**NOVEMBER 2013** 

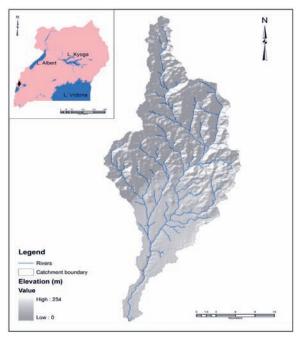




# STUDY OF THE FLOODING IN RWENZORI MOUNTAIN FOR EFFECTIVE DISASTER RISK MANAGEMENT









With support from:

# United Nations Development Programme

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# **EXECUTIVE SUMMARY**

This report presents the findings of a study that investigated the flood dynamics in Rwenzori sub-region focusing particularly on the May 2013 flood event which devastated the region. It culminates from the desire of a range of a range of stakeholders at national level for a scientific understanding of the casual factors and the need to guide on the potential interventions to secure the communities from future disasters related to flood hazards in the Rwenzori sub-region. Consequently, UNDP together with OPM/DRR platform commissioned a three month long study and tasked the Department of Geography, Geoinformation and Climate Science, Makerere University to undertake the activities leading to this report.

To address the goals of the study, the consultant developed and implemented and approach which involved; (1) review of available scientific literature and reports, (2) visits to the field to obtain both primary and secondary data through consultations with stakeholders in the region, make observations and measurements in the field (3) data processing and analysis through descriptive statics and geospatial modelling.

The occurrence of floods have increased recently especially under changing climate conditions thus pausing a great risk to human life, livelihoods and property. This report is based on a scientific study undertaken from August to October 2013. The findings indicate a myriad of factors which combined to cause and elevate the disastrous May 2013 flood event s in Kasese, including reported intensive precipitation in the upper reaches of the catchment, impervious surface caused by fire burning in February 2012 in upper catchments of Rivers Nyamwamba and Nyamugasani that cumulatively reduced the infiltration capacity culminating into increased runoff, progressive degradation of the stream banks and channels, and constriction of the river flows due to bridges and boulders. The link between the flood hazard and glacier melting on Mt. Rwenzori as earlier hypothesized to be the main cause was found to be weak. Our geospatial modelling reveals that hotspot areas are currently inhabited where the majority of people engage in a range of agricultural oriented livelihood/economic activities. These areas are within the flood plain as well as the designated buffer conservation areas according to the NEMA guidelines/policy.

Although this study was constrained by lack of long-term climatic data, we observed that floods of the magnitude that occurred in Rwenzori sub-region have a long return time typically of 20-50 years. However, in light of the increasing population and settlement, the damages can be great even with a flood of the same magnitude. Based on our analysis and the geomorphological state of the lower sections of River Nyamwamba, we posit that a complete re-coursing of the river may not be very feasible. Rather, proper management of the river bank coupled with catchment management measures in our view offer the most sustainable flood management measures in the long-term.

# **ACKNOWLEDGEMENTS**

This study would have not been possible without the support received from various people and institutions. Foremost, we are very grateful to UNDP for the financial support, and secondly the OPM/National DRR platform for endorsing our bid for the study. We also appreciate the unselfish contribution received from all the local government officials particularly the Assistant Chief Administrative Officer Kasese district, Kasese District Environmental officer, Kasese district land planning and information officer and Senior Warden Uganda Wildlife Authority. Many thanks to the local communities interacted with during the field surveys.

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#### **INTRODUCTION**

# 1.1. Background

Uganda is prone to a range of natural hazards owing to its contrasting geological, geomorphologic and pedologic set up moderated by the climatic conditions manifested by the complexity of the nexus between mountain, highland and lowlands and the associated social structures. The natural hazards are spatially varied and are quite often triggered by a range of events most commonly rainfall of diverse characteristics. Depending on their magnitude and the socio-economic setup, most hazards often translate into disaster events bringing the country at a standstill with the consequent loss of lives and property. Although natural hazards are quite historical, there has been an exponential growth of disaster related hazards over the last decade with the most prominent being landslides, floods and drought. However, as points out by Montz, (2000) the geographic and demographical growth of urban regions can potentially alter the degree of vulnerability in terms of exposure to inundation depths and spatial extent of flood waters.

Uganda has of recent experienced frequent disasters including floods, landslides, droughts, civil strife etc that have negatively impacted on the economy through loss of life and property. Despite the existing National Disaster Management Policy framework the challenges continue. There is inadequacy of financial resources necessitating therefore effective plans backed by scientific studies in order to achieve better results during response to disasters.

The Rwenzori sub-region is south western Uganda was hit with devastating floods in May 2013 which span a peak period of 3 days. This flood unusual flood was reportedly caused by heavy rains which led to the outburst of the banks of rivers, thus affecting Kasese district among others. The resulting effects were the displacement of over 7,000 people and widespread destruction of houses, crops and facilities such as bridges, roads and power lines (OPM, 2013). Major infrastructures such as a hospital and sewage treatment unit were not spared either. Two months later, the effect is still being felt. Nearly 1,800 people in Kasese municipality alone were displaced after river Nyamwamba burst its banks in the worst flooding since 1976 (Talemwa et al. 2013). The most affected areas include Nyamwamba and Bulembia divisions, through which River Nyamwamba passes, as well as the entire Kilembe valley; Acholi Quarters, Kizungu, Nyakasanga, Base camp, Kanyangeya, Kamulikwizi and Kanyaruboga. Emergency response coordinated through OPM helped to reduce human suffering and further destruction of property. It was important that a recovery program be initiated in Rwenzori sub-region considering the high level of destruction and disruption caused.

Historical evidence revealed rivers in the Rwenzori commonly flooded in the past. For instance Wells (1929) notes that river Ruimi was in flood and too deep to cross at the usual ford: about 50 feet wide and very swift. The frequent occurrence of floods, leading to human losses and material damages requires an elaborate recovery planning process to be developed in a sustained manner.

Although it has long been an aspiration of planning and various forms of planning policy at national and district level to recognize and respond to natural processes and hazards; recent floods revealed weaknesses in both flood protection and response capacity at several levels of government. They have also showed the vulnerability of communities and their weak capacity to response to these risks. Limited human capacity hampers the country's capability to respond to disasters in a timely and effective manner. Furthermore, the lack of information/communication for better and informed decision making always limits the ability of multiple actors to respond to disasters wherever they occur.

Whereas floods are hydro-meteorological events, their occurrence and magnitude are linked to a range of other causal factors including land use and land cover, geomorphology, soils among others. The scale of the obtained flood event in Kasese and the surrounding areas was quite unusual and certainly not experienced in the last 50 years following preliminary interviews with the local population. Owing to the impact and the damage emanating from the floods, many short term interventions geared at buffering the community from flood events have been proposed, albeit devoid of a good scientific base informing both on the feasibility as well as the causal factors of the May 2013 flood. Numerous causal factors have been hypothesized including melting of glaciers, fire in the alpine, intense rainfall among others. Cognizant of the desire to undertake evidence based interventions, UNDP and OPM procured consultancy services from Makerere University to undertake a scientific based preliminary assessment for a better understanding of the flood dynamics in the Rwenzori sub-region. This report therefore presents results obtained from this short term preliminary undertaking.

### 1.2. Rationale

Disasters such as floods pose a real risk to the society and many socio-economic investments in Uganda. This is more particularly so under changing climate conditions being experienced or likely to be in future. And yet there is scanty information on the causes, the magnitude and interplay of processes that led to flash flooding as evidenced in Rwenzori sub-region at the start of May 2013. Such information would enable plausible decision making on the recovery for the region after the flood devastation. For an effective comprehensive recovery plan implementation, information on flash floods is considered pertinent by the stakeholders in the local districts, OPM and DRR platform. The findings of the comprehensive study will also in general inform the national flood recovery planning process and flood disaster management.

#### 1.3. Scope and setting

The area of study covers Mt Rwenzori, which hitherto will be referred to as Rwenzori sub-region (Figure 1). The region includes the districts of Kasese, Kabarole and Ntoroko. The region is drained by many rivers and streams which empty in lakes George and Edward. The rainfall received is moderately high but increases with altitude. Broadly the area is seismically active or located in an earthquake zone thus also prone to slope failures. It has a number of protected areas – national parks and game reserves. Outside the conservation areas are dense settlements; the population growth is high. The study delineated and characterised prominent catchments in the region for detailed flood assessment.

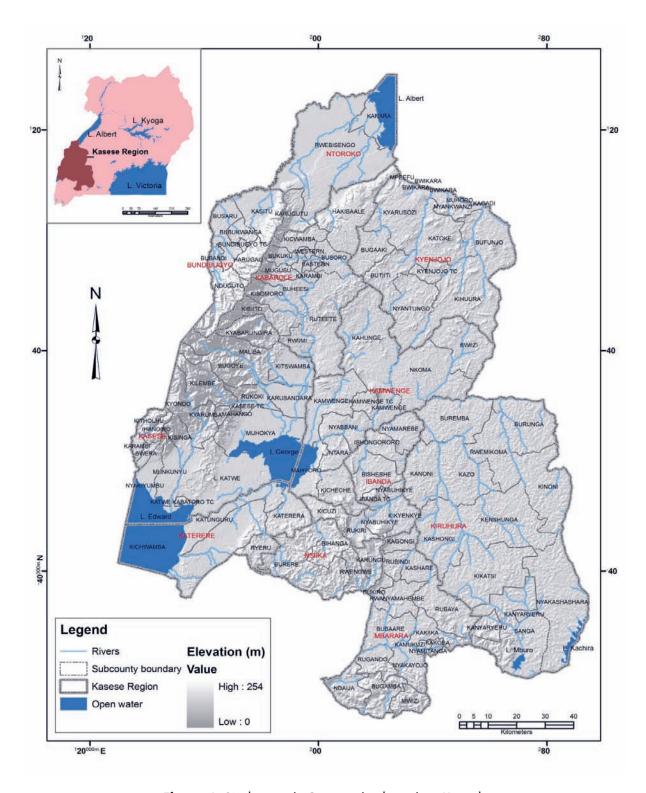


Figure 1: Study area in Rwenzori sub-region, Uganda

# 1. 4. Objectives

- I. To characterise the watersheds and examine the underlying factors responsible for the flash floods in Rwenzori sub-region
- II. To analyse the flood dynamics in Rwenzori sub-region
- III. To formulate strategies that can inform the recovery planning process in Nyamwamba catchment [Kilembe] and other related areas
- IV. To propose innovative potential measures for flood management that informs the local/ national recovery planning process

#### **METHODOLOGY**

This study adopted a multi-pronged approach entailing many methods considering the biophysical and socio-economic complexity of the flood hazards. The methods included; applied field survey, Geo-Spatial analysis and desk research. Field visits were made to familiarise with the area and validate preliminary interpretation of bio-physical and geo-spatial data. Interviews were held to obtain relevant information from the community and stakeholders.

# 2.1 Characterization of the watershed in Rwenzori sub-region

To get better insights on the water sources and dynamic landscape pathways, it was deemed necessary for a geomorphological delineation and characterization of the watershed and sub-watershed that drain the region. To undertake this activity, a Digital Elevation Model (DEM) was obtained and processed in a GIS environment. Watershed and sub watersheds were delineated following hydrological procedures in ArcGIS 10. Once the watershed and sub-watershed were delineated, geomorphologic characteristics such as watershed size, slope gradient, stream length, stream density, hypsometric curves and hypsometric integral were derived. The watersheds in the region were characterised. The data/information used included the geographical particulars of the catchments, for example, length of the river section, local administrative units, rural and urban population, and other peculiarities of the area. Hydro-meteorological information was also utilised namely; daily/monthly/annual precipitation, months of maximal and minimal precipitation, channel discharge, water level (mean annual and peak), channel roughness, channel geometry, retention behaviour, vegetation, land use, river engineering and historical analysis of local flood events. GIS was used for characterizing the area suffering from flash floods for spatial analysis and graphical representation on maps.

#### 2.2 Flash flood potential/dynamics

Flood characteristics are determined by the local topographical, geological and hydrological conditions as well as catchment characteristics, such as local climate, land use and spatial development (EA, 2009). Rainfall-runoff analysis and physically based distributed hydrological modelling approaches (HECRAS i.e. Hydrological Engineering Centre-River Analysis System) were applied as predictive tools for flash flood occurrences. HEC-RAS is an integrated system of software, designed for interactive use in a multitasking, multi-user network environment. The system is comprised of a graphical user interface (GUI), separate hydraulic analysis components, data storage and management capabilities, graphics and reporting facilities (USACE, 2002).HEC-RAS is designed to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels. The current version of HEC-RAS supports Steady and Unsteady Flow Water Surface Profile calculations, perform sediment transport simulation and perform water quality simulation.

The methodology involved in prediction included: hydro-climatic data base building, a detailed Digital Elevation Model (DEM), a land use cover, based on Land Sat-satellite imagery, and a soil map of the basin. The discharge values were used, along with the DEM, to predict flood hazard areas in the floodplains of the Rwenzori sub-region.

DEM was used to analyze and delineate the watershed boundaries and stream networks including the most important hydrologic parameters that have a direct impact on the flash flood creation. These data and the geological and geomorphological/structural map were integrated with the soil properties data and the rainfall records to evaluate the flood potentiality. HEC is a very sophisticated computer program to model water surface profiles from corresponding discharge values. The HEC-RAS model calculates water surface elevations at all locations of interest for given values. It uses Bernoulli equation (1) for subcritical flow at each cross section (Bedient and Huber, 2002):

WS1+ a 
$$V1/2q = WS2 + a V2/2 q + he$$
 (Eq. 1)

Where:

WS1 ,WS2 = Elevation of water surface at each cross section V 1 ,V2 = Mean velocity a1, a2 = Velocity coefficient g = Gravitational constant he = Energy head loss

All data were analyzed and processed using the software and procedures mentioned above. Water surface elevations predicted with HEC-RAS were used as input to generate the flood area coverage. This information allowed us to visualize (spatially) where the high hazard areas might be located. HEC-RAS model is useful in determining remedial and preventative measures for reducing flood damages to a community through the creation of hydraulic studies and flood maps (Turner, et. al. 2013).

#### 2.3 Flood mitigation measures/strategies

The measures for flood mitigation were indentified through use of PRA tools; field surveys and observations along river profile, interviews, and discussions. The measures were categorised under structural and non-structural measures. The highlights of the achievements with respect to the deliverables/objectives are provided below:

# **FINDINGS AND DISCUSSION**

# 3.1. Characterising the flood prone catchments in Rwenzori sub-region

Figures 2 and Table 1 summarise the main catchment characteristics identified and delineated in the region.

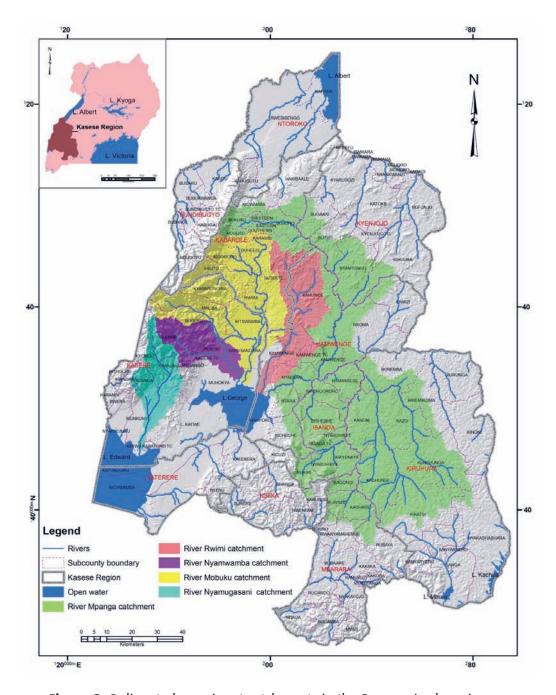


Figure 2: Delineated prominent catchments in the Rwenzori sub-region

Many of the rivers that flooded had a high percentage of bare cover ranging from 6-11% bare rock in the upper part of the catchment. Rivers Mobuku, Nyamugasani and Nyamwamba flow from a high elevation (3000 to 4500m above sea level) in the alpine zone which receive high rainfall and have dominantly steeper channels thus vulnerable to flash floods. River Mpanga had greater length followed by Mobuku and Rwimi.

Table 1: Catchment characteristics in the Rwenzori

River	Catchment area [km²]	Min Elevation [m a.s.l.]	Mean Elevation [m a.s.l.]	Max. elevation [m a.s.l.]	Mean hillslope gradient	Channel	Concavity	Bare Rock [%]	Forest/ Shrubs[%]
Ruimi	265.6	1017	2045	3984	16.4	18.3	0.2900	0.2	51.4
Mobuku	255.1	1121	2855	5015	21.6	23.7	0.3600	9.9	72.4
Nyamugasani	95.2	1343	3036	4575	23.9	22.9	0.0730	10.9	82.4
Nyamwamba	96	1384	2947	4398	23.9	23.9	0.0600	6.5	83.9
Mpanga [northern]	296.2	1355	1617	2959	8.6	80	0.0600	-	-
Mpanga [southern]	124.8	1234	1417	1598	8.6	17	0.0910	0.3	86.9

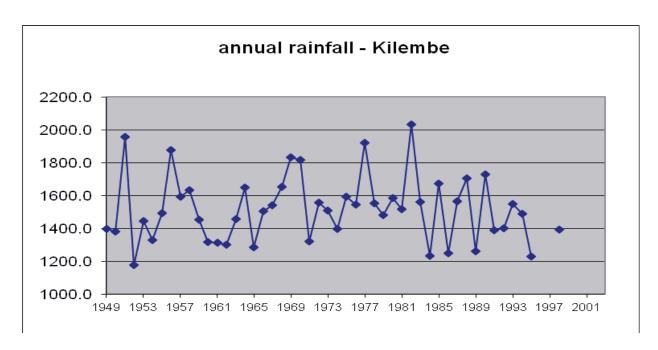


Figure 3: Annual rainfall at Kilembe mines weather station in mid R. Nyamwamba catchment

The region receives varied annual rainfall depending on altitude and aspect with respect to the mountain. The low lying parts gets lower amounts but this increases with altitude until about 3300m asl. According to Osmaston, (1996) from the base of the Rwenzori mountain around 1250 mamsl, precipitation was observed to increase with rising elevation from 1150 mm a\_1 to a maximum annual precipitation of 2600 mm a\_1 recorded at 3290 mamsl in the Heath-moss forest zone. Above this, precipitation decreased to 2000 mm a\_1 at Lake Bujuku in the Afroalpine zone (3990 mamsl) within the Central Rwenzori Massif Overtime the rainfall has also varied (Figure 3). High rainfall amount were received in 1951 and 1982, whereas the lowest ever received was in 1954. The amount and frequency of rainfal are closely linked to runoff.

The characteristic features of river streams in Rwenzori sub-region include:

- Streams and rivers have naturally changed courses overtime especially on the lower flood plains
- Deposition of boulders is a common feature along river channels and is an indicator of active rivers experiencing flash flood events
- Braided river channels were frequently observed on rivers such as Nyamwamba and Mobuku; it is also indicative of changing river courses to accommodate varied flows.
- River courses were also observed to have been tampered with. For instance R. Nyamwamba is reported to have had its course altered from the centre of the Kasese town.

# 3.2 Flash flood dynamics/potential in Rwenzori sub-region

#### 3.2.1 Discharge and Rainfall

Analysis of flow/flood dynamics in the Rwenzori sub-region was based on flood histories from interviews and desk research, and hydrographs generated from past recordings (Figure 4).

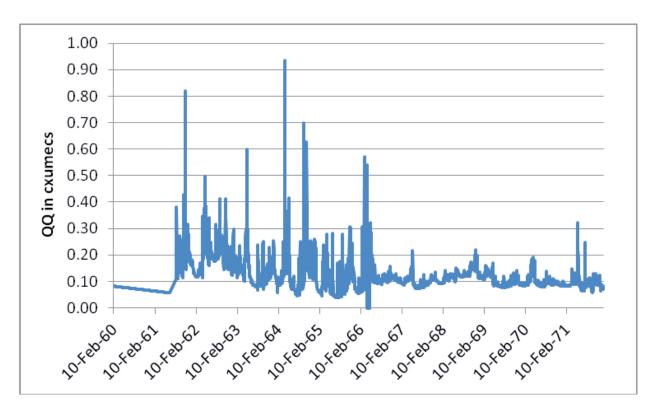


Figure 4: Hydrograph for R. Mobuku, 1951-1971

Significant flow peaks in 1961 and 1964 averaging >70 cm<sup>3</sup>/s confirm the flooding incidence reported by the responents during interviews and dicussions. The flow on R. Nyamwamba was over 80 m<sup>3</sup>/s

around 6 May 2013 and R. Rukoki a lower tributary recorded 58 m<sup>3</sup>/s

A weak correlation between rainfall and discharge (Figure 5) was recorded based on the data at a low elevation weather station at Kasese Airfield. This provides an indication that runoff due to reported intensive and prolonged rains from higher elevation of the catchment could have been a key factor in flooding. Prolonged rainfall contributed to high antecedent mositure. Therefore more rains on 1st May eqsily genrated large surface and stream runoff. However, rainfall records from high elevation weather stations were not accessible. Also the discharge records/measurements at high elevation were lacking for further analysis.

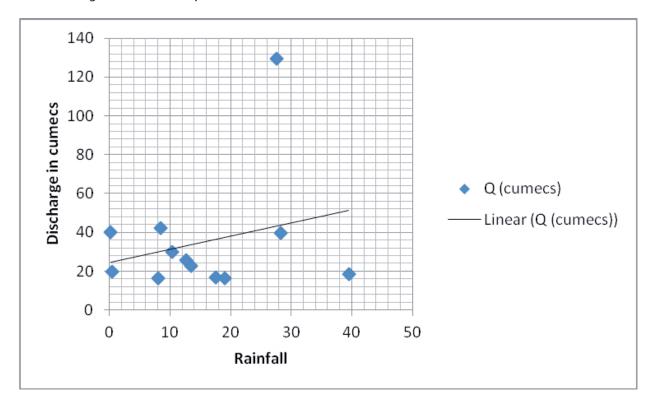


Figure 5: Rainfall and discharge relation

# 3.2.2 Spatial distribution of flood affected areas

The floods which affected Mt. Rwenzori region in general and Kasese district in particular in May 2013; have been recorded as the most severe in Uganda. Severe rains triggered floods in Rwenzori sub-region of an unprecedented scale both in terms of volume and amount of land flooded. On May 1st 2013, the combination of a week of heavy rains in the upper echelons of Mt. Rwenzoi, the relative high flow velocity and strong currents, and the steep slopes of Mt. Rwenzori resulted in the worst flooding ever experienced in the region.

The amount of rainfall received during that flood period exceeded 50mm and the peak rainfall was received in the high altitude areas. The reportedly high and intense rains in higher altitudes is likely to have resulted in higher concentrations of water in river catchments/basins which essentially made landfall on the lower slopes, raising river water levels that ultimately battered the densely populated Kilembe town with heavy floods and record storm surges.

Elements at risk of flooding identified in the region were:

- 1. Built environment Housing and Kilembe town
- 2. Agricultural fields
- 3. Road infrastructure roads and bridges
- 4. Power station Tronder power station
- 5. Water pumping station and infrastructure/pipes
- 6. National parks

Increased waters in river channels had extensive effects, leaving hundreds of residents without power (three days of power failures), causing widespread flooding throughout the region, destruction of agricultural fields, blocking and/or destruction of critical transport corridors and critical infrastructure such bridges, water lines, hospitals, and contributing to acute displacement and hopelessness. The damage to road infrastructure was extensive and this was greatest in the mid to higher altitudes where many bridges collapsed (Photo 8b) rendering some areas completely inaccessible. The flood also caused significant damage to water lines and electricity supply was interrupted.

The size and strength of the floods affected a variety of sectors throughout the region. A preliminary agricultural assessment indicated that the floods caused damages of unprecedented scale to agriculture crops, livestock, fisheries and destroyed primary infrastructure such as wells, retaining walls, water channels, household storages, houses, animal shed, personal property etc. Ultimately, the floods damaged and destroyed hundred of thousands of homes, causing tens of thousands of shillings in property damages, and killed at least 10 people in the region. Over 5,000 persons sought refugees in temporary shelters and over 1000 customers were left without power.

The distribution of flood hotspots are shown in Figure 6. In total 13 sub counties were affected by the flooding (Table 4); however, the most affected were the sub counties of Kilembe, Bulembia, central division of Nymwamba, Rukooki, and Kusandara, within the Nyamwamba catchment. These were followed by the subcounties of Maliba, and Kichamba; and Kyarumba within the Nyamugasani catchment.

**Table 2:** Sub counties in various catchments affected by flooding in Rwenzori sub-region

	Catchment/River system	Subcounties affected
1.	R. Semliki	Karugutu
2.	River Nyamugasani	Kyarumba S/C and Kyondo S/C
3.	River Nyamwamba	Kilembe S/C, Bulembia S/C, Central Divisio, Nyamwaba Division, Rukooko S/C and Karusandara S/C
4.	River Mobuku with its tributaries R. Sebwe, R. Kitakeena and R. Nkooko	Maliba S/C, Bugoye S/C, Kichwamba S/C and Hima/Ibuga S/C
5.	River Rwimi/Rume	Kichwamba S/C, Kyaburungira S/C, Buhuhira S/C, Bwesube S/C and Mahango S/C

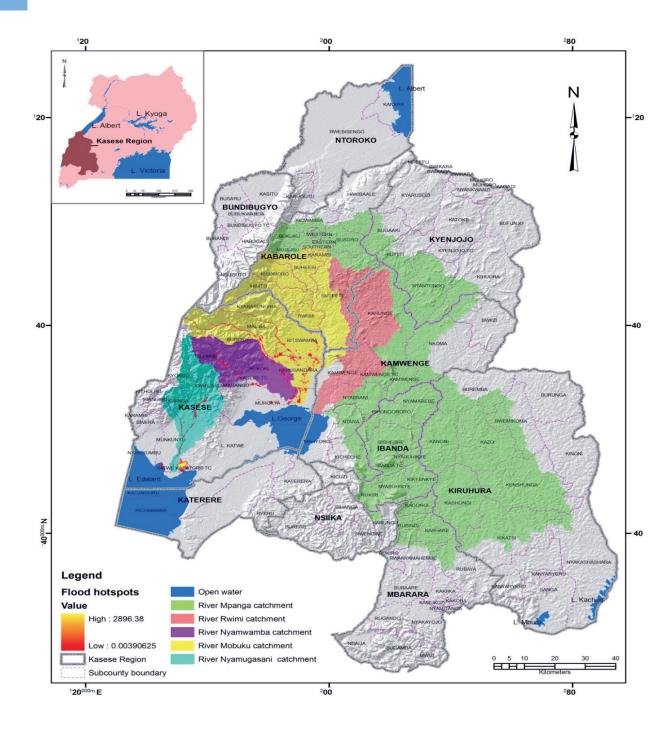


Figure 6: Flood hot spots in Rwenzori sub-region

At a larger scale areas at risk (high, moderate and low) within the flood hotspot areas are illustrated in Figure 7 a and b. Most of the high flood risk areas occur very close to the river edge and in depressions. The low risk areas lie further away (>50 m) from the immediate river banks and on higher elevation sites. These observations have serious implication on flood risk management as presented later.

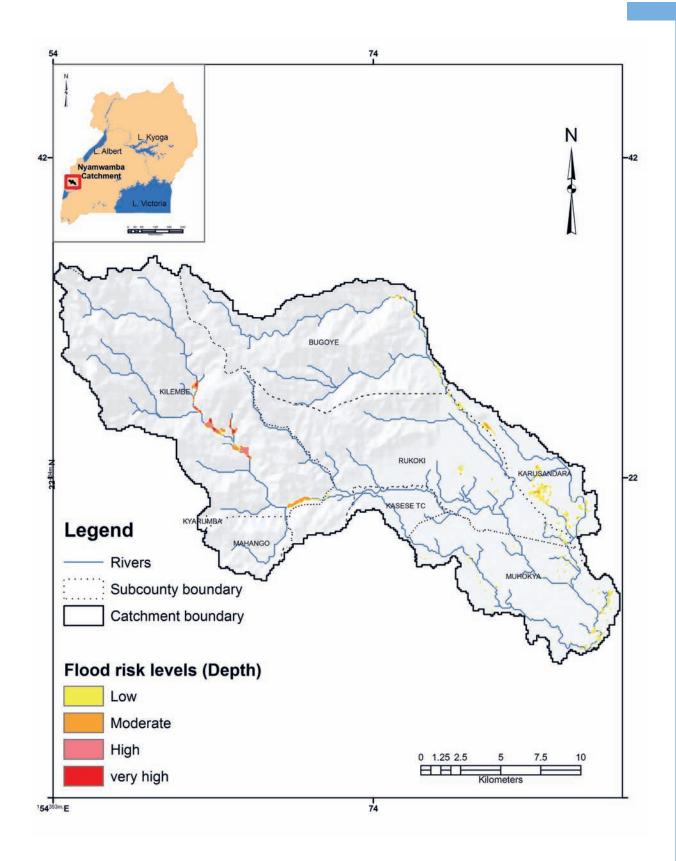
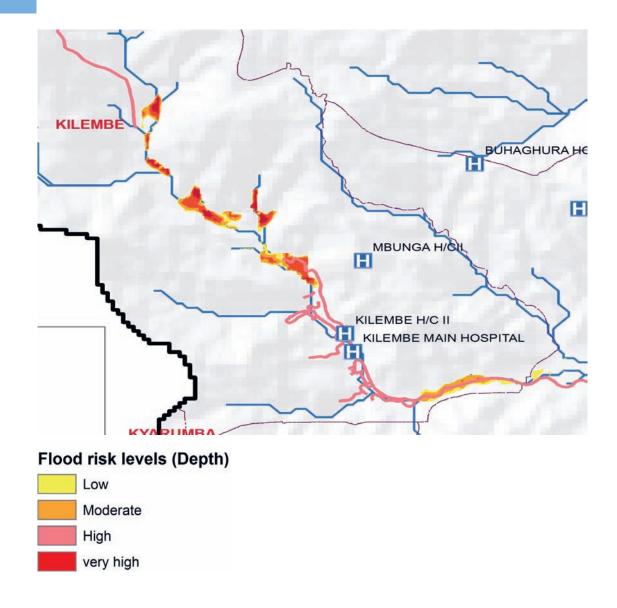


Figure 7: Flood risk areas and elements in along Nyamwamba in Kilembe



**Figure 8:** Areas and elements at flood risk in Kilembe town; roads, schools and health centres are particularly at great risk

#### 3.3. Prevailing Explanations of the floods

Interactions with district administrative staff, local leaders, Uganda Wildlife Authority staff and elders together with a review of grey literature revealed several explanations and causal factors for the floods that affected the Rwenzori sub-region in 2013:

- a) Fire destruction of vegetation at about 3000 to 4000 m.a.sl. in the upper reaches of Nyamugasani and Nyamwamba catchments in February 2012. Official data on the size of the area affected is not available although verbal reports indicated it was sizable. For purposes of this task what emerged as being unclear were the observed differences in the intensities of the floods and their associated impacts in the two catchments as reported by the affected persons.
- b) Melting of glaciers and snows was reported to have caused flooding in May 2013. Existing scientific reports indicate the glacial coverage has dramatically declined over the years (1906 to 2006) (Figure 9). Currently a small area covered by glaciers stands at less than 0.5Km<sup>2</sup> on mount Speke and Stanley (Taylor et al. 2006).

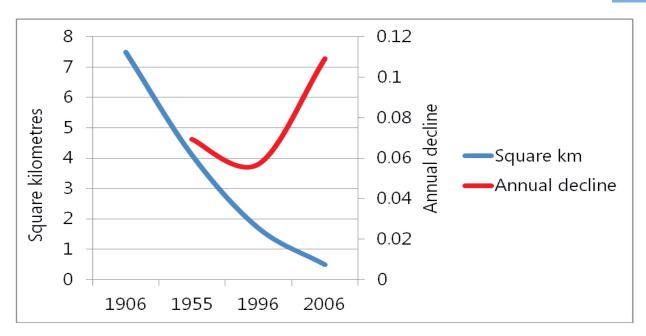


Figure 9: Glacial retreat and rates of annual decline on Mt Rwenzori (Source: Osmaston, 1996; Taylor, et al., 2006)

Figure 9 shows a dramatic decline in glaciers on the mountains and over the last 11 years there has been a decline at a rate of 0.11 square kilometres per year. However, no reports of serious floods have been reported in the mountains over the same period in the region. We can therefore say with the highest level of confidence that, glacial melting contributed little (if any) to the floods in Rwenzori sub-region. Further, the only major river in the region that is connected to glacial melting is R. Mubuku through Lake Bujuku and therefore, glacial melting could not in any way, have contributed to the extensive flooding witnessed in May 2013.

- c) The ghosts of Kilembe still haunt R. Nyamwamba and surrounding communities. The reported releases of excess water which had for many years accumulated in the old mines in Kilembe. Unverified reports by local residents in Kilembe town indicated that with the reopening of Kilembe Mines Limited, several volumes of water that had accumulated in the mines since its closure over 30 years ago, were released and these intensified the floods in the lower reaches of R. Nyamwamba.
- d) Another explanation for the severity of floods in Rwenzori sub-regions and especially those experienced along R. Nyamwamba is that the occurrence of landslides in the upper reaches of the river that must have dammed the river. The increasing accumulation and pressure of water behind the 'dams' at high altitudes eventually caused failures in several sections of the river, thus the flash floods experienced downstream.
- e) The collapse of traditional river bank management regimes coupled with an increasing number of human activities along the river bank certainly should have contributed to the severity of the floods in Rwenzori sub-region. Increasingly the crop cultivation in the valleys and river banks together with diversion of river waters for crop growing, sand and murram extraction is liable to have intensified the floods. River Nyamwamba river banks show clear signs of the original soil structure being tampered with/manipulations of several layers of soil.

f) Collapse of the river bank management regime that had been practised by Kilembe Mines Limited during its operations. There was a sustained effort to desilt the river within Kilembe zone. Following the closure of Kilembe Mines Limited, the desilting regimes of the river valleys in the upper Kilembe zones of Nyamwamba river stopped altogether. Over the years, boulders of various sizes have accumulated in the river and essentially reduced the effective width, channel volume and river transport capacity.

However, this study classifies the drivers of floods in Rwenzori sub-region into several categories:

# 3.3.1 Underlying factors causing flooding in the Rwenzori sub-region

On-spot assessments and key informant interviews integrated with historical data revealed that flooding may be attributed in part to multiple bio-physical and social factors. Human activities including land use changes and in form of modifications in the river channels are possible factors explaining the extent and effects of the observed flooding in May 2013. The intrusion into natural drainage by the indiscreet construction of bridges, roads, culverts, houses, and other infrastructure without provision of proper drainage exacerbated the inundation problem and yet a very negligible amount is spent on drainage management.

# 3.3.1.1. Bio-physical factors (Proximate causes)

# (a) Intensive rains in the upstream catchments

Intensive and prolonged rains reported at high altitude contributed to accumulation of runoff and therefore the intense downstream flooding. This view is supported by other experts such as Taylor (personal communication. 2013) who explains that the extreme flood event that occurred earlier this year in the Rwenzoris is associated with rainfall intensification.

'The outcome is essentially this... under warming (observed over the last 4 decades and set to continue for the foreseeable future), peak flows with increase and low flows will decrease under an intensification of rainfall falling below the ice fields. Melting glaciers have absolutely nothing to do this.'

# (b) Shallow soils and rocky surface

Areas in the catchments with shallow soils and rocky surface are associated with low infiltration rate. When heavy rains occur such areas can witness rapid surface runoff accumulation hence the potential of downstream floods. Carpenter et al. 2007) also noted that steep slopes and thin soils promote the rapid concentration of storm runoff to confined streams and narrow river valleys, often resulting in flash flooding. Critical observations made along the River Nyamwamba indicated that the built environment and other critical infrastructure in Kilembe town council including Kilembe Sub county and neighbouring villages is underlain by a weak manipulated layer of loose backfilled soil. When this weak soil structure came into contact with the heavy river flows, certainly, it couldn't stand the wear and tear by boulders.

The characteristic feature of the physical geography of the region, the river systems and surrounding environments in the region show that the area is underlain by huge rock particles/ boulders. The area especially in the upper catchments with steep slopes is associated with frequent rock failures; when these were saturated with intense rains which occurred over a seven day period, the shear stress decreased. It is believed that these huge boulders blocked the river streams and created artificial dams upstream. Hell broke loose when the increased amounts of water behind the artificial barriers were released causing intense destruction along its path downstream.

# (c) Aggradations and degradation of river channels

River aggradation could have contributed to flooding as a result of deposition of sediment load including boulders (Figure 8) given that the continued deposition of such materials reduces the depth of channels.





Figure 10: (a) Part of the River bank [see white arrow, near Bulembia primary School] that over flowed causing flooding in Kilembe town. Note the deposition of boulders in the channel on the right. (b) Destroyed bridge following blockage of flow by large boulders

# 3.3.1.2. Social factors [Indirect, or direct causes]

# (a) Constructions

Bridges constitute part of the structures that constrict the active river channel and sometimes inhibit sediment transportation through the river system [for example. R. Mobuku crossing the Kasese-Fort Portal road]. This led to river bank overflow where the river carried large boulders.

#### (b) Reduction of riparian vegetation

Loss of riparian vegetation through various human activities such as deforestation reduces (Figure 8) bank slope stability and increases sedimentation into the rivers. Virtually all the river catchments were affected though the major riparian areas where the loss of vegetation is a factor included the Mubuku and Nyamwamba rivers.



Figure 11: Land use in the upper Nyamwamba catchment; steep slopes are cultivated up to the park boundary while others are almost bare with exposed rocks. In the fore front is the deposit of boulders in R. Nyamwamba, evidence of bank-full and fast flowing stream.

Fire burning (Figure 11) occurred in the upper part of the forest-alpine zone in February 2012 affecting mainly the catchments of Nyamwamba and Nyamugsani. The cause of the fire remains a mystery; it could be linked to human errors or natural cause. Burning was quite extensive covering over 15 km<sup>2</sup> and exposed the underlying rock and boulders, and most likely had negative effects on vegetation retention capacity, thus increasing runoff and erosion. It also reduced the organic matter hence the water retention capacity.



Figure 12: Fire burning occurred in the upper part of the forest-alpine zone in Feb 2012; note the bare rocks, reduced vegetation cover hence the high potential for downstream surface run off and flooding

#### (c) Gravel extraction

Gravel extraction includes removal of sand and other sediments. This leads to head cut erosion in the channel and sedimentation as observed along Rivers Nyamwamba and Mubuku valleys. These findings on degradation of the river bank and channel are in agreement with the assessment by the team from OPM (2013) who reported that human activities especially encroachment and weakening of the river banks and physical diversion of the entire specific river sections are the most likely factors accounting for the extent of the effects of the floods in the different rivers.

#### 3.3.2 Flood mitigation strategies/measures

Broadly the flood control measures include the structural and non structural measures. Structural measures consist of different types of works and interventions aimed at either controlling flood or reducing flood peak. Thus structural measures tend to mainly consider the hydrological and hydraulic implications of flooding. Some of the structural flood mitigation practices identified in Rwenzori sub-region include river bank tree planting, flood wall (raised stone concrete river bank wall) and de-silting/channelling, enhancing natural levees, artificial levees, flood ways for large long time recurring floods. Catchment-wide interventions can be effective to decrease surface runoff and soil erosion and therefore to reduce flood peak.

Non-structural measures consists of risk acceptance and risk reduction strategies and offer a variety of possibilities, which range from awareness and perception, land use planning to constructions and structure management codes, soil management and acquisition policies, insurance, public information actions, emergency systems and post-catastrophe recovery, which contribute towards the mitigation of flood-related problems. These measures are effective and less expensive. If the population is responsive and there is good institutional network these measures can be efficient.

The flood mitigation measures are described below with reference to the May 2013 devastating flooding in the Rwenzori sub-region.

#### 1. Pre-flood disaster of May 2013

Analysis of the history of flood management in Rwenzori sub-region shows:

- De-silting of the river channels and mechanical removal of boulders from the river bed was regularly effected by the Kilembe Mines Limited in the 1960s and 1970s.
- Avoidance of flood prone areas; traditionally the communities avoided settling on flood plains.
- Mobilisation of the local community followed by an aggressive tree growing campaign with funding from the MacArthur Foundation by Uganda Wildlife Authority (UWA). UWA encouraged tree planting for improved livelihood and river bank restoration along R. Nyamwamba.
- Grass bunds developed into terraces and agro-forestry on agricultural lands for delayed runoff.

#### 2. Post May 2013 flood disaster

- Awareness campaigns about climate change, indiscriminate fires and relocation to other safe places.
- Modified Access trails both in and outside the Mt Rwenzori national park which are climate proof with new bridges that are flood resistant [lengthened, strengthened and raised height] but using low cost materials.

- Established rescue sites and alternative trails both in the Mt. Rwenzori national park and
  in areas where the local community live, for example in Kilembe Town. The Rwenzori
  Trekkers Service and UWA are setting up a helicopter pad(s) for improved rescue mission
  in the park.
- Pre-suppression measures such as the establishment of fire lines and clearing of flammable materials in alpine fire risk areas in Mt. Rwenzori national park
- Education of the youth population about flood and other disasters. This should, however, be a long term strategy to engage and involve the youth off the existing but dwindling farmland in critical disaster prone areas.



**Figure 13:** Embankment enhanced by tree planting on R. Nyamwamba, upper Kilembe Town,

The above pre- and post- flood measures are summarised in Table 5:

**Table 3:** Table 5 – Structural and Non-Structural flood measures

11	STRUCTURAL MEASURES	RISK ACCEPTANCE	<ol> <li>Catchment-wide interventions (agriculture and forestry actions and water control works)</li> <li>River training interventions</li> <li>Other flood control interventions (passive control, and river corridor enhancement, rehabilitation and restoration)</li> </ol>				
	NON-STRUCTURAL MEASURES*	Tolerance strategies	Toleration Emergency response systems				
		Prevention strategies	Delimitation of flood areas and securing of flood plains Implementation of flood areas regulation				
	RISK REDUCTION	Mitigation strategies	Modified access routes & bridges in and outside the park Emergency actions based on warnings Public information and education*				

#### **CONCLUSION AND EMERGING ISSUES**

#### 4.1. Conclusion

A diversity of catchments existing in Rwenzori sub-region are largely characteristised by steep terrain, thin soils and high surface runoff which tend to favour flooding among other disasters. Intense rains commonly result into flash floods that pose a great risk to loss of life, destruction of infrastructure and loss of gardens. Flooding disasters are likely to be worsened by changing climate conditions. Modeling of the dynamics of floods using HEC-RAS model show areas at different risk levels. The existing measures to address floods were found to be indequate. This study makes recommendations aimed at controling flash floods. These measures can be realised through short term and moderate to long term planning. A holistic approach integrating all stakeholders in catchments is commended. However, hydromet data was noted to be scanty particularly in virtually all upper mountain catchments. Acuracy of the HEC RAS model for better output can improved through availing such data.

# 4.2. Emerging Issues for Flood Disaster Management in the Rwenzori sub-region

While the effects of the floods in Rwenzori sub-region were devastating, there is a need to prepare for incidents that are larger, more complex, of greater magnitude and frequency. The strategies presented in this report are crucial for improving the ability of multi-level governance systems in the country to respond to and recover from future incidents. Re-coursing of the river Nyammwaba is not advisable or feasible considering the geomorphological analysis carried out rather adoption of holistic catchment managagement practices described below can suffice.

In recognition of the size and magnitude of the floods and the associated level of destruction and the rebuilding challenges facing the region, there is a need for:

#### **SHORT TERM**

- a) Structural engineering: The application of structural engineering measures and the protection offered by concrete structures is well understood and for this reason is regarded as the optimal solution. This factor is particularly relevant for flood mitigation projects where fast, but effective solutions are required for the future protection of local communities, particularly in the short term 1- 2 years. Specific hotspots that require these measures include:
  - **Flood wall** in high risk areas within Kilembe town especially close to the Kilembe hospital and stretch from Bulembia to above the Rwenzori safari trekkers
  - Artificial levees need to be enhanced on upper R. Nyamwamba from below the park boundary to downstream sections

- **De-silting of the channels** this needs to be done on a regular basis to avoid over accumulation of debris that may limit channel capacity during flood time. Hot spots include R. Mobuku crossing the Kasese-Fort Portal road and R. Nyamwamba. Private investment could be encouraged in removal and crushing of stone for sell and use in building/construction.
- **Redesigned flood proof bridges [high and strong]** for example. two bridges in Kilembe town should be considered for this as a matter of urgency.
- **Rock rolls (gabions) and retaining walls** were routinely applied in the higher reaches of River Nyamwamba especially where flow velocities are too high and in the sections where the river was in direct contact with infrastructure and housing. This report still argues that such structure; flexible 'sausages' of crushed rock contained with nylon netting that are placed at river banks to prevent undercutting and fluvial scour; are still important to protect the most vulnerable sections of River Nyamwamba. Rock rolls are typically 300 to 400mm in diameter and come in 2 m or up to 5 m lengths.



Figure 14: Re-construction of wall at the bridge near Nyamwamba sub-county and roll stone protecting

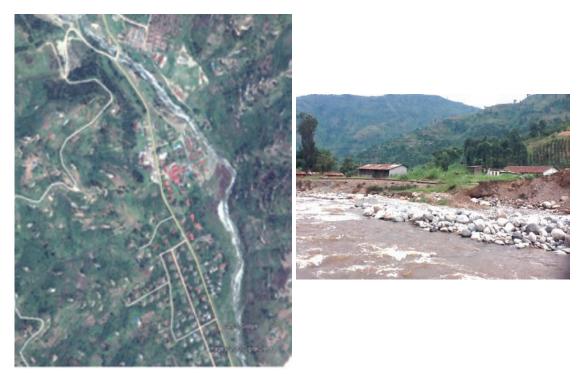
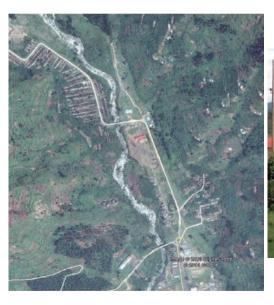


Figure 15: Section on R. Nyamwamba being proposed for constructing a flood wall [re-embankment] close to the Kilembe Hospital shown by white dotted line)





**Figure 16:** Section on upper Kilembe town stretching near water treatment along R. Nyamwamba; proposed for an artificial leeve and construction of a flood wall or embankment (white dotted) down past Bulembia P.S.

b) Bio-engineering and river bank stabilization - To manage river bank instability and erosion and protect communities against flash flood intrusion, there is a need for the application of robust river bank erosion control and shoreline/bank stabilisation measures (Figure 13). This assessment recommends the application of VETIVER grass. There are opportunities to utilise Vetiver grass technology as an alternative to structural engineering measures. Vetiver grass has been used extensively in several other regions of the world for shoreline stability and it is expected that there would be a natural reluctance by responsible agencies to promote the use of Vetiver grass or for communities to adopt it but what is required is the demonstration trials to verify the suitability of the grass. The main advantages of Vetiver grass over concrete are the considerable saving in construction costs and the lower maintenance requirements in the longer term. It is thus possible to construct significantly longer sections of bank protection for the same cost resulting in a significant increase in the area benefited for a given works budget. In addition, the inevitable involvement of local communities in the propagation, planting and maintenance of the grass following the adoption of Vetiver grass technology may in the future require less demands for major inputs from governmental agencies as the communities adopt a self-help approach using their skills and knowledge of vetiver to carry out their own protection projects.



Figure 17: Use of tree planting and other vegetation to enhance the structural measure

#### c) Non -structural measures

**Adoption of a holistic or integrated watershed approach**- in view of the complexity and high costs in terms of loss of property and casualties involved, it is important to consider use of a holistic approach (broader river basin/catchment management planning systems or interventions) for the flash floods in Rwenzori sub-region. This should involve use of both structural and non structural practices.

**Capacity building/Social and community engineering** measures - Awareness campaigns need to be intensified in all flood prone catchments to address proper soil water conservation and land use; training the local staff at the sub county and district in flood risk management is very urgent in monitoring, analysis and early action.

**Flood Early Warning System (FEWS)** needs to be established to alert downstream communities on what action to take whenever the flood threats arise. This will need to develop better processes for recording rainfall upstream and flood event data - including the extent and impact of flood events as they occur, to inform future prevention and planning activities. However, the warning process needs to be seen as a complex social process, rather than the issue and receipt of a warning message. Understanding how people interpret warnings helps explain why they often do not respond to warnings as those issuing warning expect and want.

#### MEDIUM TO LONG TERM MEASURES

**Flash flood legislation** is lacking to regulate use of flood prone areas. The regulation need to be enacted in a participatory manner and implemented. Awareness should be created for areas subject to serious flood recurrence of 30 years and 50 years.

**Shared and integrated budgets**- Recurrence of flash floods is a real problem in the region and likely to impact further on the local and national economy. Because of the recurrence of flash floods, the payment of economic contribution after each disaster would require great expenditures of public resources by the administrations. One of the ways of approaching this is that financial support for the planning, constructing and maintaining structural interventions could be shared and integrated in budgets at national, regional and local levels.

**Mechanisms to introduce disaster offices and disaster committes** especially in disaster prone regions in the country, These offices and committees should be be empowered. There is also a need to clarify command relationships across its numerous field structures and enhance coordination with district, local, and tribal partners in disaster prone areas.

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# **APPENDICES**

#### Appendix 1: TERMS OF REFERENCE FOR

# COMPREHENSIVE FLOOD ASSESSMENT FOR INFORMING THE RECOVERY PLANNING PROCESS **IN RWENZORI SUB-REGION**

# 1. Background

Uganda has of recent experienced frequent disasters including floods, landslides, droughts, civil strife etc that have negatively impacted on the economy through loss of life and property. Heavy rains at the beginning of May 2013 caused the banks of rivers to burst, which resulted in flooding in Western Uganda's Kasese district. The resulting effects were the displacement of over 7,000 people and widespread destruction of houses, crops and facilities such as bridges, roads and power lines.

Emergency response coordinated through OPM helped to reduce human suffering and further destruction of property. However, to ensure better results a recovery program was initiated in Rwenzori sub-region. Initial assessment for the recovery plan was undertaken by OPM. This resulted in a report covering estimated costs of flood damage or loss among others.

A priority issue identified was guiding the process on how to reduce the risk of Future River flooding in the area. The initial recovery plan assessment did not examine the catchment characteristics that control the flood regime.

This Terms of Reference is drafted to quide further studies in securing detailed information about the flood risks and mitigation strategies.

#### 2. Scope

- The scope of this assignment will include the following:
- Characterise the underlying factors that led to the flash floods in Rwenzori sub-region
- Assemble an inventory of watershed characteristics underlying flood management dimension in the region
- Characterise flood dynamics on the basis of the available bio-physical and socioeconomic data in Rwenzori sub-region
- Propose possible/potential measures for flood management that informs the local/ national recovery planning process

Suggest appropriate strategies/practices that can inform the recovery planning process in Nyamwamba catchment and other related areas

# 3. Approaches and methodology

The following approaches and methodology will be used:

- a) Hold meeting(s) with OPM for clarification and understanding of the task
- b) Review the available reports
- c) Conduct field studies/surveys
- d) GIS spatial analysis
- e) Prepare and submit report for sharing

# 4. Qualification and competence

The consultant should have minimum qualifications of PhD and proven experience in related hazard and disaster assessment work good knowledge of the local context.

#### 5. Remuneration

OPM will pay the consultant a total amount of US \$4000 (UGX 10 M) inclusive of field costs and transport, and hire of necessary equipment. The payment will be in two instalments of 60% at the inception and 40% after final report submission.

# 6. Application

During its meeting on 25th July 2013, the DRR platform identified and recommended one of its members, Makerere University, represented by Geography Department, Geoinformatics & Climate Sciences to undertake the task. They have the necessary expertise. Applications should be channelled to the OPM/DRR platform for consideration



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