FLOOD PLAIN MAPPING OF BUNGA-SOYA

FINAL YEAR PROJECT REPORT

BY

NAME	REG NO
MUGELA CHARLES	BSCE/44740/143/DU
JAFARI HAMISI	BSCE/43829/143/DU

Project Supervisor:

DR. LAWAL

KAMPALA INTERNATIONAL UNIVERSITY

SCHOOL OF ENGINEERING AND APPLIED SCIENCES

DEPARTMENT OF CIVIL OF ENGINEERING

Final year Project handed in to the School of Engineering and applied sciences Kampala International University as one of the partial requirements for the award of a Bachelor of Science in Civil Engineering.

SEPTEMBER, 2018

DECLARATION

We, hereby declare that the information contained in this project is to the best of our knowledge, and that it's our original work hence no part of this project has ever been submitted to any academic institution for the award of a degree.

MEMBERS	**SIGNATURE**
MUGELA CHARLES	………………………….
JAFARI HAMISI	…………………………….

Date …………………………………

APPROVAL

This final year project of a flood plain mapping of Bunga-Soya has been prepared under my supervision and it is ready for submission to the school of engineering and applied sciences of Kampala International University in partial fulfillment of the requirement for the award of the degree of bachelors of Science in civil engineering.

DR. LAWAL

Signature…………………………………….

Date……………………………………………

ACKNOWLEDGEMENT

We sincerely give thanks to all those people who have been giving us all the necessary kind of assistance in the making of this project proposal.

We express our gratitude to the supervisor Dr Lawal who has through his vast experience and knowledge been able to guide us, both ably and successfully towards the completion of the project. We express our gratitude to the school of Engineering and Applied Sciences Kampala International University especially the college of Civil Engineering.

We would hereby make most of the opportunity by expressing our sincerest thanks to the faculties whose teaching gave us conceptual understanding and clarity of comprehension, which ultimately made our project easy to write.

ABSTRACT

This report comprises of 5 chapters, reflecting the activities that are to be carried out.

Chapter 1. Presents a detailed introduction of the project.

Chapter 2. Is the Literature Review presenting information concerning flood analysis related topics.

Chapter 3. Methodology. This shows the different methods and approaches which were used to execute the project.

Chapter 4. Results and findings. This chapter shows the results obtained using the methods detailed in the methodology.

Chapter 5. Conclusions, discussions and recommendation. This chapter summarizes all the various information encountered during the course of the project.

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CHAPTER 1

1.1 INTRODUCTION

Bunga-soya lies in Makindye Division, one of the five administrative Burroughs of the city. It is located in a wet land which is adjacent to the Lake Victoria, it experiences flooding during some months the year mostly the wet ones.

Floods are among the most recurring and devastating natural hazards impacting upon human lives and causing severe economic damages throughout the world.

According to Abha s, Jha, and Jessica (2012), in 2010 alone, 178 million people were affected by floods and the total financial losses in the exceptional years such as 1998 and 2010 exceeded $40 billion.

Water related disasters in Uganda such as droughts, floods, landslides, windstorms and hailstorms contribute well over 70% of the natural disasters and destroy annually an average of 800,000 hectares of crops making economic losses in excess of 120 billion shillings (UNWD, 2005)

Most of the time non-structural measures like flood forecasting, proper early warnings and conducting awareness programs among the flood affected community can be very effective.

Flood modeling can easily be accomplished using the readily available tools such as HEC HMS/RAS and GIS tools. When calibrated well, the results of the models offer a reliable tool to be used in decision making by the district and national policy makers in the country

HEC RAS/HMS tools have been tested and widely used globally in flood modeling for several years (Maidment & Seth, 1999)

1.2 PROBLEM STATEMENT

- According to the new vision report on Kampala flood problems and proposed solution dated 25 January 2015, Kansanga drainage channel is one of the major Kampala drainage channels which passes through soya crossing the Ggabba road to Lake Victoria. Bbunga- soya is a floodplain area which experiences numerous floods with in the peak wet months of the year.

- Floods are natural hazards which have significant impacts in the area like reduction of the integrity of gabba road, delays and destruction of human property.
- Due to absence of flood maps, people are unknowingly settling in the flood plain areas.

1.3 SIGNIFICANCE

- It is impossible to predict when a flood will occur, but historical data can help identify where it will most likely take place (Flood Safety, 2009). Preparing for or avoiding a flooding disaster normally is relevant to areas located in floodplain areas.
- The project informs that Urbanization may add to flood risks by creating more impervious surfaces with new houses, streets, and parking lots. As a result, flood zoned areas are continually expanding.

1.4 JUSTIFICATION

- This project creates a platform in doing a flood management plan which may include, flood risk analysis, flood evacuation policy, compensation policy and others.

1.5 MAIN OBJECTIVE

To do a floodplain mapping of the increasing flooding in Soya-Bunga located in Kampala along Ggabba road almost 5km from Kampala town.

1.6 SPECIFIC OBJECTIVE

- To designate the area of the study
- To determine discharge of various rainfall events
- To generate a flood simulation
- To do a flood hazard mapping

1.7 SCOPE

The project is limited to the use of HEC-RAS, ARCGIS, HEC-GEORAS and RAS-MAPPER.

The project is also limited to the generation of the flood hazard mappin

CHAPTER 2

LITERATURE REVIEW

STUDY	REFERENCE	OUTCOME
Flood Hazard Assessment and Mapping of Flood Inundation Area of the Awash River Basin in Ethiopia using GIS and HEC-GeoRAS/HEC-RAS Model	Getahun and Gebre, J Civil Environ Eng 2015.	Flood hazard map of awashi river basin
Integrated flood modelling in lubigi catchment kampala	Herve Villard Habonimana February 2014	Highest flood depth and longest duration of floods
Application of hec hms/ras and gis tools in flood modeling: a case study for river sironko – uganda	Okirya Martin, Albert Rugumayo & Janka Ovcharovichova 2015	Flood hazard map for 10, 50, 250 and 500 year return flood.

Flood

A flood is an overflow of water that submerges land that is usually dry. **The European Union (EU)** Floods Directive defines a flood as a covering by water of land not normally covered by water. In the sense of "flowing water", the word may also be applied to the inflow of the tide.

Flooding may occur as an overflow of water from water bodies, such as a river, lake, or ocean, in which the water overtops or breaks levees, resulting in some of that water escaping its usual boundaries, or it may occur due to an accumulation of rainwater on saturated ground in an area flood. While the size of a lake or other body of water will vary with seasonal changes in precipitation and snow melt, these changes in size are unlikely to be considered significant unless they flood property or drown domestic animals.

Floods can also occur in rivers when the flow rate exceeds the capacity of the river channel, particularly at bends or meanders in the waterway. Floods often cause damage to homes and businesses if they are in the natural flood plains of rivers. While riverine flood damage can be eliminated by moving away from rivers and other bodies of water, people have traditionally lived and worked by rivers because the land is usually flat and fertile and because rivers provide easy travel and access to commerce and industry.

Some floods develop slowly, while others such as **flash floods**, can develop in just a few minutes and without visible signs of rain. Additionally, floods can be local, impacting a neighborhood or community, or very large, affecting entire river basins.

Etymology

The word "flood" comes from the Old English flod, a word common to Germanic languages (compare German Flut, Dutch vloed from the same root as is seen in flow, float; also compare with Latin fluctus, flumen). Deluge myths are mythical stories of a great flood sent by a deity or deities to destroy civilization as an act of divine retribution, and they are featured in the mythology of many cultures.

Principal types

- **Areal**

Floods can happen on flat or low-lying areas when water is supplied by rainfall or snowmelt more rapidly than it can either infiltrate or run off. The excess accumulates in place, sometimes to hazardous depths. Surface soil can become saturated, which effectively stops infiltration, where the water table is shallow, such as a floodplain, or from intense rain from one or a series of storms. Infiltration also is slow to negligible through frozen ground, rock, concrete, paving, or roofs. Areal flooding begins in flat areas like floodplains and in local depressions not connected to a stream channel, because the velocity of overland flow depends on the surface slope. Endorheic basins may experience areal flooding during periods when precipitation exceeds evaporation.

- **Riverine (Channel)**

Floods occur in all types of river and stream channels, from the smallest ephemeral streams in humid zones to normally-dry channels in arid climates to the world's largest rivers. When overland flow occurs on tilled fields, it can result in a muddy flood where sediments are picked up by run off and carried as suspended matter or bed load. Localized flooding may be caused or exacerbated by drainage obstructions such as landslides, ice, debris, or beaver dams.

Slow-rising floods most commonly occur in large rivers with large catchment areas. The increase in flow may be the result of sustained rainfall, rapid snow melt, monsoons, or tropical cyclones. However, large rivers may have rapid flooding events in areas with dry climate, since they may have large basins but small river channels and rainfall can be very intense in smaller areas of those basins.

Rapid flooding events, including flash floods, more often occur on smaller rivers, rivers with steep valleys, rivers that flow for much of their length over impermeable terrain, or normally-dry channels. The cause may be localized convective precipitation (intense thunderstorms) or sudden release from an upstream impoundment created behind a dam, landslide, or glacier. In one instance, a flash flood killed eight people enjoying the water on a Sunday afternoon at a popular waterfall in a narrow canyon. Without any observed rainfall, the flow rate increased from about 50 to 1,500 cubic feet per second (1.4 to 42 m3/s) in just one minute. Two larger floods occurred at the same site within a week, but no one was at the waterfall on those days. The deadly flood resulted from a thunderstorm over part of the drainage basin, where steep, bare rock slopes are common and the thin soil was already saturated.

Flash floods are the most common flood type in normally-dry channels in arid zones, known as arroyos in the southwest United States and many other names elsewhere. In that setting, the first flood water to arrive is depleted as it wets the sandy stream bed. The leading edge of the flood thus advances more slowly than later and higher flows. As a result, the rising limb of the hydrograph becomes ever quicker as the flood moves downstream, until the flow rate is so great that the depletion by wetting soil becomes insignificant.

- **Estuarine and coastal**

Flooding in estuaries is commonly caused by a combination of sea tidal surges caused by winds and low barometric pressure, and they may be exacerbated by high upstream river flow.

Coastal areas may be flooded by storm events at sea, resulting in waves over-topping defenses or in severe cases by tsunami or tropical cyclones. A storm surge, from either a tropical cyclone or an extratropical cyclone, falls within this category. Research from the NHC (National Hurricane Center) explains: "Storm surge is an abnormal rise of water generated by a storm, over and above the predicted astronomical tides. Storm surge should not be confused with storm tide, which is defined as the water level rise due to the combination of storm surge and the astronomical tide. This rise in water level can cause extreme flooding in coastal areas particularly when storm surge coincides with normal high tide, resulting in storm tides reaching up to 20 feet or more in some cases."

- **Urban flooding**

Urban flooding is the inundation of land or property in a built environment, particularly in more densely populated areas, caused by rainfall overwhelming the capacity of drainage systems, such as storm sewers. Although sometimes triggered by events such as flash flooding or snowmelt, urban flooding is a condition, characterized by its repetitive and systemic impacts on communities that can happen regardless of whether or not affected communities are located within designated floodplains or near any body of water. Aside from potential overflow of rivers and lakes, snowmelt, stormwater or water released from damaged water mains may accumulate on property and in public rights-of-way, seep through building walls and floors, or backup into buildings through sewer pipes, toilets and sinks.

In urban areas, flood effects can be exacerbated by existing paved streets and roads, which increase the speed of flowing water.

The flood flow in urbanized areas constitutes a hazard to both the population and infrastructure. Some recent catastrophes include the inundations of **Nimes (France) in 1998** and **Vaison-la-Romaine (France) in 1992**, **the flooding of New Orleans (USA) in 2005**, and **the flooding in Rockhampton, Bundaberg, and Brisbane during the 2010–2011 summer in Queensland (Australia)**. Flood flows in urban environments have been studied relatively recently despite many centuries of flood events. Some recent research has considered the criteria for safe evacuation of individuals in flooded areas.

- **Catastrophic**

Catastrophic riverine flooding is usually associated with major infrastructure failures such as the collapse of a dam, but they may also be caused by drainage channel modification from a landslide, earthquake or volcanic eruption. Examples include outburst floods and lahars. Tsunamis can cause catastrophic coastal flooding, most commonly resulting from undersea earthquakes.

Causes

- **Upslope factors**

The amount, location, and timing of water reaching a drainage channel from natural precipitation and controlled or uncontrolled reservoir releases determines the flow at downstream locations. Some precipitation evaporates, some slowly percolates through soil, some may be temporarily sequestered as snow or ice, and some may produce rapid runoff from surfaces including rock, pavement, roofs, and saturated or frozen ground. The fraction of incident precipitation promptly reaching a drainage channel has been observed from nil for light rain on dry, level ground to as high as 170 percent for warm rain on accumulated snow.

Most precipitation records are based on a measured depth of water received within a fixed time interval. Frequency of a precipitation threshold of interest may be determined from the number of measurements exceeding that threshold value within the total time period for which observations are available. Individual data points are converted to intensity by dividing each measured depth by the period of time between observations. This intensity will be less than the actual peak intensity if the duration of the rainfall event was less than the fixed time interval for which measurements are reported. Convective precipitation events (thunderstorms) tend to produce shorter duration storm events than orographic precipitation. Duration, intensity, and frequency of rainfall events are important to flood prediction. Short duration precipitation is more significant to flooding within small drainage basins.

The most important upslope factor in determining flood magnitude is the land area of the watershed upstream of the area of interest. Rainfall intensity is the second most important factor for watersheds of less than approximately 30 square miles or 80 square kilometers. The main channel slope is the second most important factor for larger watersheds. Channel slope and rainfall intensity become the third most important factors for small and large watersheds, respectively.

Time of Concentration is the time required for runoff from the most distant point of the upstream drainage area to reach the point of the drainage channel controlling flooding of the area of interest. The time of concentration defines the critical duration of peak rainfall for the area of interest. The critical duration of intense rainfall might be only a few minutes for roof and parking lot drainage structures, while cumulative rainfall over several days would be critical for river basins.

- **Downslope factors**

Water flowing downhill ultimately encounters downstream conditions slowing movement. The final limitation is often the ocean or a natural or artificial lake. Elevation changes such as tidal fluctuations are significant determinants of coastal and estuarine flooding. Less predictable events like tsunamis and storm surges may also cause elevation changes in large bodies of water. Elevation of flowing water is controlled by the geometry of the flow channel. Flow channel restrictions like bridges and canyons tend to control water elevation above the restriction. The actual control point for any given reach of the drainage may change with changing water elevation, so a closer point may control for lower water levels until a more distant point controls at higher water levels.

Effective flood channel geometry may be changed by growth of vegetation, accumulation of ice or debris, or construction of bridges, buildings, or levees within the flood channel.

- **Coincidence**

Extreme flood events often result from coincidence such as unusually intense, warm rainfall melting heavy snow pack, producing channel obstructions from floating ice, and releasing small impoundments like beaver dams. Coincident events may cause extensive flooding to be more frequent than anticipated from simplistic statistical prediction models considering only precipitation runoff flowing within unobstructed drainage channels. Debris modification of channel geometry is common when heavy flows move uprooted woody vegetation and flood-damaged structures and vehicles, including boats and railway equipment. Recent field measurements during the 2010–11 Queensland floods showed that any criterion solely based upon the flow velocity, water depth or specific momentum cannot account for the hazards caused by velocity and water depth fluctuations. These considerations ignore further the risks associated with large debris entrained by the flow motion.

Some researchers have mentioned the storage effect in urban areas with transportation corridors created by cut and fill. Culverted fills may be converted to impoundments if the culverts become blocked by debris, and flow may be diverted along streets. Several studies have looked into the flow patterns and redistribution in streets during storm events and the implication on flood modelling.

EFFECTS

- **Primary effects**

The primary effects of flooding include loss of life, damage to buildings and other structures, including bridges, sewerage systems, roadways, and canals.

Floods also frequently damage power transmission and sometimes power generation, which then has knock-on effects caused by the loss of power. This includes loss of drinking water treatment and water supply, which may result in loss of drinking water or severe water contamination. It may also cause the loss of sewage disposal facilities. Lack of clean water combined with human sewage in the flood waters raises the risk of waterborne diseases, which can include typhoid, giardia, cryptosporidium, cholera and many other diseases depending upon the location of the flood.

Damage to roads and transport infrastructure may make it difficult to mobilize aid to those affected or to provide emergency health treatment.

Flood waters typically inundate farm land, making the land unworkable and preventing crops from being planted or harvested, which can lead to shortages of food both for humans and farm animals. Entire harvests for a country can be lost in extreme flood circumstances. Some tree species may not survive prolonged flooding of their root systems.

- **Secondary and long-term effects**

Economic hardship due to a temporary decline in tourism, rebuilding costs, or food shortages leading to price increases is a common after-effect of severe flooding. The impact on those affected may cause psychological damage to those affected, in particular where deaths, serious injuries and loss of property occur.

Urban flooding can lead to chronically wet houses, which are linked to an increase in respiratory problems and other illnesses. Urban flooding also has significant economic implications for affected neighborhoods. In the United States, industry experts estimate that wet basements can lower property values by 10–25 percent and are cited among the top reasons for not purchasing a home. According to the U.S. **Federal Emergency Management Agency (FEMA),** almost 40 percent of small businesses never reopen their doors following a flooding disaster. In the United States, insurance is available against flood damage to both homes and businesses.

Benefits

Floods (in particular more frequent or smaller floods) can also bring many benefits, such as recharging ground water, making soil more fertile and increasing nutrients in some soils. Flood waters provide much needed water resources in arid and semi-arid regions where precipitation can be very unevenly distributed throughout the year and kills pests in the farming land. Freshwater floods particularly play an important role in maintaining ecosystems in river corridors and are a key factor in maintaining floodplain biodiversity. Flooding can spread nutrients to lakes and rivers, which can lead to increased biomass and improved fisheries for a few years.

For some fish species, an inundated floodplain may form a highly suitable location for spawning with few predators and enhanced levels of nutrients or food. Fish, such as the weather fish, make use of floods in order to reach new habitats. Bird populations may also profit from the boost in food production caused by flooding.

Periodic flooding was essential to the well-being of ancient communities along the Tigris-Euphrates Rivers, the Nile River, the Indus River, the Ganges and the Yellow River among others. The viability of hydropower, a renewable source of energy, is also higher in flood prone regions.

Flood safety planning

At the most basic level, the best defense against floods is to seek higher ground for high-value uses while balancing the foreseeable risks with the benefits of occupying flood hazard zones: 22–23 Critical community-safety facilities, such as hospitals, emergency-operations centers, and police, fire, and rescue services, should be built in areas least at risk of flooding. Structures, such as bridges, that must unavoidably be in flood hazard areas should be designed to withstand flooding. Areas most at risk for flooding could be put to valuable uses that could be abandoned temporarily as people retreat to safer areas when a flood is imminent.

Planning for flood safety involves many aspects of analysis and engineering, including:

- Observation of previous and present flood heights and inundated areas,
- Statistical, hydrologic, and hydraulic model analyses,
- mapping inundated areas and flood heights for future flood scenarios,

- Long-term land use planning and regulation,
- Engineering design and construction of structures to control or withstand flooding,
- Intermediate-term monitoring, forecasting, and emergency-response planning, and
- Short-term monitoring, warning, and response operations.

Each topic presents distinct yet related questions with varying scope and scale in time, space, and the people involved. Attempts to understand and manage the mechanisms at work in floodplains have been made for at least six millennia.

In the United States, the Association of State Floodplain Managers works to promote education, policies, and activities that mitigate current and future losses, costs, and human suffering caused by flooding and to protect the natural and beneficial functions of floodplains – all without causing adverse impacts. A portfolio of best practice examples for disaster mitigation in the United States is available from the Federal Emergency Management Agency.

Control

- **Flood control**

In many countries around the world, waterways prone to floods are often carefully managed. Defenses such as detention basins, levees,[29] bunds, reservoirs, and weirs are used to prevent waterways from overflowing their banks. When these defenses fail, emergency measures such as sandbags or portable inflatable tubes are often used to try to stem flooding. Coastal flooding has been addressed in portions of Europe and the Americas with coastal defenses, such as sea walls, beach nourishment, and barrier islands.

In the riparian zone near rivers and streams, erosion control measures can be taken to try to slow down or reverse the natural forces that cause many waterways to meander over long periods of time. Flood controls, such as dams, can be built and maintained over time to try to reduce the occurrence and severity of floods as well.

In the United States, the U.S. Army Corps of Engineers maintains a network of such flood control dams.

In areas prone to urban flooding, one solution is the repair and expansion of man-made sewer systems and storm water infrastructure. Another strategy is to reduce impervious surfaces in streets, parking lots and buildings through natural drainage channels, porous paving, and wetlands (collectively known as green infrastructure or sustainable urban drainage systems (SUDS)). Areas identified as flood-prone can be converted into parks and playgrounds that can tolerate occasional flooding. Ordinances can be adopted to require developers to retain storm water on site and require buildings to be elevated, protected by floodwalls and levees, or designed to withstand temporary inundation. Property owners can also invest in solutions themselves, such as re-landscaping their property to take the flow of water away from their building and installing rain barrels, sump pumps, and check valves.

- **Analysis of flood information**

A series of annual maximum flow rates in a stream reach can be analyzed statistically to estimate the 100-year flood and floods of other recurrence intervals there. Similar estimates from many sites in a hydrologically similar region can be related to measurable characteristics of each drainage basin to allow indirect estimation of flood recurrence intervals for stream reaches without sufficient data for direct analysis.

Physical process models of channel reaches are generally well understood and will calculate the depth and area of inundation for given channel conditions and a specified flow rate, such as for use in floodplain mapping and flood insurance. Conversely, given the observed inundation area of a recent flood and the channel conditions, a model can calculate the flow rate. Applied to various potential channel configurations and flow rates, a reach model can contribute to selecting an optimum design for a modified channel. Various reach models are available as of 2015, either 1D models (flood levels measured in the channel) or 2D models (variable flood depths measured across the extent of a floodplain). HEC-RAS, the Hydraulic Engineering Center model, is among the most popular software, if only because it is available free of charge. Other models such as TUFLOW combine 1D and 2D components to derive flood depths across both river channels and the entire floodplain.

Physical process models of complete drainage basins are even more complex. Although many processes are well understood at a point or for a small area, others are poorly understood at all scales, and process interactions under normal or extreme climatic conditions may be unknown. Basin models typically combine land-surface process components (to estimate how much rainfall or snowmelt reaches a channel) with a series of reach models. For example, a basin model can calculate the runoff hydrograph that might result from a 100-year storm, although the recurrence interval of a storm is rarely equal to that of the associated flood. Basin models are commonly used in flood forecasting and warning, as well as in analysis of the effects of land use change and climate change.

Flood forecasting

- **Flood forecasting and flood warning**

Anticipating floods before they occur allows for precautions to be taken and people to be warned [32] so that they can be prepared in advance for flooding conditions. For example, farmers can remove animals from low-lying areas and utility services can put in place emergency provisions to re-route services if needed. Emergency services can also make provisions to have enough resources available ahead of time to respond to emergencies as they occur. People can evacuate areas to be flooded.

In order to make the most accurate flood forecasts for waterways, it is best to have a long time-series of historical data that relates stream flows to measured past rainfall events.[33] Coupling this historical information with real-time knowledge about volumetric capacity in catchment areas, such as spare capacity in reservoirs, ground-water levels, and the degree of saturation of area aquifers is also needed in order to make the most acrate flood forecasts.

Radar estimates of rainfall and general weather forecasting techniques are also important components of good flood forecasting. In areas where good quality data is available, the intensity and height of a flood can be predicted with fairly good accuracy and plenty of lead time. The output of a flood forecast is typically a maximum expected water level and the likely time of its arrival at key locations along a waterway,[34] and it also may allow for the computation of the likely statistical return period of a flood. In many developed countries, urban areas at risk of flooding are protected against a 100-year flood – that is a flood that has a probability of around 63% of occurring in any 100-year period of time.

According to the U.S. National Weather Service (NWS) Northeast River Forecast Center (RFC) in Taunton, Massachusetts, a rule of thumb for flood forecasting in urban areas is that it takes at least 1 inch (25 mm) of rainfall in around an hour's time in order to start significant ponding of water on impermeable surfaces. Many NWS RFCs routinely issue Flash Flood Guidance and Headwater Guidance, which indicate the general amount of rainfall that would need to fall in a short period of time in order to cause flash flooding or flooding on larger water basins.

In the United States, an integrated approach to real-time hydrologic computer modelling utilizes observed data from the U.S. Geological Survey (USGS), various cooperative observing networks,[37] various automated weather sensors, the NOAA National Operational Hydrologic Remote Sensing Center (NOHRSC),[38] various hydroelectric companies, etc. combined with quantitative precipitation forecasts (QPF) of expected rainfall and/or snow melt to generate daily or as-needed hydrologic forecasts. The NWS also cooperates with Environment Canada on hydrologic forecasts that affect both the USA and Canada, like in the area of the Saint Lawrence Seaway.

The Global Flood Monitoring System, "GFMS," a computer tool which maps flood conditions worldwide, is available online. Users anywhere in the world can use GFMS to determine when floods may occur in their area. GFMS uses precipitation data from NASA's Earth observing satellites and the Global Precipitation Measurement satellite, "GPM." Rainfall data from GPM is combined with a land surface model that incorporates vegetation cover, soil type, and terrain to determine how much water is soaking into the ground, and how much water is flowing into stream flow.

Users can view statistics for rainfall, stream flow, water depth, and flooding every 3 hours, at each 12 kilometer grid point on a global map. Forecasts for these parameters are 5 days into the future. Users can zoom in to see inundation maps (areas estimated to be covered with water) in 1 kilometer resolution.

ARCGIS

ArcGIS is a geographic information system (GIS) for working with maps and geographic information. It is used for creating and using maps, compiling geographic data, analyzing mapped information, sharing and discovering geographic information, using maps and geographic information in a range of applications, and managing geographic information in a database.

The system provides an infrastructure for making maps and geographic information available throughout an organization, across a community, and openly on the Web.

ARCMAP

ArcMap is the main component of Esri's ArcGIS suite of geospatial processing programs, and is used primarily to view, edit, create, and analyze geospatial data. ArcMap allows the user to explore data within a data set, symbolize features accordingly, and create maps. This is done through two distinct sections of the program, the table of contents and the data frame.

HEC-RAS

Hec-ras is a computer program that models the hydraulics of water flow through natural rivers and other channels. Prior to the recent update to Version 5.0 the program was one-dimensional, meaning that there is no direct modeling of the hydraulic effect of cross section shape changes, bends, and other two- and three-dimensional aspects of flow. The release of Version 5.0 introduced two-dimensional modeling of flow as well as sediment transfer modeling capabilities. The program was developed by the US Department of Defense, Army Corps of Engineers in order to manage the rivers, harbors, and other public works under their jurisdiction; it has found wide acceptance by many others since its public release in 1995.

The **Hydrologic Engineering Center (HEC)** in Davis, California developed the River Analysis System (RAS) to aid hydraulic engineers in channel flow analysis and floodplain determination. It includes numerous data entry capabilities, hydraulic analysis components, data storage and management capabilities, and graphing and reporting capabilities.

HEC-RAS is a computer program for modeling water flowing through systems of open channels and computing water surface profiles. HEC-RAS finds particular commercial application in floodplain management and flood insurance studies to evaluate floodway encroachments. Some of the additional uses are: bridge and culvert design and analysis, levee studies, and channel modification studies. It can be used for dam breach analysis, though other modeling methods are presently more widely accepted for this purpose.

CHAPTER 3

METHODOLOGY

The methodology consists of data collection and data basing required for floodplain mapping

3.1DESIGNATION OF STUDY AREA

To obtain the study area, the kansanga drainage channel was followed up to a point where it had less noticeable impact using google earth. To mark that area, placemarks were placed on four corners on google earth and saved as kml files which can be loaded in Arc gis and converted into layer files which can be used to both reduce DEM downloaded and also act as a georeferencing mechanism.

3.2 DATA USED (COLLECTION)

a) Topographic and GIS Data

Gis data (DEM) for Kampala was obtained from https://earthexplorer.usgs.gov. Since the data obtained was too big (for a large area) it had to be reduced to a more manageable size.The size decided was the same as the designated study area and the place marks were used to reduce the size using the clip function in arc GIs. After obtaining the DEM, a hydrologic correction was done on it using the fill function in spatial analysis extension.

The fill file was now used to generate the contour map of the area using the contour command in spatial analyst tool in arc gis

The land use map was created using the Landsat data which was also downloaded from https://earthexplorer.usgs.gov and also reduced to the designated area.

Using the image classification, unsupervised classification option, the image Was classified into 3 different land use

SOIL MAP.

The soil map obtained was for makindye which covers the designated study area

b) **Meteorological data**

This was obtained from Makerere metrological center under Uganda National Metrological Authority (UNMA)

3.3 HYDROLOGIC ANALYSIS

The hydrology analysis was done in arc gis on the fill file of the DEM of designated study area. The main purpose of this is to find out the watershed of which contribute to the flooding of the channel.

The extension / tool used was spatial analyst tool in arc gis

1. **FLOW DIRECTION**

   The input for this was the fill file which we had already obtained after correcting the DEM file of the study area

2. **FLOW ACCUMULATION**

   The input for this function was the flow direction obtained from above

3. **RASTER CALCULATOR**

   This was used to develop the different streams in the study area and the input for this is both the flow accumulation and also the value in height at which the streams should be shown a smaller value resulted into very many streams shown while a high value resulted into very few streams shown hence an optimum value of 250 was selected in calculating the streams. The output is called a stream raster.

4. **STREAM ORDER**

   This was to clearly show the calculated above steams and uses the above result to create a stream file which can be manipulated and actually worked on. The inputs are the stream raster and the flow direction

5. **CREATION OF A POINT SHAPE FILE**

   This point was selected at the end of the channel near the entrance to Lake Victoria. This point is to act as the pour point such that all the area which is to contribute water to that point can be considered as the watershed.

6. **WATERSHED**

This was the final step in the analysis and the watershed is the output while the pour point and the flow direction being the input.

3.3.1 CALCULATION OF RETURN PERIOD

The approach to calculate discharge used return period as an input. The return period calculated was for the obtained rainfall events in the meteorological data.
The method used is the Gringorten method.
T= (N+0.12)/ (M-0.44);

Where,

M = Highest rank or total number of items
N=Rank

3.3.2CALCULATION OF DISCHARGE

The method used to calculate discharge was the **rationale method**

Q = CIA/360

Where;

Q – Discharge in m^3/s

C – Runoff coefficient (dimensionless)

A – Area of the watershed. HECTARES

I – Rainfall intensity (mm/hr)

a) **runoff coefficient (c)**
   Using the land use data and table 4.7 of Uganda drainage manual volume 2 the runoff coefficient was found.

b) **time of concentration**
   Tc =0.06628 L^(0.77) x S^(-0.385)

Where;

L= length of longest flow path.

S= slope

c) **RAINFALL INTENSITY (I)**

This was calculated from

Intensity (i) =80T^(0.2)/(Tc +12)^(0.5)

Where;

T= Return periods

Tc = Time of concentration in minutes.

3.4 HYDRAULIC ANALYSIS

Application of HEC-RASto obtain flood extent and depth. HEC-GeoRAS and HEC-RAS software will be used.

HEC-GeoRAS is specifically designed to process geospatial data for use with the Hydrologic Engineering Center's River Analysis System (HEC-RAS). The tools allow users to pre and post process the data for HEC-RAS. It creates an input file for HEC-RAS containing geometric attribute data from an existing DTM and complementary data sets.

HEC-RAS is a 1D flow model in which the stream morphology is represented by a series of cross sections indexed by river station. Each cross section is defined by a series of lateral and elevation coordinates that are typically obtained from DTM.

PREPARATION OF DATA FOR HEC RAS.

3.4.1.1 CREATION OF A TIN FILE

This is because hec georas which is used in the creation of data which is to be used in hec-ras requires a tin file which is to be used as the terrain. The process of creating a tin file in Arc gis is as follows;

a) Contouring (spatial analysis)

This is the process which uses the dem as an input and creates the contour map.

b) Create tin (3d analyst)

This was the last step in the creation of the tin file. It uses the contour map as an input and also a coordinate should also be input. The classes which should be shown on the tin file can then be selected from symbology option in properties.

HEC- GEORAS PROCESS

a) Save the project.

Before any work can start, the project was be saved using the saving option in Arc gis.

b) Layer setup

At this point the layer setup option was selected from the ras geometry tab in the hec ras toolbar. At this point, the created tin file was loaded.

c) Create ras layers.

The ras layers were then loaded in the project. The load all layers option was selected.

d) River

This option was to create the centerline of the channel. The editor tool command was used and a line was drawn to map that.

e) Id

The river id was an option used in order to name the channel and reach. Since we had only one centerline, we only needed to id it only once.

f) Centerline attributes

This was used in order to give the centerline attributes. Those attributes were automatically calculated using both the drawn centerline and the tin file. The attributes are shape length, name and stations.

g) Banks

The banks were selected. These are maximum areas where the water reaches normally and the editor tool was still used and lines were on both banks were selected.

h) Flowpath

The editor tool was also used to draw the flowpath on both sides of the centerline.

i) Assigning line type attribute

The two flowpath lines are selected and given types i.e. left and right.

j) Xcutlines

This is an option meaning cross section lines and they were selected cutting through the area of interest. Still done using the editor command

k) Xcutlines attribute

This is also an automatic process which after being selected, it uses the river data, flow path and terrain to fill the various attributes of the cross sections.

l) Manning's n value

This one was extracted directly of the makindye soil map.

m) Export ras data.

After double checking, the data was exported to hec ras using the export ras data option.

DATA PREPARATION FOR FLOOD SIMULATION IN HEC RAS

a) Create new project.

The first process was the creation of a new project where the name and save location was selected.

b) Creation and saving of geometry data file.

The geometry data option is selected and saved so that all changes in the geometry can be saved in that file.

c) Data import.

The data which was imported in this step is the geometry data exported form GIS. This was done from the geometry tab.

d) Cross section point filter.

This command was performed under the geometry tab and it was used to reduce the number of cross section points to those needed. This is because some points are redundant and have no value so they would have ended up slowing down the process.

e) Creation of flow data.

   The approach used was steady flow. The flow data was first created in the menu and then saved.

f) Specification of available data.

   This process involved selection of the number of data which would be worked on. The number depended on the number of discharge calculated for various rainfall events.

g) Upstream boundary condition.

   This is the selection of the condition upstream and its input is the calculated discharges in cfs (cubic feet per second)

h) Downstream boundary condition.

   This is the selection of the condition downstream. The input is the normal depth slope. A constant value of 0.01 is advised.

i) Creation of a plan.

   This is the file which will be run to give put the flood simulation. It uses the geometry data and the flow data as input.

3.5 FLOOD SIMULATION

The simulation could now be run since all the data is available. The process involved in the run of the model is

a) Selection of flow regime.

   The regime selected could be critical, subcritical or mixed regime.

b) Floodplain mapping

   This option was selected such that the output could be mapped in any mapping software (hec georas or ras mapper)

c) Assigning of short id.

   This was used in order to identify different results of different discharges.

d) Compute

This was the command used in order to run the model. When selected the model is run and the results can then be displayed.

3.6 CREATION OF TERRAIN.

Before the flood terrain could be mapped, the terrain which the water will be sitting from had to be created and the process was as follows.

a) Exportation of the DEM.

   The dem used in hec georas is the one needed by ras mapper. Since the file is in a format only recognized by arc gis, it has to be converted in a format which is recognized by hec ras. The file is then exported in form of a tiff file and saved.

b) Conversion in hec ras.

   The saved tiff file is then converted in hec ras to create the terrain. The option selected is create new terrain in hec ras which allowed to select the tiff file and then create a new terrain file which can be saved and loaded as the terrain.

3.7 FLOOD MAPPING

The output from the simulation could now be mapped in ras mapper and the process is as follows.

a) Selection of projection.

   This was the first and most important step. Without the projection, the result could not be shown. Since projection requires a previous ras file which has a projection, we skipped it and selected the option of using the projection of the terrain.

b) Loading of existing terrain.

   The option of loading the existing terrain was then selected. When loading the projection was set to follow the projection of the terrain.

c) Loading of map layer.

   This was a Google map layer which could clearly show the affected areas when the results are super imposed on it.

d) Loading of the results.

Some results from the simulation could now be loaded to map the flooded area. The results are in the following data.

GEOMETRY

This was to show the various cross sections created in hec georas.

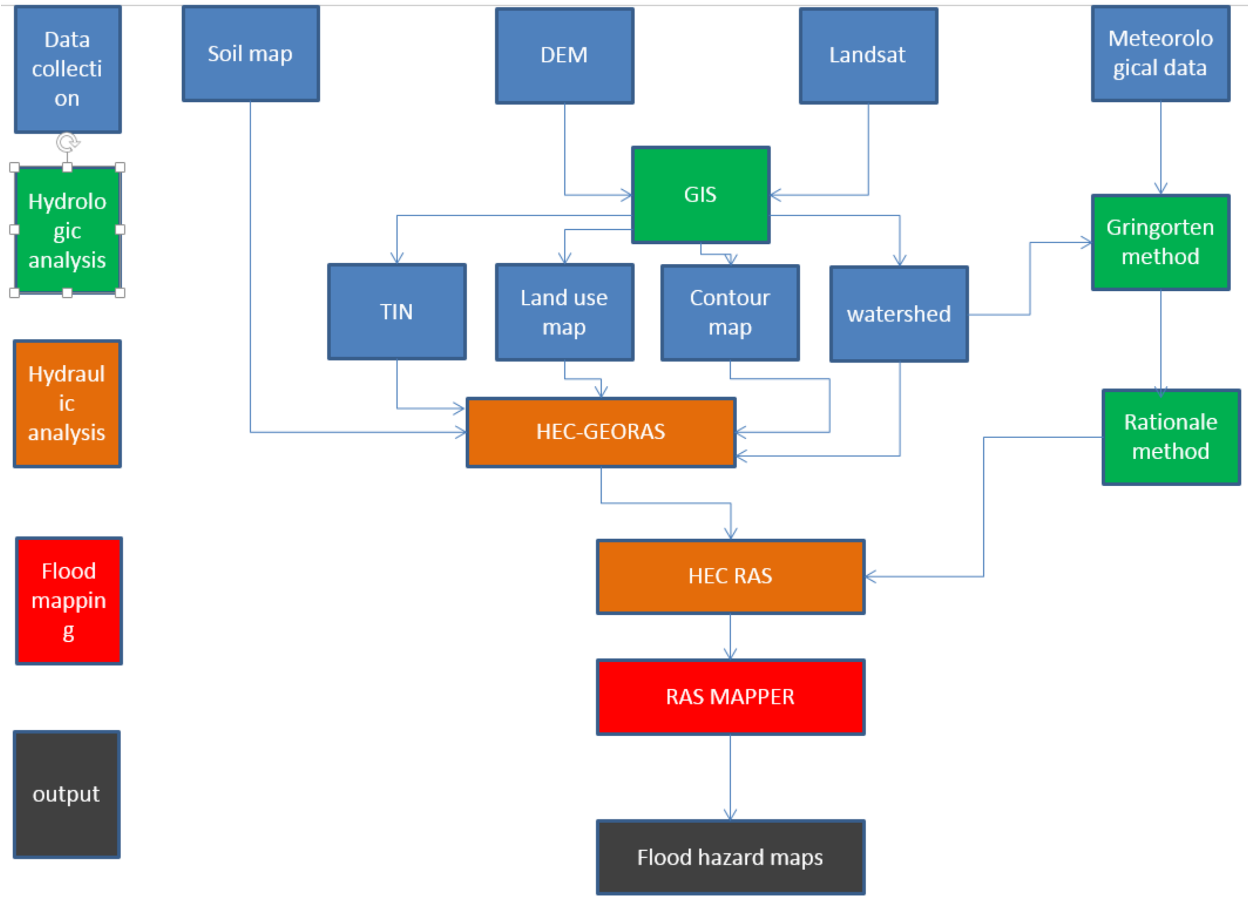
WSE

This showed the water surface. That is to say, the flood extent

DEPTH

This showed the flood depth

The flow chart of procedure to obtain the flood extent and depth is



Model Inputs

Implementation of HEC-RAS requires inputs which come from three basic categories of data; (a) Geometric data

(b) Basin characteristics and

(d) Flow data

a) Geometric Data

The requisite geometric data includes stream centerlines and cross section cut lines and these are prepared using the HEC-GeoRAS user interface. It is a set of procedures, tools, and utilities for processing geospatial data in ArcGIS. It also allows the import of the prepared data into HEC-RAS model. The creation of the import file requires a digital terrain model (DTM) of the area. Having imported the data into the HEC-RAS system, the cross section data were adjusted to suit the available bathymetric profiles.

b) Basin Characteristics

Manning's friction coefficient 'n' falls under this category. The Manning's 'n' value is highly variable and depends on a number of factors including surface roughness, vegetation, channel irregularities, channel alignment, scour and deposition, obstructions, size and shape of the channel, stage and discharge, seasonal changes, suspended material and bed-load. Land-use map will be used to extract the Manning's n value in this study.

c) Flow Data

Discharge and water level values make the upstream and downstream boundary conditions. For computing flood extent for rainfall of 50 year return period, flows computed using HEC-HMS will be used as upstream boundary condition.

3.8 FLOOD HAZARD MAPPING

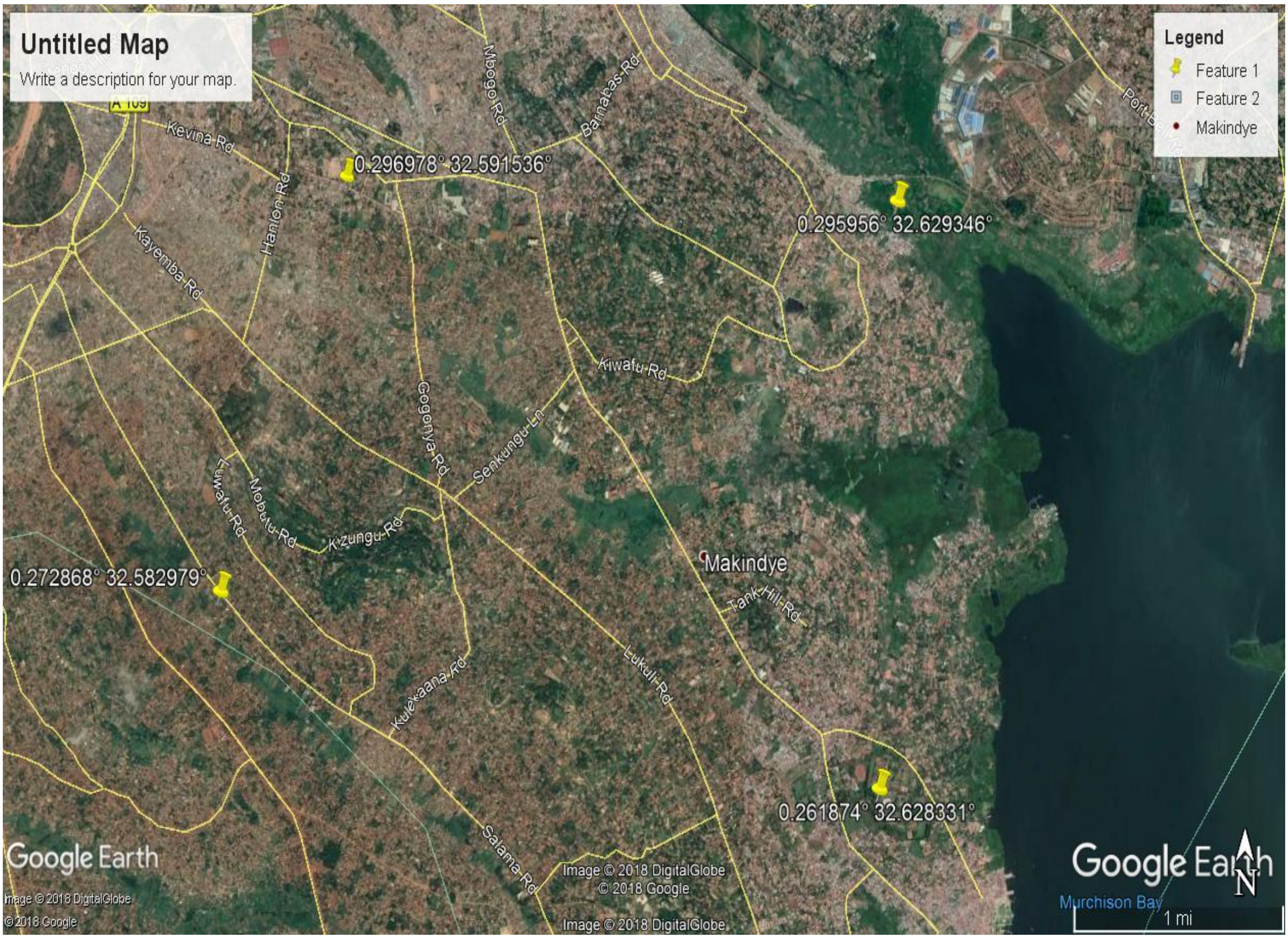
Flood hazard is categorized based on the level of difficulties in daily life and/or damage to properties. Flood hazard assessment is the estimation of overall adverse effects of flooding. It depends on many parameters such as **depth of flooding**, **duration of flooding**, **flood wave velocity** and **rate of rise of water level**. One or more parameters can be considered in the hazard assessment. The intensity of flood hazard is always given by a relative scale, which represents the degree of hazard and is called a **hazard rank**. A smaller hazard rank was assigned for a lower depth or low hazard while larger hazard rank was used to indicate a higher hazard. An illustration showing how the ranking was done

Flood parameter	Hazard category	Hazard rank
Hazard free	No hazard	0
$X<P\leq Y$	Low	1
$Y<P\leq Z$	Medium	2
$Z<P$	High	3

CHAPTER 4

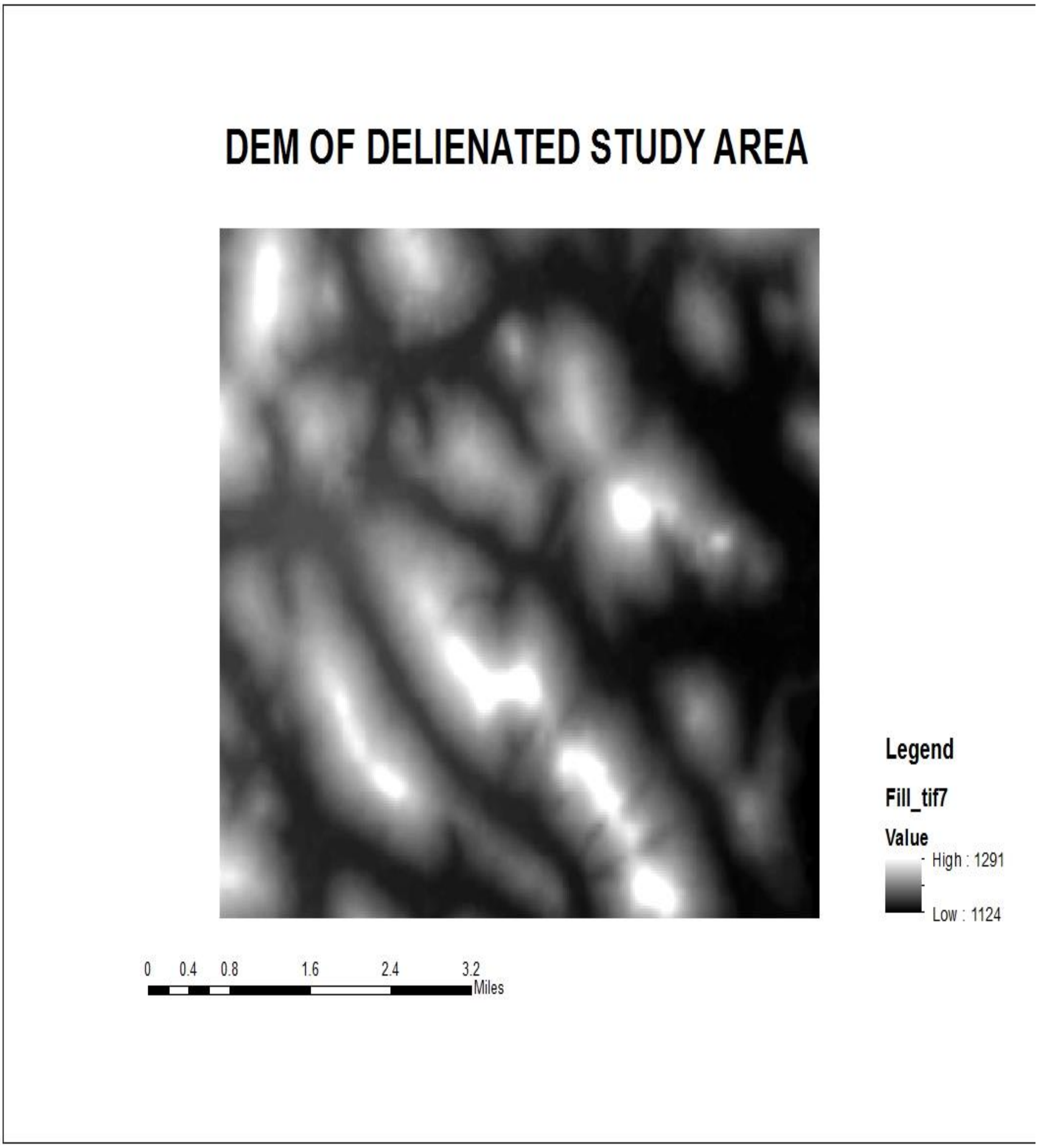
RESULTS AND FINDINGS

4.1 DESIGNATION OF STUDY AREA

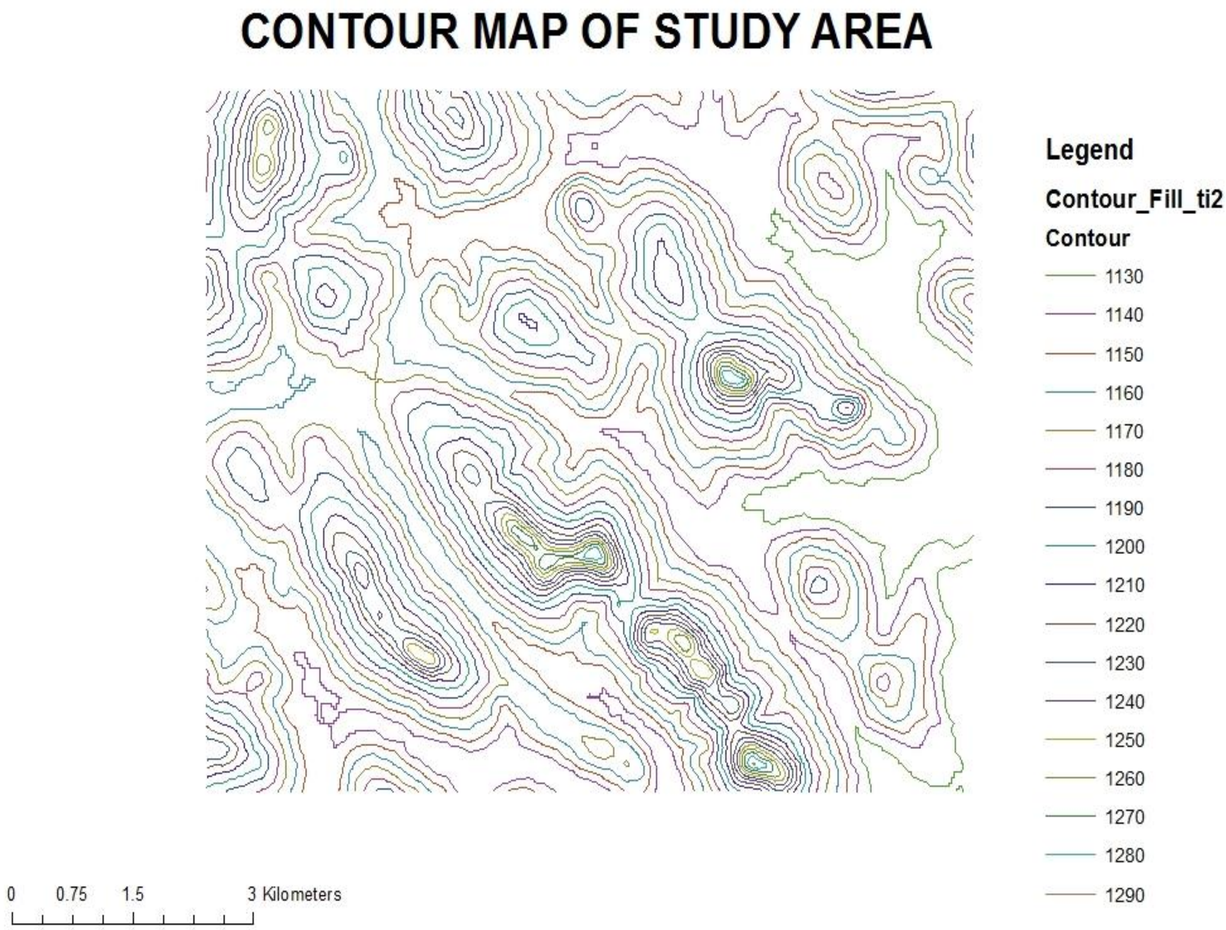


4.2 DATA COLLECTION

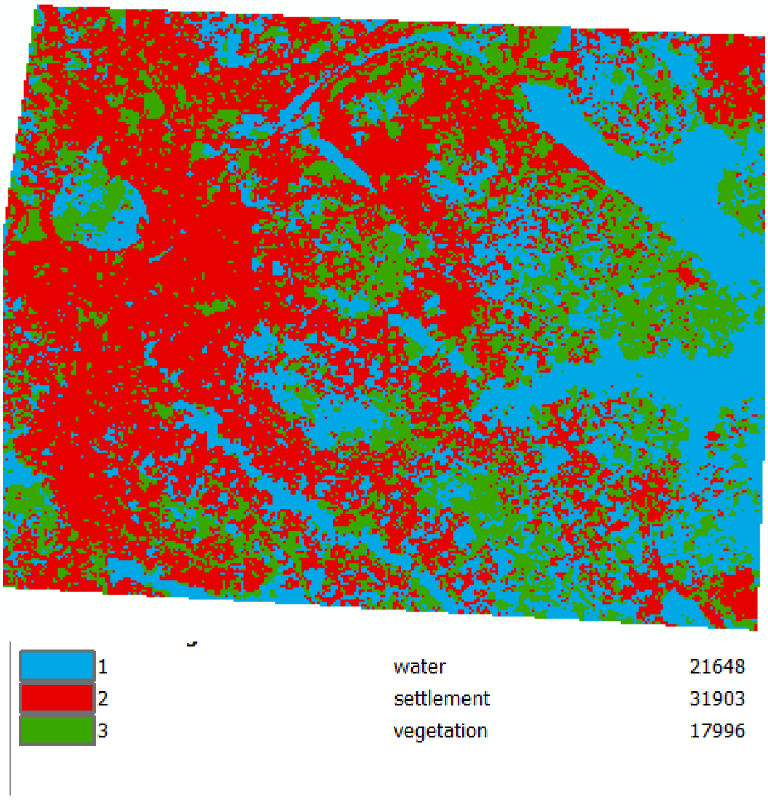
- DEM



- Contour map



- Landuse map



METEOROLOGICAL DATA

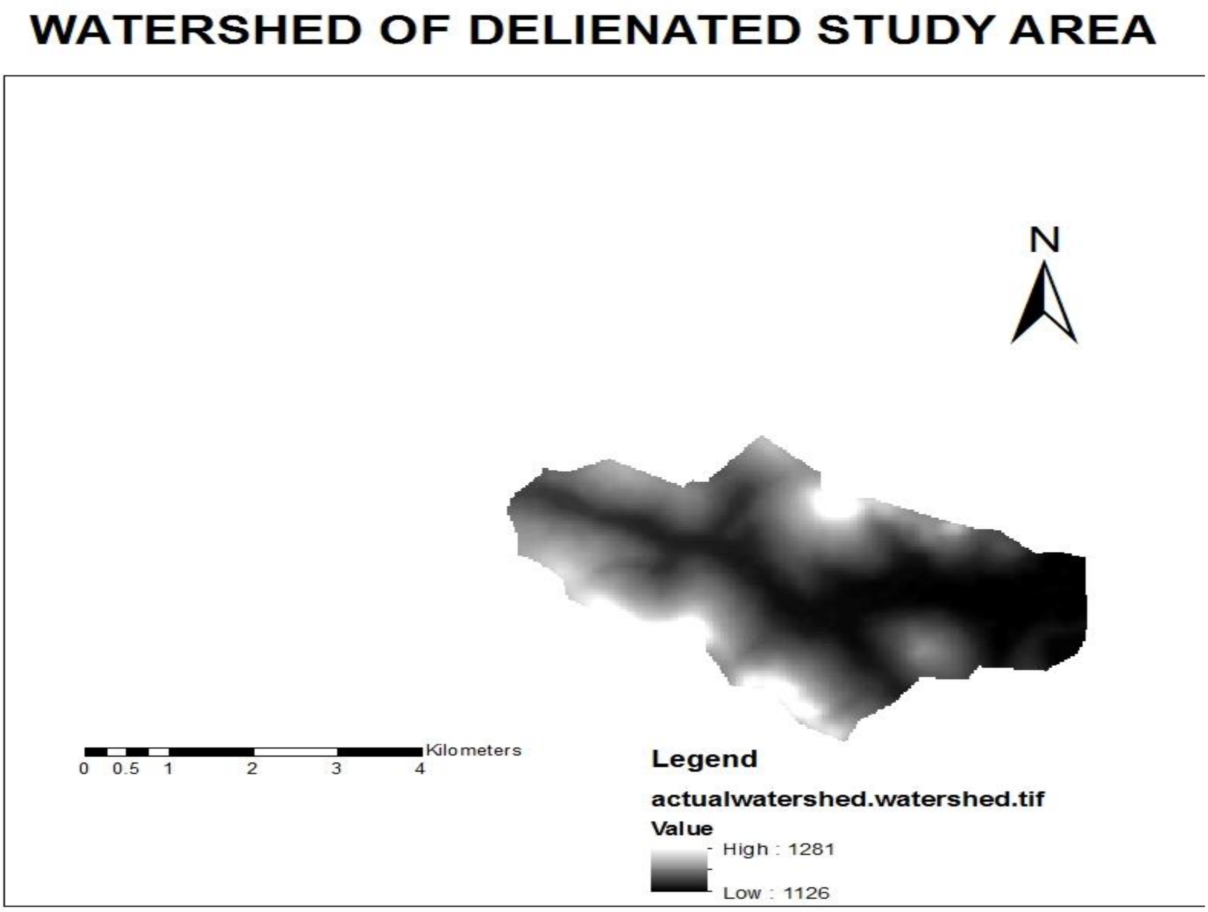
. Precipitation data for daily extreme (peak) rainfall eventsfor Kampala area

Year	Rainfall, X(mm)	Year	Rainfall, X (mm)
1985	62.8	2001	90.9
1986	61.3	2002	79
1987	47.3	2003	84
1988	91.5	2004	63.6
1989	31.6	2005	31.4
1990	31	2006	61.1
1991	70.6	2007	165.1
1992	45.7	2008	64.2
1993	76.5	2009	50.1
1994	60.3	2010	73.4
1995	48.7	2011	69.7
1996	26.9	2012	65
1997	124.5	2013	58
1998	47.1	2014	56.5
1999	82.3	2015	91.5
2000	85.1	2016	74

Source: Makerere metrological center under Uganda National Metrological Authority (UNMA)

4.3 HYDROLOGIC ANALYSIS

The end result of the analysis which is the watershed for our area was as follows.



Characteristics of the watershed

A=1531.1m^2.

This was measured using the 'measure area of a polygon function' in Arc gis.

L=6.363km

This was measures using the length measurement function

Slope(s)=1281-1126/6363=0.03

This was obtained using the DEM file highest and lowest elevation of the watershed

RETURN PERIOD

Calculations of the return periods using the Gringorten method;

T=(N+0.12)/ (M-0.44);

Where,

M = Highest rank or total number of items

N=Rank

RANK(M)	RAINFALL(mm)	FREQUENCY(years)
1	165.1	57
2	124.5	20
3	91.5	13
4	90.9	9
5	85.1	7
6	84.0	6
7	82.3	5
8	79.0	4
9	73.4	3
10	69.7	3
11	65.0	3
12	64.2	3
13	63.6	2
14	61.3	2
15	61.1	2
16	60.3	2
17	58.0	2
18	56.5	2
19	50.1	2
20	48.7	2
21	47.1	1
22	45.7	1
23	31.6	1
24	31.4	1
25	31.0	1
26	26.9	1
27	26.4	1
28	24.1	1
29	22.7	1
30	22.4	1
31	20.2	1
32	19.3	1
M = 32		

RATIONALE METHOD

Therefore, discharge was calculated using the rationale method.

From;

Q = CIA/360.

A=1531.1 hectares

L=6.363 km

Slope(s)=1289-1125=0.03.

RUNOFF COEFFICIENT (C)

Conjugate c

C= (0.7x6715)+ (0.11x4713)/(11478)

C= 0.45.

TIME OF CONCENTRATION (Tc)

Tc= 0.06628x6.363^(0.77) x 0.03^(-0.385).

Tc= 1.062hrs.

Tc= 64mins.

RAINFALL INTENSITY (I)

Using a 60 years return period storm

(i) =80x60^(0.2) /(60+12)^(0.5)

Intensity=21.4mm/hr.

DISCHARGE

Discharge (Q)= CIA/(360)

Q= 0.45 x 21.4 x 1531.1 / 360.

Q = 40.92m^3/s.

Conversion to cfs (cubic feet per second)

1 m^3/s = 35.1 cfs

40.92 m3/s = 1436.292 cfs

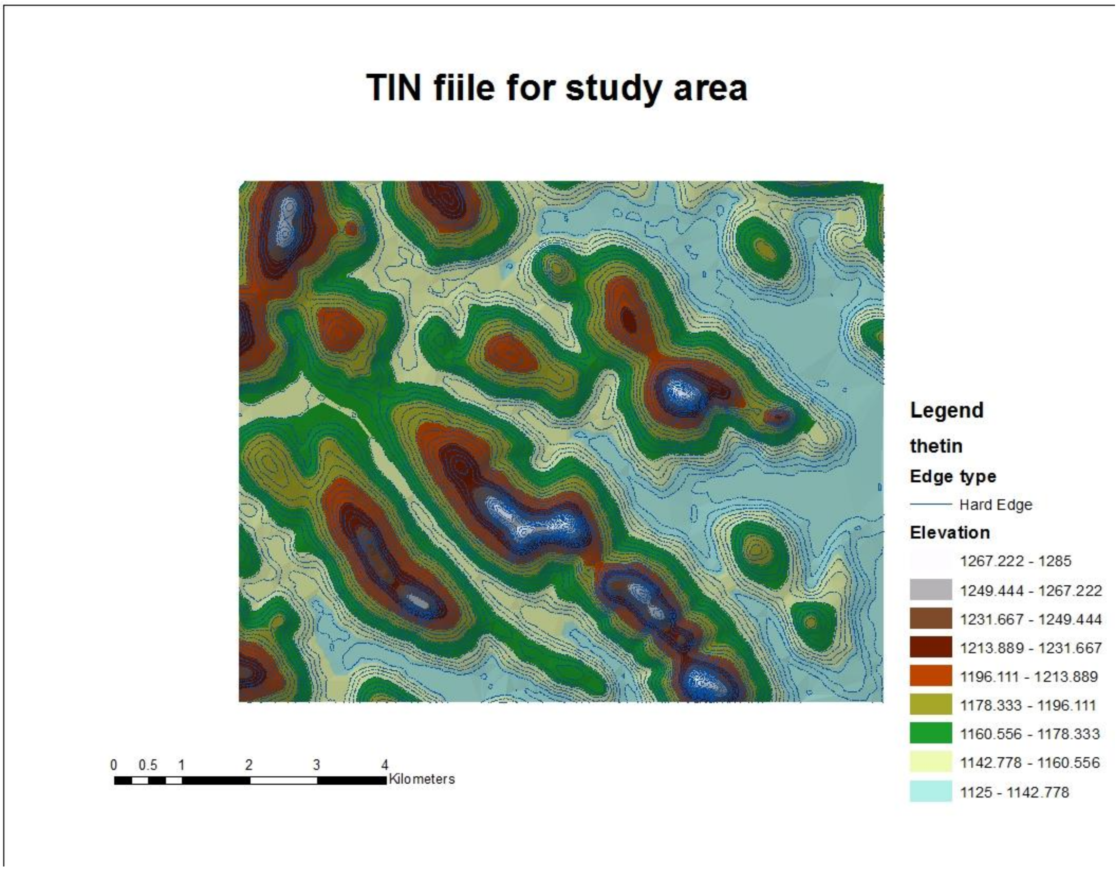
This is because hec ras uses cfs units

Constant (C)	Frequency / Return periods. (years)	Intensity (I) (mm/hr)	Discharge (Q) (M^3/s)	Discharge (Q) (cfs)	Profile (p)
0.45	1	9.2	17.61	618	7
0.45	2	10.54	20.2	709	6
0.45	5	12.66	24.23	850	5
0.45	10	14.5	27.75	974	4
0.45	20	16.71	32.1	1126	3
0.45	50	20.1	38.47	1350	2
0.45	60	21.4	40.92	1435	1

4.4 HYDRAULIC ANALYSIS

PREPARATION OF DATA FOR HEC RAS.

1. TIN FILE



2. River attributes

River

Shape *	OID *	Shape_Length	HydroID	River	Reach	FromNode	ToNode	ArcLength	FromSta	ToSta
Polyline	1	7119.897256	1	kansanga channel	thru gabba	1	2	7119.897	0	7119.897

3. Banks attributes

Banks

Shape *	OID *	Shape_Length	HydroID
Polyline	1	7931.69737	3
Polyline	3	7089.643238	5

4. Flow path attributes

Flowpaths

Shape *	OID *	Shape_Length	LineType
Polyline	1	7102.159202	Right
Polyline	2	7049.630134	Left

5. XCut lines

XSCutLines

Shape *	OID *	Shape_Length	HydroID	Station	River	Reach	LeftBank	RightBank	LLength	ChLength	RLength	NodeName
Polyline	1	2054.441663	6	6898.244	kansanga channel	thru gabba	0.29864	0.40147	290.729	0.213	290.516	<Null>
Polyline	2	1905.813127	7	6417.729	kansanga channel	thru gabba	0.2896	0.41606	261.174	0.431	260.743	<Null>
Polyline	3	2190.567713	8	5725.241	kansanga channel	thru gabba	0.32018	0.42102	273.061	7.518	280.579	<Null>
Polyline	4	2223.916978	9	5034.913	kansanga channel	thru gabba	0.3089	0.53355	668.588	1.628	666.96	<Null>
Polyline	5	1964.564284	10	4363.968	kansanga channel	thru gabba	0.313	0.53688	455.397	1.08	456.477	<Null>
Polyline	6	1917.370017	11	3548.341	kansanga channel	thru gabba	0.50349	0.72318	428.985	0.937	428.048	<Null>
Polyline	7	2260.020727	12	2753.395	kansanga channel	thru gabba	0.40504	0.78315	385.022	1.021	384.001	<Null>
Polyline	8	2262.901085	13	2049.116	kansanga channel	thru gabba	0.33241	0.60429	619.262	0.299	618.963	<Null>
Polyline	9	2135.733706	14	1432.303	kansanga channel	thru gabba	0.31187	0.55814	694.556	10.961	683.595	<Null>
Polyline	10	2470.033222	15	743.3171	kansanga channel	thru gabba	0.25196	0.62532	531.875	5.284	537.159	<Null>
Polyline	11	2148.527716	16	204.9279	kansanga channel	thru gabba	0.25623	0.72978	200.144	4.364	204.508	<Null>
Polyline	12	1879.241256	17	3909.526	kansanga channel	thru gabba	0.42083	0.63497	356.461	1.271	357.732	<Null>
Polyline	13	2030.354853	18	3122.417	kansanga channel	thru gabba	0.47232	0.80698	376.084	5.82	370.264	<Null>
Polyline	14	2019.26421	19	2364.494	kansanga channel	thru gabba	0.35396	0.71871	306.392	16.38	322.772	<Null>
Polyline	15	1923.063262	20	5450.87	kansanga channel	thru gabba	0.30484	0.45121	383.623	27.526	411.149	<Null>
Polyline	16	1733.777166	21	6156.899	kansanga channel	thru gabba	0.30559	0.45611	430.106	2.204	427.902	<Null>
Polyline	17	1673.45707	22	6608.404	kansanga channel	thru gabba	0.24729	0.38041	191.284	0.154	191.13	<Null>

6. Manning table

Edit Manning's n or k Values

River: kansanga channel   Edit Interpolated XS's   Channel n Values ha a light green background

Reach: thru gabba   All Regions

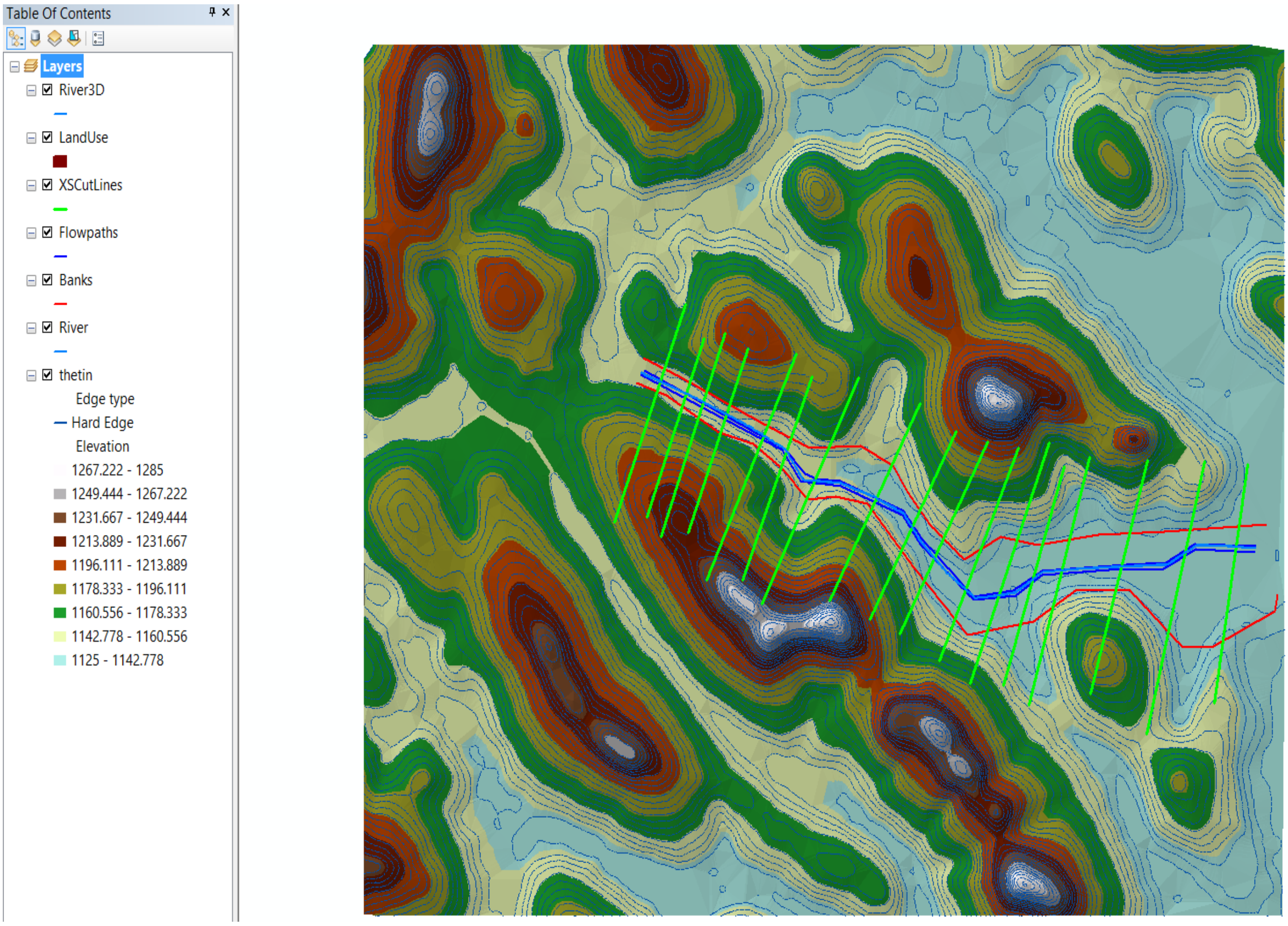
Selected Area Edit Options

Add Constant ...   Multiply Factor ...   Set Values ...   Replace ...   Reduce to L Ch R ...

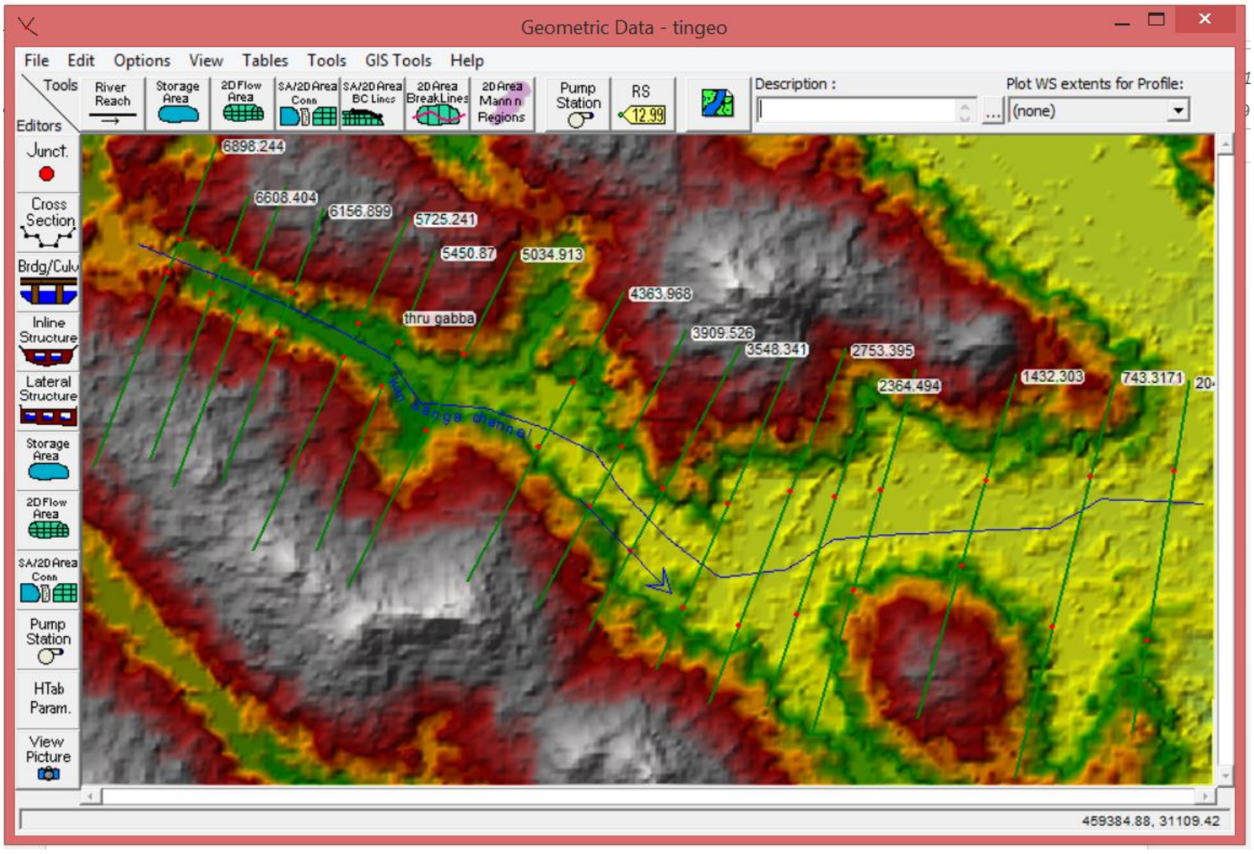
	River Station	Frctn (n/K)	n #1	n #2	n #3
1	6898.244	n	0.6	0.6	0.6
2	6608.404	n	0.6	0.6	0.6
3	6417.729	n	0.6	0.6	0.6
4	6156.899	n	0.6	0.6	0.6
5	5725.241	n	0.6	0.6	0.6
6	5450.87	n	0.6	0.6	0.6
7	5034.913	n	0.6	0.6	0.6
8	4363.968	n	0.6	0.6	0.6
9	3909.526	n	0.6	0.6	0.6
10	3548.341	n	0.6	0.6	0.6
11	3122.417	n	0.6	0.6	0.6
12	2753.395	n	0.6	0.6	0.6
13	2364.494	n	0.6	0.6	0.6
14	2049.116	n	0.6	0.6	0.6
15	1432.303	n	0.6	0.6	0.6
16	743.3171	n	0.6	0.6	0.6
17	204.9279	n	0.6	0.6	0.6

DATA PREPARATION FOR FLOOD SIMULATION IN HEC RAS

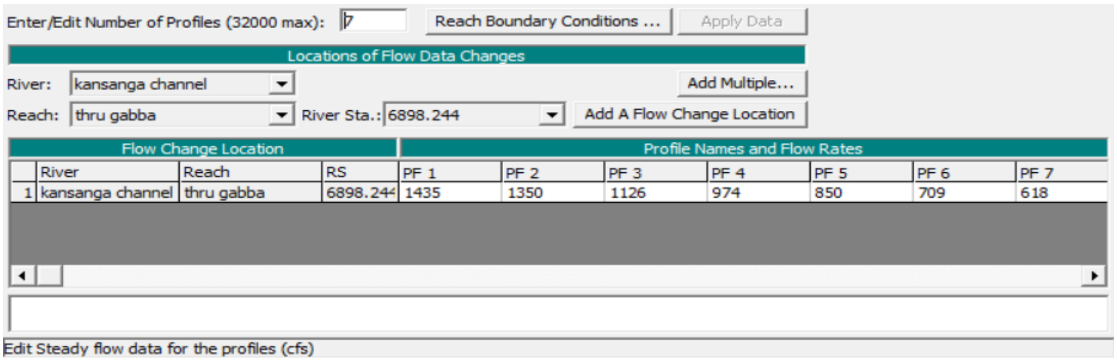
1. Final model to be imported



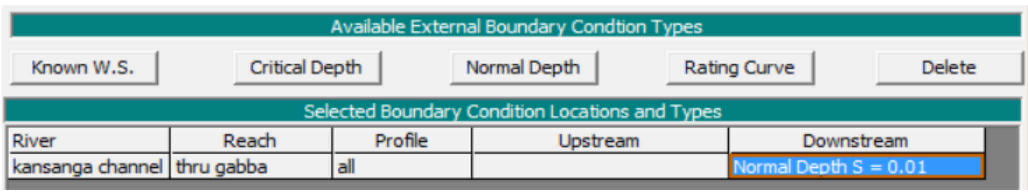
2. Edited geometry data



3. Upstream boundary condition

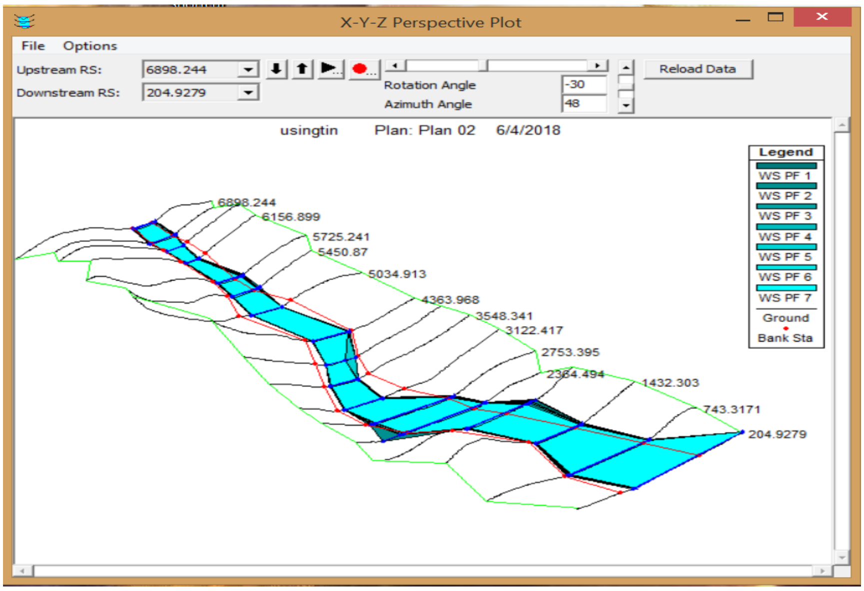


4. Downstream boundary condition

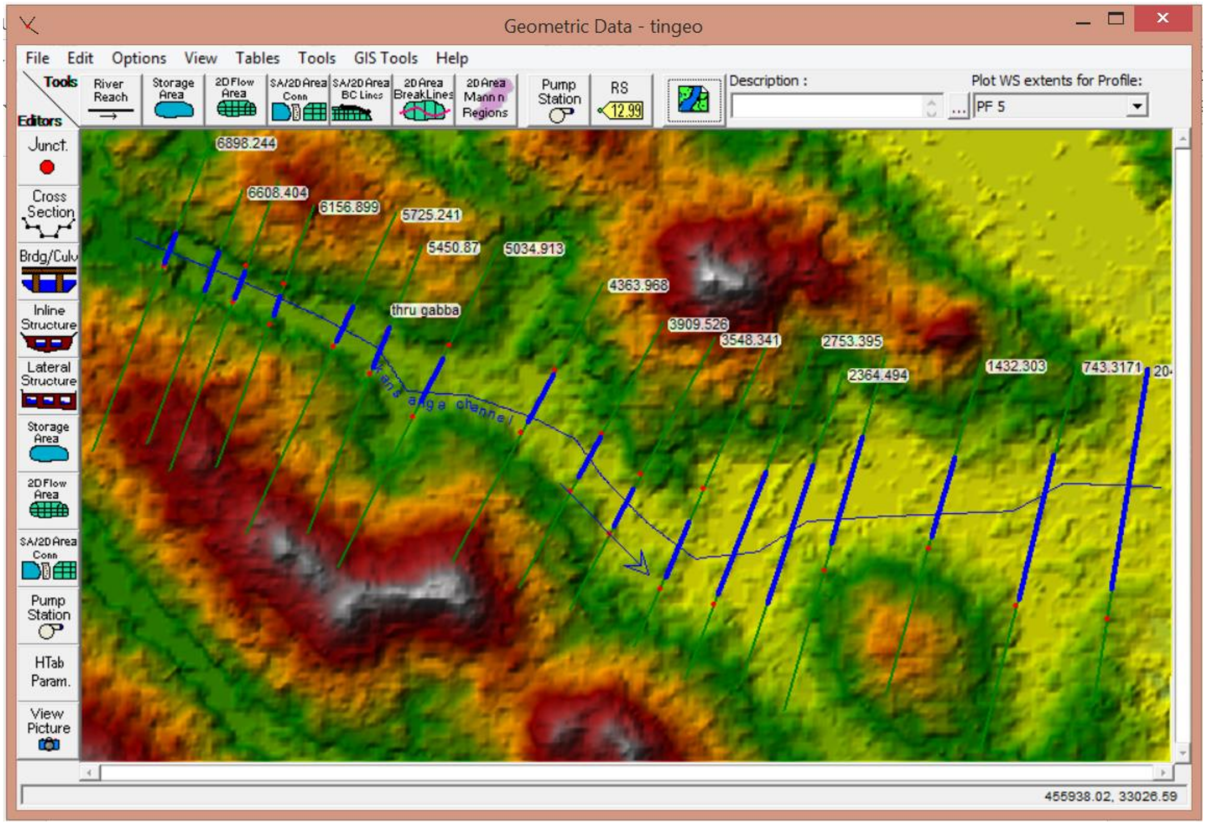


SIMULATION RESULTS

1. XYZ PLOT OF RESULTS



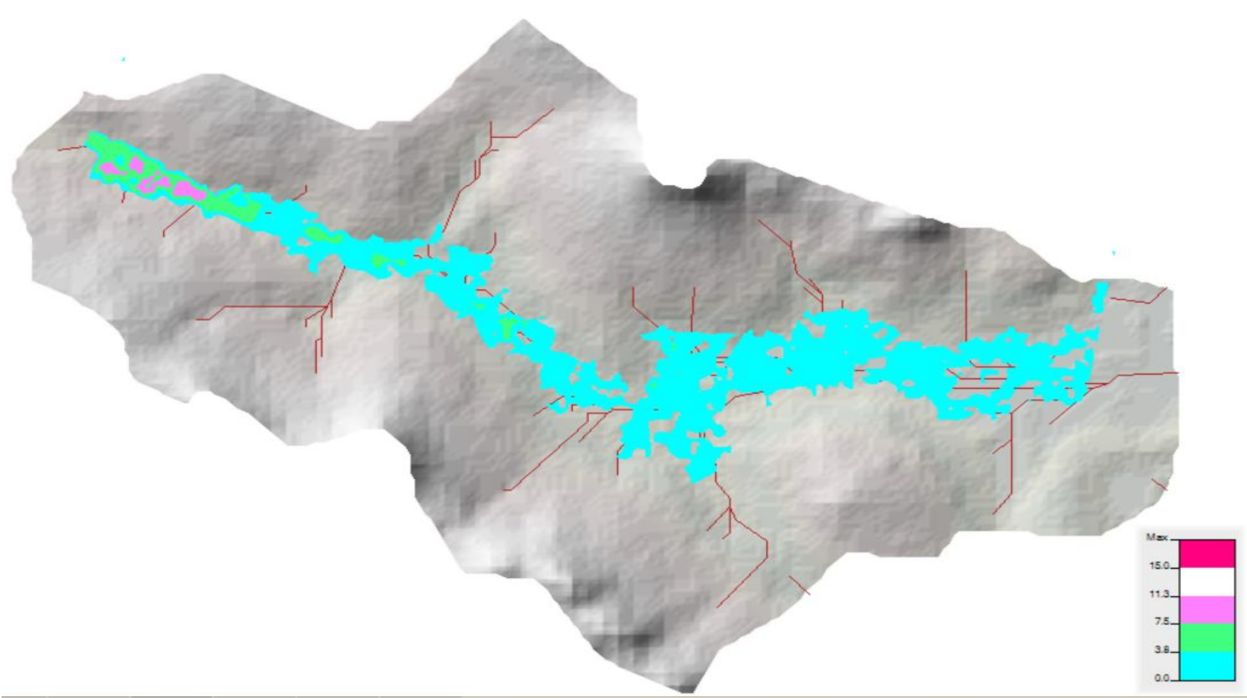
2. GEOMETRIC DATA WITH SIMULATION RESULT



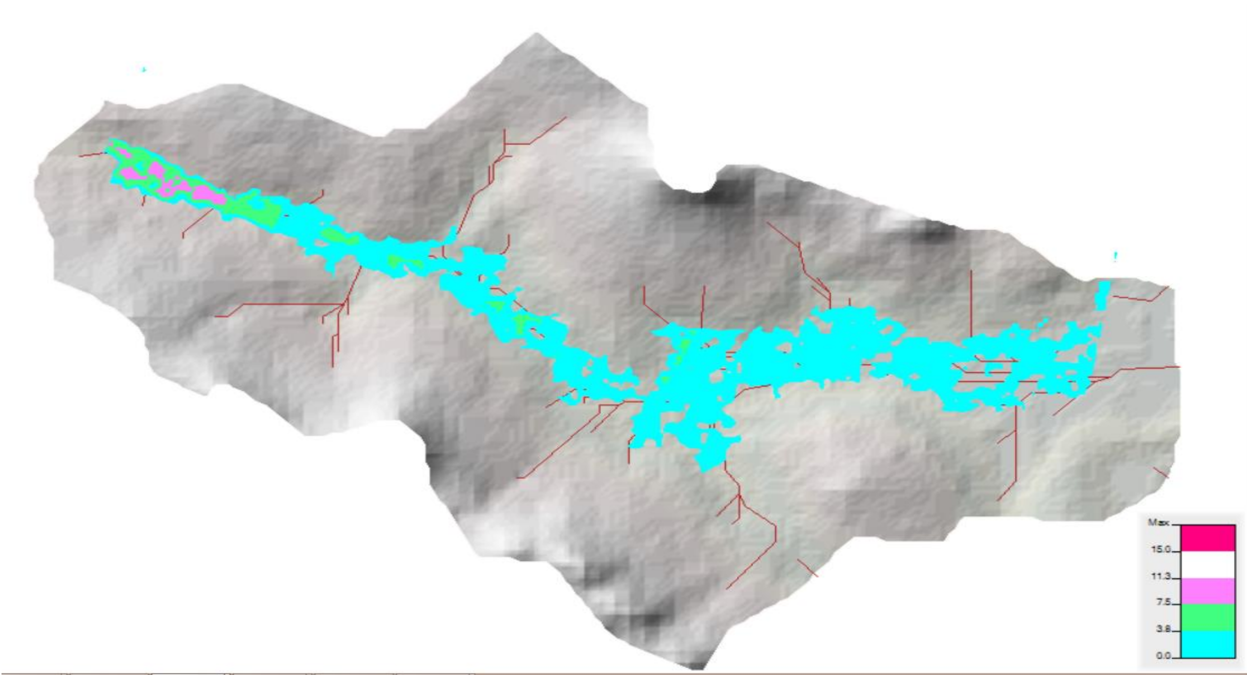
4.5 FLOOD HAZARD MAPPING

FLOOD MAPS SHOWING FLOOD DEPTH IN FEET OF DIFFERENT PROFILES

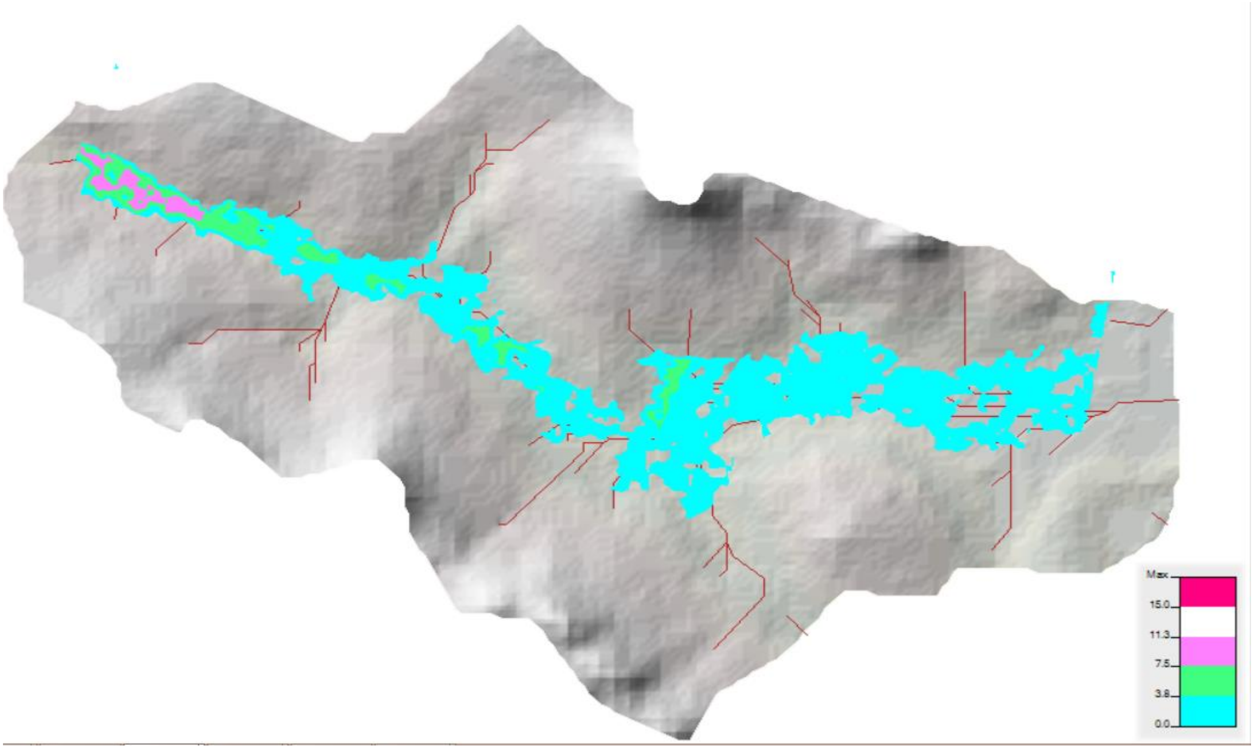
1. PROFILE 7 (1 year return period)



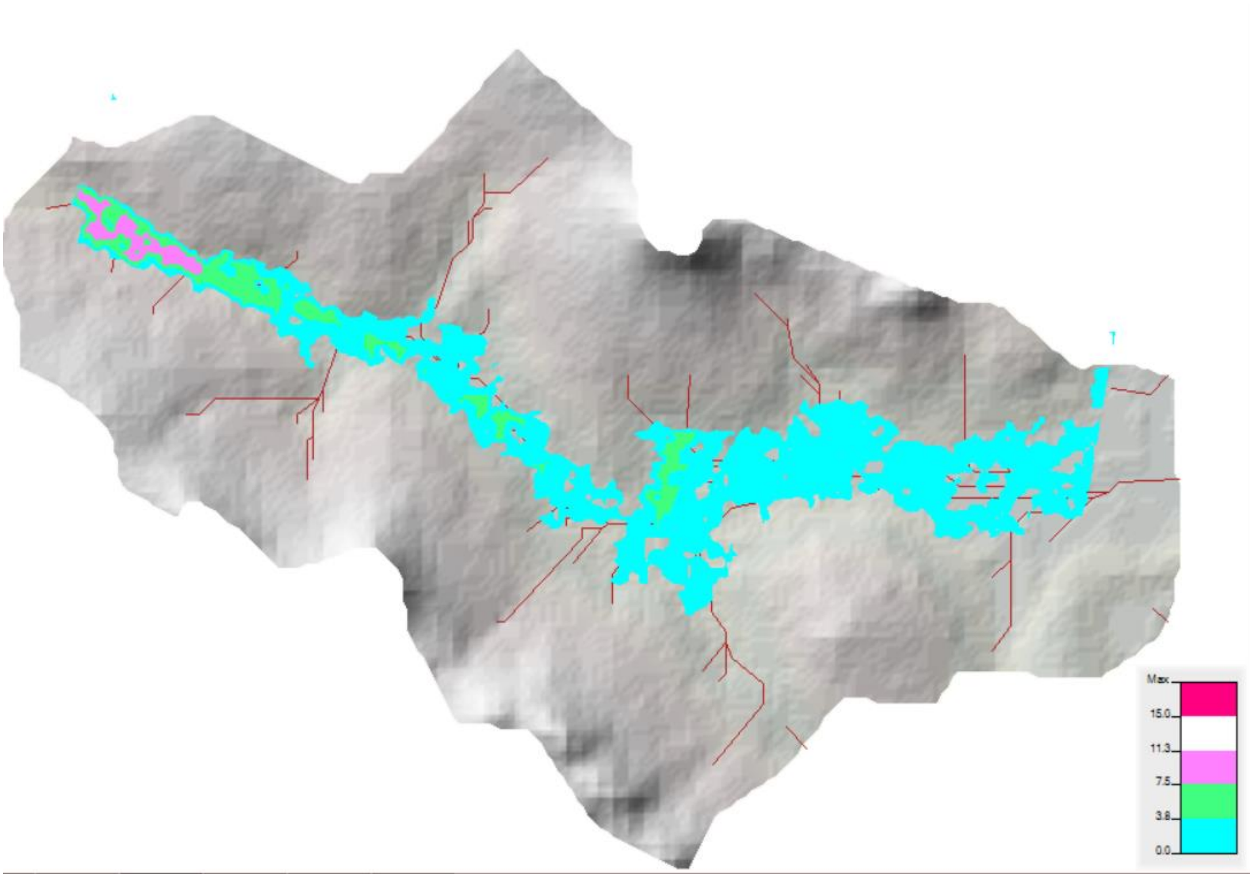
2. PROFILE 6 (2 year return period)



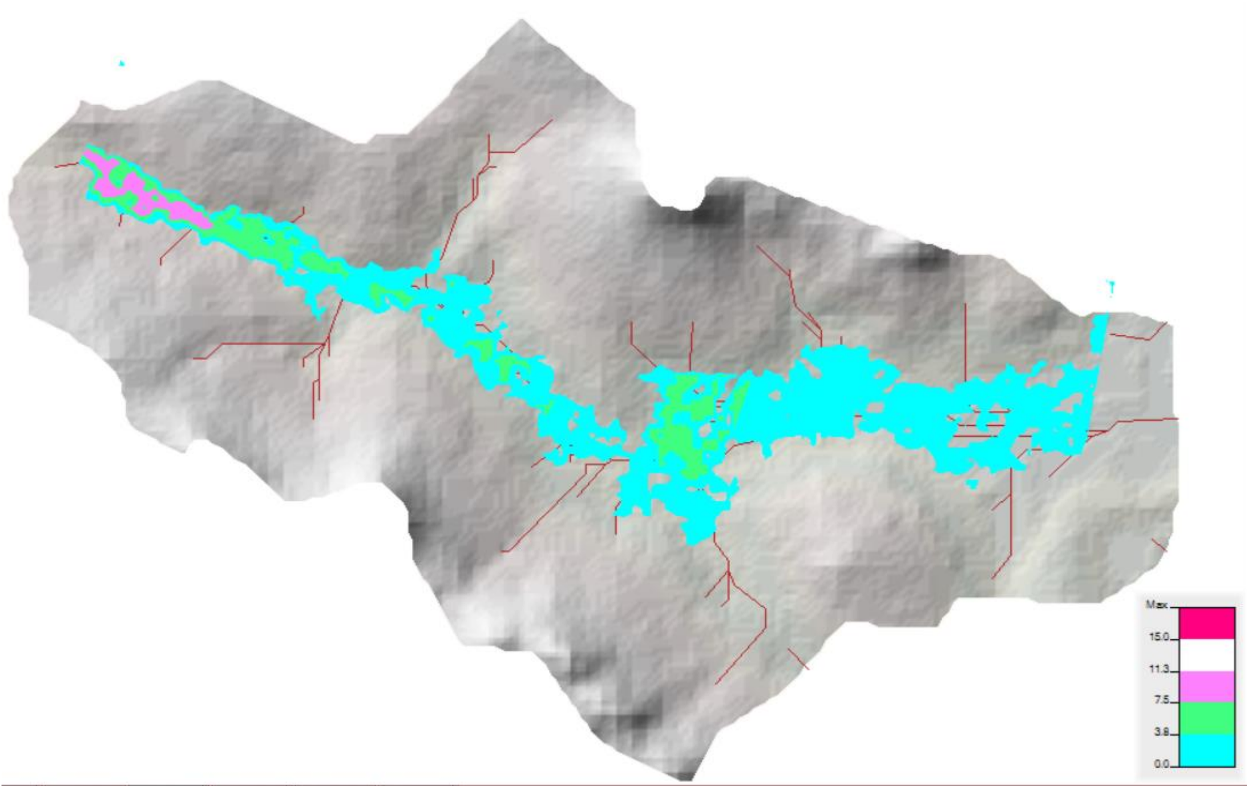
3. PROFILE 5 (5 year return period)



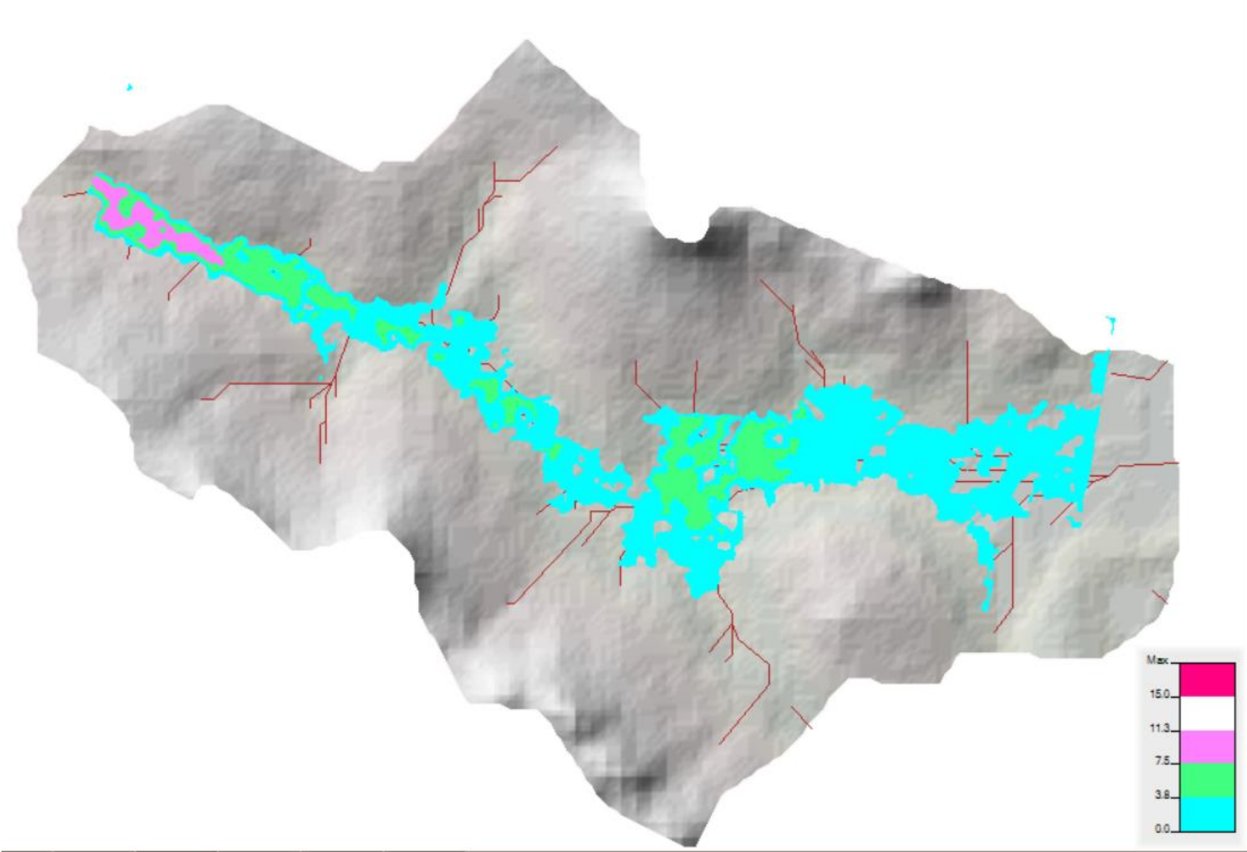
4. PROFILE 4 (10 year return period)



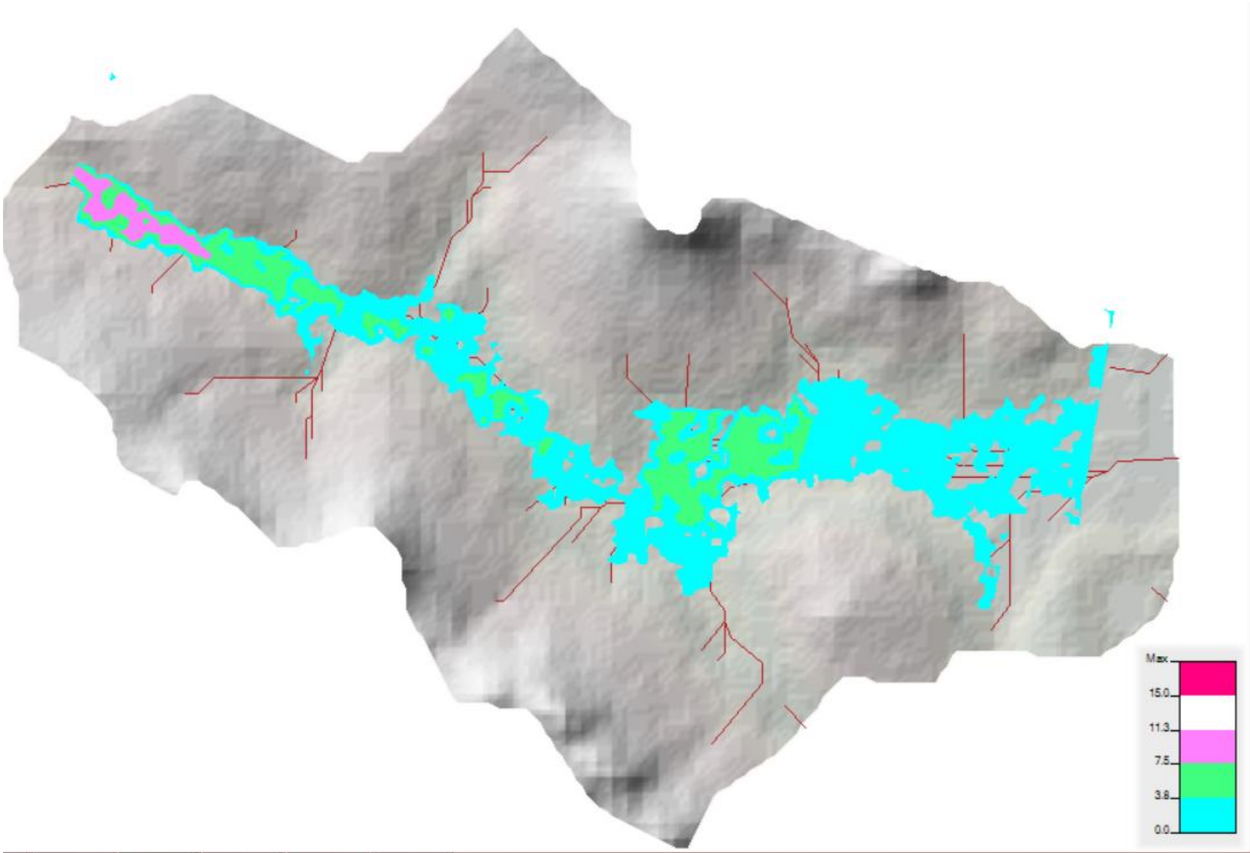
5. PROFILE 3 (20 year return period)



6. PROFILE 2 (50 year return period)



7. PROFILE 1 (60 year return period)



FLOOD HAZARD RANKING ACCORDING TO DEPTH OF FLOOD

Flood parameter Depth (ft)	Hazard category	Hazard rank
Hazard free	No hazard	0
0<D≤3.8	Low	1
3.8<D≤7.5	Medium	2
7.8<D≤11.3	High	3

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS.

5.1 CONCLUSION

- **Hydrological modeling**

  Hydrological modeling (rainfall – runoff analysis) was calculated using ARC GIS, gringorten and rationale method. The return periods were 1, 2, 5, 10, 20, 50 and 60 years. Their respective discharges in m3/s were 618, 709, 850, 974, 1126, 1350 and 1435.

- **Hydraulic modeling**

  RAS hydraulic model was calibrated and then used to simulate the floods for return period of 1, 2, 5, 10, 20, 50 and 60 years. The depth of floods varied between 0 – 11.3 feets.

- **Flood hazard maps**

  The flood hazard maps for the 1, 2, 5, 10, 20, 50 and 60 year floods were generated. From the hazard maps for 1, 2, 5 and 10 return period flood most areas were found to be between 0-3.8 feets flood depth. The risk of the depth changes greatly in the return period of 20, 50 and 60.

5.2 BENEFITS

The process developed for automating terrain modeling and floodplain delineation has several noteworthy benefits:

a) **User interface**. Through the use of menu items and sample exercises, floodplain mapping is automated and simplified. The user need not be a GIS expert to quickly and easily produce detailed floodplain maps. In addition to showing the aerial extent of flooding, the floodplain delineation includes flood depth information.
b) **Digital output**. Rendering the floodplain in digital GIS format allows the floodplain data to be easily compared with other digital data, such as digital

orthophotography and GIS coverages of infrastructure, buildings, and land parcels.

c) **Integrated terrain model**. Currently, there are no available methods with which to combine hydraulic model data with a DEM. The terrain models produced by the procedure are detailed in the stream channel, but also represent the general landscape. The integrated terrain model is comparable in quality to terrain model data acquired solely through aerial photogrammetry. The integrated terrain modeling approach could be used to prepare input data for hydraulic modeling.

d) **Resource savings**. Many floodplain maps need to be revised because they are outdated. The automated mapping approach developed for this research saves time and money versus conventional floodplain delineation on paper maps. Thus, floodplain maps can be updated more frequently, as changes in hydrologic and hydraulic conditions warrant.

5.3 LIMITATIONS (CHALLENGES)

a) Limited access to data
b) Insufficient data

5.4. RECOMMENDATIONS

During the course of this project, several important concepts were discovered and noted, that have an important effect on the ease of the hydraulic data mapping process and the quality of the resulting output. These concepts are shared in the following paragraphs.

a) Alone, 30m and 10m DEMs do not provide sufficiently detailed channel representations for floodplain modeling.
b) Datum's, map projections, and units are very important. For this project, the HEC-RAS data were described in feet. .
c) Use a DEM for stream centerline definition. This is because this reduces errors brought about by the conversion of DEM to other terrain outputs
d) Make sure enough cross-sections are defined in HEC-RAS. This ensures that most of the data in the terrain is captured.

e) Limit HEC-RAS coordinate data to two decimal places. This is because more decimal placed increase the simulation time and may result to more errors.
f) Further research.

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