of hydraulic modelling. Fully 2D or 1D-2D analysis would be needed to properly capture the complex flows across the Sudd;
- Development of a full climate change impact assessment to establish the most likely evolution of flood risk in the future, so that potential flood protection measures can incorporate this into their design, incorporating the regional projections for the Horn of Africa, developed by the IGAD Climate Prediction and Application Centre in their Climate Change Risk Atlas (online information concurs with the information presented in this report; details may be obtained for further in-depth study), or more updated forecast from the CMIP6[22] project if available;
- Development of a morphodynamical study to identify possible changes in erosion/accretion patterns as well as channel displacements in order not to compromise the feasibility of potential flood protection measures.

5.1.2 Recommendations from field mission

Recommendations for spatial planning integrating flood safety for the inhabitants of Bor and their properties and livelihoods.

- Obtain high-resolution elevation data, e.g. using drone or LiDAR;
- Develop GIS with detailed Digital Elevation Model (DEM) / Digital Terrain Model (DTM);

[22] Round 6 of the Coupled Model Intercomparison Project of the World Climate Research Programme, see https://www.wcrp-climate.org/wgcm-cmip/wgcm-cmip6

- Develop and conduct participatory spatial planning processes for external (Nile-focused) and internal (local and inland rainfall drainage focused) flood control, utilising lessons learned from Dutch Room for the River programme and best practices from Strategic Environmental and Social Assessment processes;
- Develop short-term and long-term approach to reduce flooding and to mitigate impacts of floods and dry season water needs under current and future climatic conditions;
- Integrate traditional, context relevant, cost-effective and efficient water harvesting / storage technologies, such as *haffirs* and enhanced natural depressions, in the design of the Khor Hong sheet flow diversion channel. This will improve water availability for cattle for (mainly) incoming cattle holders from the East (Murle people) in the dry season, by storing part of the excess sheet flow from the southeast. This needs to be combined with prevention or minimisation of water-borne diseases such as Bilharzia and Guinea worms, by fencing off the waterbodies, keeping distance between residential areas and standing waters and if feasible, by promoting refreshment of such stored surface water by means of river-based oscillation or active pumping / flushing;
- Plan for optimal deployment of locally available equipment and work force in order to achieve maximum skills transfer (sustainability) and highest value for money;
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- Include repair, upgrade, and operation & maintenance costs for locally available equipment, for optimal value for money and to enhance sustainability and capability to maintain drainage systems and flood protection works within the authorities (costs of repair and maintenance of current equipment are presented in Appendix D);
- Collaborate with Dr John Garang Memorial University of Science and Technology for optimal value for money and maximum transfer of knowledge (sustainability).

5.2 Key considerations

A number of key considerations was summarised before moving towards development of an intervention logic for a larger Bor Flood Control Initiative.

- Develop context relevant / locally applicable solutions for three timescales:
  - Current and next wet season;
  - Mid-term (2-5 years);
  - Long-term (>5 years);
- And three spatial scales:
  - Homestead;
  - Neighbourhood / quarter;
  - Town and environs;
- Introduce dedicated knowledge management and capacity building for:
  - The current generation of water managers in Urban and State government through learning by doing;
  - The future generation through internships and fellowships and collaboration with higher learning institutions in Bor (Dr John Garang Memorial University of Science & Technology) / South Sudan;
- Raise awareness among the population to obtain buy-in for spatial measures – a climate resilient Bor supports peace building and sustainable socio-economic development through:
  - Flood resilience;

– Drought resilience.

An important technical consideration is that the two main areas of flood risk management are related physically where urban drainage networks discharge into the main river. At current, the dyke along the river separates the town hydrologically from the river, leading to uncontrolled interventions by the local population: they cut through the dyke to allow excess drainage water to be released to the river. As soon as the river rises, the authorities have to come out to restore the dyke again. This could go on forever and is not sustainable. Moreover, if river levels rise unexpectedly or simply before the authorities are able to plug them, the areas behind the gaps in the dyke would be flooded. At those locations, outlet structures need to be constructed. An example of such an outlet structure is indicated in Figure 16[23]. This type of outlet structure is equipped with an automatic flap gate, preventing river water to flood the adjacent land. During low water levels, excess rain water can be drained to the river.

It is also important to link up with other initiatives in Bor. EKN supports Unicef in addressing potable water supply, and other donors may be involved in other public service delivery, river transportation, and other interventions within Bor or nearby, which need to be reflected in e.g. an integrated spatial plan for Bor. Adhering to the participatory planning principles of SEA / SESA safeguards proper incorporation of all relevant stakes and stakeholders in the process. Upon initial investigation of stakes and identification of stakeholders, detailed collaboration plans with key stakeholders must be described in a stakeholder engagement plan.

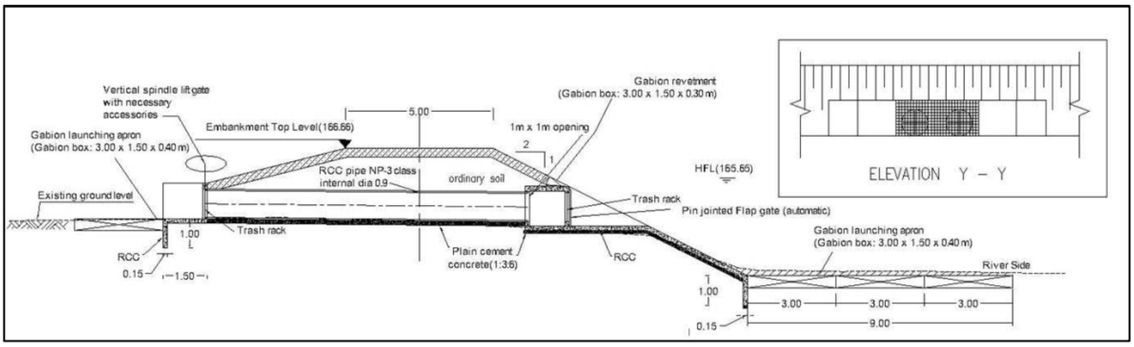

Figure 16: Example of a drainage outlet structure in a river dyke (source: Mott MacDonald)

Based on the findings and considerations in this report, a project intervention logic was developed for the Bor Flood Control Initiative, focused on the top three layers of the capacity building pyramid (Figure 17). An important role is given to knowledge management, as a means to truly build staff technical competence in order to maximise sustainability of any intervention in Bor itself, but also to enhance opportunities for replication throughout South Sudan beyond the lifetime of the Bor Flood Control Initiative. The starting point is in obtaining better data (a suitable high-resolution DEM/DTM) to inform wise decisions on drainage and flood control (Figure 18). This also informs timing of activities: whereas it is important that the local authorities continue with the emergency drainage works and dyke repairs that they have started, the first activity that could be supported by EKN would be the development of a suitable DEM/DTM. Spatial data can be collected by drone or aircraft-based LiDAR technology and turned into spatial information by using specialist software and skills. The information product will be disposed to the authorities and a team that can further support participatory decision making around external flood control and internal and inland drainage and water harvesting. Ultimately, the integrated urban master plan, containing a drainage plan as building block, will

[23] Example taken from a flood control project of Mott MacDonald in Nepal

inform decision making about investments to be made to protect the population of Bor from floods and other nuisance from too much or too little water.

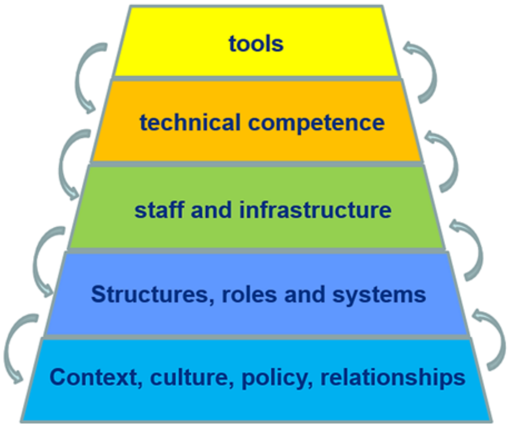

Figure 17: Capacity building pyramid, after Potter and Brough

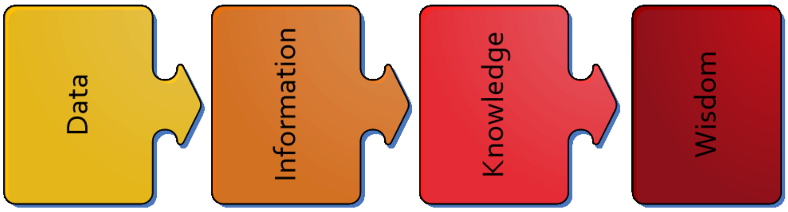

Figure 18: From data to wisdom - the key to knowledge management

5.3 Objectives of a future Bor Flood Control Initiative

The overall objective of a future Bor Flood Control Initiative could be formulated as follows.

To safeguard the population of Bor from river floods, incoming sheet flow from inland rainfall and from poor drainage in urban areas.

Specific objectives would then be:

- To develop suitable the knowledge base required to plan and implement sustainable urban water management and spatial planning;
- To develop the managerial and technical capacities and skills required to allow affective planning and implementation of drainage networks and river dykes;
- To plan, design and implement a selection of priority interventions in the field using the newly acquired capacities and skills.

5.4 Components of a future Bor Flood Control Initiative

The Bor Flood Control Initiative can then be built around five main components:

1. Internal resilience to storm water (local rainfall) and sheet flow (inland rainfall);
2. External resilience to increasing River Nile water levels and discharges due to climate change (upland rainfall);
3. Integrated urban spatial planning for sustainable development;
4. Knowledge management and capacity strengthening;

5. Support implementation of works (e.g. through a basket investment fund).

Components have been broken down into sub-components, in the following sections.

5.5 Component 1 – Internal resilience to storm water and sheet flow

5.5.1 Component 1.1 – Develop high resolution Digital Elevation Map

Develop a high resolution and high accuracy elevation map.

- Obtain GIS files of topographical map of Bor Town and Environs of 2009 from Sudan National Survey Authority GIS department;
- Deploy drone or LIDAR to collect high-resolution elevation data in dry season (allow ample time for logistics and customs clearance), and;
- Develop Digital Elevation Map at high resolution from point 2, triangulated with data from point 1 (if made available).

5.5.2 Component 1.2 – Calculate design discharges

- Develop high resolution sub-catchment delineation maps
- Assess design peak flows per urban sub-catchment by direct rainfall modelling:
  - Per main sub-catchment outlet to River, and;
  - Per micro-catchment within town.
- Assess magnitude of rural sheet flow from south/east by direct rainfall modelling:
  - Develop delineation of relevant rural sub-catchments;
  - Assess potential contribution of sheet flow entering Bor Town from southeast;
  - Investigate current potential for Khor Hong as rural sheet flow diversion channel, accommodating UNMISS base at current location in Khor, and;
  - Develop design for Khor Hong as rural sheet flow (creeping flow) diversion drain and natural physical boundary of urban area, integrating water harvesting and storage to overcome water shortages in the dry season.

5.5.3 Component 1.3 – Develop urban drainage plan

- Inventory existing drainage network:
  - Channels;
  - Structures (culverts, bridges, fords, pumps, etc), and;
  - Effectiveness of current emergency drainage measures.
- Develop urban drainage plan:
  - Based on overlaying and analysis of elevation map, sub-catchments, road network, settlement plan, and evaluation of emergency measures
- Support authorities in implementing priority drainage infrastructure interventions through component 5

5.6 Component 2 – External resilience to increasing River Nile water levels and discharges

5.6.1 Component 2.1 – Develop quantitative assessment of flood risks

- Rapid assessment of available monitoring data and climate change scenarios; field visit to dyke (this scoping mission);
- Resume monitoring Nile at Bor;
- Develop Bahr el-Jebel flood model, covering a significant section upstream/downstream Bor including floodplain
- Develop design discharges and water levels (current & future peak flows)
- Assess Nile-based flood risks for Bor town (current & future)

5.6.2 Component 2.2 – Develop flood management plan

- Develop a 'Room for the River' type flood management plan
  - Design and agree upon participatory process (SESA)
  - Investigate 'Room for the River' potential to reduce peak water levels in main river to alleviate flood risks for Bor town (use model and drone)
  - Liaise with river transport authorities and other stakeholders and communities
  - Jointly develop draft plan for flood management works in/around town and/or in main channel and/or floodplain
  - Perform public consultation (government, stakeholders, communities), incorporate and respond to feedback, and develop final plan
  - Address links between drainage system and river – flexible solution preventing back-flow based flooding
  - Consider options for smart land reclamation along main river by means of dykes and embankments

5.7 Component 3 – Integrated urban spatial planning for sustainable development

5.7.1 Component 3.1 – Integrated urban plan for sustainable development to support peace

- Participatory process
  - Process of Strategic Environmental and Social Assessment (SESA)
  - Planning for and with stakeholders and communities
  - Creating buy-in from the start, to facilitate implementation towards end
- Topics of interest
  - Incorporate space for water (as in 'Room for the River') in urban planning
  - Address urban drainage as public service
  - Urban water supply and Sanitation
  - Potential for irrigation within or outside city limits
  - Drought and water scarcity: water storage in city and rural area, in Khor Hong, etc
  - Prevent stagnant water
  - Migration routes for cattle and wildlife

  - Eco-tourism, recreation, and private sector development
  - All different water uses and users, including fisheries, aquaculture
  - Riverside land reclamation for different uses
- Long term focus
  - Sustainable development of town of Bor
  - Integrated public services delivery approach, reserving public space in spatial plan for distribution and collection networks (drainage, water supply, electricity, gas, fiber for internet, etc)
  - Bor as model town for sustainable urban planning and development
  - Starting point for long term renewed relationship NL-SS in Jonglei State
  - Coordination of humanitarian relief and development initiatives

5.8 Component 4 – Knowledge management and capacity strengthening

Wise decisions require an entire knowledge management chain:

- Monitor and survey to obtain reliable data (reinstate staff gauge at Bor)
- Turn data into information by analysis, modelling, interpretation
- Absorb information to develop knowledge
- Use knowledge to develop wisdom
- Use wisdom to take the right decisions

Note: the costs of not knowing (and wrong decisions) are often higher than those of generating the required knowledge

5.8.1 Component 4.1 – Urban drainage management skills

- Develop drainage design and maintenance manual
  - How to calculate design discharge for any given area
  - How to design a drainage channel for any given design discharge
  - How to design a culvert, bridge, or ford etc for any given design discharge
  - How to develop criteria for pumps, gates, and other special structures
  - How to maintain drainage channels and structures
  - How to cost development and maintenance of channels and structures
- Train government staff in design, implementation and maintenance
- Develop visual awareness raising materials (infographics) for residents of Bor, to optimise drainage of individual plots and to create buy-in for (co)maintenance of public drainage infrastructure

5.8.2 Component 4.2 – Build capacity of and with higher learning and research sector

- Develop collaboration with knowledge institutions
  - Dr. John Garang Memorial University of Science and Technology
  - Other higher learning centres
  - Investigate opportunities to trickle down to Technical and Vocational Education and Training, e.g. through Nuffic (Netherlands funding for international collaboration in higher learning)

  - Objective is to build local capacities and skills to replicate and extend sustainable urban planning and climate resilience

5.8.3 Component 4.3 – Equipment and tools – hardware and software

- Rehabilitate / overhaul available machinery
- Procure additional machinery and/or spare parts for sustainability
- Train technicians in maintenance of machinery
- Train operators in optimal operation of machinery

5.9 Component 5 – Support implementation of works

5.9.1 Component 5.1 – Develop and manage fund for implementation of works

- Demonstrate added value of integrated planning
- Enhance learning by doing
- If possible, set up basket fund for integrated public investments that relate to water and urban public services delivery
  - Road rehabilitation with roadside drainage
  - Other distribution / collection networks for public services
    - Water supply
    - Electricity
    - Fibre optics cable (internet)
    - etc
- Independent fund management to accelerate implementation

Appendices

A. Support letter MWRI

The Republic of South Sudan
Ministry of Water Resources & Irrigation
Juba
Office of the Undersecretary

Our Ref: RSS/MWRI/J/OU/1/26

22 August 2019

Hon. Ayom Mac
Minister, Ministry of Physical Infrastructure,
Jonglei State,
Bor

Re: Flood Control Assessment Initiative in Bor Town and Surroundings (23-28 August 2019)

Hon. Minister,

I am writing in response to inform you esteemed Ministry that a team composed of two consultants is scheduled to travel to Bor to for a week-long scoping mission.

The objective of the mission is to conduct a full assessment of recent floods that devastated Bor, possible causes and options to address the frequent flood problems.

This initiative is being supported by the Embassy of the Kingdom of the Netherlands in Juba. Therefore, this letter is to request the Ministry of Physical Infrastructure and state institutions and their partners to provide any assistance the team may need in regards to facilitating their local movements to access information and areas of interest in order to complete their mission on time.

The names of the consultants are:

1. Rob Nieuwenhuis [Dutch National]
2. Isaac Liabwel C. Yol (South Sudanese)

Please accept assurance of our usual cooperation.

Yours sincerely,

THE REPUBLIC OF SOUTH SUDAN
Office of the Undersecretary
Date:
MINISTRY OF WATER RESOURCES AND IRRIGATION

Alier Bullen N. Oka
Undersecretary

Cc: Hon. Minister, Ministry of Water Resources and Irrigation.
Cc: Hon. Mayor of Bor
Cc: File

Physical Address: Plot No. 11, Block No. AXII, Hai el-Cinema **P.O. Box:** 476, Juba. **Web:** www.mwri-goss.org

B. Meeting notes

B.1 22nd August 2019

B.1.1 Meeting at Mott MacDonald

Rob from Nairobi and Isaac from Addis Ababa converged early afternoon (around lunch time) at Euroconsult Mott MacDonald office in Juba, where they familiarized with one another and agreed on the conduct of the mission.

B.1.2 Meeting at MWRI-RSS

After lunch, the mission members went to the Republic of South Sudan (RSS) Ministry of Water Resources and Irrigation (MWRI) to meet the Undersecretary, Mr. Alier Bullen Ngong Oka at 15:00 hr. After self-introduction and introduction of the mission by Rob, Mr. Oka welcomed the mission members and said this is a start of the job; and he informed the team that he has just returned from an urban water supply mission with UNICEF to Bor and he saw himself the suffering people are undergoing as a result of flooding in Bor. He further said that he is on his way to the World Water week in Stockholm, Sweden, to which he has been invited to by Stockholm International Water Institute (SIWI), to present/speak on climate induced water insecurity. From the discussion with undersecretary, MWRI-RSS, following points can be recapped:

- Obtainment of town planning maps
- There are numerous Khors/streams, which flow into the river whose courses have been obstructed. Also, these streams act as river outlets when the river rises
- There is no monitoring on and preparedness against flooding

B.1.3 Meeting at EKN

After the meeting with undersecretary, MWRI-RSS, the mission members proceeded to the Embassy of the Kingdom of the Netherlands (EKN) in Juba, at which they met with Mr. Marc Mazairac, Head of Development Cooperation, and Richard Aludra, Policy Officer for Water. After self-introduction, they asked the assessment team from Mott MacDonald on how they intend to proceed with the task; and after the team Leader, Mr. Rob explained to them that the methodology of this scoping mission is mainly comprised of desk review, GIS / remote sensing work, field inspection and use of other experiences, the following can be recapped from the interaction:

- Both rains and high flows are reportedly causing floods
- Participatory and integrated / multi-disciplinary approaches, i.e., combining of
  - environmental management with flood control planning
  - technical approach with knowledge management, e.g., through monitoring
  - water and food aspects with private sector and support to women/youth groups
  - types of solutions with simple investment and prerequisite capacities
- Use of relevant experiences elsewhere, such as room for the river flood management approach in the Netherlands
- Need for push and pull factors, to achieve flood resilient urban planning

- This flood control initiative will be linked to the EKN hubs of stability approach and resilience programming with more other partners

B.2 23rd August 2019

B.2.1 Reception at Bor Airport

The mission team was received and welcomed by the Lord Mayor of Bor, Dr. Mach Majier Gai, at the airport.

B.2.2 Security debriefing

At the airport, the Interpreter, Mr. Awan Isaiah Mayom and the WS (Insights) Security Company personnel, Mr. Bol Deng joined the team. Mr. Bol then took the mission team for a security debrief at UNMISS compound, next to the airport in the eastern side.

B.2.3 Courtesy call to H. E. the Governor of Jonglei State

Accompanied by the Lord Mayor, the team went straight to Office of the Governor, H. E. Maker Thiong Maal; and from the interaction with him the following can be recapped:

- According to his understanding, sources of flooding at Bor are the
  - River water from equatorial lakes
  - Eastern Drainage (sheet flow)
  - Dams downstream (in Sudan and Egypt) leading to backwaters
- Water is a blessing if managed properly
  - we just need technology
  - there is no infrastructure
  - we need a drainage system
- Development of a full project is urgent
- Training of youth needs to be incorporated for sustainability

B.2.4 Meeting with technical experts from Jonglei State Ministry of Physical Infrastructure (MoPI)

In the company of the Lord Mayor, the mission team met the D. G. Ministry of Physical Infrastructure, Eng. Elijah Mabior Bol and the Director of Survey, Eng. Deng Kur, at Bor Park Palace Hotel. At the meeting, following technical presentations accompanied with discussions and a way forward were made:

- Rob presented the preliminary findings from the desk review, maps and testimonies from the former Dutch expert who had been to the area in 1970s-1980s (Mr. Sjoerd Zanen, known as Tong Mabior, a name given to him by the local Dinka community); and records and drainage catchments across the town by the team hydrologist, David Ocio.
- Deng Kur presented the work in progress on town planning mapping and revealed that topographic survey of Bor town was carried out by the Sudan National Survey Authority and he will share hard copies of the maps, which were produced in 2009
- From the discussions, the following can be recapped
  - The flood control focus was the initiative of the Ministry, picked up by the Mayor and then now supported by the Embassy of the Kingdom of the Netherlands
  - Team work is needed, e.g., consultants, institutions, partners and the people

- We should not make plans indoors, we need to go out and consult people
- We need information, so that we decide on informed basis
- Role of humans in aggravating nature's behaviour and impacts back on humans
- Flooding water stagnates in town, leading to waterborne diseases
- Need for protection against floods from the Nile

B.2.5 Site visits and inspection of town drainage works with efforts by the Bor Municipal Council

After the meeting, in the company of Lord Mayor, D. G. Ministry of Physical infrastructure and the Director of Survey, the mission team carried on in the field, to observe how the self-initiated drainage works have practically helped in draining parts of the town, with water being drained into the river along natural depressions and (re)excavated drainage channels.

B.3 24th August 2019

Site visits and inspection of the dyke condition and possible realignment

B.4 25th August 2019

Site visits and inspection of the excavator works and the existing and possible drainage paths

B.5 26th August 2019

B.5.1 Meeting with the other sectors

In the company of Lord Mayor, D. G. Ministry of Physical infrastructure and the Director of Survey, the mission team met with the Minister of Agriculture and the technicians from the Ministries of Agriculture, Forestry, Animal Resources and Fisheries; and Health and Environment; in addition to Urban Water Corporation (Bor Area/Station). The discussions storyline, is as follows:

The Mayor opened the meeting, welcomed, introduced and thanked all, for accepting on short notice, many thanks for coming despite bad weather, he added. He then explained the Assessment for Bor Flood Control Initiative mission, informing them that the mission team has been carrying out field inspection since 23rd August 2019; and they are now reaching out to you other stakeholder and partner ministries, institutions and organisations for awareness creation and additional information, to support development of the project proposal. This is an important moment to share knowledge for best project development.

DG MoPI: Today is the day for obtaining missing information and consult opinions of other stakeholder/partner sectors.

Isaac: We want to hear from you, the other stakeholders, your interests and opinions.

Rob: further elaborated on scope of the mission and emphasised the need for more information, e.g., on migration routes of cattle and wildlife.

Mr. Deng Ajak Biar, Director of Environment, Ministry of Health and Environment (MoH): There is a need for cooperation with municipalities and communities, to plant more trees in the towns; and that they recently planted 200 trees within and around their compound, including lemons, which are important as medicines. He stressed the importance of environmental considerations, in any project; and that is why the power station has been moved from near the river to an inland location. There are environmental and health issues and concerns. MoH is among the collaborators with the Mayor; and he requested that there should be a general monthly meeting with every town quarter. Stagnant water from flooding such as the one in Hai Fangak area, leads to diseases such as Bilharzia, malaria and others. He observed that people in Jonglei state have problems of excavating out soils within the towns, hence there are borrow pits and big holes, especially where new ministry buildings are planned. Department of Environment was established 2-3 years ago and there are problems of moving it from place to place. Isaac asked if National Ministry provided State Ministry with information on climate change adaptation. Rob asked for figures on water borne diseases. MoH has departments for control of malaria and other diseases. MoH would like to minimise stagnant water for more than 3 days. Isaac requested the Director of environment to liaise with colleagues to provide statistics on water borne diseases, to help substantiate project impacts. Mayor will assist in reaching out to the Minister and DG of the MoH. Some data are considered confidential. Yet it was mentioned that at current, families spend up to half their income on medicine against water borne diseases such as malaria. Money that could instead be spent on development. Rob added that a good baseline is important for EKN – impact and value for money. The Director of Environment is a forester by education; and MoPI also has an environmental officer.

Minister of Agriculture, Hon. John Dut Kuch welcomed Rob and Isaac; and he pointed to the fact that water issue has been there as a challenge. Any governor is always challenged by water and waterborne diseases. He was very happy for the visit by the Dutch Ambassador and appreciated continuous support from EKN. The technical experts are here, the DG is here and the Director of fisheries is on his way. They should provide technical inputs into the project proposal, stressing that the Ministry of Agriculture is bigger than other ministries, as it comprises of different number of previous ministries. It has now 3 DGs. Many of other related activities to today's activity, such as migratory routes of animals, may cease to exist in the future due to urban development. Three main cattle migratory routes existed. One through Leudiet (northern part of town); the second through the southern side of the town seems to have been blocked due to encroachment of town planning/demarcation and people are not using it. In fact, South Sudan Hotel is the one affecting that route. Recently, people use riverside crossing, which might be covered later by urban planning that is associated with a lot of conflict of interest. When the dyke was built, animal routes were affected – leading to cuts in dykes. November – January is a period of migration. The DG will provide more technical details. He has to attend another meeting but will return to co-own this project. Isaac asked about preserving livestock routes, so that they are not affected in future? The Minister responded that urban planning will affect routes – these need to be relocated. Isaac explained that Nairobi is a grazing ground for Masaai livestock, lamenting why is the urban settlement taking up all the lands, including the one in front of the old booster pump, the scheme and some sections of the old irrigation canal. Also water courses have been blocked. Town needs food from agriculture and cattle. Dykes can be designed in such a way that cattle movement is not obstructed. Someone in policy making position needs to be involved in planning. Tomorrow we will have a presentation to the State Cabinet, and we will highlight some of such concerns.

After the Minister of Agriculture left for another meeting Mr. Atem de Gak, DG, Ministry of Agriculture (Miniagri), gave an overview on the sources of flood water as: 1) Sudd region (i.e. the Nile); 2) High rainfall on the neighbouring highlands and when rivers flowing down from there overflow, we are flooded; 3) Jonglei canal embankment disturbs natural riverine discharge direction, creating excess water, even Duk (meaning highland) are being flooded, due to blockages by the canal embankment; and 4) creeping flow from the eastern plains – affects Bor town. This is the understanding of DG of where water comes from. In many catchments, water does not follow actual streams, but discharges as sheet flow, and this aggravates flooding in Bor, he stressed. People adapt themselves by developing bunds. Water is seen as curse by many, but if we can control it, we might become rich. Drainage capacity is not sufficient to deal with sheet flow, unless a big canal is developed around Bor to divert sheet flow again to the river, north/downstream of the town. Then the rain in Bor can easily be drained. Mentioned sheet flow also comes from as far as Eastern Equatoria (Isaac: Confirmed that it comes from the Imatong Mountains' watersheds, Southeast of Bor). Another solution: these waters are a blessing to us. Why not making artificial lakes to harvest the waters, hence converting water from destroying to utilising; and we can be very rich. For agriculture, both water harvesting and a canal around Bor town are important. This is how DG Miniagri perceives the problem and its solution. D. G. for fisheries, Miniagri, also concurred that artificial reservoirs would facilitate fisheries development/production. Rob and Isaac: Interjected that the design needs to accommodate year-round water (depth to be larger than annual evaporation); and Rob further said these should be accompanied with development of a proper, healthy ecosystems, to avoid diseases such as malaria and bilharzia. DG Miniagri then continued further, saying that within Boma – Jonglei landscape, to the north there is Bahr el Zeraf game reserve, which needs to be preserved. Environmentally, we have the Sudd, the forests towards Ethiopian highlands leeway, Equatorial lakes and Congo basin (the second lung of the world, after Amazon). South Sudan is partly located in that basin. There are about 9 countries in the basin. Convection from the basin determines weather in this region. Similar convection happens in Jonglei, due to the Sudd and Acacia forests. Rain has always been very stable, thanks to these main ecosystems. Has seen how interventions in Yellow River basin have been made around major Chinese cities. Natural resources in Jonglei state need to be preserved for next generations. Question MoH: you say we can dig another canal. Answer DG Miniagri: yes, we can develop a diversion canal around Bor town. At this juncture, Rob explained Room for the River flood control approach and the Strategic Environmental and Social Assessment (SESA); and the DG Miniagi said that under Nile Waters Agreement, interventions can have broad transboundary benefits and impacts. For instance, a hydropower dam at Fula could have negative environmental impacts in Uganda. Question Khor Hong (or Wong): is it connected to the river? Other channels are fed by the river and return to the river.

Isaac explained main drainage basins of South Sudan. Next, asked the DG Miniagri of his opinion on why current drainage is not sufficient. DG Miniagri: town area is almost flat. Any depression anywhere holds water. This is town planning issue. Depressions when allocated as plots need to be drained off. Three canals can be developed as main drains, including Makuac junction at akuot ayol to achendiir.

Question: about occupation of the irrigation canal upstream of booster pump. Why? In future, the persons now occupying the plot with original canal could be compensated to restore the canal. Isaac explained how urban master plan needs to incorporate more than just settlement but also drainage, migration routes, etc.

Rob checked the status of perceptions of the water system functioning as expressed by DG Miniagri. The DG Miniagri agreed that his are interpretations / perceptions, which may or may not be the actual and complete truth. All agree that the new project needs to lay the scientific knowledge base for the development of the eventual flood resilience plan and related urban planning. Further data collection and modelling is necessary to support decision making based on jointly agreed upon knowledge base.

After that the Minister of Agriculture re-entered the meeting and DG MoPI gave a quick summary of the scoping mission to date for the sake of DG fisheries, Mr. James Majok Maper who had also, just entered; and he then invited him to provide his views, according to his understanding. DG fisheries said his ministry is dealing with natural water fisheries. No aquaculture yet, but if we conserve water, we can benefit. He said that there is over 300,000 metric ton / year fish stock in the Sudd. If well managed, we can harvest 150,000 annually. We need to know how much fish enters Bor town, Juba, etc. Currently there is no monitoring. Regarding fish culture, one can stock fingerlings to breed fish. This can augment food security and stimulate private sector growth. Currently not done in Jonglei. It is not difficult, but needs facilities for the entire value chain. DG worked in fisheries since 1978. River fisheries have been vital to sustain population of Bor throughout difficult times. Combine Eastern drain with experience from Aboba in Ethiopia (artificial reservoir with fisheries / aquaculture). Isaac: there was a small conflict between fishermen and dyke function. How can flood protection by dyke be reconciled with fisheries practice along the river? Are the issues remaining? DG Fisheries stated that dykes should only be opened to allow river water to enter to floodplains in dry times for grass to grow for cattle, not for fisheries. There is no much interference between fishing activities and the floods control dikes, as fishing takes place in the deep waters into the river behind dikes.

DG Miniagri: British had built concrete riverbank structure, to protect it against erosion and overtopping during floods. After 1956 independence, subsequent governments neglected it; and the materials were vandalised. He advised that dyke embankment should follow the actual river bank, i.e., aligned with the normal meandering of the river. Dykes are sometimes problematic. Some people want to reclaim land. In some locations previous homesteads were flooded due to inland development of dykes, rather than curbing them out of the river.

DG Env. MoH asked: why is fish so expensive in the market, while quantities are so high? Currency, as well as number of steps required in the value chain. Fishermen have expenses for operation and maintenance in USD, from overseas. If facilities are better, supply and prices can improve. Good thing is that local fish competes with foreign supplies.

DG MoPI: environmental issues may cause fish to migrate. Visited Sudd in March. Those lakes are now threatened by water hyacinths. Alien species that arrived from Lake Victoria. This impedes fish ecosystems. Fish production needs to be monitored closely. Bangladeshi soldier told him that global demand for fish is very high – South Sudan could become global supplier. Fish here die of old age – a tremendous opportunity for economic development. Better future development scenario than oil. Jonglei water resources and environment need to be protected to protect fish stocks of high quality and quantity. Environmental challenges might impede opportunities if not controlled properly. Also, humans use mosquito nets to catch fingerlings, impeding reproduction capacity. A size restriction needs to be adhered to. DG Miniagi said: natural water bodies may need to be protected from fishing – only for nurseries and hatching. Breeding further in ponds. EKN intends to do intervention around fisheries, the Mayor informed the colleagues to be prepared.

Deputy Director / Acting Area Manager, Urban Water Corporation (UWC) – Bor Area/Station, Mr. Moses Mayol: Informed the meeting that the water supply station was established in 2009 and officially opened in 2010. Its production capacity is 4,800 m3/day. All the required facilities and inputs are not enough, hence it only operates five hours a day, producing 750 m3. They don't have enough Operation and Maintenance (O&M) capacity to work the whole day. Network does not cover the whole town, there is only 21 km distribution network within town, starting from the treatment plant to the airport, then to Tibet than to Leudiet; and Blocks 1,2 & 3 up to Lekyak. There is a problem with the network in the town in relation to roads. Main pipes and standpipes (water kiosks) can be in the middle of a road or crossing a drain. This scenario happened like this because the town water supply network was constructed before alignment and opening of the roads. We need to coordinate with the municipality, e.g., when they are opening ways for drainage, their ditches should be high enough above the pipes (in other words: pipes should be laid deep enough to facilitate crossings with drainage channels); and UWC needs to inform on locations of the pipelines, which are in most cases always about 0.75

– 1 m deep. Only around block 1, they are 50 cm deep. Dir of Survey MoPI: designed urban planning versus squatters. Not up to date. Roads are made bigger to allow for service delivery systems: water, sewage, power, gas, drainage, fibre optic. (Rob: Interjected that one should make sure all supply lines are mapped in GIS with their metadata for the long term, so that the plan can become a true master plan). Map of Bor town before 1983 is cancelled. Old roads were small and have been discontinued. Isaac mentioned that straight roads are not always the best solution – build upon existing (curved) paths where suitable. UWC has map of network, but it is not complete. Mostly restricted to existing network. Isaac: UNICEF came to help. Asked if UWC knows where their consumers are. They collect fees to operate, whereas salaries come from HQ. Challenge: networks have not reached the entire town. The plant capacity is not utilised fully. Sincen power plant was opened, main consumption takes place during power hours in two shifts: 2 hours in morning, 3 hours in evening. DG MoPI: storage capacity of tanks was only 120,000 litres. Last year ICRC promoted capacity by building another tank – now 320,000 litres. Restriction of operation hours is only due to fuel limitations. Boreholes water is free or cheaper than piped water, but quality is not safe. Awareness raising is needed. needs to be combined with extension of service delivery. Mayor: Bor has a population that has a rural living pattern within town. Besides UWC, MoPI has department for Urban Water and Sanitation.

Director of Survey mentioned that the Sudan National Survey Authority has been migrated to the Ministry of Defence; and this requires EKN and the Republic of South Sudan Ministry of Foreign Affairs and International Cooperation to assist in obtaining GIS files (shapefiles) from Khartoum. Isaac started drafting the letter – we need to know the protocol to be followed in this regard. Director of Survey also, said that there is a map of greater Jonglei. He will provide contact details in Juba to obtain GIS files from the National Ministry of Lands and Urban Development, in Juba. MoA DG mentioned a booklet of environment for Jonglei state – softcopy to be obtained in Juba.

Towards the end, DG MoPI made the remarks, saying that this meeting has been a very good opportunity to exchange information, perceptions and opinions. After that he Invited the Mayor to close the meeting. The Mayor reiterated that we have a letter from MWRI-RSS undersecretary that allows the government to provide all required information to the consultants. He stressed that Jonglei got the best opportunity to be advised, and the Dutch are the best in water management. Today we were able to look beyond town limits.

B.5.2 Meeting at UNMISS and Inspection of Khor Hong

After the meeting with the other sectors/subsectors, in the company of Lord Mayor, D. G. Ministry of Physical infrastructure, the Director of Survey and the UWC Ag. Area Manager, the mission team went to visit UNMISS Camp and inspect Khor Hong; because the Camp is entirely lying across the Khor.

The team was met by Mr. Isidore Boutchue, Senior Civil Affairs Officer, TL - Bor Field Office and Acting Head of Office at the time of the visit; Samuel Sarpon, Civil Affairs Officer; Liban Haji, Field Administrative Officer – FAO; and Benjamin, an engineer working with Liban.

The Mayor introduced the team and Bor Flood Control Initiative scoping mission, in relation to the EKN.

Rob explained the reason for visiting the UNMISS, being the fact that it is located in the centre of Khor Hong.

Isaac asked about drainage of the camp. Liban and Benjamin explained that the drainage covers the interior of the camp, being surrounded by a large bund. Pumps are used to pump out excess water. Natural topography and depressions are used as drainage network, augmented with channels dug, to collect rainwater and channel it to collection points.

The IDP camp is most flooded, even though it is also surrounded by a bund; and water is also pumped out. When it rains two days, the area is totally flooded. Less intense rain does not cause flooding problems. This camp was not inspected during this visit.

After the meeting with the civil affairs managers, the team was given two staff from UNMISS to visit sites and inspect drainage and flood control network within the UNMISS Compound and Khor Hong outside it.

B.6 27th August 2019

B.6.1 Conceptualisation and presentation to the Cabinet

In company of the Mayor, on this day, Rob and Isaac spent the first morning on conceptualising and discussing on the situation and possible solutions. After that Rob finalised the presentation, which was presented in the afternoon to the extended Cabinet of the Jonglei State Government, chaired by the Governor and Moderated by his Deputy. Also in attendance were the Speaker of the State Legislative Assembly; Gubernatorial Advisors; Ministers; MPs; the Mayor; VC of Dr. John Garang Memorial University of Science and Technology; Secretary General of the Jonglei State Government; Senior Technical Directors from the Ministries of Agriculture and MoPI. Following are the excerpts from the presentation and discussion:

- For the benefit of the audience, Rob gave the chronology in renaming of almost the same consultancy firm that was known to them, from ILACO to Euroconsult, Euroconsult Mott MacDonald and now often just referred to as Mott MacDonald.
- Political will does not only come from the top, it is wherever you are placed.
- The Mayor was appreciated for making a difference in his position.
- A first time for an expert to come and find out the flooding problem, what you saw is a quarter of what we go through each year; the determination of Tong Mabior has become true.
- Flooding problem is partly due to development of roads without making proper drainage.
- We want to be friends to water and water to us, and we just want to know how to do so.
- There is lack of sewerage or the whole sanitation value chain.
- If you don't want to change, you cannot change, most of the residents are not urban, they are rural people displaced to the town; and a few of us who were already residing in towns must try to change their mind-sets, so as to make the city accommodative.
- Question: What about the plans to dredge the river? Here Rob explained that in the Netherlands we do dredge our rivers,as standard maintenance for navigation and to maintain the rivers' discharge capacity. As such, it is one of the possible measures in a room for the river flood control approach but not the only one. Room for the River is a Dutch approach in which hydrological and hydraulic problems (related to increasing river discharges due to climate change) are addressed by a combination of technical studies and participatory spatial planning, for integrated solutions for flood control, nature conservation, and socio-economic development. Principles of Strategic Environmental Assessment are adhered to in order to create consensus from the start in the planning phase, rather than having to overcome resistance in the implementation phase. This approach has been very effective and efficient in the Netherlands, where Room for the River was the first large public infrastructure programme to be completed on time and within budget.

B.7 28th August 2019

B.7.1 Debriefing at EKN

On return to Juba, on 28/08/2019, the Assessment for Bor Flood Control Initiative scoping mission team members who went to the field, Rob Nieuwenhuis and Isaac Liabwel, went straight away to the Mott MacDonald Offices in Juba, where they updated the presentation, in the light of the Cabinet comments/discussion; and also in line with the mission TOR. After that they proceeded to the Embassy and Rob presented the conceptualised preliminary findings on the situation and possible interventions/solutions to Mr. Michel Deelen, Deputy Head of Mission and Richard Aludra, Policy Officer for Water. From the discussion with them, following points can be recapped:

- The comprehensive presentation was much appreciated by EKN – there is no need for a separate Aide Memoire, go straight to draft and final report.
- Recommendations should be well structured.
- Many towns are flooded this year – the flood problems go beyond Bor. In that sense, Bor Flood Control may set an example for other towns in South Sudan.

C. Unit costs of civil works equipment and materials

Table 6: example of commercial unit prices for materials and equipment

Yei Road, Customs Area, Juba - South Sudan

SALE PRICES

As of June 27, 2016

ITEM	PRODUCTS & SERVICES	UNIT	RATE (USD)	RATE (SSP)
	Aggregate			
1	Aggregates - "1" , 3/4, 3/8	m3	$ 41.00	750
2	Quarry Dust	m3	$ 27.00	350
3	Stone Base	m3	$ 34.00	610
4	Hard Core(medium size 20cm)	m3	$ 27.00	500
5	River Sand (Rough)	m3	$ 5.00	120
6	Marrum	m3	$ 6.00	100
7	Quarry Waste	m3	$ 5.00	80
8	Transport-14m3 (From Jebel crusher)	Trip	$ 80.00	1,500
9	Transport -14m3 (from Luri crusher)	Trip	$ 155.00	2,900
	Iron sheets			
10	Cover Max or Liner Profile (300*83*30G)	Pcs	$ 12.00	210
11	Versatile Profile (300*83*30G) Gulvanised, duel Coat	Pcs	$ 12.00	210
12	Ridge Cap	Pcs	$ 6.00	80
	Concrete			
13	Ready Mix Concrete Class 25/20	m3	$ 480.00	9,600
14	Ready Mix Concrete Class 30/20	m3	$ 536.00	10,720
15	Concrete Blocks No. 4 (40cm*10cm*20cm)	Pcs	$ 1.00	20
16	Concrete Blocks No. 9 (40cm*10cm*20cm)	Pcs	$ 2.00	40
17	Cover Stone, Road cap (100cm*15cm*25cm)	Pcs	$ 6.00	120
18	Interlock White (20cm*12cm*7cm)	Pcs	$ 1.00	20
19	Interlock coloured (20cm*12cm*7cm)	Pcs	$ 1.00	20
	Culvert			
20	RC Pipe (600 mm Diameter)	Pcs	$ 140.00	2,800
21	RC Pipe (1000 mm Diameter)	Pcs	$ 225.00	4,500
22	RC Pipe (1500mm Diameter)	Pcs	$ 300.00	6,000
	Equipment Services			
23	Motor Grader	8hrs	$ 1,500.00	52,500
24	Steel Drum Roller	8hrs	$ 1,000.00	35,000
25	Vibrating Roller	8hrs	$ 1,000.00	35,000
26	Tyre Roller	8hrs	$ 1,200.00	42,000
27	Water Tank	8hrs	$ 900.00	31,500
28	Prime Coat/Bitumen Distributor	8hrs	$ 1,300.00	45,500
29	Truck Within Juba	8hrs	$ 700.00	24,500
30	Asphalt Pavor	8hrs	$ 2,000.00	70,000
31	Bob Cat	8hrs	$ 800.00	28,000
32	Hyd. Excavator (CAT-320D)	8hrs	$ 1,500.00	52,500
33	Wheel Loader	8hrs	$ 1,300.00	45,500
34	Hyd. Breaker + Excavator	8hrs	$ 1,800.00	63,000
35	Low Bed (within 30Km)	8hrs	$ 1,400.00	49,000
36	Bull Dozer	8hrs	$ 1,500.00	52,500
37	Crane	8hrs	$ 1,600.00	56,000

Equipment hiring prices are not including fuel.

Issued by:

Nunu Lillian M.
Sale Manager

Tel: 956908647
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THAI - SOUTH SUDAN CONSTRUCTION CO. LTD
ABMC

Approved by:

Engr. Ky Win
Director of Projects

D. Quotation for repair of equipment

The following pages present an updated quotation from the Caterpillar representative in South Sudan, for repairs and maintenance of large civil engineering equipment of the Ministry of Physical Infrastructure of Jonglei State, currently available in Bor. Carrying out the required maintenance and repair work would allow the authorities in Bor to continue carrying out civil engineering works for flood control.

Ezentus CAT

EZENTUS FZE COMPANY LTD
Plot No.1, Industrial Area, Terekeka Rd.
P.O. Box 198 - Juba
Republic of South Sudan

QUOTATION

QUOTE NO: 1112/19
Date: 11,Sep,2019
Deadline>11,Oct,2019

Genuine Parts

To: Jongle State
Ministry of Physical Infrastracture

Qty	Part Number	Description	Unit Price	Total Price
1	5I-8670	filter-oil Advanced Eff	206.91	206.91
1	179-9806	filter Element As oil	444.68	444.68
1	093-7521	filter-oil Advanced Eff	205.73	205.73
1	174-9570	filter GP-water sep	396.45	396.45
1	283-3074	switch As-toggle	159.83	159.83
2	221-8859	sensor As pressure	5,307.27	10,614.54
1	157-3198	monitor GP-operator	10,913.79	10,913.79
1	279-7860	turbocharger GP	9,376.29	9,376.29
1	247-5212	motor As governer	6,633.17	6,633.17
1	070-0195	precleaner As	1,037.76	1,037.76
1	6I-2501	filter Element As air	290.13	290.13
1	6I-2502	filter Element As air	215.12	215.12
1	6I-4464	cover As air	293.42	293.42
1	4P-5524	seal o ring	63.63	63.63
1	255-2966	indicator As air	147.27	147.27
1	212-8585	belt serpentine	667.46	667.46
1	1R-0739	oil filter	65.06	65.06
1	094-9725	plug	8.34	8.34
1	095-2038	washer	4.14	4.14
1	1R-0751	fuel filter	91.43	91.43
1	297-7662	cap oil fill	65.42	65.42
1	7X-7700	cap As fuel	408.98	408.98
5	205-6612	coolant	259.58	1,297.88
10	EN200062-204	engine oil	55.13	551.25
10	EN240003-090	hydraulic oil	237.44	2,374.35
10	EN222002-202	gear oil	39.30	393.00

Total Parts Value		$ 46,925.97
Tax		0.00
Total Amount		$ 46,925.97

EZENTUS Bank account details:

Bank Name: Kenya Commercial Bank (KCB)
Address: Ministry Road, Buluk/ Juba South Sudan
Account Name: Ezentus FZE
Account Number: 5500953109
Swift Code: KCBLKENX

EZENTUS CO. LTD PARTS JUBA, SOUTH SUDAN

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EZENTUS FZE COMPANY LTD
Plot No.1, Industrial Area, Terekeka Rd.
P.O. Box 198 - Juba
Republic of South Sudan

QUOTATION

QUOTE NO: 1112/19
Date: 11,Sep,2019
Deadline:11,Oct,2019

Genuine Parts

TO: Jongle State
Ministry of Physical Infrastructure

Qty	Part Number	Description	Unit Price	Total Price
2	1G-8878	Filter PKG	292.13	584.25
2	462-1171	Filter Lube	70.97	141.93
1	252-5001	Primary Elem	430.79	430.79
1	252-5002	Elem As Sec	296.40	296.40
2	1R-0751	Filter As	91.43	182.85
2	326-1644	Filter As	166.31	332.61
1	417-7782	Thermostat	289.79	289.79
1	284-8207	Kits G	6,153.09	6,153.09
1	281-8744	Gasket	32.49	32.49
1	485-4895	Kit Pump	1,798.35	1,798.35
1	287-7430	Gasket Cover	71.97	71.97
1	225-8019	Gasket Pump	71.97	71.97
1	176-3141	Head Gasket	296.63	296.63
5	205-6612	Coolant	259.58	1,297.88
8	EN200062-204	ENOC Oil	55.13	441.00
10	EN222002-202	ENOC Gear Oil	39.30	393.00
10	EN240003-090	ENOC Hyd Oil	237.44	2,374.35
2	3T-5760	CAT Battery	931.32	1,862.64

Total parts value		$	**17,051.97**
Tax			**0.00**
Total Amount		$	**17,051.97**

EZENTUS Bank account details:
Bank Name: Kenya Commercial Bank (KCB)
Address: Ministry Road, Buluk/ Juba South Sudan
Account Name: Ezentus FZE
Account Number: 5500953109
Swift Code: KCBLKENX

EZENTUS CO. LTD PARTS JUBA, SOUTH SUDAN

EZENTUS FZE
Dubai Airport Free Zone
Building 5WA, Office G29
P.O. Box 54847, DAFZA, Dubai U.A.E
Direct: +971-4-292 9016 / Fax: +971-4-299 3442

Ezentus CAT

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QUOTATION

Genuine Parts

TO: Jongle State

Ministry of Physical Infrastracture

QUOTE NO: 11/2019

Date: 11,Sep,2019

Deadline: 11,Oct,2019

Qty	Part Number	Description	Unit Price	Total Price
1	300-6152	cable As	249.74	249.74
1	312-0378	cable As	248.10	248.10
1	310-7256	cable As	435.63	435.63
1	317-3168	cable As	207.14	207.14
1	318-2063	cable As	1,005.20	1,005.20
2	3T-5760	battery	931.32	1,862.64
1	212-5081	cover As	564.53	564.53
1	245-6375	filter element	324.33	324.33
1	245-6376	filter element	206.85	206.85
1	247-9730	valve As-check	102.68	102.68
2	242-3360	hose	0.51	1.02
1	261-9367	cartrdge	4,286.06	4,286.06
1	349-7059	Cap As	408.98	408.98
1	9P-7121	strainer fuel	209.27	209.27
1	345-3661	gauge oil level	361.04	361.04
1	246-4611	cap As Air	340.86	340.86
1	250-2984	pipe-extension	580.34	580.34
1	219-0314	clamp	35.91	35.91
4	3D-2981	gasket	34.28	137.10
4	7D-6567	cover As	292.35	1,169.40
32	0S-1621	bolt	2.85	91.20
1	2D-2654	ring-lock	222.02	222.02
1	8W-9566	flange	1,547.21	1,547.21
1	290-1505	rim As	7,003.10	7,003.10
2	1R1807	filter As lube	85.65	171.30
2	326-1644	filter fuel	166.31	332.61
1	220-8678	seal	2.51	2.51
1	343-5527	bowl	134.75	134.75
2	1R-0762	filter As-fuel	130.97	261.93
3	118-9573	bolt	29.58	88.74
1	207-1517	starting motor	7,657.13	7,657.13
1	248-2169	sensor	731.03	731.03
1	296-8060	sensor	731.03	731.03
2	256-6453	sensor	191.24	382.47
8	205-6612	coolant	259.58	2,076.60
12	EN200062-204	engine oil	55.13	661.50
15	EN240003-090	hydraulic oil	259.94	3,899.03
10	EN222002-202	gear oil	39.30	393.00

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1	CA1573165	Module	4,973.51	4,973.51
1	6V-5853	Blade As-wiper	110.87	110.87
1	6V-8259	Arm As-wiper	283.08	283.08
2	123-4354	Arm As-wiper	200.93	401.85
2	123-4355	Blade As-wiper	81.51	163.02
2	115-6806	Glass Side	392.88	785.76
1	8X-2228	Glass Front	2,355.60	2,355.60
1	5P-5768	Seal (4.3-M)	65.34	65.34
2	5P-5768	Seal (3.7-M)	65.34	130.68
1	102-9372	Glass Rear	1,740.65	1,740.65
2	149-3409	Glass	824.79	1,649.58
1	3E-9413	Seal (454-CM)	0.86	0.86
2	3E-9413	Seal (254-CM)	0.86	1.71
2	8X-3938	Glass	952.83	1,905.66
2	8X-4448	Glass	802.56	1,605.12
2	5P-5768	Seal (2.9-M)	65.34	130.68
2	5P-5768	Seal (2.8-M)	65.34	130.68
1	462-3542	Mirror As	349.56	349.56
2	5P-6871	Mirror As	524.69	1,049.37
1	131-3739	Tie Rod	1,299.75	1,299.75
1	131-3738	Tie Rod	810.48	810.48
1	131-3737	Tie Rod	793.95	793.95
2	131-3736	Tie Rod	704.88	1,409.76
2	5D-0269	Elbow	34.77	69.54
2	5K-7577	Hose As	6.84	13.68
2	9M-8662	Coupling	40.55	81.09
14	107-1983	Lamp (24-volt)	3.78	52.92
1	196-4150	Panel	850.52	850.52
4	202-1138	Elbow	17.96	71.82
1	383-8496	Gauge As-Cluster	2,279.43	2,279.43
1	288-5756	Film Identification	98.97	98.97
1	288-5757	Film Identification	98.97	98.97
2	304-6958	gauge As Brake	236.78	473.55
1	335-9387	Harness As-Panel	1,313.79	1,313.79
1	287-8562	Panel	611.97	611.97
2	234-4323	Lamp (24-volt)	175.14	350.28
1	334-3343	Harness As-Panel	1,066.47	1,066.47
1	344-3457	Lamp As-Head (24-volt)	858.93	858.93
1	344-3458	Lamp As-Head (24-volt)	858.93	858.93
1	384-7615	Harness As-Chassis	7,719.51	7,719.51
1	110-7887	Switch As-Start Key	520.13	520.13
1	185-2197	Switch As-Rocker	595.13	595.13
1	335-1894	Harness As-Console	1,561.38	1,561.38
1	3E-5239	Relay As (24-volt)	128.19	128.19

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1	8H-5306	Key Battery Disconnect	18.68	18.68
2	6V-8186	Nut-Full (5/16-24-THD)	1.08	2.16
2	7H-3641	End-Rod (5/16-24-THD)	90.00	180.00
2	8L-8598	Rod End	91.35	182.70
2	146-0705	Rod	204.29	408.57
3	17.5X25-16PR	Camso/Solideal European Brand	2,208.00	6,624.00

Total parts value		**$ 88,362.68**
Tax		**0.00**
Total Amount		**$ 88,362.68**

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