Master Thesis
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Local solutions for water management at Muhanga Resource Center, Uganda

Using ArcGIS based computer model and PRA field study methods

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Division of Water Resources Engineering
Department of Building and Environmental Technology
Lund University

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Abstract

Uganda has experienced extreme weather for example droughts and flooding for many years resulting from rainfall deficits and variability. With the increased manifestation of negative effects related to climate change and global warming, this challenge is becoming greater and greater. And with increased public awareness about disasters and disaster risks, communities are ceasing to portray droughts and floods as mere acts of nature and are therefore eager to contribute to sustainable solutions to prevent them.
On the project site Muhanga, Uganda, a new resource center is planned to be built for multiple purposes. However, water related issues such as flooding, landslides, water shortage and sanitation have been a big problem and a risk for the new site, so does the existing building which has suffered from erosion and water related problems for quite a long time. Human and social vulnerability are coupled with overall capacity to predict, respond to and reduce the disaster impact on site. Local solutions for stormwater management require to be brought up aiming to prevent this situation happening again and again and make the local people live in a better life.

Objectives of this study:
(i) Evaluate the water resources problem on site in Muhanga, Uganda;
(ii) Evaluate the capacity of storm water that can be collected on site in Muhanga, Uganda;
(iii) Propose a local storm water solution handling for normal and extreme rainfall (particularly in the rainy reason) without flooding or means to contain flood waters and safely convey them out of the urban area deviating the flows to some other usages to minimize the threat of flooding for example water storage for dry season or irrigation system;
(iv) Evaluate the drinking water quality and quantity in the site and improve a better solution as water supply resource;
(v) Propose a proper sanitation proposal.

This paper demonstrates an integrated process of solutions pursuing by using a variety of methodologies especially in ArcGIS Hydrology Model for computer simulating modelling in lab and Participatory Rural Appraisal (PRA) for on-site field study in Muhanga.

Results of computer analysis and field study will be illustrated by presenting a simulated and practical hydrological and water resources situation of Muhanga site in different aspects and subjects.

Several solutions will be put forward for stormwater problems handling, with proposals for drainage, roof gutter, retaining wall, wood structure and vegetation; a water harvesting feasibility investigation will be explained by mathematic calculation details, combining with a new site plan afterwards; sanitation solution will be eventually chosen with traditional latrines.
After various comparison of different ways; recommendations for future plans will be proposed at last; a correction improvement of limitations in this study will be suggested, which gives a guidance procedure that needs to be considered for similar future works and research.

Key words
Uganda, Muhanga, Stormwater, ArcGIS, PRA, Flooding, Drought, Water Harvesting, Sanitation, Solutions

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1. Introduction

This chapter introduces a general background of Uganda and the specific study site area problem at Muhanga parish. The objectives of this study are also presented.

1.1 Background

Development of society and human life, depletion, wastage and pollution of water resources are on the increase and attributed mainly to rapid population growth, expanding urbanization, bad land management, growing industrialization, weak sanitation services and poor waste management all over the world, especially in Africa. This is also connected to the reasons for climate change. Extreme droughts have significant negative effects on water resources, hydropower production, agriculture and the overall economy.

Africa has warmed by 0.7 ℃ in the last century according to Intergovernmental Panel on Climate Change reports (IPCC, 2001). Projected warming for 21st century for Africa ranges from 0.2 to over 0.5 ℃ per decade (IPCC, 2001). The world is changing and Uganda is no exception. A major hazard in Uganda is the potential for drought. El Niño and La Niña episodes have been the principal causes of most severe climate change-related disasters. After the extreme and prolonged drought of 2004-2005, the water level of Lake Victoria dropped dramatically by one meter in 2006 due to high evaporation from the lake surface, low rainfall in the headwaters of rivers draining into the lake contributed to the excessive removal of water for power generation from Owen Falls Dam to meet the growing demand for electricity in the country (IPCC, 2001). In addition, the ice caps on the Rwenzori Mountains are disappearing. Also, the melting of ice caps on tropical mountains has negative effect on downstream water availability, eco-tourism and the overall economy. As the temperature increases, however, there is a general increase of malaria incidence throughout the country, particularly in the south-west in the cold highland areas, where Muhanga is located, has reached epidemic proportions. It is Uganda’s fastest warming region (UNDP & UNEP, 2009).

In the last century, frequency and intensity of extreme climatic events have generally been on the increase. Drought is the largest risk in Uganda. More than 3.5 million people are exposed to drought. Latest droughts have affected up to 1 million people (Groen & Jacobsen, 2012). In the 1991–2000 decade alone, Uganda has experienced 7 drought episodes. Near 12% of the population are exposed to the hazard of drought (UNDP & UNEP, 2009). The highest drought risk is in the northeast of the country. In 2008, a massive drought affected over a million people, especially in the region of Karamoja (Candia, 2010). Due to a lack of rainfall in this area, cattle suffer and food is still lacking. Often however, drought and excessive flooding follow each other. Dry earth is not able to soak up rainfall after a dry period that leads to flooding.

Floods are also serious consequences. Uganda is exposed to heavy flooding almost every year. Exposure is said to be low, yet heavy rainfall has been seen to cause floods in the past, affecting more than 700,000 lives and displacing tens of thousands (Groen & Jacobsen, 2012). Heavy rains can also instigate landslides in the east which can kill several hundred people at once. In 2007, 700 thousand people were affected by flooding in central Uganda due to unusual heavy rain from July to September, destroying crops as well (Mutagamba, 2011).

Moreover, problems of droughts and flooding alongside other disasters such as soil erosion, siltation and landslides are expected to become more frequent and more severe with the impending climate change, and the reality that water demand is increasingly not being met especially in Uganda.

Under the threat from the increasingly frequent periods of drought and flood, as an important role for household and community production and social economic activities, water supply has had an adverse effect on both the quantity and quality of water resources; Meanwhile, soil erosion resulting from heavy rainfalls is the most severe and extensive form of degradation in the country. Unstructured soft loose soil which lacks proper vegetation on slopes creates landslides and mudflow, particularly occurred in eastern part near the Kenyan border. Recently, a mudslide killed nearly 400 people in 2010 in the district of Bududa along the slopes of Mt. Elgon (Daranyi, 2012). It is also considered to be a serious threat to agricultural development (Vanlauwe, et al., 2014). As with the depletion of soil nutrients, they both are the major contributors to declining productivity and increasing poverty (Stroosnijder, et al., 2010) Erosion by water following the clearance of the natural vegetation directly reduces agricultural productivity and, as a consequence, reduces food security (Mutekanga, 2012). In Uganda, 68% of the population depends mainly on subsistence farming for their livelihood (Haan, et al., 2009). Their agricultural practices are leading to the degradation of the soil and water resources (Isabirye, et al., 2008).

In order to find a way to solve these issues, locally applied solutions have been discovered in different ways in this area. Proper utilization of extra flood water into scarce water resources becomes a key concept.

1.2 Project Description

Uganda lies astride the equator, between latitudes $4^{o}\,12'$ N and $1^{o}\,29'$ S and longitudes from $29^{o}\,34'$ W to $35^{o}\,0'$ E (FAO, 1999). The country is at an average altitude of 1,200 meters above mean sea level with the minimum altitude of 620 meters (Albert Nile) and the maximum altitude is 5110 meters (Mt. Ruwenzori Peak) (FAO, 1999). Uganda is well endowed with fresh water resources; among others, significant water features such as River Nile, the longest river in Africa that has its source at Lake Victoria, which is also, the largest lake in Africa. The vegetation is mainly composed of Savanna grass, bush and tropical high forests. The country experiences moderate climatic conditions throughout the year with a rainfall varying from 750 mm in Karamoja to 2000 mm per year (Hakuza & Waita, 2008).

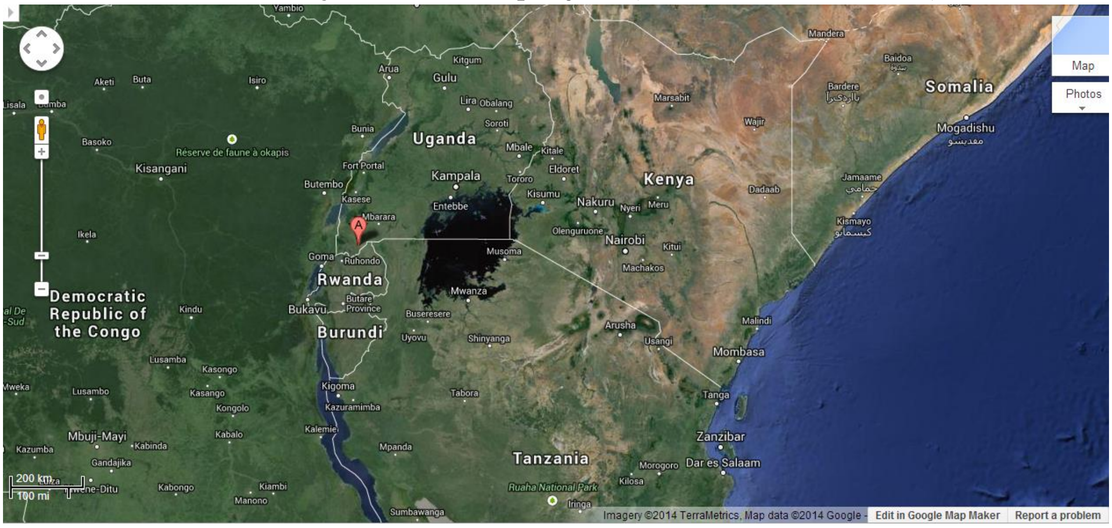

Figure 1 Location of the planned resource center in Google Map (GoogleMap, 2014)

A new Resource Centre is currently being planned to be located at the project site just outside Muhanga parish, Uganda (Figure 1). The purpose of the new construction is to host the ongoing projects and activities at St. Catherine Vocational Development while establishing a meeting place and an information center for the community. The first phase comprises a resource center that is multipurpose and can house vocational training activities, a library, basic services and dormitories for the people that come from far away and need a place to stay.

There is an existing resource center constructed 10 years ago. Unfortunately, landslides and mudflows have affected the buildings almost every year after extreme heavy rainfalls, base and foundation were damaged through big flood events. The situation of houses is becoming worse and worse due to climate change for unpredictable disaster events. Social work activities have had to be shut down during the rainy season. Meanwhile, agricultural fields next to the building were destroyed. Torrential rains and flooding could ultimately affect food security by spoiling the current harvest, washing away the crop in the field and cutting off access to affected areas. That is why a renovation work is immediately required. There is no way of constructing a new resource center somewhere else due to a land ownership limitation. Where the old resource center is located is the only land and place to be planned on.

The overall goal of St. Catherine Vocational Development Project is to secure the education for about 500 children in Muhanga, Southern Uganda. At the moment 522 children at 15 schools in the area are involved. The project work with short term projects such as providing school material and books as well as long term projects such as creating sustainable sources of income for parents and providing better school buildings and workshops for vocational practice such as mushroom project and sewing project which is ongoing at the moment.

The planned St. Catherine Resource Centre aims to become a resource for both children and adults in Muhanga. The assignment to design the resource centre has been given to ASF Sweden (Skåne) in co-operation with St Catherine Sweden. As the resource centre will consist in the relation between the indoor and outdoor environment, in the sense that the built structure always relates to the surrounding setting, there is a need to increase focus on the landscape features of the site, too.

When looking at the site and existing buildings, ASF St Catherine together with local building experts came to the conclusion that the existing steep slope behind current architecture is a dangerous location. It is agreed that flooding issue is the highest priority to be solved. A long-term solution would demand a new reinforcement of the slope and some kind of local solution for storm water management.

Moreover, for water supply, groundwater has been extracted for years in the parish as a drinking water resource. It is not convenient for villagers according to the long distance between the village and the well. Water quality and quantity of the aquifer have not been detected yet. The current problems in the area today are intestinal worms among small children and an unknown disease affecting the eyes. An Ebola related disease had an outbreak in the area in July and August 2012. To provide the site with confirmed safe water is specifically mentioned as one of the great challenges.

Furthermore, the sanitation situation is not acceptable. As a result of lacking water, traditional dry toilet (latrine) has been used for years. Considering the agricultural fields nearby, a sustainable eco-toilet or decentralized wastewater treatment plant is expected to be constructed on the site in order to provide fertilizer for crops. However, participatory processes become another challenge.

In order to change this situation and make the local people live in a better environment, this report demonstrates an integrated process of solution findings by using different methodologies; with an consideration the limited project budget, several locally adjusted solutions will be put forward eventually with recommendations for future research and studies.

1.3 Objectives

(i) Evaluate the water resources problem on site in Muhanga, Uganda;

(ii) Evaluate the capacity of storm water that can be collected on site in Muhanga, Uganda;

(iii) Propose a local storm water solution handling for normal and extreme rainfall (particularly in the rainy reason) without flooding or means to contain flood waters and safely convey them out of the urban area deviating the flows to some other usages to minimize the threat of flooding for example water storage for dry season or irrigation system;

(iv) Evaluate the drinking water quality and quantity in the site and improve a better solution as water supply resource;

(v) Propose a proper sanitation proposal.

1.4 Procedure

The whole study mainly consists of computer modeling and field study for a period of 6 months. Computer modeling is based on ArcGIS Hydrology Model for hydrological situation simulation in Muhanga with geographic data insertion in lab during June-September, 2014. A pre-study of the study site in theory is required before any further field survey; then, field study has been taken by Participatory Rural Appraisal (PRA) method in Muhanga, Uganda by the author for a 30 days field investigation in July, 2014. Results, discussions and solutions will be presented afterwards in this study among the whole process.

2. Methodology

2.1 Literature Review

Rainwater management including flood handling, water harvesting, storage and careful use of the water are ways of addressing the problems of water issues in Sub-Saharan areas of Africa.
Basically, a thorough study of all available literature regarding storm water management in developing and developed countries especially in Africa consist the foundation for this thesis, giving an idea of a proper reason of flood and droughts plus solution with designs, technologies, constructions, and implementation.

2.2 Modeling

Natural disasters for example floods are a worldwide phenomenon and a serious threat to mankind. Flood simulations are applications of disaster control, which are used for the development of appropriate flood protection. When modeling the flow of water, human beings may want to know where the water came from and where it is going. These fields require an understanding of how water flows across an area and how changes in that area may affect that flow. Computer models for example ArcHydro and Rainfall Runoff Modeling are both considerable simulation models for the purpose of flood estimation. However, not only a geometry data, but also soil type map, rainfall daily data are required. More detailed and specific initial input is needed in these models, which are potential difficulties for basic data collection for projects in developing countries due to a lack of complete monitoring and mapping. Trying to find a suitable model for adequate flooding simulations with access to necessary data are urgently needed.

In this case, for river basin scale investigation, which is defined as study for a whole river or stream basin, ArcGIS Hydrology Model has been used to model the watershed surrounding the site region to explain the hydrological status at different time steps. Hydrology tool is a set of data tools and models that functions within ArcGIS to support temporal and geospatial data analysis (ESRI, 2014). It explains how to use the hydrologic analysis functions to help model the movement of water across the surface, the concepts and key terms regarding drainage systems and surface processes, how the tools can be used to extract hydrologic information from a digital elevation model (DEM), and sample hydrologic analysis applications. Main use of this model is to see the location of my study area in the basin (for example if it is downstream or upstream; if it is close to a major stream or not, and also to see what happens if a major rainfall occurs. By using this model combining with a monthly precipitation with extreme rainfall-runoff have be simulated and see what happens to the study area; Annual rainfall data from some station in the catchment and nearby towns have been added to make the simulation more specifically. Completing this, a large-scale basin-wide flood problem can be evaluated, and then local-scale flood problems, referring a town or village, can be linked to.

Information about the topography land surface is useful for many fields, such as agriculture, regional planning, and forestry. Cell-based digital elevation models (DEMs) is the most common digital data of the shape of the earth's surface (ESRI, 2011). A DEM can be categorized as a raster (a grid of squares, also known as a height map when demonstrating elevation or as a vector-based triangular irregular network (TIN)) representation of a continuous surface, usually referencing the surface of the earth. This data is used as an input to quantify the characteristics of the land surface. The accuracy of this data is determined primarily by the resolution, which is the distance between sample points (Vterrain, 2015). All datasets are captured with satellites, airplanes or other flying platforms. Initially**,** GTOPO30 was selected as a raw satellite map data to insert. It is a global digital elevation model (DEM) with a horizontal grid spacing of 30 arc seconds (approximately 1 kilometer) provided by USGS. GTOPO30 was derived from several raster and vector sources of topographic information (USGS, 2012). Nevertheless, the resolution was quite low and coarse for hydrology modeling in a specific small area particularly the study site Muhanga. After all, The NASA Shuttle Radar Topographic Mission (SRTM) is available as 3 arc second (approx. 90m resolution) DEMs has been preferred with a resolution of 90m at the equator, which is 10 times better than GTOPO30 (CGIAR-CSI, 2008a).

The SRTM digital elevation data, produced by NASA originally, provides a major advance in the accessibility of high quality elevation data for large portions of the tropics and other areas of the developing world. It has been processed to fill data voids and to facilitate its ease of use by a wide group of potential users. The existence of no-data regions in a DEM cause significant problems in using SRTM DEMs, especially in the application of hydrological models which require continuous flow surfaces. For the CGIAR-CSI SRTM data product, they apply a hole-filling algorithm to provide continuous elevational surfaces. The interpolated DEM for the no-data regions is then merged with the original DEM to provide continuous topographical surfaces without no-data regions. This entire process is performed for tiles with large overlap with neighboring tiles, thus ensuring seamless and smooth transitions in topography in large void areas (CGIAR-CSI, 2008b).

The data is projected in a Geographic projection, with the WGS84 horizontal datum and the EGM96 vertical datum (Gamache, 2014).

Flow across a surface will always be in the steepest downslope direction. The elevation model is used to determine which cells flow into other cells - the flow direction (ESRI, 2012a). Once the direction of flow out of each cell is known, it is possible to determine which and how many cells flow into any given cell. This information can be used to define watershed boundaries and stream networks. Figure 2 shows the process of extracting hydrologic information, such as watershed boundaries and stream networks, from a digital elevation model (DEM).

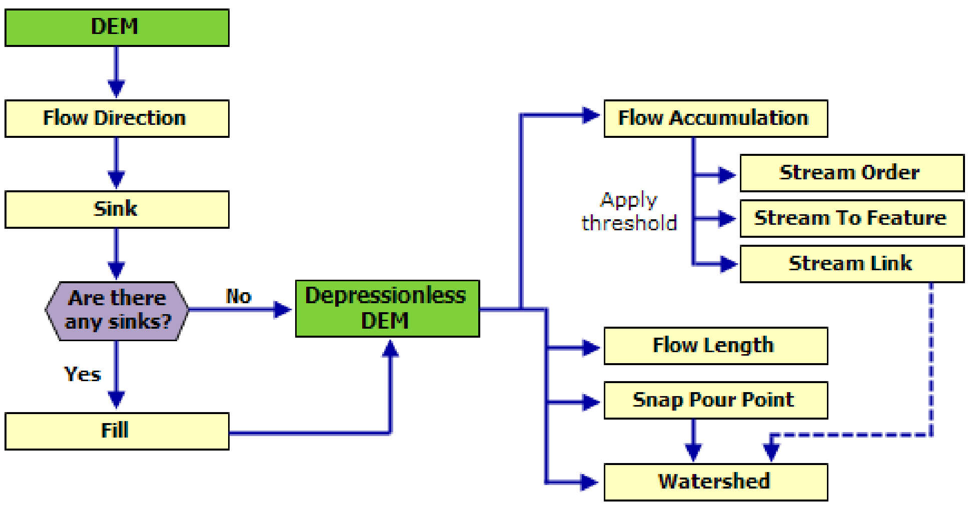

Figure 2 Hydrological modeling flowchart (ESRI, 2012a)

2.2.1 Sink and Fill

However, if there are errors in the elevation model or if its modeling includes karst or glacial geology, there may be some cell locations that are lower than the surrounding cells. If this is the case, all water traveling into the cell will not travel out. These depressions are called sinks (ESRI, 2012b). A sink is an area surrounded by higher elevation values and is also referred to as a depression or pit (ESRI, 2012c). This is an area of internal drainage, preventing downslope flow routing of water. Errors in DEMs are usually classified as either sinks or peaks. Likewise, a spike, or peak, is an area surrounded by cells of lower value. These are more commonly natural features and are also detrimental to the calculation of flow direction. Errors such as these, especially sinks, should be removed before attempting to derive any surface information. A profile view of a sink and peak changing process is shown in Figure 3 and Figure 4.

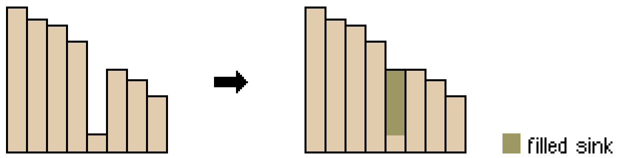

Figure 3 Profile view of a sink before and after running Fill (ESRI, 2012d)

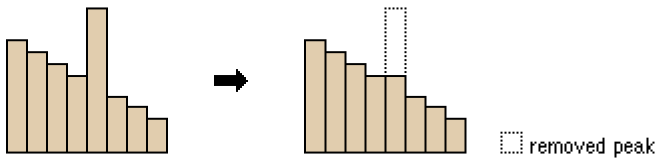

Figure 4 Profile view of a peak before and after running Fill (ESRI, 2012d)

The hydrologic analysis tools will identify the sinks and fill them. The result is a depressionless elevation model. Then flow direction can be determined on it.

2.2.2 Flow Direction

This tool takes a surface DEM as input and outputs a raster showing the direction of flow out of each cell. Once the output drop raster option is chosen, an output raster is created showing a ratio of the maximum change in elevation from each cell along the direction of flow to the path length between centers of cells and is expressed in percentages. If the all edge cells to flow outward option is chosen, all cells at the edge of the surface raster will flow outward from the surface raster (ESRI, 2012e).

There are eight valid output directions relating to the eight adjacent cells into which flow could travel. This approach is commonly referred to as an eight-direction flow model and follows an approach presented in (Jenson & Domingue, 1988).

When a direction of steepest descent is found, the output cell is coded with the value representing that direction. If the direction of steepest drop was to the left of the current processing cell, its flow direction would be coded as 16 (Figure 5). If a cell is lower than its eight neighbors, which cell is given the value of its lowest neighbor, and flow is defined toward this cell.

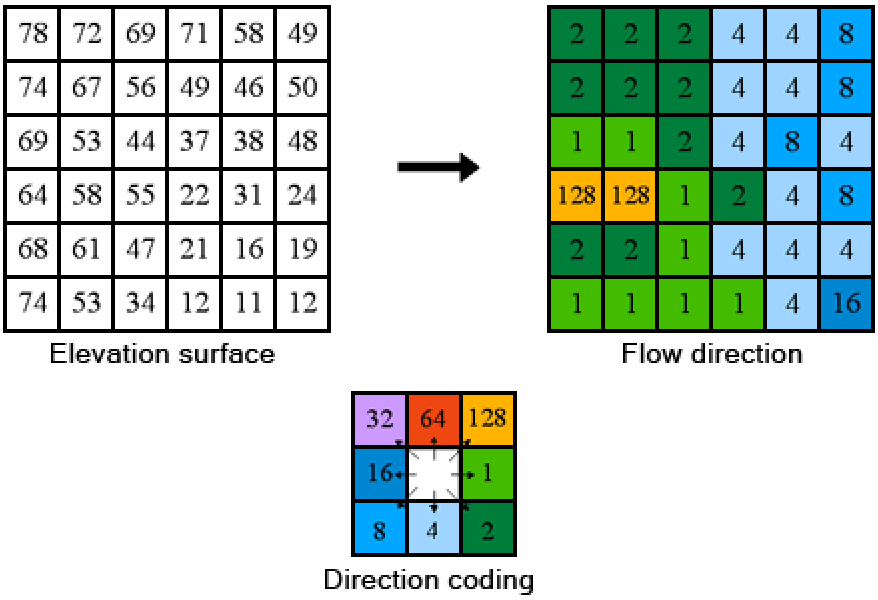

Figure 5 The coding of the direction of flow (ESRI, 2012e)

2.2.3 Flow Accumulation

The tool calculates accumulated flow as the accumulated weight of all cells flowing into each downslope cell in the output raster (ESRI, 2012f). A sample usage of the Flow Accumulation tool with an input weight raster might be to determine how much rain has fallen within a given watershed. In such a case, the weight raster may be a continuous raster representing average rainfall during a given storm. The output from the tool would then represent the amount of rain that would flow through each cell, assuming that all rain became runoff and there was no interception, evapotranspiration, or loss to groundwater. This could also be viewed as the amount of rain that fell on the surface, upslope from each cell. If no weight raster is provided, a weight of 1 is applied to each cell, and the value of cells in the output raster is the number of cells that flow into each cell (ESRI, 2012f).

In Figure 6, the top left image shows the direction of travel from each cell and the top right the number of cells that flow into each cell.

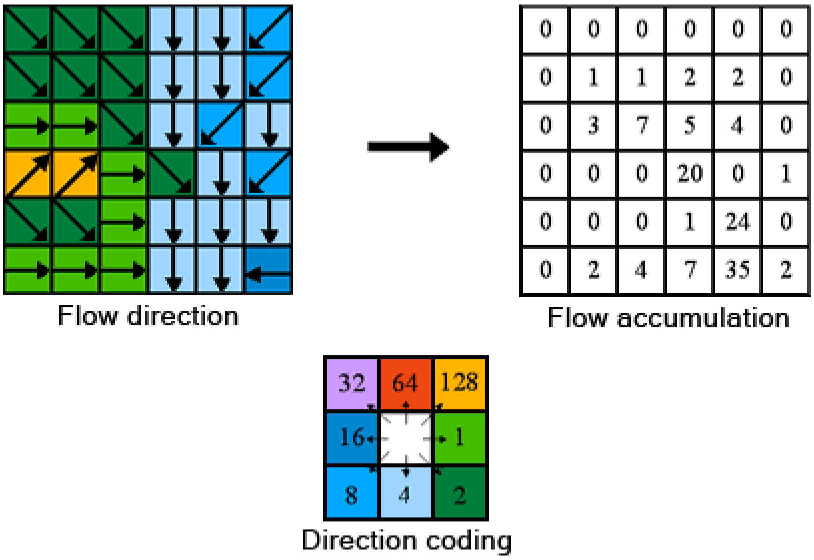

Figure 6 Determining the accumulation of flow (ESRI, 2012f)

2.2.4 Flow Length

Flow length means the distance between upstream and downstream or weighted distance along the flow path for each cell. A primary use of the Flow Length tool is to calculate the length of the longest flow path within a given basin. This measure is often used to calculate the time of concentration of a basin (ESRI, 2012g). It can also be used to create distance-area diagrams of hypothetical rainfall and runoff events using the weight raster as impedance to movement downslope.

2.2.5 Stream Network

When enough water flows through a cell, the location is considered to have a stream passing through it. Stream networks can be delineated from a digital elevation model (DEM) using the output from the Flow Accumulation tool. Flow accumulation in its simplest form is the number of upslope cells that flow into each cell. By applying a threshold value to the results of the Flow Accumulation tool using either the Con or Set Null tools in Map Algebra (ESRI, 2012h); a stream network can be delineated. For example, to create a raster where the value 1 represents a stream network on a background of No Data, the tool parameters could be as shown in Figure 7.

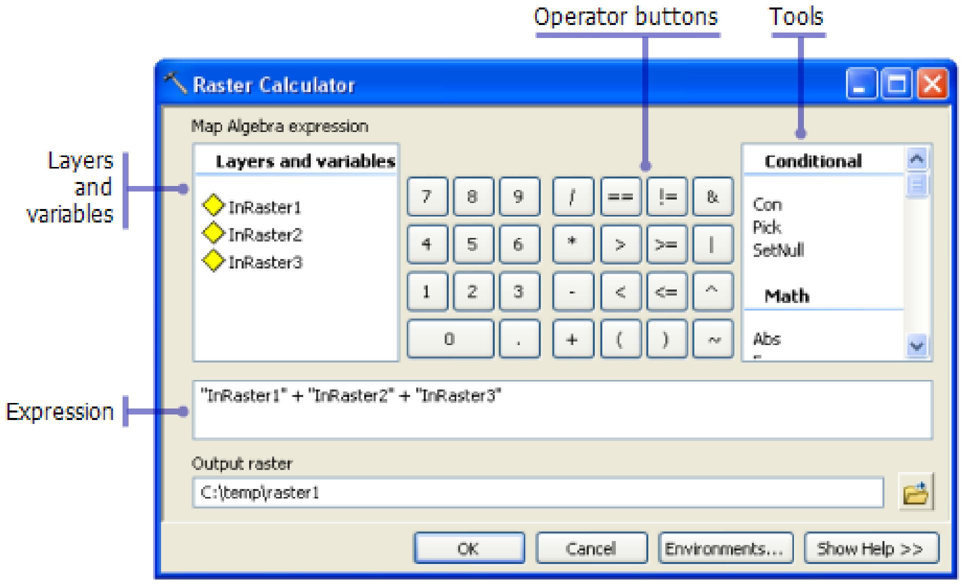

Figure 7 Raster Calculator tool dialog box example (ESRI, 2012i)

With the Con tool:
Input conditional raster : flowacc
Expression : "Value > 100"
Input true raster or constant value : 1
Input false raster or constant value : ""
Output raster : stream_net
All cells with more than 100 cells flowing into them will be part of the stream network. The network through which water travels to the outlet can be visualized as a tree, with the base of the tree being the outlet (Figure 8). The branches of the tree are stream channels. The intersection of two stream channels is referred to as a node or junction. The sections of a stream channel connecting two successive junctions or a junction and the outlet are referred to as stream links.

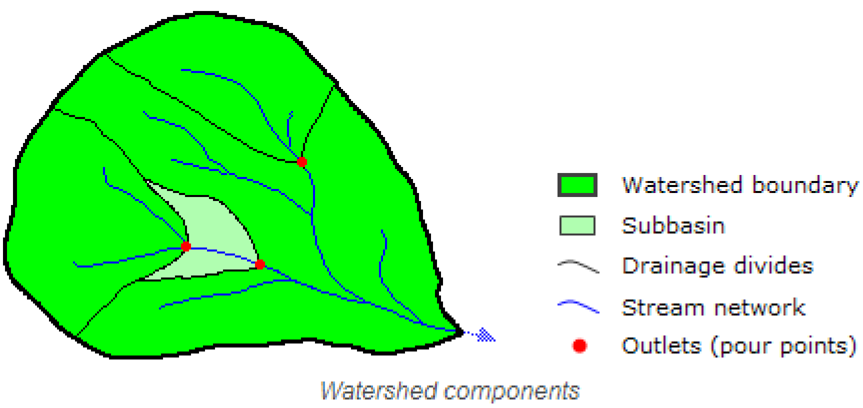

Figure 8 Watershed components (ESRI, 2012j)

The area upstream a water stream that collects rainfall and the network through which it travels to an outlet are referred to as a drainage system. The flow of water through a drainage system is only a subset of what is commonly referred to as the hydrologic cycle, which also includes precipitation, evapotranspiration, and groundwater flow. The hydrology tools focus on the movement of water across a surface.

2.2.6 Stream Order

Stream ordering is a method of assigning a numeric order to links in a stream network (ESRI, 2012k). This order is a method for identifying and classifying types of streams based on their numbers of tributaries. Some characteristics of streams can be inferred by simply knowing their order.

For example, first-order streams are dominated by overland flow of water; they have no upstream concentrated flow. Because of this, they are most susceptible to non-point source pollution problems and can derive more benefit from wide riparian buffers than other areas of the watershed.

The tool has two methods to use to assign orders. These are the methods proposed by (Strahler, 1957) and (Shreve, 1967)

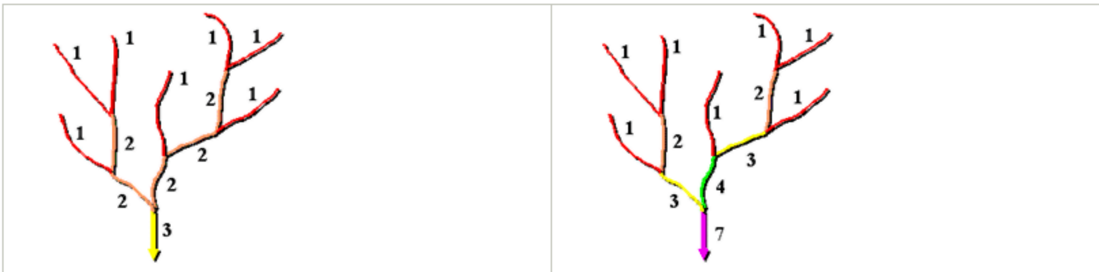

Figure 9 Strahler stream ordering method and Shreve stream ordering method (ESRI, 2012k)

All cells with more than 100 cells flowing into them will be part of the stream network. While the default Strahler method is the most common one, the Shreve method offers the benefit of not being as sensitive to the addition and removal of links from further analysis.

In both methods, the upstream stream segments, or exterior links, are always assigned an order of 1.

Strahler method

In the Strahler method, shown in Figure 9, all links without any tributaries are assigned an order of 1 and are referred to as first order.

The stream order increases when streams of the same order intersect. Therefore, the intersection of two first-order links will create a second-order link, the intersection of two second-order links will create a third-order link, and so on. The intersection of two links of different orders, however, will not result in an increase in order. For example, the intersection of a first-order and second-order link will not create a third-order link but will retain the order of the highest ordered link.

The Strahler method is the most common stream ordering method. However, because this method only increases in order at intersections of the same order, it does not account for all links and can be sensitive to the addition or removal of links.

Shreve method

The Shreve method accounts for all links in the network (Figure 9). As with the Strahler method, all exterior links are assigned an order of 1. For all interior links in the Shreve method, however, the orders are additive. For example, the intersection of two first-order links creates a second-order link, the intersection of a first-order and second-order link creates a third-order link, and the intersection of a second-order and third-order link creates a fifth-order link.

Because the orders are additive, the numbers from the Shreve method are sometimes referred to as magnitudes instead of orders (ESRI, 2012k). The magnitude of a link in the Shreve method is the number of upstream links.

2.2.7 Basin

The Basin tool creates a raster delineating all drainage basins (ESRI, 2012l). A drainage basin is an area that drains water and other substances to a common outlet. The drainage basins are delineated within the analysis window by identifying ridge lines between basins. The input flow direction raster is analyzed to find all sets of connected cells that belong to the same drainage basin. This results in a raster of drainage basins. This area is normally defined as the total area flowing to a given outlet, or pour point. The boundary between two basins is referred to as a drainage divide or watershed boundary.

2.2.8 Snap Pour Points

Snaps pour points are the cell of highest flow accumulation within a specified distance (ESRI, 2012m). The output is an integer raster. It is used to ensure the selection of points of high accumulated flow when delineating drainage basins using the Watershed tool. Snap Pour Point will search within a snap distance around the specified pour points for the cell of highest accumulated flow and move the pour point to that location.

2.2.9 Watershed

A watershed is the upslope area that contributes flow—generally water—to a common outlet as concentrated drainage (ESRI, 2012j). It can be part of a larger watershed and can also contain smaller watersheds, called sub-basins. The boundaries between watersheds are termed drainage divides, shown in Figure 10.

Watersheds can be delineated from a DEM by computing the flow direction and using it in the Watershed tool. When delineating watersheds, pour points (locations for which we want to know the contributing watershed) need to be identified. Usually these locations are mouths of streams or other hydrologic points of interest, such as a gauging station. Pour point is the point at which water flows out of an area. This is usually the lowest point along the boundary of the drainage basin. Stream network could be inserted as the pour points or assign a specific one by using the hydrologic analysis tools. This creates watersheds for each stream segment between stream junctions.

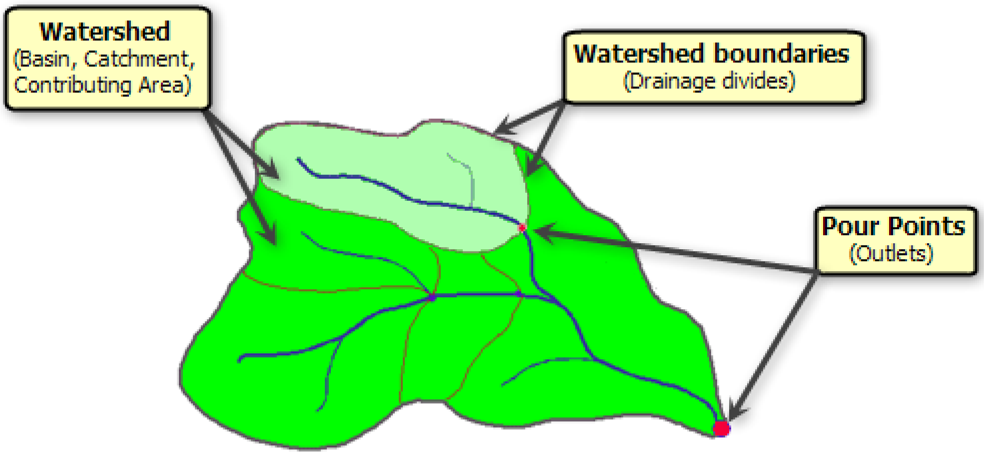

Figure 10 Components of drainage basin (ESRI, 2012n)

2.3 Data Collection

The data needed for the Muhanga project including rainfall data, elevation, land use map, soil properties map, vegetation type, location map were collected free from the Meteorology Department of Uganda, European soil portal and cooperated Makerere University in Kampala, Uganda; the aerial map has been collected from Google Maps. More precise data such as the dimension of site constitutions (e.g., houses, roads, agricultural fields and forests), water consumption, estimated population and location chosen were collected by field investigations with interviews and questionnaire taking place during a five-week period field study between July and August in 2014 using a participatory approach through group discussions and vulnerability ranking of design solutions during workshops, which organized with community people and officials. .

2.4 Field Study -Participatory Rural Appraisal (PRA)

For local-scale flood problem, interviews and site investigation of municipality citizens and water users have been conducted by using Participatory Rural Appraisal (PRA) in Uganda regarding to water related issues by the author in order to know their water usage habit and make accurate estimation of water consumption; Accomplished renovation work for rainwater management on existed building during my stay in summer 2014 have been conducted together by discussions with the board of St. Catherine Sweden and local engineers in Muhanga parish to achieve a transient solution with limited budget. To identify possible improvements and sustainable solutions, results from the field study have been compared with findings in literature and combined together aiming to make the solution locally adapted as well as efficiently implemented.

Participatory Rural Appraisal (PRA) has been introduced in this case as guidance in field study towards the site and local people. PRA is a family of approaches and methods to enable rural people to share, enhance, and analyze their knowledge of life and conditions, to plan and to act (Chambers, 1994). It describes a growing family of approaches and methods to enable local people to enhance, share and analyze their knowledge of life and conditions, to plan and to act. Methods under headings of visualized analyses are interviewing, sampling methods and group brainstorm.

There are four major types of processes during PRA implementation:

(1) Participatory appraisal and planning;

(2) Participatory implementation, monitoring and evaluation of programs;

(3) Topic investigations;

(4) Training and orientation for outsiders and villagers.

All of the above can be achieved by various workshops, interviews, questionnaires, surveys and chatting, etc.

Categories and terms have been listed below for site investigations that require to be considered.

(1) Participatory analysis of secondary sources, such as tiles, reports, maps, aerial photographs, satellite imagery, articles and books. A plenty of maps, photographs, articles and books can be provided by different departments for further analysis for this study;

(2) Participatory mapping and modeling, in which local people use simple materials to present natural resource (soils, trees and forests, water resources etc), or farm maps, or construct three-dimensional models of their land (Mascarenbas & Kumar, 1991). Soil type, vegetation and plantation situation, water resources condition, 3-D model can be illustrated by local interviewers;

(3) Time lines and trend and change analysis. Chronologies of big events in town, such as droughts, floods, landslides, mudflows and other natural disasters, water-borne epidemic disease, listing major remembered events in a village with approximate dates; ecological histories, changes in land use and cropping patterns, changes and trends in population;

(4) Transect walks. Walking with or by local people through an area, observing, asking, listening, discussing, identifying different zones, soils, land uses, vegetation, crops, livestock, local and introduced technologies, etc; seeking problems, solutions and opportunities; and mapping and diagramming the zones, resources and findings (Mascarenhas, 1990); general types of transect walk include slope, combing, and loop;

(5) Seasonal calendars**.** By major season or by month to show seasonal changes such as days and distribution of rain, amount of rain or soil moisture crops, agricultural

labor, nonagricultural labor, diet, food consumption, types of sickness, prices, animal fodder, fuel, migration, income, expenditure, etc;
(6) Oral histories and ethno biographies discussion. Oral histories (Slim & Thompson, 1993), and local histories of, for example, a crop, an animal, a well, a pest, a plant;
(7) Estimates and quantification. Using local measures, judgments and materials such as pipes, bricks, cement, stones, etc, sometimes combined with participatory maps and models, matrices, card sorting and other methods to make an estimation of a quantity of these materials;
(8) Daily time use analysis indicating relative activities, sometimes indicating seasonal variations. For example water consumption per day per family and water usage habit;
(9) Key probes; Asking questions which can lead direct to key issues;

During my stay there, I went to 6 schools in the project in that region taking interviews and questionnaire in different workshops with kids and teacher (mainly water users) about water consumption and water usage habitat, which will be useful for water consumption assumption and water tank designing.
Examples of questionnaire paper:
(1) What is your water source at school.
(2) How much water do you drink every day at school.
(3) How much water do you want at school.
(4) What do you use water for at school.
(5) Do you have enough water during dry season at school.
(6) How many times do you go to toilet every day at school.
(7) Have you heard about water harvesting.
(8) Have you heard about eco-san.
(9) Do you have agricultural field at school; If you have, what plants do you plant.
(10) Can you describe or draw a picture about the school during dry season.
(11) Can you describe or draw a picture about the school during rainy season.
Questions between teachers and kids are not the same. But with this result, it will be easy for water engineers to make estimations of water usage information in order to make further design of water harvesting systems and come up with genius water solutions.

(10) Participatory planning, budgeting, implementation and monitoring, in which local people prepare their own plans, budgets and schedules, take action, and monitor and evaluate progress. The local board of St. Catherine Uganda has been organizing meetings with us regards to these topics for details discussion;
(11) Presentation and analysis-where maps, models, diagrams, and findings are presented with local people, or by outsiders, and checked, corrected and discussed. Workshops concerning different purpose have been conduct with various groups of people in Muhanga;

(12) Group discussions and brainstorming, by local people alone, by focus groups of local people, by local people and outsiders together, or by outsiders alone. During different workshops, internal and external discussions have been risen up for different purposes. Leaving an independent space for different groups may contribute to a more realistic and objective reaction.

The physical characteristics of the site reflect the existing status of runoff and storm water. Consideration should be made of what the natural drainage and runoff conditions would have been, as well as the existing situation. This will enable potential problems, and opportunities, to be identified. Land surface factors such as topography, geology and vegetation along with soil properties determine the potential for groundwater contamination and hydrology issues.

The following are some of the main features that should be considered and collated in the form of a site analysis assessment that should be used to inform the design process.

2.4.1 Topography

Topography can inform the feasibility of different locations for storm water routes, outlets and flooding areas. Gradients dictate the direction of flow and runoff routes naturally formed over land, identifying areas of flooding area and accepting pond.

2.4.2 Geology, Soils and Groundwater

A geology, soil and groundwater condition is an important factor in assessing the infiltration potential of the site. Areas of high groundwater levels here can limit the possibilities and desirability of groundwater recharge and filtration methods. In the absence of sufficient documented groundwater information, the seasonal and long-term ground water fluctuations might be determined, based on the available hydrological, geological and climatic information. Soil properties such as depth, texture, and permeability will help to determine the rate of groundwater recharge, as well as protection from groundwater contamination.

2.4.3 Climate

Climate is a measure of the average pattern of variation in temperature, humidity, atmospheric pressure, wind, precipitation, atmospheric particle count and other meteorological variables in a given region over long periods of time. It can be classified according to the average and the typical ranges of different variables, most commonly temperature and precipitation.

The general climatic characteristics of an area will also impact on the site and stormwater systems implemented, i.e. whether the site is generally waterlogged or dry and if evaporation levels are high or low.

2.4.4 Hydrology

It is essential, for successful, sustainable and integrated storm water management, that the existing and natural hydrological response and functions of the site are understood. The hydrology of the development area is a function of much of the other data.

2.4.5 Natural Ecosystems, Flora and Fauna

Vegetation and animals have roles or functions that can improve water quality, amelioration and infiltration.

2.4.6 Ecological Characteristics of Freshwater Ecosystems

The occurrence of streams or other watercourses on the site has been identified. The storm water discharge and receiving capacity of channels and drainage courses could be determined by rainfall data to establish the levels of integration of the natural.

2.4.7 Sanitation

Sanitation generally refers to the provision of facilities and services for the safe disposal of human urine and faeces. Inadequate sanitation is a major cause of disease world-wide and improving sanitation is known to have a significant beneficial impact on health both in households and across communities.

2.4.8 Study Site

Study site plays the most important role in this research. All the factors contributed to the results are linked to this final receiver which is the original reason for rebuilding the resource center with a solution of storm water problems and water shortage. All the architectural and technical designs concerning about this topic are regarded as a benefit of it.

2.5 Delimitation

This methodology is aiming to apply in the field of storm water management in sub-Saharan area, especially with tropical weather consisting of 2 typical rainy and dry seasons each year, as a guidance manual for researches with field study in Participatory Rural Appraisal combing with computer modelling in ArcGIS, in order to achieve a theoretical and practical result of local solutions in water management particularly in storm water issues.

3. Results of the Study

3.1 Site Analysis

The study site named Muhanga Shalom Primary School is located in Muhanga Parish, which is a small trading center in Kabale district on the highway from Kampala to Kigali. Kabale District is a highland district. The district covers 1,827 square kilometers and has a population of about 44,100 people of which 31,914 people, or 72 %, are benefiting from municipal water supply and 81 % has access to safe water. The Area obtains its water from Lake Bunyonyi from where it is led to 2 treatment plants with a combined practical capacity of 3,600 m^3 per day and an average production of 1,477 m^3 per day. The system has a network length of 121 km and a sewer network length of 9 km. The major challenge of the area is the hilly terrain which makes an extension of the water mains difficult and costly. Stabilization ponds are used for sewerage treatment (MWE, 2010). The topography is mainly green, interlocking and heavily cultivated hills with spectacular valleys. The altitude of the district ranges between 1,219 meters and 2,347 meters above sea level, making it colder than the rest of the country.

3.1.1 Topography

Muhanga is situated in a quite hilly area in Western Uganda region. The extensive pastures on the hilly, semi-mountainous plateau are poorly conserved, eroded and overgrazed.

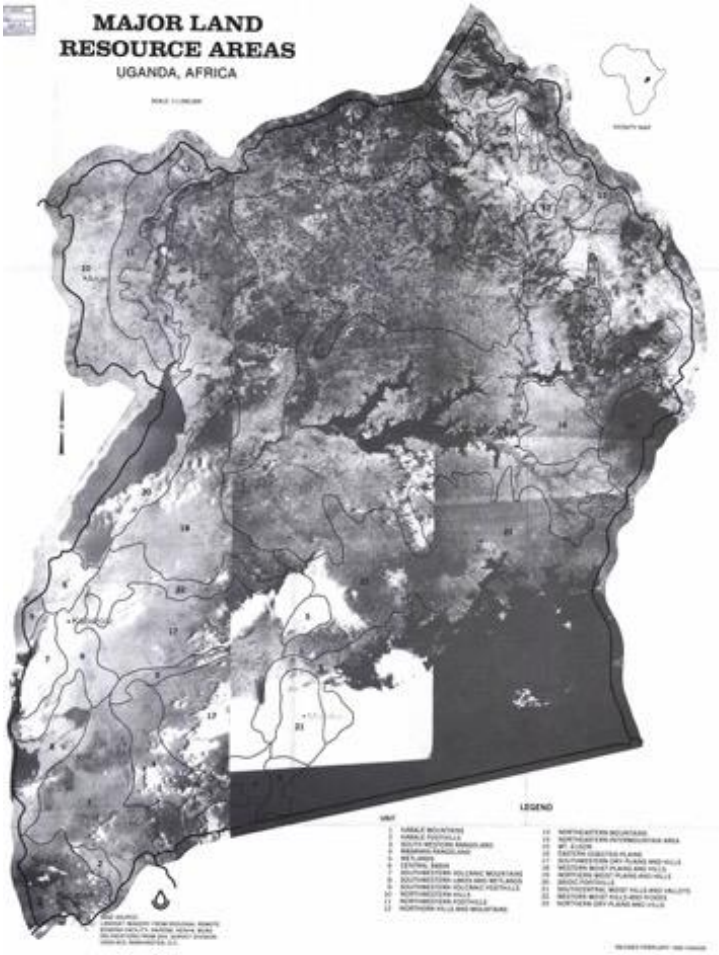

Figure 11 Major Land Resource Areas, Uganda (Landsat Mosaic) (Yost & Eswaran, 1989)

According to Figure 11, Uganda has been divided into 23 units consisting of different topographic images such as foothills, mountains, plains, ridges and valleys. Muhanga is just situated close to the border line between area ‘1’ and ‘2’ corresponding to Kabale Mountains and Kabale foothills but on the ‘mountain’ side.

Where the school is located is in close proximity to the lowest valley line of whole catchment area next to a natural stream (Figure 12, 13). Main storm water routes are located along it.

Figure 12 Muhanga Shalom Primary School (GoogleMap, 2014)

Figure 13 An overview of the experimental site

According to Figure 14, a natural steep slope exists right behind the school buildings with a distance of 1.45 m to the building base, which is much shorter than I expected. The length of main building is 32.5 m long which makes up a rectangular receiving area of $47.1m^2$, and it is one of the reasons that storm water flooding in rainy seasons is regularly occurring and has been a big issue for the school structure for quite a long time.

Figure 14 Backside of the school building, 2014

In ecological terms, different habitats, some of higher conservation value than others, are frequently associated with changes in topography, as long as the vegetation on the slope. Water consuming trees for example Eucalyptus and other plants have grown on the slope from bottom to top. The slope was almost 90 ° this summer, increasingly steeper than last year. Compared to previous taken a year ago, the slope shows a higher density of grass and plants. (Figure 15).

Figure 15 Slopes behind the school building, 2014

From an environmental and storm water management perspective, as the slope increases, the erf sizes should also increase to prevent excessive run-off and potential erosion. However, this is not possible due to a relatively small area of $47.1m^2$.

The big slope sometimes influences the potential for erosion to occur. Tons of earths could fall down with heavy rains as mudflow and landslides in one day directly towards the classroom-building wall, or sometimes stuck where it is nearby on the base-step, adding an extra load of the building and foundation.

Earthworks are required in some areas, which are very flat, for example in both walkways besides classroom building, to provide sufficient grade for drainage. Man-made small drainage ditches have been dug diverting to natural stream in agricultural field close by (Figure 16).

Figure 16 Natural and man-made drainage pathways

Road and planning layouts could also reflect the topography of this area, to enable integrated storm water design and management. A locally-named highway from Kampala to Kigali, the capital of Rwanda, is situated 50m away in an attitude a bit higher than the school, separating the uphill and downhill with a runoff passageway underneath (Figure 17).

Figure 17 The highway goes through Muhanga

There is a plain area 20m above the site bought by local municipality for unknown long-term purpose plan, which might result on new influence for the school.

3.1.2 Soils, Groundwater and Hydrogeology

(1) Soil

Soil type is determined by the size of pore space and interconnectivity of the spaces, it affects surface permeability and hence runoff rate.

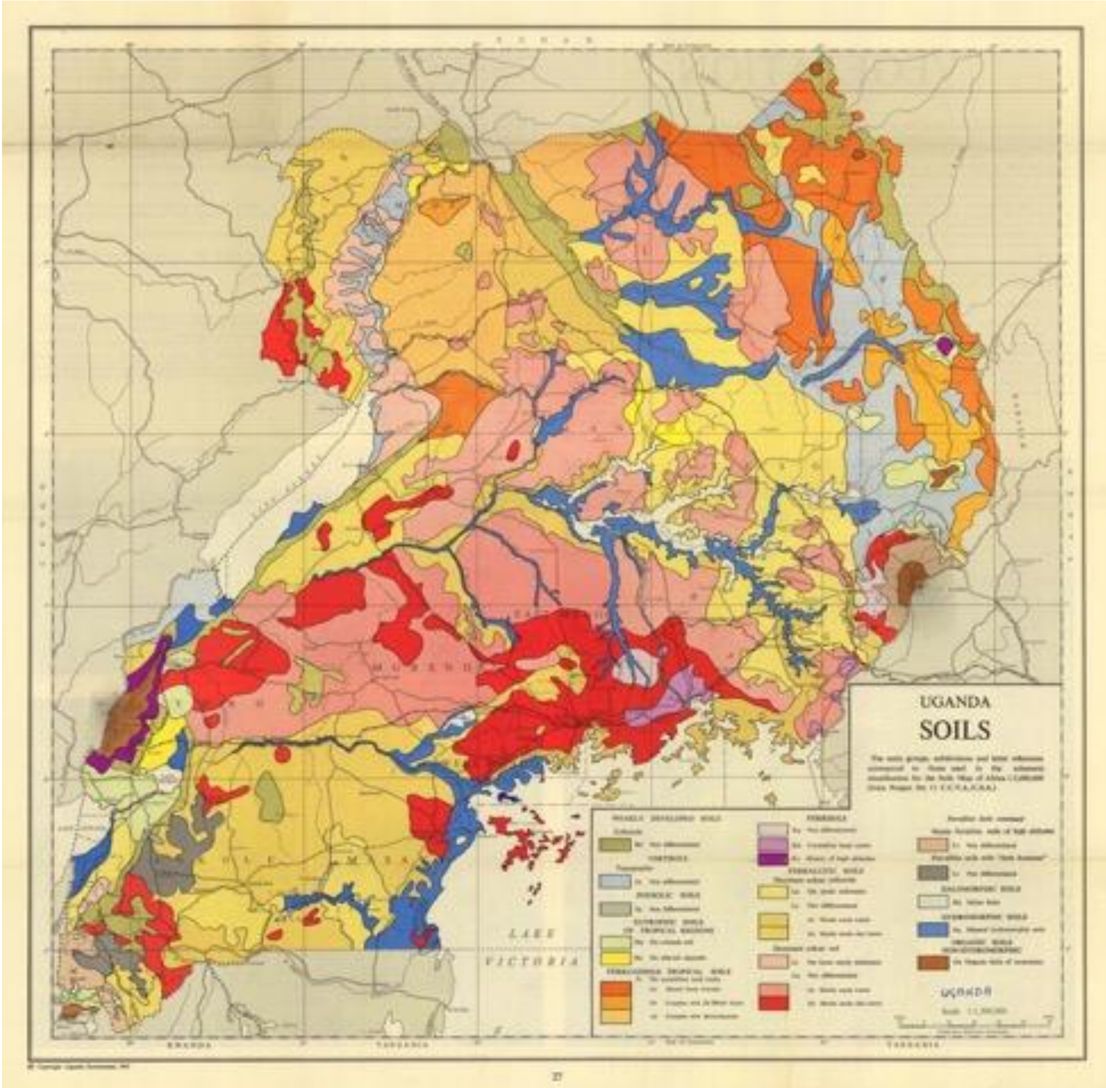

Figure 18 Uganda soils (UgandaGovernment, 1967)

As it demonstrated in Figure 18, in the area of Kabale district, the main identified soil type in this area is ferrallitic soil in yellowish color, which is a kind of excellent well-known raw materials for brick industry. There are five types of sandy clay loams with low to medium productivity in this area, mixing with volcanic soils with medium to high productivity. Sands have larger pore spaces than clays, but they both have high porosity. All of them vary randomly from various levels of infiltration, permeability and water-bearing capacity (Figure 19).

Figure 19 Soil on site

(2) Groundwater

The mapping of geology and soils indicates the feasibility of different locations for storm water treatment areas and the potential for groundwater recharge and reserve underground. Indeed, groundwater resources have been widely discovered in this region. Kabale District has a total of 3,193 domestic water points of which 61 have been non-functional for more than 5 years and are considered abandoned (MWE, 2010). The main water supply technologies are the public stand post and the protected spring technologies.

Chronic water scarcity and sparse population contribute to a complex water resources condition. There are nearly 10 public and private wells in town providing tap non-drinkable water for free or cost small amount of money (Figure 20). Groundwater and spring water source have become the mayor drinking water supply in this village for many years. Nevertheless, there are some places for example Muhanga Modern Primary School drinking mountain spring water for affordable price.

Figure 20 Public water tap in Muhanga

Water quality of these water sources have not been detected due to lack of lab facility in the village. I have been using one of the water sources in Muhanga while I was there for fieldwork for nearly 4 weeks for showering and boiled water drinking. It is a water source from mountain springs. The outlet is 15min walking distance from where the school is located.

Figure 21 Public water spring outlet

The municipality renovated this water source intake infrastructure several years ago with concrete and cement (Figure 21). A water bucket has been applied as a man-made valve to control the flow rate of spring water out of the outlet (Figure 22).

Figure 22 Temporary water spring intake

From a first glance, the water is transparent without any visible particles; the water has no strange smell, and good for showering and washing.

However, there is still risk of water contamination, which may pose a threat to surface and groundwater quality. Traditional latrines have been used for years in every houses. Latrine can refer to a toilet or a simpler facility used as a toilet. In this case, latrine means a simple dry pit with a small hole as inlet (WHO, 2014). Wherever the houses are, there will be latrines constructed (Figure 23).

Figure 23 School latrine in the middle

Due to the mountainous topography, many houses are built on hills and so are the latrines. Excrement from humans and animals could be infiltrated with rainwater down to groundwater level and mixed with aquifer. Frequent flooding could impact pit latrines, resulting in inoperable toilet systems and the contamination of water resources. Therefore, the water could be dangerously polluted.

(3) Hydrogeology

Areas of high groundwater levels here can limit the possibilities and desirability of groundwater recharge and filtration methods. In the absence of sufficient documented groundwater information, the seasonal and long-term ground water fluctuations might be determined, based on the hydrological, geological and climatic information available. Figure 24 shows a self-made hydrological cycle in Muhanga drawn by myself.

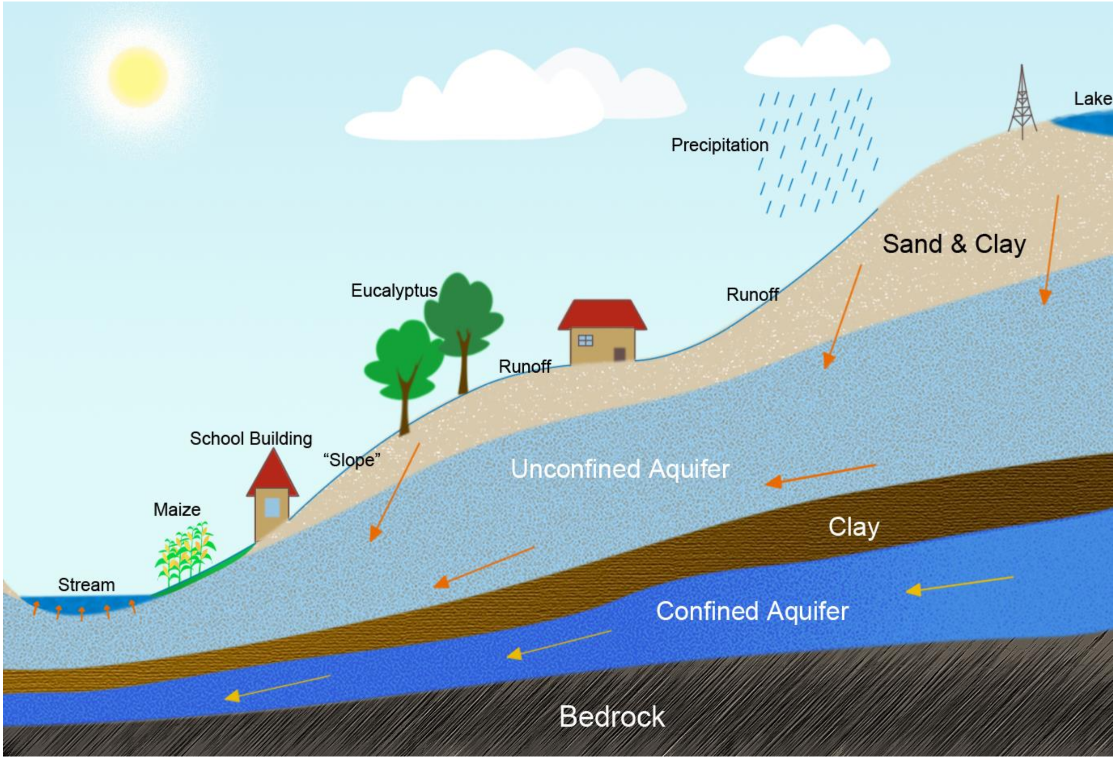

Figure 24 Principle hydrogeology of Muhanga

The sloping soil towards the school buildings and farmland is fairly wet, which could be a result of high groundwater level. So is the place under an apple tree farmland.
Field tests by excavating revealed that the groundwater level is about 1 meter below the soil surface. The soil is clay which the locals use as brick-making material. Villagers drain the soil by ditches of a rectangular transects to redirect the flooding runoff and to prevent the agricultural fields from being damaged (Figure 25). In these ditches there is a continuous base flow. However, after heavy rains, the flow is increasing. Seasonal and longer-term trends in groundwater level fluctuation can be noticed in these ditches. It is said that in rainy season the ditches become wider and have more runoff from the upstream. The general flow direction is heading south down to Kabale, the biggest city in western Uganda region.

Figure 25 Natural drainage ditches on site

3.1.3 Climate

Climate in Muhanga is typical tropical weather. The average monthly temperatures are around 18 ℃ and can fall to 10 ℃. The relative humidity is between 90% and 100% in the morning and decreases to between 42% and 75% in the afternoon, all the year around (KabaleDistrict, 2015). This means it is generally rainy (particularly during the months of March to May, September to November), while the remaining months (December to February, June to August) comprise its two dry seasons. Rainfall distribution in Southern Uganda is bimodal. Around Lake Victoria the annual rainfall averages 1,200-1,500 mm, and is well distributed. Dry periods at the end of the year become longer, with annual rainfall ranging between 900-1,300 mm, this restricts the range of crops that can be grown, allowing two crops annually, and adequate grazing for livestock throughout the year. These conditions are not suitable for bananas but favour extensive livestock production.

When the author was there, it was approaching the end of dry season this year. Several small rains have been experienced on site with only 20min each with a typical peak curve of precipitation. With the climate change tendency around the world, the fastest warming has apparently been in the so-called western Uganda region, where Muhanga is located. The rate is approximately 0.3 ℃ per decade (USAID, 2012).

Heavy rains and strong sunlight by the equator are the main issues; they could be both problematic and useful. Temperatures are not a big problem as long as one can keep out of the sun. The altitude at site is between 1500-1800m, affecting the climate there in a way.

Storm rainfall parameters are major design factors and must be carefully taken care of. Precipitation data has been acquired from the meteorology department of environmental ministry in Uganda. Details will be discussed in Chapter 5.2.1.

The general climatic characteristics of an area will also impact on the site and storm water systems implemented, i.e. whether the site is generally waterlogged or dry and if evaporation levels are high or low.

3.1.4 Hydrology

The hydrology response of the area is described in Chapter 3.2 as a result of modeling.

3.1.5 Natural Ecosystems, Flora and Fauna

Local serving as fodder for goats and Eucalyptus are growing above the slope up until the flatter uphill areas (Figure 26).

Figure 26 Plants grown on slope

It should be noted that large-scale plantations of certain vegetation types, such as Port Jackson (Acacia saligna) and Bluegums (Eucalyptus), which consume large volumes of water, might significantly lower groundwater levels, particularly Eucalyptus, which is the most common plants grown in this area (Figure 27). But on the other hand, soil types indicate this likely occurrence of particular plant communities, some of which may play a role in the storm water management. Plants and vegetation are the most sustainable long-term solution for erosion mitigation. Plants could grow fairly quickly in this climate. Especially Eucalyptus is the world ́s most fast growing tree.

Figure 27 Eucalyptus planted on site

Figure 28 Vegetation map of the site

In area 6 shown in Figure 28, a grass slope leads up to a flat plateau of the red soil with a Matokee[1] field nearby; eucalyptus and other small bushes are growing above the steep slope. In the northwest corner there is a grass covered playing field and a slope garden with some plants. The areas for growing should be well evaluated since it is a part of the project to develop these kinds of skills.

Land is owned and grazed in common; ways of caring for it have not yet evolved. The sparse vegetation has low quality grasses with many thickets and bushes. Apart from Acacia saligna and Eucalyptus, corns have been planted in agricultural field at school since last year. However, Maize is not a well-known water-consuming crop. Two grey crowned cranes are fed by villagers nearby (Figure 29).

Figure 29 Grey crowned cranes

This is the most famous bird in eastern Africa, especially in Uganda. It is treated as a national bird. Dead birds are buried with a proper funeral. These cranes are omnivores, eating plants, seeds, grains, insects, frogs, worms, snakes, small fish and the eggs of aquatic animals (ICF, 2015). Their influence to the ecosystem should be noticed. No livestock have been farmed at the site. Sometimes chicken might show up for a short time.

3.1.6 Ecological Characteristics of Freshwater Ecosystems

The agricultural field is acting as a floodplain and ecological buffer on site. These buffers provide open space systems within which the more space-consuming “soft technologies” of storm water management can be accommodated, without posing a conflict with development pressure.

[1] Matokee is the fruit of a variety of starchy banana, commonly referred to as cooking bananas in South Western Uganda.

It is ecologically important to note that wetlands, lake, pond and rivers are main recipients of storm water discharge and the quality and quantity of storm water discharges into such systems should be regulated to minimize downstream impacts and reduce the peak flows to increase the time-to-peak through detaining the runoff and releasing it at a gradual rate to mimic pre-development responses to storms.
Nonetheless, due to a lack of water test instrument and experimental facilities, quality and quantity of them can't be detected on site. Cognizance should be taken of cumulative impacts to water bodies occurring, as a result of discharge from several sources.

3.1.7 Sanitation

Due to limited sewer coverage in urban areas, most of the population depends on onsite sanitation. Services for onsite sanitation are the responsibility of households or local councils for public places. Both the households and local councils depend on the private sector for the different services, which offers a broad range of services.
Dry latrines have been widely constructed as a receptacle (as a pit in the earth) for excrement. It can refer to a toilet or a simpler facility which is used as a toilet within a sanitation system, or a communal trench in the earth or a hole 1-2m deep in the ground. For most people, it has the connotation of something being less advanced and less hygienic than a toilet. This is the most common seen sanitation method in Uganda. Every pit latrine is a mix of urine and faeces producing wet, substantial odorous faecal sludge, which has to be removed by someone when the pit latrine is full.
There are several places in that region using eco-san. Eco-san, which is commonly abbreviated for ecological sanitation, is an approach, rather than a technology or a device which is characterized by a desire to 'close the loop' (nutrients and organic matter) between sanitation and agriculture in a safe manner (WBG, 2015). When properly designed and operated, eco-san systems provide a hygienically safe, economical system to convert human excreta into nutrients to be returned to the soil, and water to be returned to the land. The most common technology used in eco-san systems is the urine-diverting dry toilet. However, eco-san is not widely constructed in Kabale and Muhanga County.
By conducting interviews and participatory approach with local people, it is not a priority to construct eco-san in town especially for public places. Some people call it may be more expensive to build than pit latrines, even if in the longer term they are cheaper to maintain. According to my questionnaire, 100% of the interviewers propose that they can't afford to build an eco-san instead of traditional latrine. A reason for this could be the high cost of construction and also complex subsequent maintenance. A number of school headmasters mentioned that they would like to promote the concept of eco-san to the students but they can't do it at the school on account of the number of users and huge volumes. In addition, they may suffer from the same issues as any other type of school toilets, if clear responsibilities and a dedicated budget for school toilets' maintenance is lacking, then the toilets may easily

fall into disrepair, e.g. with blocked urine pipes or faeces vaults that are not being emptied. Therefore, eco-san is more recommended in small scale unite for example household or private buildings.

Eco-san example in Kabale town in an office building consisted of several organizations and governmental sectors.

Figure 30 Collecting chamber outside the building

A collecting chamber is put in the outside of the toilet (Figure 30). All the faeces have been transported down to the container with ash. On one hand, the entire solid will be kept inside for several weeks and then used as fertilizers for farmland. On the other hand, urines are transported by wastewater pipes to the wastewater treatment plants trough municipal system. A ventilation pipe to exhaust moisture and odors from the vault or pit is installed on the top of storage chamber.

Figure 31 Eco-san toilet

As is shown in Figure 31, inside the toilet, faeces and urines are separated from the initial source in a squatting pan. A bucket filled with dry cover material has been put by the side to reduce odor and speed up the drying process, ash is used here. While a user finishing releasing the faeces, a ladle of ash needs to be poured into the faeces inlet mix with excreta.

3.1.8 Project Site Condition

Figure 32 Site plan map

The whole project site mainly consists of a school building with an administrative office, a library, 2 classrooms, a mushroom cultivation room and a kitchen.

(1) Building Status.

The school workers have repaired some of the walls for the library, by replacing bricks with new bricks and mortar. And they have put some plaster on the wall on the inside of the building. However, it is said that the rest of the building is in a worse state than last year, with deep gaps where the water has dug out mortar and the ground under the buildings.

In addition, the office building has significant water damages on the wall turning towards the slope, which looks even worse than before according to the school administrator. They have made effect to repair it by putting some new plaster on the inside of the wall of the office; however, there is a still significant sign of water 30-40 centimeter up. The wall against the slope also shows some fairly deep cracks, and the wall was moving slightly if someone pounds on the wall. The back wall of office building has been renovated with cement. Nevertheless, water erosion trace can still be seen (Figure 33).

Figure 33 Backwall of school building

The bricks that have been used are local burned bricks with irregular shape in pretty bad quality. It can even be broken by throwing towards the ground.

(2) Water Erosion

Roof is mainly constructed with iron sheet (Figure 34). The length and width are 32.5m and 5.5m on each side for the classroom building. It will be really big area to collect roof water with an area of 178.8m^2. A rough assumption of rainfall depth of 600mm has been made onsite during rainy season for several months, runoff coefficient can be 0.85, and then a volume around 90m^3 may be received for the whole rainy season. This will be a plenty of water for the school kids and staff. Right now the school doesn't have any water reservoir at the moment. Kids can get hot food during lunch, but the food is mainly porridge made of maize and water. The school guard fetches water from the spring to site every day with buckets.

Figure 34 Iron sheet roof

A small plastic water tank with 100L cost around 30,000 SH (90 SEK) excluding the cost of any connections. An investigation of local material market has been conducted for plastic water tanks, which the maximum volume is 12,000L. The author did a visit to a Ugandan friend's summer house at the border between Uganda and Rwanda, he has water harvesting system connected to one tank with 12,000L and a manually pump imported from Czech Republic ranging 15m providing water for the whole house. When the author was there, it was Later July close to the end of dry season and the housekeeper said they still had a half volume in the tank. And there are normally 4-5 people living in the house everyday where they have flushing toilet and shower.

When the visit was conduct in July, 2014 in Muhanga, it was close to summer holiday in the school, and due to some management problem last semester there, there were only 20 kids at school and they were all under 7 years old. The administrator said they wouldn't have this teacher shortage problem for the coming semester. Therefore there will be at least 50 people at school. And after new building's constructing, there will be more people and visitors coming. More details about water consumption estimation will be discussed in Chapter 5.2.1 later about water harvesting.

Figure 35 Water consumption workshop with local school students

The result of these workshops is presented in Appendix 3.

The biggest problem around the existing buildings is the loss of rain pipes under the roofs. Since all water from the metal sheets drips straight on to the foundation it both ruins the foundation and makes holes when it drops to the ground. How far out the roof reaches and where it leaves the drops must be considered.

Local construction techniques are observed in nearby buildings such as a self-made gutter system crafted in iron sheet which seem to work well.

Fortunately, even it was the dry season there in July and early August, several small rains at the site had been recorded. Though they were incredible small and only took less than 1 hour, the ground didn't even get wet.

The lower parts of the houses are damaged when the drops hit the plain concrete foundation's surface and bounce up against the wall. Therefore the long sides of the house are most damaged since it's where the water drips down. The house that actually seems to handle water best is the mud house; since its foundation-surface is rougher and the water bounces less towards the wall. The fact that the level behind is higher than in front also keeps the water from gathering around it.

Figure 36 The experimental site after a small rain

While it rains, as is shown in Figure 36, it is dry on the ground under the gutter. And on the right side without any gutters, an obvious water line has been shown up consisting of falling water drops from roof. So is it in the front side. Currently, the existed gutter is not connected to any outlet.

Figure 37 Raindrop effects on the ground

As is seen from Figure 37, when water drop goes down, first of all, a straight line will be created. Then when the rain becomes bigger and bigger, more and more water will

be accumulated on the area next to the base since it’s not flat and water will go directly down to the right side base. After excavation of ditch, excavated soil can be collected from the ditch to the front side to even some uneven ground in front of classroom.
The school administrator also thought the mainly water damage was the water flowing from the roof since water are flowing down directly down to the foundation and walls.

(3) Slope stabilization
The most sustainable way for slope stabilization is vegetation plantation. Eucalyptus is everywhere in that region and it’s the main raw material for wood industry in this region but it seems they don’t function well there for soil stabilization. The reliability of stabilizing is doubtable. The steep angle of the slope makes everything difficult. Since the field group don’t have enough time to stay there supervising a vegetation plan, installing mesh or nets have been thought about as cheaper and useful solutions to prevent mud flowing down, and digging the ditch as is planned in Chapter 5.1 around the buildings.

3.2 Computer Modeling in ArcGIS

3.2.1 DEM

Digital Elevation Map (DEM) data of Eastern Africa have been downloaded from SRTM (NASA Shuttle Radar Topographic Mission) and inserted in ArcMap10.0. After projecting with the WGS84 horizontal datum and the EGM96 vertical datum, a grid cell size is generated in 92.5m. By using resampling tool, grid width has been adjusted to 90m eventually.
In Figure 38, where the green dot located is the location of study site---Muhanga Shalom Primary School.
On the right side Muhanga, a huge light green rectangular area is the well-known Lake Victoria. As is presented, Muhanga is not far from the coastal line of the biggest lake in Africa among a mountainous region in southern Uganda, hiding in the orange areas nearby. It is close to a geology border between the orange area and yellow area on the top right. Behind the border, the terrain goes straight down rapidly from approximately 2,000m to 1,500m in a big inclined slope. Climbing over the ridge, an endless plain can be overlooked incredibly.

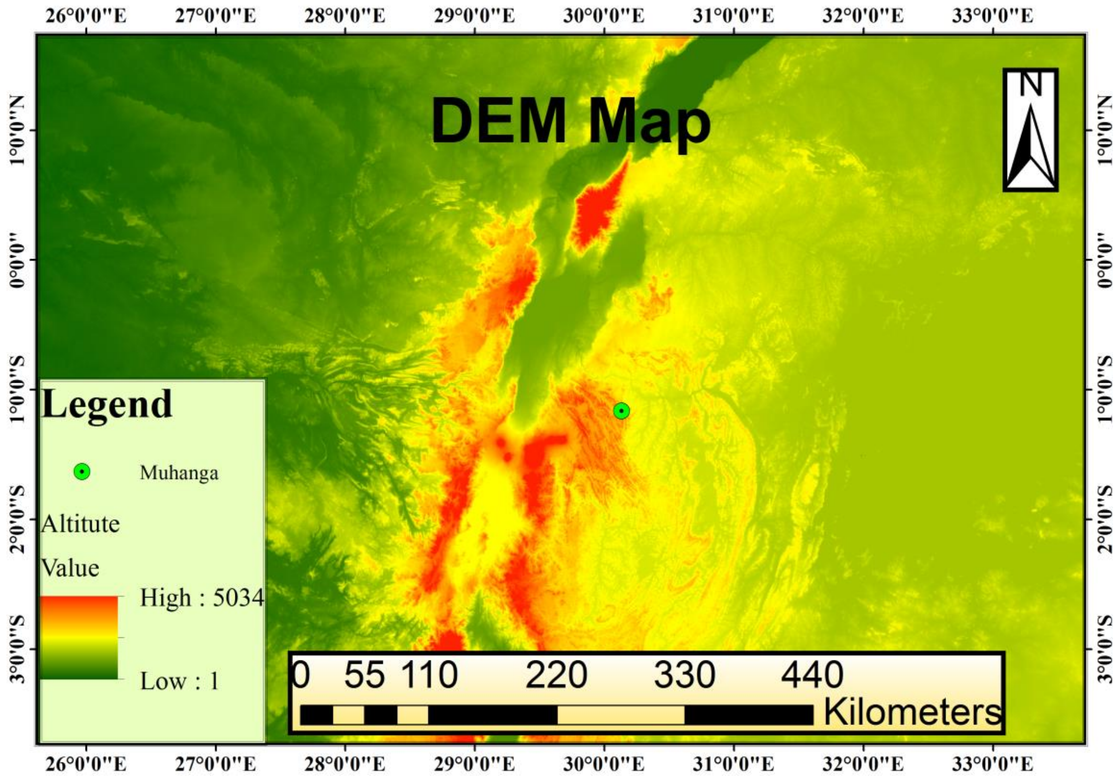

Figure 38 DEM map in big scale

3.2.2 Sink and Fill

Whatever the DEM map is, there are always no data (void) areas. Using Sink tool, all the sinks could be founded. Figure 39 presents a map of all the sinks around Muhanga. Most void places are in the valleys or low attitude areas.

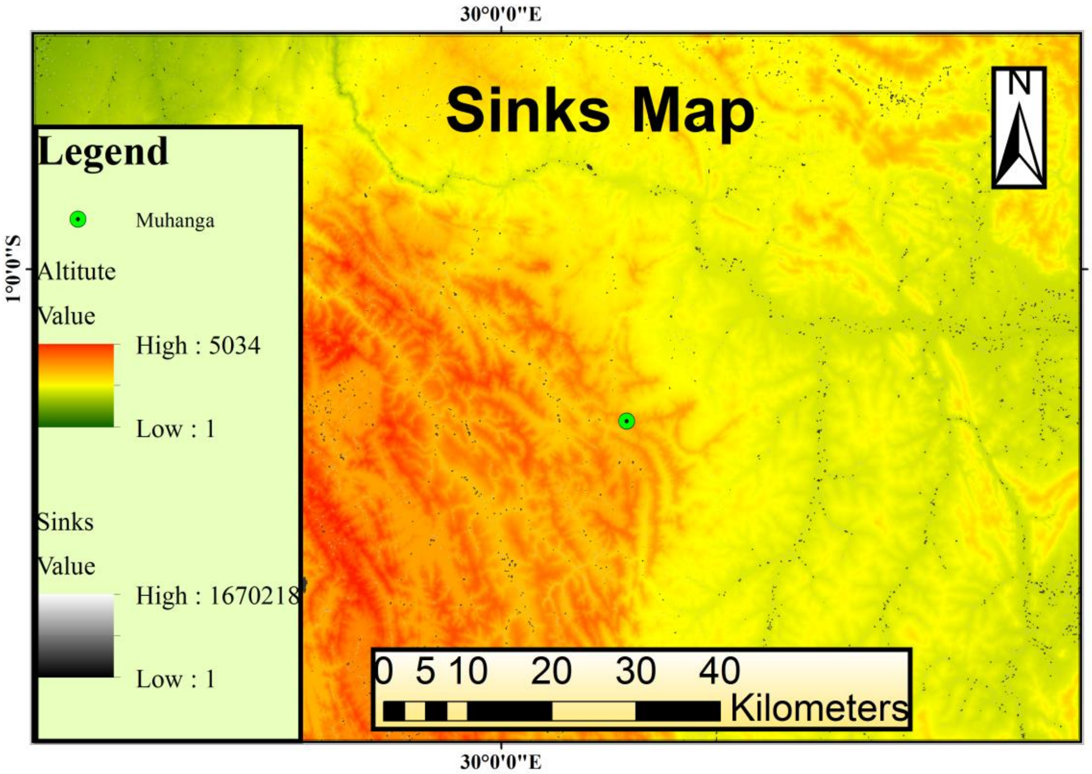

Figure 39 DEM map with sinks of the region around Muhanga

By using Fill tool, extra sinks and peaks are filled and removed by automatically calibrated programme with nearby cells. Results are illustrated in Figure 40. Most green areas are becoming yellow in new DEM map, presenting a more accurate topography database.

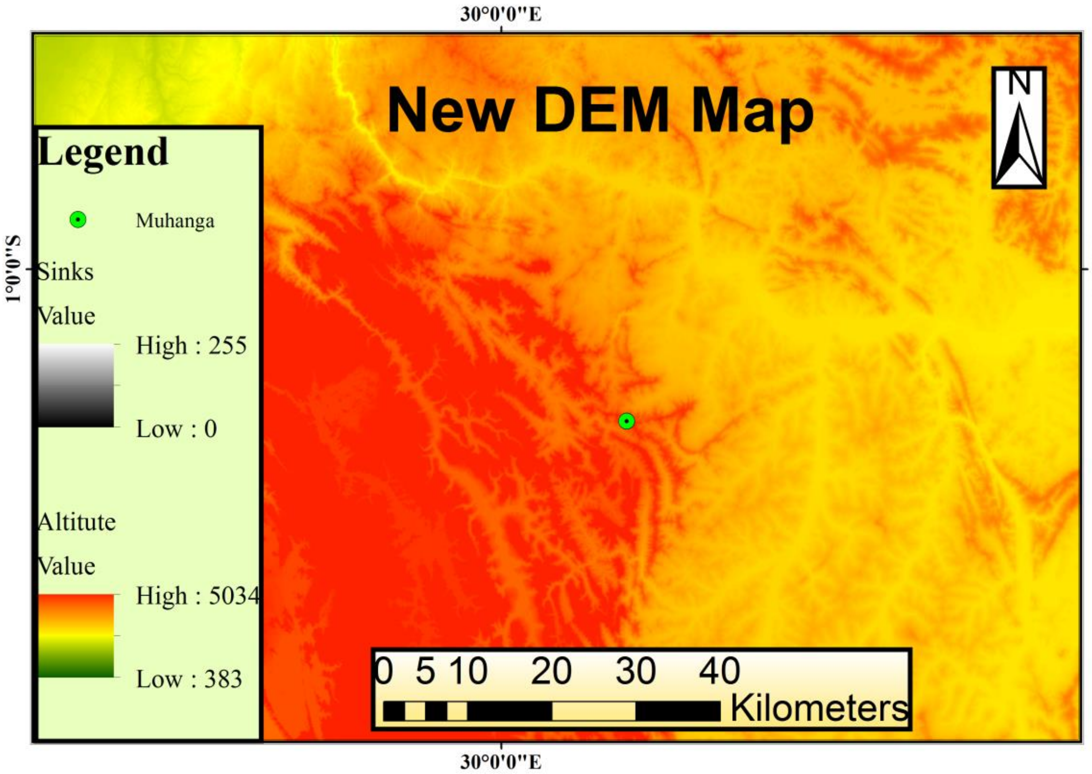

Figure 40 DEM map around Muhanga after Fill tool without any sinks

The sinks value is still not zero in this case due to several reasons for example DEM error. However, it doesn't affect quite much for the related site areas at least there is no sinks in the region around Muhanga.

3.2.3 Flow Direction

Flow direction output has been described in Figure 41. This represents the flow direction of each cell. This result is mainly used as input data for continuous tool run. There are 8 colors of direction in total showing where the runoff water goes on the surface.

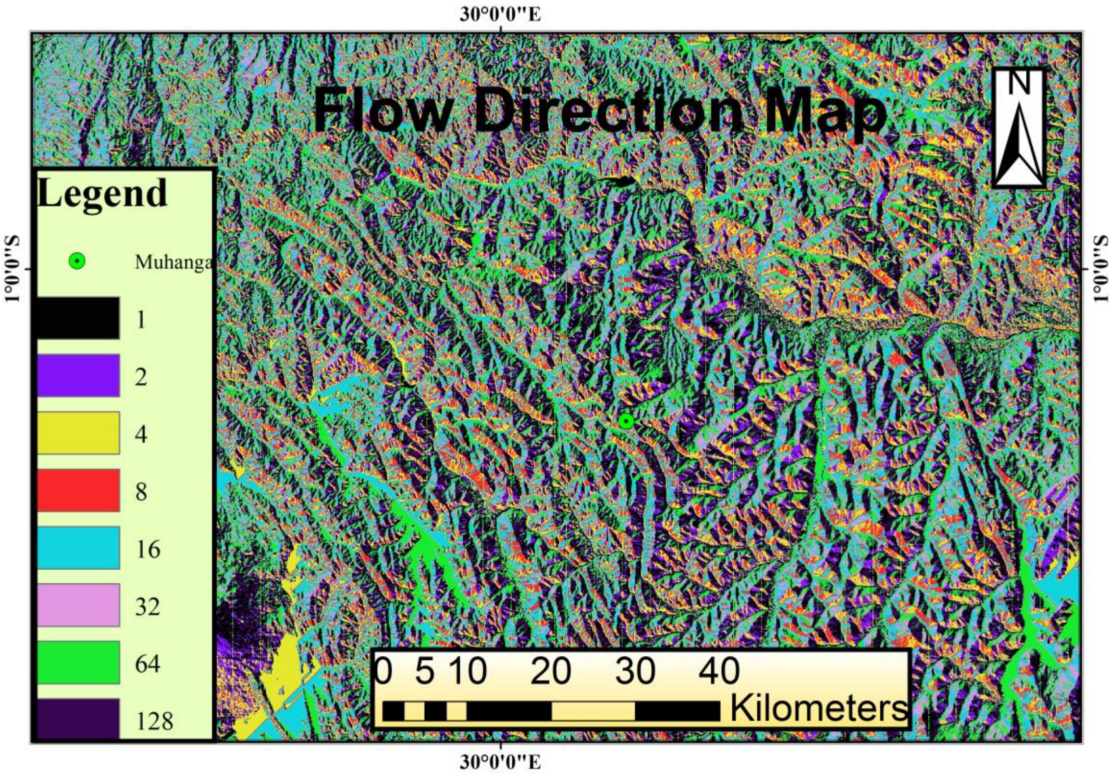

Figure 41 Flow direction map of the region

3.2.4 Flow Accumulation

By using the output of flow directions input, a flow accumulation output can be acquired. Several main flow accumulation lines come out in red showing potential river and stream trails around Muhanga. These are the main streamlines generated by the computer programme.

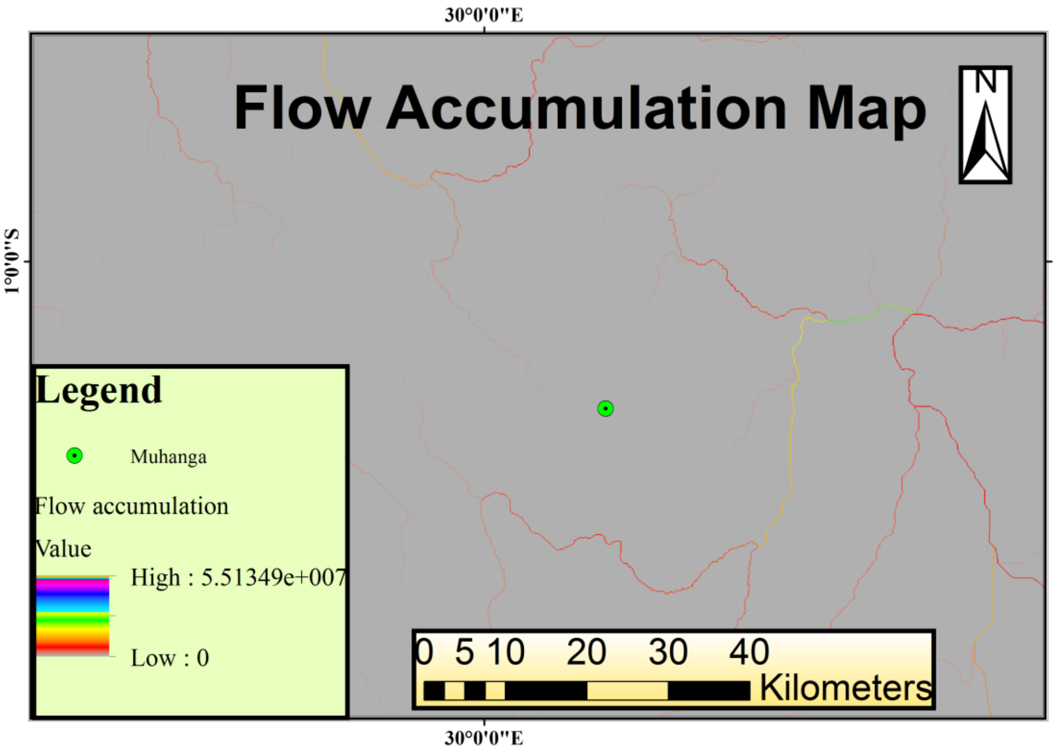

Figure 42 Flow accumulation of the region around Muhanga

3.2.5 Flow Length

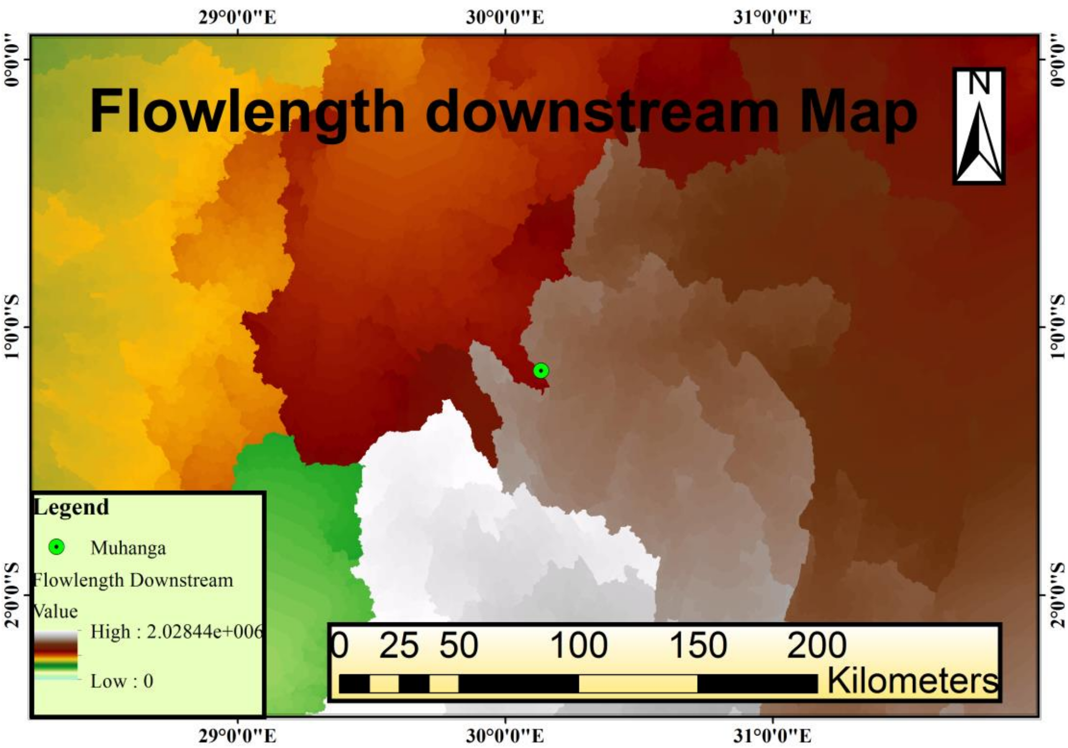

Figure 43 Flowlength downstream map

As is shown in Figure 43, flow length to downstream value is very high in the region around Muhanga, which means it could be an area with several stream upstreams or river sources. This is also certified by real topography within the mountains.

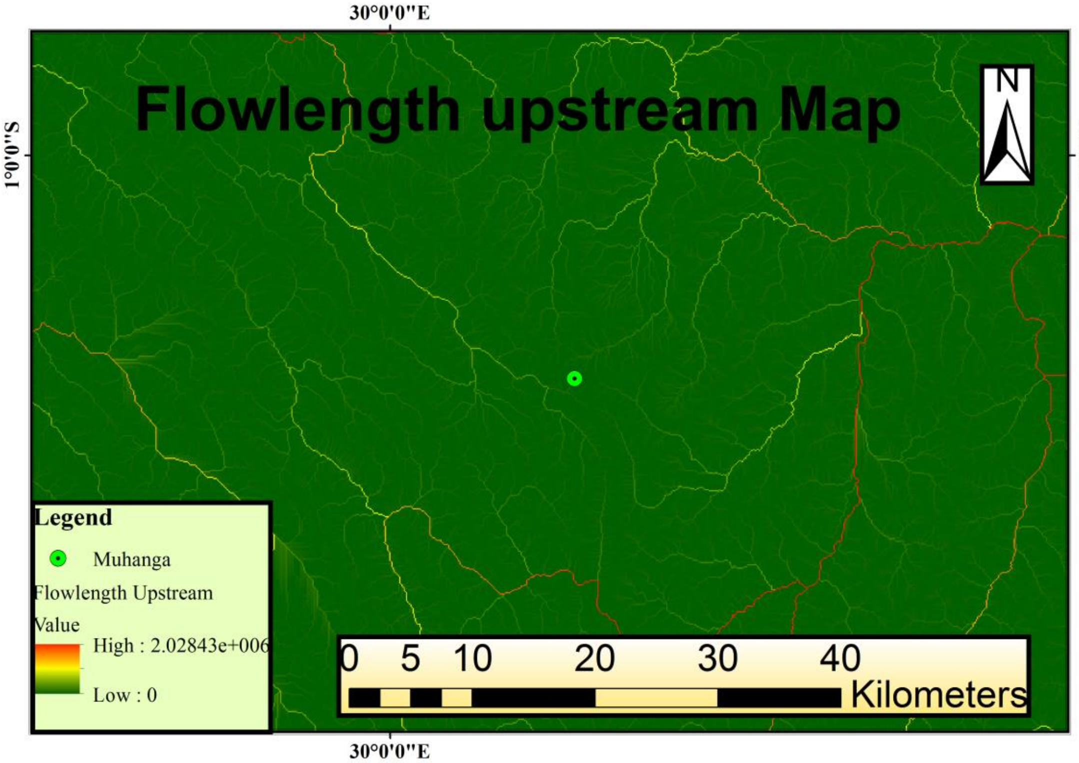

Figure 44 Flowlength upstream map

In Flowlength upstream map of Figure 44, the distance between upstream and each point is illustrated by different colors. In the region around Muhanga, dark green which presents a low value is mainly calculated; it is happened to be the exact opposite result of the downstream flow length, standing for a upstream intensive area.

3.2.6 Stream Network

All cells where flow accumulation values of 800 or greater go to one become part of the stream network. As is resulted in Figure 45, there is at least one big stream flow from southeast towards northwest derives from southern Muhanga.

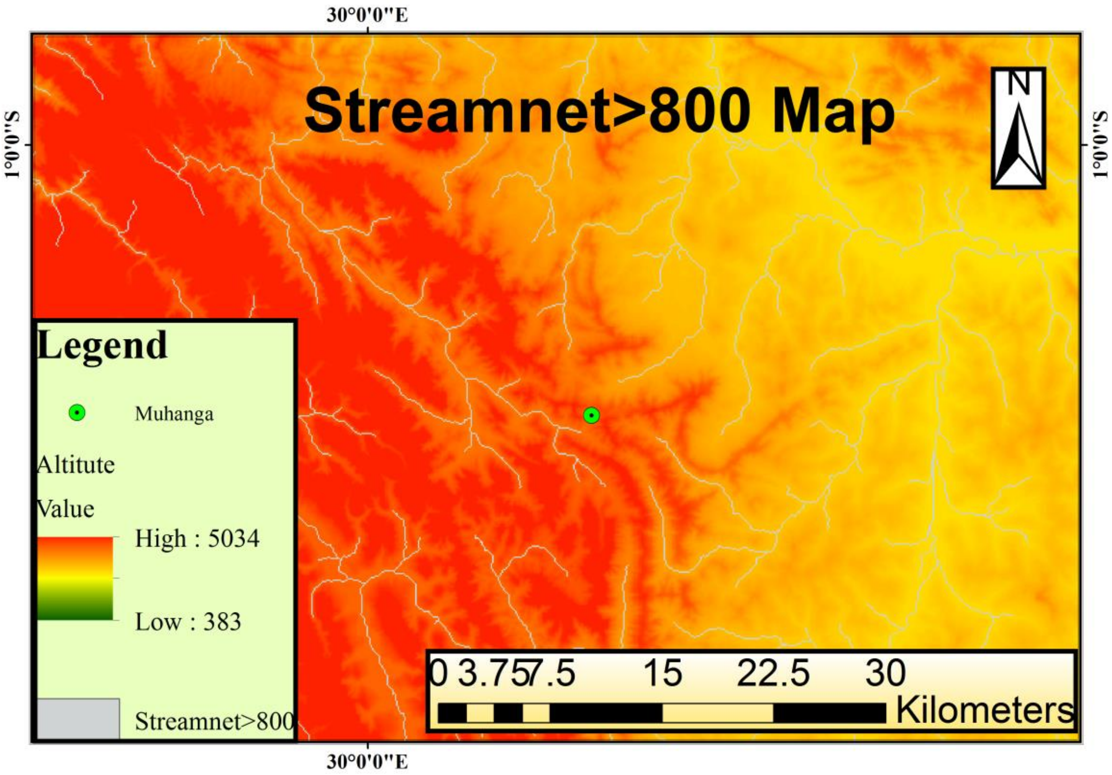

Figure 45 Stream network with flow accumulation values over 800

All cells where flow accumulation values of 500 or greater go to one constitute part of the stream network. As is shown in Figure 46, more flow trees are appeared along the main stream.

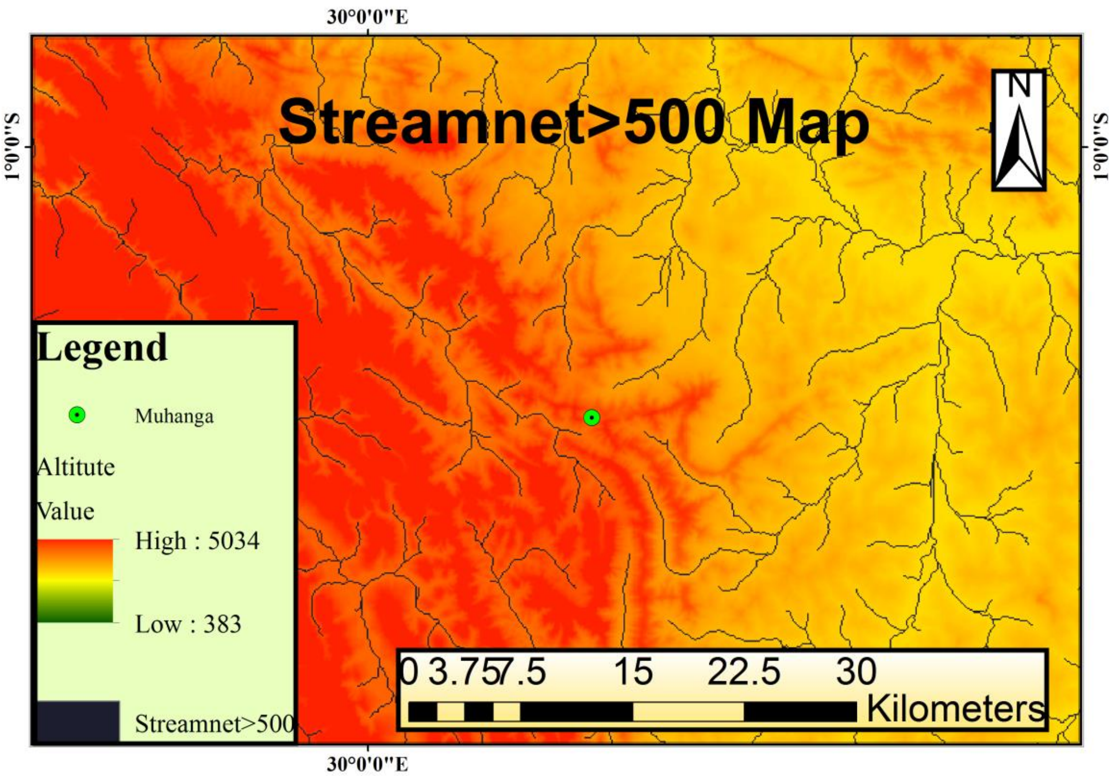

Figure 46 Stream network with flow accumulation values over 500

All cells where flow accumulation values of 100 or greater go to one contribute to part of the stream network in Figure 47. One sub-stream has been simulated out initially originates from Muhanga. This might be a main outlet flow of the whole watershed catchment around Muhanga.

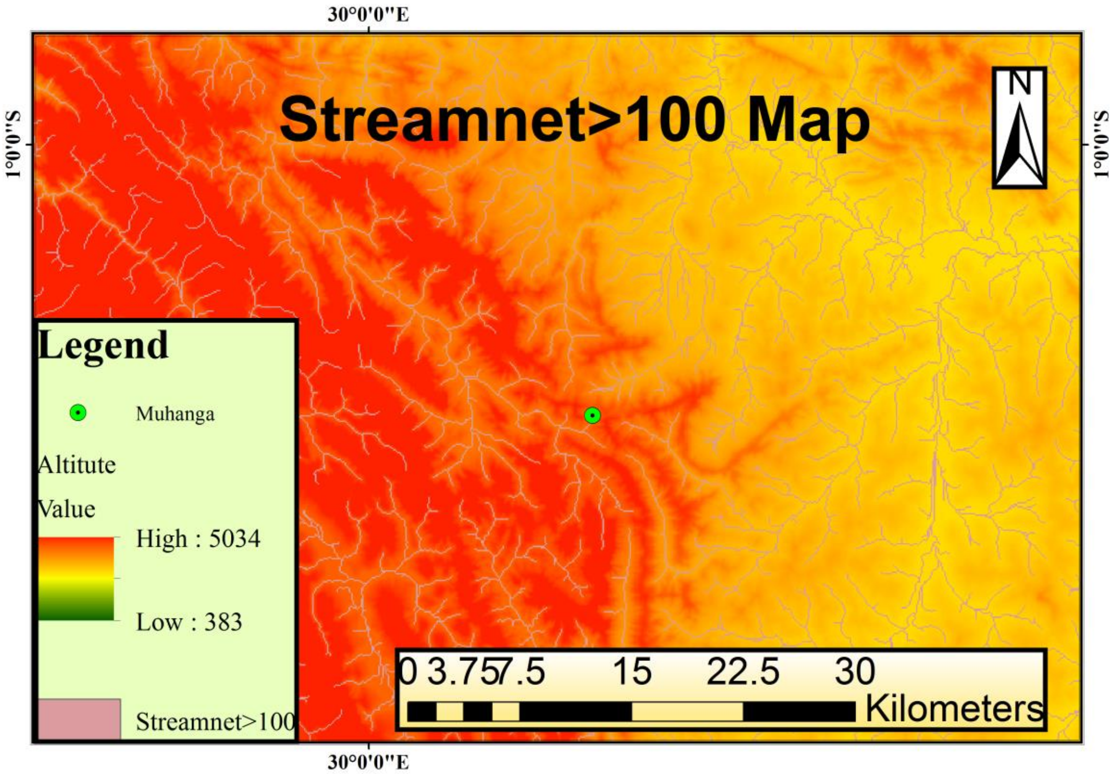

Figure 47 Stream network with flow accumulation values over 100

All cells where flow accumulation values of 50 or greater go to one consist of part of the stream network in Figure 48. More and more streams coming from Muhanga shalom primary school side are shown in upstream direction.

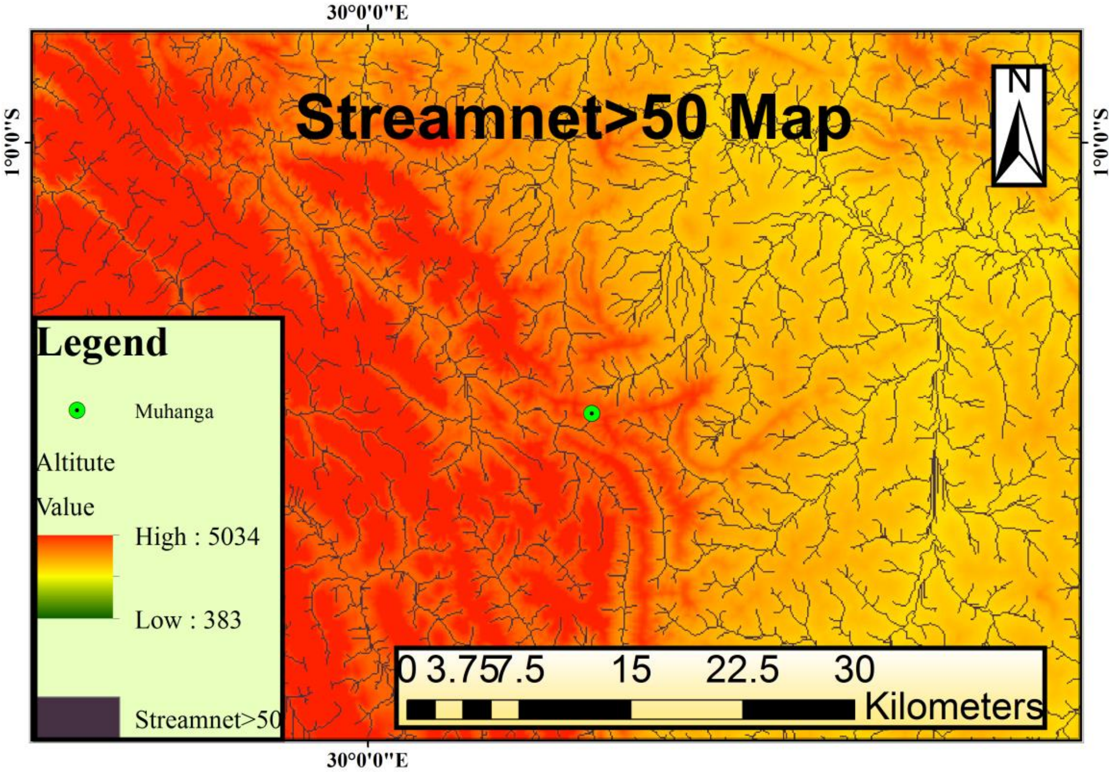

Figure 48 Stream network with flow accumulation values over 50

All cells where flow accumulation values of 20 or greater go to one form part of the stream network in Figure 49. Small streams start to appear in upstream area before Muhanga, which could be a flooding contributing area for school building. Rainfall runoff sources should be found through these ‘trees’.

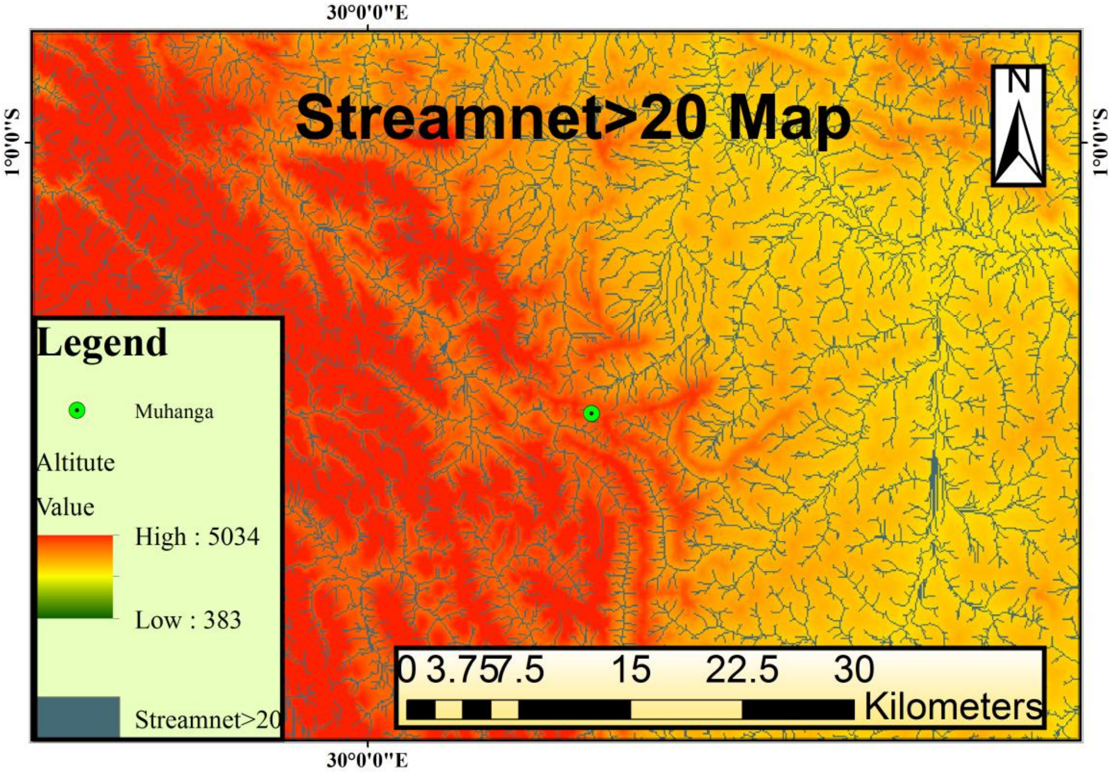

Figure 49 Stream network with flow accumulation values over 20

3.2.7 Stream Order

By using Strahler method analyzing a stream net with flow values equals to 20 and more, a numeric order to segments of a raster representing branches of a linear network has been assigned. The output of Stream Order is presented in Figure 50, and it will be of higher quality since the input stream raster and input flow direction raster are derived from the same surface.

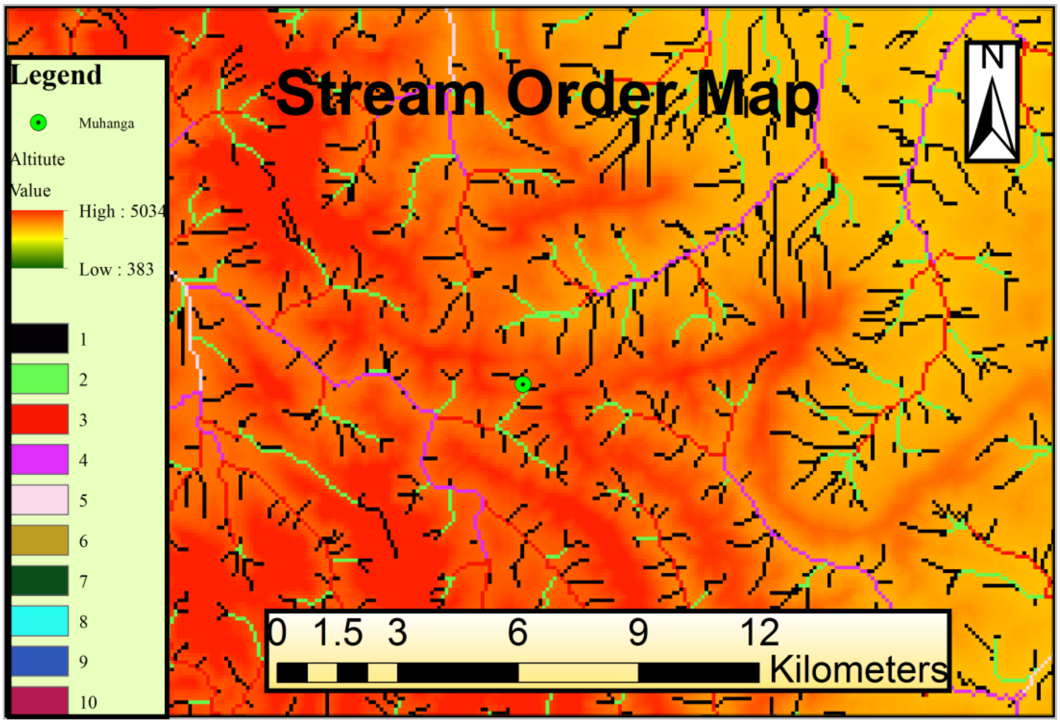

Figure 50 Stream order by using Strahler method

3.2.8 Basin

Big basins have been divided by using Basin tool. As the same sign as DEM, Muhanga is situated just next to the geological border between 2 basins (Figure 51). One of which is a mountainous basin in red brown with tons of valleys and water catchment, the other one is the endless plain behind the border on the right side in orange. The border also plays a role of water divide in this case. Rain drops falling down on one side are flowing towards the red brown basin; rain drops falling down on the other side are flowing into the orange basin contributing another catchment area (Figure 52).

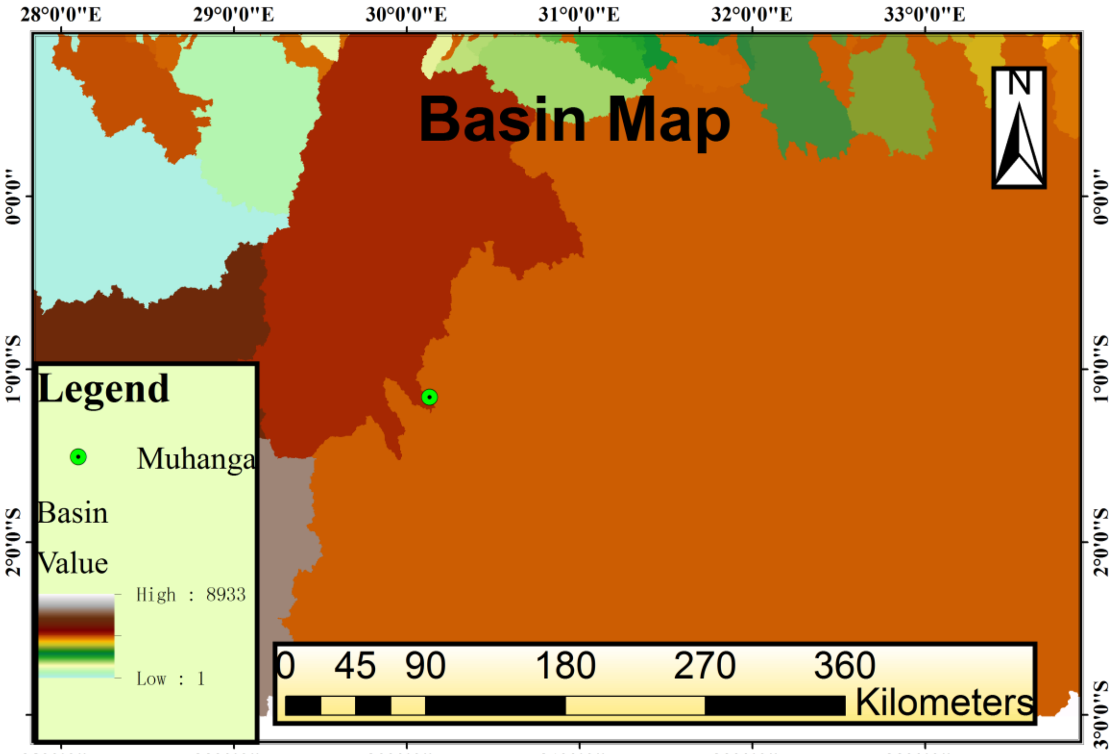

Figure 51 Big Basin division in different colors

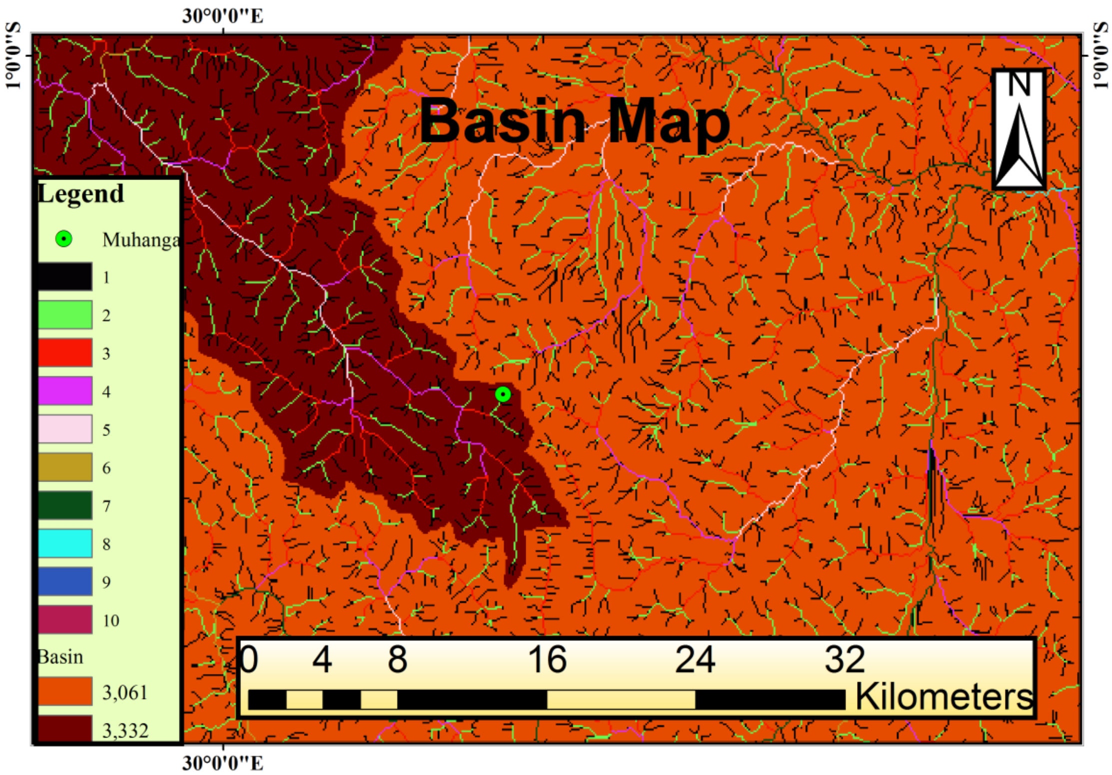

Figure 52 Basin division of the region with stream orders

3.2.9 Snap Pour Point and Watershed

In the area around Muhanga, 6 snap points have been pointed in order to know a water contributing catchment area for the school site.

By using Snap Pour Point tool and Watershed tool, the pink triangle (Figure 53) which is just behind the green point of Muhanga site is the flow accumulating place for the yellow area, representing a whole water catchment for all the rainwater runoff, including all the water flowing into the ‘black sub-stream’ and ‘green stream’ from both tree branch sides.

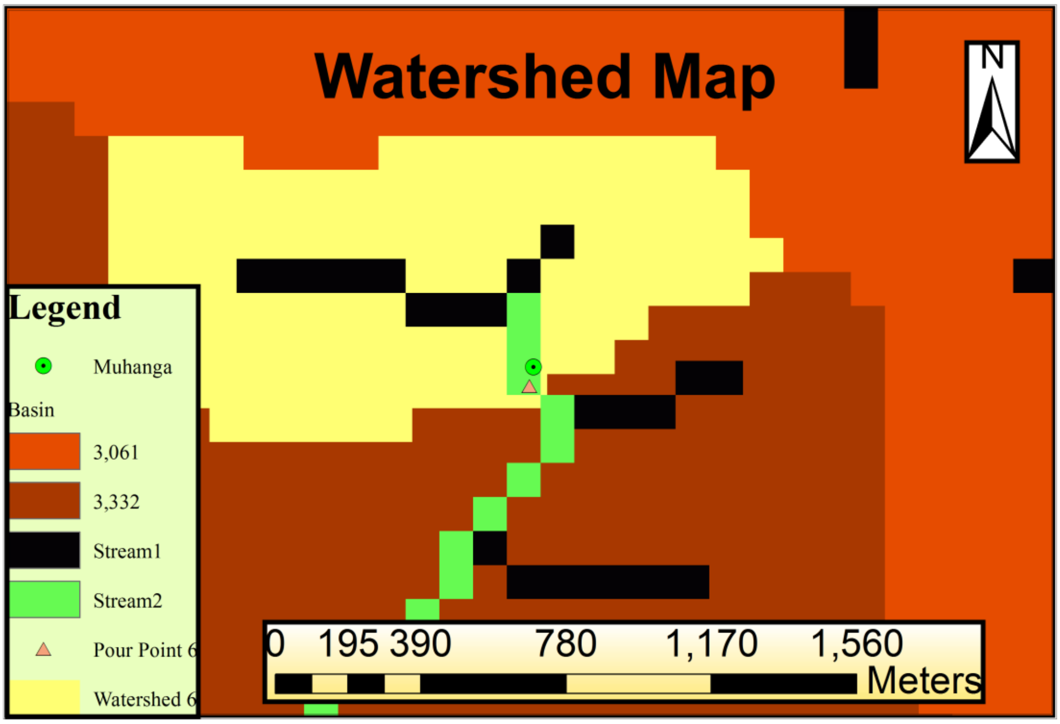

Figure 53 Yellow watershed by pink triangle after the site

For rose red triangle point which is ahead of the green point of Muhanga site, the purple part in Figure 54 represents the catchment area of snap pour point rose red. As is shown, the purple area is a bit smaller than the yellow one in last figure, lack of the catchment area for stream branch between pink and rose red snap points which is actually the tiny area in yellow in Figure 54.

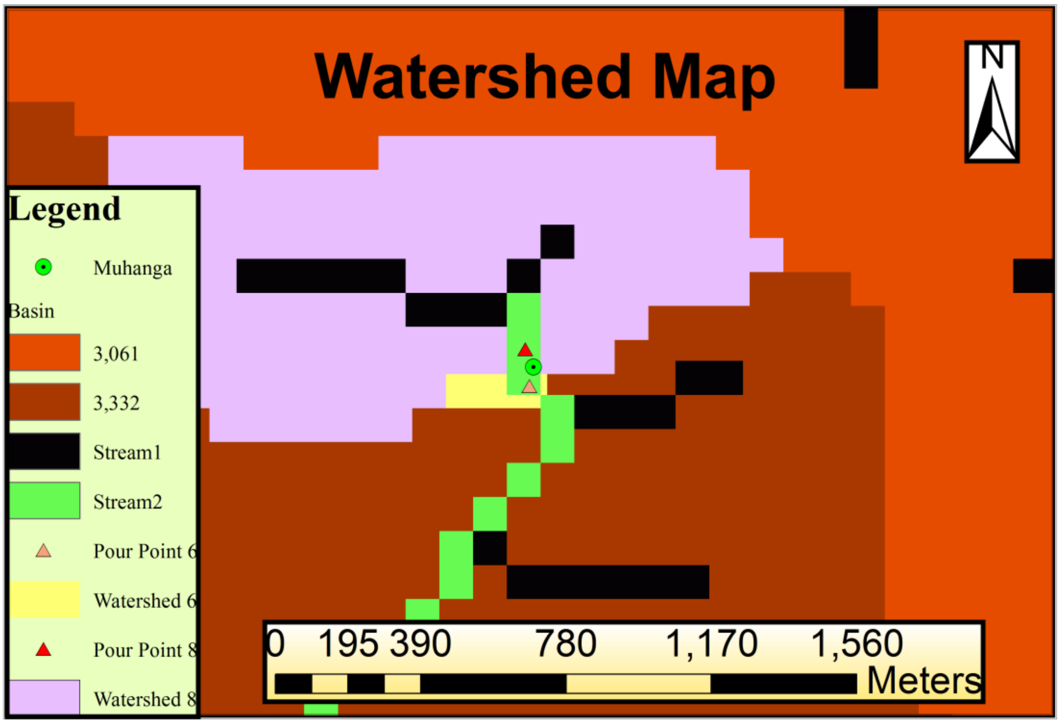

Figure 54 Purple watershed by rose red triangle before the site

More snap pour points are pointed in Figure 55. The yellow triangle point and light blue triangle point account for the brown area on the left of grass green area on the top respectively; the purple point on the right represents the blue area within a black sub-stream inside; on the bottom where the black sub-stream meets the main green stream locates the blue triangle point, which holds a contributing run-off area in dark green for the whole region, collecting all the rainfall water by these streams.

Considering the flooding problem for the site in Muhanga is mainly from the slope side on the right of the school, a catchment area that is just among the purple area but doesn't belong to grass green watershed and also falling outside of dark green area, which is pointed out in Figure 55 has been selected and calculated as the rainfall contributing area for flood. 7 grids have been chosen as a watershed for the site. It is $90\text{m}\times 90\text{m}\times 7=56{,}700\text{m}^2$ in total.

In reality, combining with the PRA field study in all perspectives, the result of ArcGIS hydrology model matches the result of field survey accordingly. All the geological and topographic divisions and streams or potential stream networks are validated during the site investigation. In other words, even the ArcGIS hydrology model only considers an input of geological map data in regardless of any other factors such as soil type, vegetation, human activities, hydrogeology, climate, etc, by putting together the site survey result in these aspects, the reliability and accuracy of the whole method are both in good conditions.

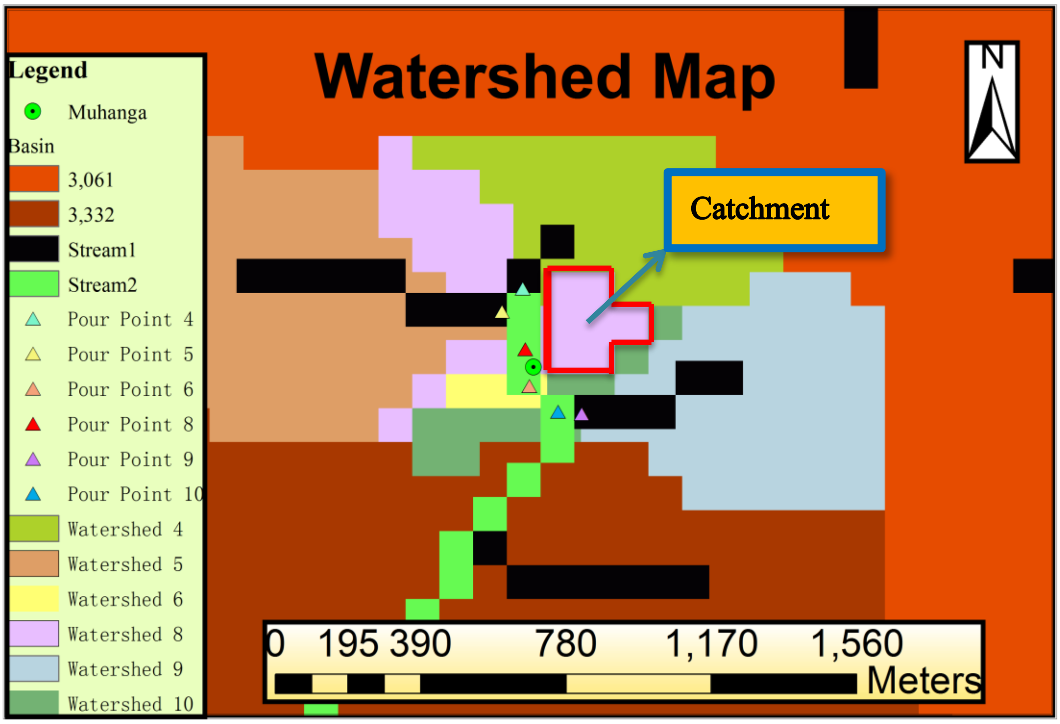

Figure 55 Different catchment areas by different triangles around the site

4. Discussion of the Results

4.1 Flooding and Water Harvesting

As for many people in Uganda, water is life. This is one of the reasons that citizens, organizations and to some extent governments have realized the importance of rainwater harvesting. Making the most of what they have. Even groundwater source has been widely used in Muhanga site in an inconvenient way, in order to pursue a more sustainable environmental way of water resources using, locally rainwater harvesting can be used both to increase production and to provide domestic water.
In Uganda, houses with hard surfaced roofs are very common and constantly increasing, which is promising for the spreading of rainwater harvesting. The technology is also socially accepted and “traditionally” used in rural areas. Using paint bucket to collect runoff is quite common.

4.1.1 Climate

Precipitation data is essential when designing rainwater harvesting systems and very difficult to obtain in Uganda, which makes designs rather rough. Data is available through some websites. However, this data is often not recorded from weather stations but calculated from interpolations between different points. According to the meteorological institute of Uganda, data is not available online but could be purchased from them.

A monthly precipitation table of Kabale gauge station from 2000-2013 has been illustrated in Table 1. It is originally provided by the meteorology department of environmental ministry in Uganda.

Table 1 Precipitation data (mm) from 2000-2013 in Kabale

KABALE (01 15S, 029 59E)				**Altitude=1869m**								
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	50.9	83.5	118.9	120.7	55.7	8.1	5.9	69.6	69.9	179.8	146.8	83.8
2001	86.3	51.2	83.9	135.9	78.5	22.4	34.7	65.7	230.9	192.9	95.4	63.9
2002	120.2	89.7	63.1	74.9	109.2	0.0	0.0	47.5	52.4	186.6	84.9	91.5
2003	66.9	80.6	74.7	139.1	96.0	29.0	22.8	25.5	82.6	86.5	94.0	57.3
2004	73.6	93.8	84.5	183.2	84.1	0.0	1.1	31.9	67.5	76.5	114.2	124.9
2005	25.7	121.8	170.1	123.4	122.1	40.5	0.0	29.0	84.0	107.6	66.1	37.5
2006	85.5	133.5	127.7	112.7	207.8	2.9	30.1	79.5	74.2	70.7	156.2	62.3
2007	55.2	102.5	80.3	103.6	87.9	34.1	114.3	23.6	140.5	112.1	162.9	25.2
2008	99.0	65.3	206.1	54.2	53.5	65.9	24.0	36.5	77.4	172.8	107.6	99.1
2009	61.0	114.2	122.7	99.5	90.7	19.8	1.1	94.6	87.0	86.6	174.1	98.8
2010	97.7	189.0	149.1	132.9	97.7	9.3	1.4	16.4	104.8	197.0	86.4	69.0
2011	33.1	67.0	164.0	125.3	63.9	62.5	12.1	103.8	71.7	73.9	158.4	54.7
2012	2.8	52.8	110.6	197.0	147.0	11.6	9.4	62.6	98.7	114.4	179.8	128.0
2013	42.9	35.2	129.3	76.8	70.5	0.0	0.1	53.5	175.2	135.8	97.0	81.6
LTM	**65.6**	**80.8**	**113.3**	**140.3**	**97.4**	**28.4**	**18.5**	**54.9**	**98.5**	**128.1**	**117.4**	**88.6**
LTM=	Long Term Mean Rainfall											

Kabale is a mayor town located in the southern part of the Western Region of Uganda, 50km away from Muhanga. This is the nearest gauge station to the site in Muhanga.

As is shown, a number of data are missing in the table or irregularly small in Table 1 for example in July and June 2002, July 2005 and June 2013. There could be various reasons by an assumption of failed measurement or gauger’s mistake. However, it is also could be true with this small amount of rainfall during dry season for some specific years. For example in 2013, Muhanga has experienced an extremely drought during June and July with almost 0 mm rainfall for the whole dry season; In January 2012, the weather was also particularly dry comparing to other January; the same extreme flood happened in January 2002, too. These unusual rainfall performances are reflecting the extreme weather that climate change has influenced in Muhanga, giving rise to unpredictable troubles and disasters for human life and infrastructures.

Except from this station, the second nearest gauge station is in Bushenyi, another small town located 100 km away.

Here attached a rainfall data table for Bushenyi from the same source.

Table 2 Precipitation data (mm) from 2006-2012 in Bushenyi

Bushenyi												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2006	54.1	45.1	131.9	197.5	87.0	10.6	47.5	140.0	182.8	61.5	177.2	118.7
2007	47.2	56.2	102.5	124.0	107.3	73.5	28.0	74.0	259.6	137.3	223.0	135.9
2008	67.7	71.9	242.4	32.4	48.1	62.9	24.5	74.9	86.4	105.3	103.3	42.8
2009	42.2	100.1	68.1	57.5	55.4	52.0	0.4	60.6	95.7	185.8	140.5	88.7
2010	157.7	156.1	112.6	155.8	155.9	61.0	0.0	73.0	166.3	307.6	130.8	140.2
2011	47.9	45.5	111.6	136.0	164.7	114.7	44.9	169.0	217.3	121.6	88.9	197.7
2012	15.4	55.8	87.8	197.7	106.1	18.4	39.5	67.8	191.8	227.8	203.0	147.4
LTM	**61.7**	**75.8**	**122.4**	**128.7**	**103.5**	**56.2**	**26.4**	**94.2**	**171.4**	**163.8**	**152.4**	**124.5**
LTM=	Long Term Mean Rainfall											

As it illustrates in Table 2, even it is 100km away from the study site and has limited reference effects to the study site, similar problem of data missing and irregularly unusual data happens in comparison with the rest information. In other words, this could be an influence of real weather condition in this region.

Figure 56 is a graph of the long term monthly mean precipitation data in this continuous 14 years.

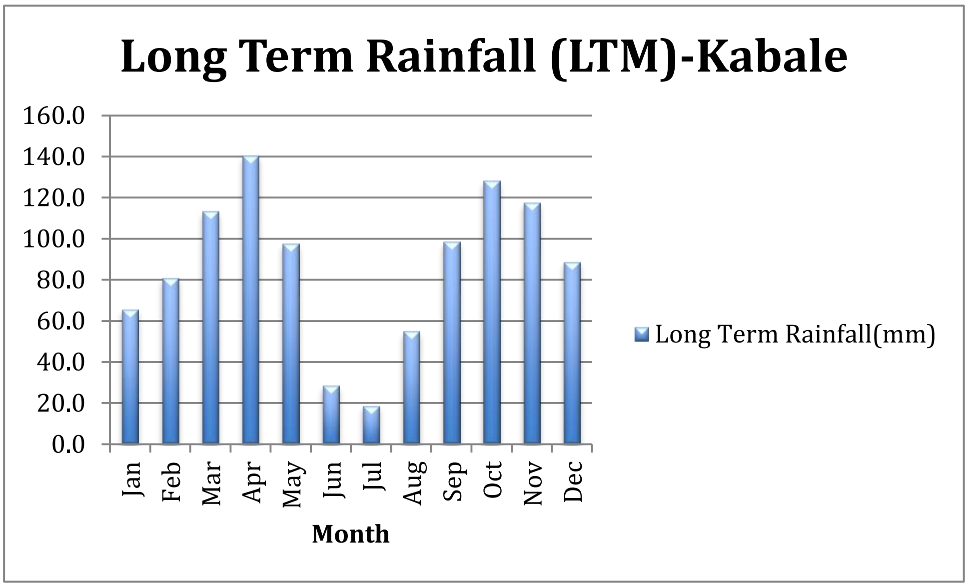

Figure 56 Long term precipitation data in average in Kabale

As is shown in Figure 56, a typical tropical climate in Muhanga has been shown by curve shape in this graph. It is generally rainy season particularly during the months of March to May, September to November, while dry seasons during the remaining months from December to February and June to August respectively. The dry season during January is a bit wetter than that in June and July. That's why the rainfall data is a little higher at the beginning of every year. Therefore, these obvious four seasons distribution bring up a perfect base for water harvesting system.

A rough estimate is that 50 % of the yearly rains fall in each of the wet seasons. 10 % is received during each dry season. Usually it falls more rain during the wet season from August to December and the drought in June and July is more severe than the one in the beginning of the year.

A similar shape curve is present in Figure 57 for Bushenyi town with a same looking 4 seasons. This also demonstrates the fact that the first dry season every year is a bit wetter than the other dry season in summer time.

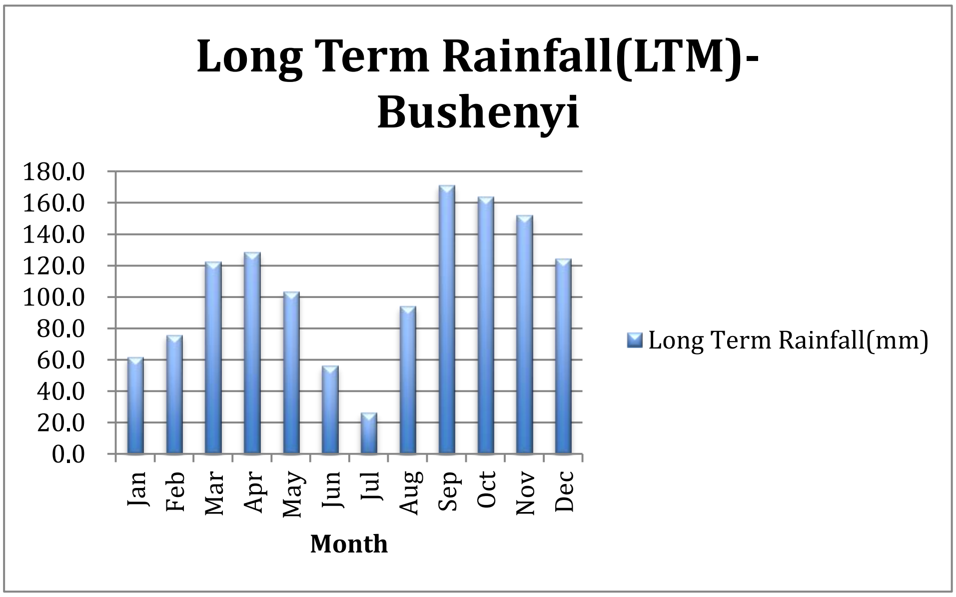

Figure 57Long term precipitation data in average in Bushenyi

In addition, Muhanga is close to the Equator in Tropics, which is a main suffering area for El Niño and La Niña episodes phenomenon. Both phenomenons cause global changes of both temperatures and rainfall. It is obvious to see extreme dry season and wet season in every few years in Kabale. This comes against the backdrop of climate change that is leading to disasters in form of droughts and floods. The frequency of these extreme weather events is increasingly becoming more regular. The closest one is in 2012. In January, there was only 2.8mm precipitation comparing to an average value of 65.6mm. Another irregular year can be 2007. In July, there was 114.3mm rain falling down in such a dry season contrasting with an 18.5mm value in 14 years, which is quite unusual relatively. Even the reasons for abnormal climate haven't been confirmed yet and there are always different opinions for it, these changes must be paid attention to from now on.

4.1.2 Flooding

Based on the results from modelling, a catchment area has been divided as 56,700m^2 in total contributing the flooding runoff around the site. A runoff coefficient for a ground catchment such as a maroon road is usually 0.2-0.7. 0.5 is a good number to use in this case.

Equation 1

$$\text{Captured water}\left(m^3\right) = \text{Rainfall}\left(m\right) \times \text{Area}\left(m^2\right) \times Rc$$

As the equation demonstrates above, if we choose an average long term rainfall data among 14 years, during the first rainy season in March, April and May, a total precipitation depth is calculated to 351mm; during the second rainy season from September to December, the rainfall depth is calculated to 344mm in total.

Based on the modelling result shown before, a catchment area of 56,700m^2 has been selected as a rainfall contributing area. According to Equation 1, a maximum total captured water volume during rainy season has been calculated:

$$\text{Captured water}\left(m^3\right) = 0.351m \times 56700m^2 \times 0.5 = 9950.6m^3$$

This volume will flow to the natural stream next to the school site.

If the rainiest month is chosen according to the average long-term rainfall, then the precipitation in April has been selected with 140.3mm. And daily rainfall can be estimated as

$140.3mm / 30 = 4.7mm / day$

Then the captured water volume every day will be:

$$\text{Captured water}\left(m^3\right) = 0.0047m \times 56700m^2 \times 0.5 = 132.7m^3$$

On account of site field measuring, a rectangular receiving area of 47.125m^2 with a width and length of 1.45m and 32.5m has been defined respectively. Therefore, an estimated water depth of rainfall water can be calculated:

$$\text{Depth} = \text{Volume} / \text{Area} = 132.7m^3 / 47.1m^2 = 2.8m$$

However, this value is absolutely much higher than the exact real case because of the receiving length and other influence factors, for example possible outflow and vegetation absorption. As a practical field investigation, not all the catchment water go to this small receiving area, there is an extending distance up in the north of school site with a flat apple tree field approximately 50m long. Therefore, if the receiving length is defined as 50m+32.5m=82.5m, with a width of 1.45m, a new estimated depth can be calculated as 1.1m/day. And this is the worst situation for the site with all the worst estimation with all the input in theory. However, in practical, the other 50m long area can’t have a receiving width with only 1.45m instead of 30m, which can decrease the value of site water depth rapidly.

So all in all, a daily flooding depth less than 1m can be estimated at the site mixing with soil and sand falling from the slope, giving rise to a high risk of landslides in the back.

4.1.3 Water Harvesting

For a more sustainable and environmental friendly future for Muhanga people in water resources, proper usage of rainwater recycling is suggested to be a solution. A rainwater harvesting system consists of three components: a catchment, a delivery system and storage. The catchment should ideally be a hard impenetrable roof surface that does not affect the quality of rainwater. Appropriate surfaces at the site are in general galvanized corrugated metal roofs.

The delivery system should transport the water as efficiently as possible and reduce the amount of dissolved and suspended material, organic or inorganic, entering the storage. Model plastic material gutters and pipes with proper inclination are considerable. Several technologies to improve the quality of the runoff have been developed. The simplest one consists of a fine mesh, removing large particles. More advanced systems hinder the “first flush” from entering the storage. The first flush is the first volume of water running from a roof during a rainfall and it contains high concentration of dissolved metals and bacteria generally. “First flush” technology can improve the water quality significantly but requires high technical skills to construct and constant maintenance, which is not usually recommended to be implemented in rural settings of east Africa.

The storage should protect water from contamination as well as ensuring supply during long periods of drought. Therefore, a proper volume depending of roof size, rainfall distribution and consumption is necessary.

Furthermore, “the human factor” also plays and important role in a rainwater harvesting system. Contamination can be caused by inadequate practices and should also be notified when implementing new systems.

Rainwater is normally quite clean, especially in rural areas with no industries or heavy traffic. Iron roofs are very good catchments since humans with deceases rarely come in contact with these surfaces. Pathogens can also be killed on a roof since the aerobic, dry and hot environment exposed to direct. However, roofs, as catchments, should be kept as clean as possible from organic matter and animal effects. Access by animals for example lizards and birds should also be taken care of. Chemical contamination may not be a big issuer in the site considering there is no heavy industry nearby. However, roofs might be painted with toxic paint, containing heavy metals. Good cares should be taken if roof is covered with lead paint to assess if the roof is suitable as a catchment. Leaves should be removed in flashing especially gutters and pipes.

Gutters can accumulate organic matter that could harbor pathogens (organisms causing human deceases). Organic matter and stilling water is also essential for mosquito breeding and can thus cause spreading of malaria. Leaves can also block the gutters, stopping water from entering the storage. If gutters have proper inclination and organic material is regularly removed, gutters will not jeopardize the quality of the runoff. Water from underground tanks should not be consumed without treatment due to the large risk of contamination, especially during the process of withdrawal. However, this recommendation depends on what the usage is. For example, if untreated water is not used for drinking, an underground tank provides water with comparably good quality.

Storage of water reduces concentrations of pathogens with time if there is no organic matter or sunlight is allowed to enter the tank, the microbes may “starve” to death. Natural purifying processes such as flocculation at surface and sedimentation will remove heavy metals and store them in bottom sludge. It is thus important that this sludge is removed once in a while and that the outlet is located some centimeters above the bottom of the tank. Therefore it is essential to cover all openings with a durable. Animals entering the tank can also spread pathogens and destroy the water when they die and rot. An interesting case happened in Uganda that a dead lizard was found inside the tank at the end of rainy season then the user had to empty his water tank all over.

Rainwater is slightly acidic with a pH below 5.6, depending of industries and traffic in the region. The use of cement in construction will increase pH to between 8 and 9 and thus make it more suitable for using and drinking. If organic matter is not present in the tank, clear water without any smells from a proper maintained roof catchment is probably safe to drink without treatment. However, most people boil the water before drinking it. Great care should be taken in construction and maintenance to decrease the amount of organic matter entering the tank. Deep boiling is recommended by the author, too.

When calculating the amount of runoff that can be harvested from a roof, it is common to include a runoff coefficient. This coefficient accounts for the fact that some roof surfaces are more efficient than others at collecting rainwater (Table 3). Runoff coefficient (Rc), a measurement of the efficiency of the system. The water that ends up in storage which is divided by the total amount of water that falls onto the catchment. If 6 liters falls on a roof and 3 liters end up in the tank, the runoff coefficient is 0.5.

For example, a pitched metal roof is typically the most efficient type of roof for collecting water, delivering 95% of the water that falls on it. Conversely, a flat tar-and-gravel roof is typically the least efficient roof type, delivering 80-85% of the water that falls on it.

Table 3 Runoff Coefficients for common roof materials

Runoff Coefficients for common roof materials	
Metal	0.95
Asphalt	0.9
Concrete	0.9
Tar and gravel	0.8-0.85

In a very light rain event, the runoff coefficient can equal to 0.00, since no rainwater will flow through your catchment system into the cistern.

In this case, roof material will be metal for the new resource center as it is the best material for water harvesting. 0.95 will be used in the following design chapter as runoff coefficient. Detailed design process with plan layout and calculation procedure will be demonstrated in Chapter 5.2.1.

4.2 Sanitation

4.2.1 Eco-san

Considering the practical situation and results from field work, even an eco-san toilet design can be used as agriculture fertilizer for school farmland; eco-san is not suggested for the resource center and new school buildings. In fact, eco-san systems can be "unsustainable" for example if there is too little user acceptance or if the costs of the system are too high for a given target group of users, making the system financially unsustainable in the longer term.

Additionally, there are plenty of disadvantages compared to pit latrines such as higher capital costs (although whole-of -life costs might be lower), more awareness required by the user who has to use it properly (no urination into faeces compartment) and react appropriately when the urine vessel is full, or there are problems with the urine soak pit and pipe or the faeces containers are full. Many users do not have an interest in handling their excreta which is an understandable reason. Also for fertilizers, according to my questionnaire, the locals prefer to buy organic manure more than making ecological fertilizer from the excretions.

4.2.2 Decentralized Wastewater Treatment

Decentralized wastewater treatment can also be a way to consider even no one is using it in suburban area in Muhanga except some of the hotels. It consists of a variety of approaches for collection, treatment, and dispersal/reuse of wastewater for individual dwellings, clusters of homes and entire communities. Uponor Small Scale Treatment Plant (Uponor, 2015) and Alnarp Cleanwater Technology (Cleanwater, 2015) have both been considered on the site as a replacement for traditional dry latrines.

There are a number of advantages and disadvantages for decentralized system. On one hand, it is a green and sustainable way to handle wastewater particularly for small scale group of people; but on the other hand, sometimes it is a bit complicated for uneducated users to maintain the whole system working in a good condition, especially for people in suburban area in Africa with little education. Moreover, it may have some problems for installation and operation of this kind of system in tropical countries without a stable electrical network and dozing material supply.

4.3 Slope Handling

Looking at the deep slope, promote a multi-functional use of storm water management systems is immediately preferred in order to solve the slope problems. Resources such as land and water are becoming increasingly scarce, and multiple usages of them must be strived for. Creating a storm water system for the slope

handling and providing a wide range of opportunities for multi-functionality.
Short-term involvement need to be thought of at the beginning and considered the sustainability of the measure. All relevant factors that will impact on future operation and maintenance should be taken into account. Maintenance requirements should be minimized as far as possible in order to maximize the available local authority funding, personnel and equipment. Responsibilities for maintenance must be resolved with the relevant local authority department at an early stage of the design.
A ditch and retaining wall could be a temporary solution for the site. However, instead of constructing a ditch or wall, a combined idea could be used to improve the quality of natural and urban environment. The development of land use, conservation, can be alleviated by combining compatible land uses by recreating storm water systems. For example, walking trails and roads can be considered on the slope as a water contributing way.
Environmental policies such as promoting the use of locally indigenous vegetation in planting programs will also reduce the long-term maintenance requirements of the development.
Vegetation is also named as 'Soil Bioengineering'. It is a method related to the use of biology to reduce and modify the impact of nature damage. This discipline is used for remediation of landscape damages. Vegetation can consolidate the soil by root system, change hydraulic effects (turbulence) against erosion and the effect of microorganisms on soil structure.

5. Local storm water solutions

5.1. Existing Building

5.1.1 Renovation Work Proposal

One of the most important works to do in Muhanga was the renovation work. The whole project had a very limited budget this year for renovation in order to prevent rain erosion and flooding from backside of the building. When the field study group arrived at the site, erosion was even worse than any time before. Therefore, after talking with local people and concerning the local materials market, the actual construction work was a bit different from our design at the beginning about roof gutter and ditches.

(1) Roof gutters
Gutters are recommended under the roof to save the house from rainwater running from the roof, splashing from the ground towards the walls and collecting around the slab (Figure 58).
Wood has been used traditionally in Swedish constructions but the amount of water

and the higher temperature makes it risky. There is always risk for water leading to the walls where the gutters are attached if the pipes are leaking. Wood gutters works with the same method as wooden boats, when it gets wet it swells and stops leaking. Since the gutters are hanging outside they also get time to dry which helps them not to become mouldy. Wood is an experiment but maybe the only solution the project budget can afford right now.

The attachment of gutters meeting roof and wall must be further investigated at site, considering the existing roof structure (Figure 59). Steel is the most common used material as roof gutters, however, wood might be a cheaper solution.

Figure 58 Roof gutter installed in Sweden

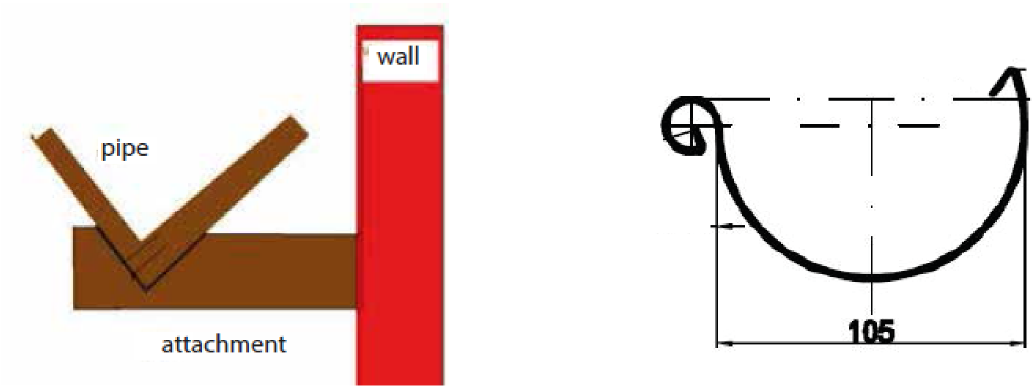

Figure 59 Examples of gutter shape

(2) Ditch

A section of the sloped condition and the existing building is shown in Figure 60. The reason why to build a ditch is so that the rain water can flow around the building during heavy rain. It is believed that a ditch filled with stones will be good enough to lead the water away from the building.

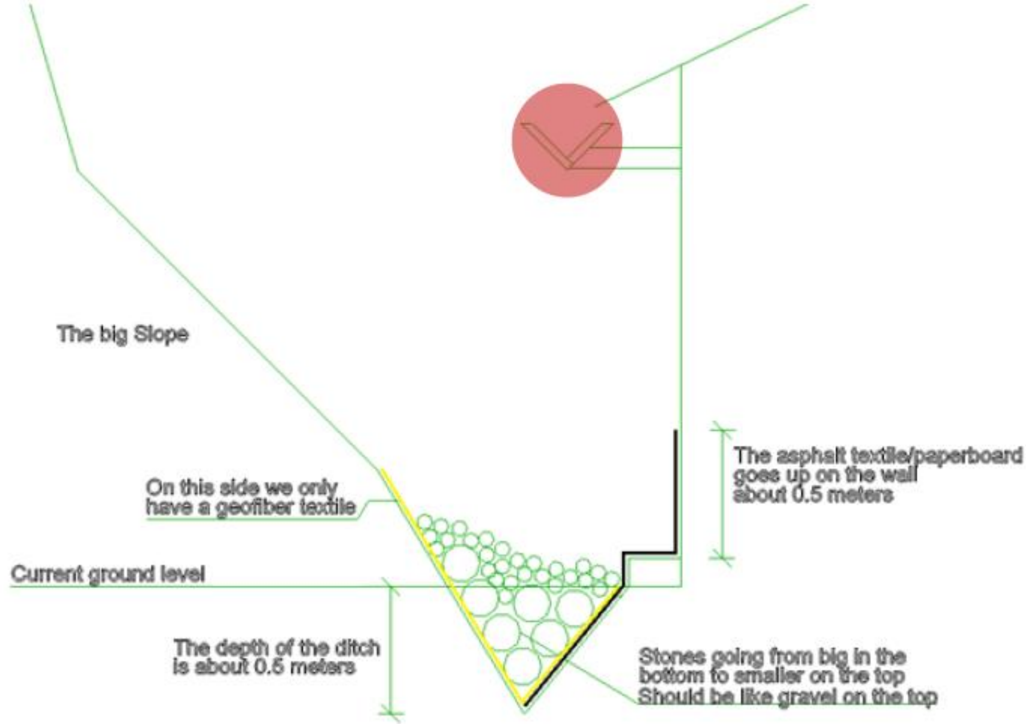

Figure 60 Ditch proposal

The reason for choosing an asphalt/tar paper is that during a worst case scenario the water will flow down the hill and on to the wall, but will then continue to flow around the building. The asphalt/tar will stop the water from being absorbed by the wall thus avoiding further water damages on the building. The Geofiber textile will stop clay and mud from the ground from clogging up the space between the rocks and there for allowing water to be transported in the gaps between the rocks.

The big stones will allow for water to pass in between the gaps they create. The smaller stones will allow for easier maintenance and so that people can walk on it, the ditch might otherwise become a trap. We calculate it to be about 8 m^3 of stones in total inside the ditch.

Figure 61 shows a previous plan of overview of the ditch. The ditch will run between the slope and the building and continue on both sides of the building all the way out to the smaller slope. So the water will flow around the building and down to the platform.

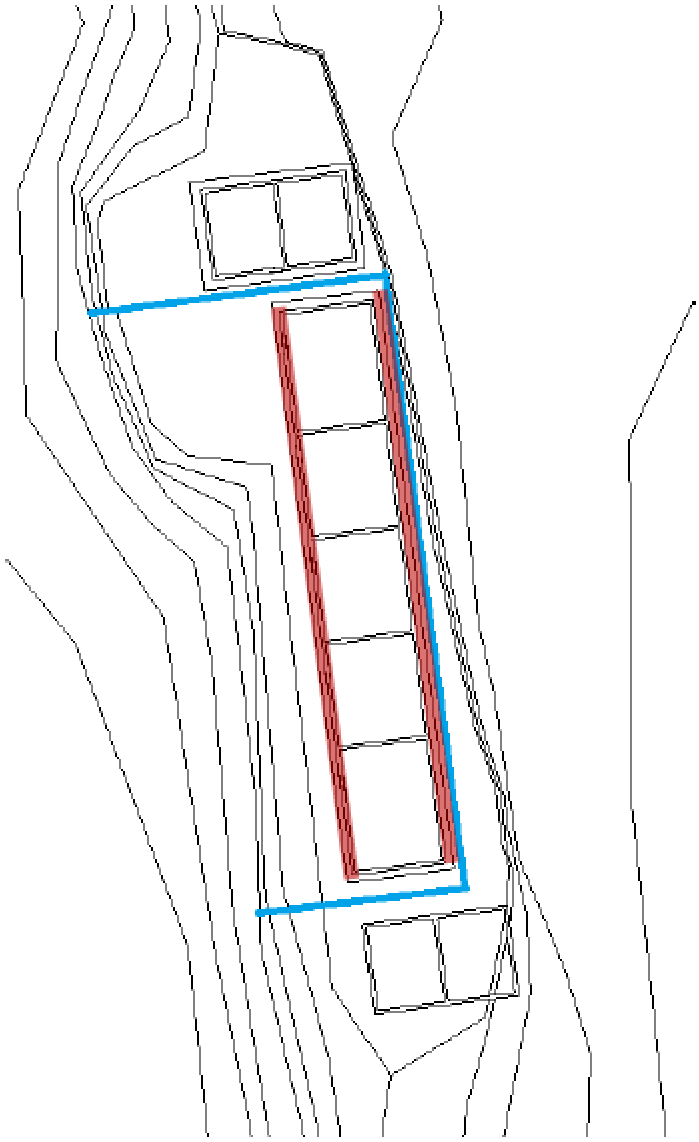

Figure 61 Plan of gutter and ditch proposal layout

BLUE: Shows where the ditch will be dug
RED: Shows where gutters will go
YELLOW: Shows where the Geofiber textile will be placed
BLACK: Show where the Asphalt/Tar paper will be placed

5.1.2 Implementation Work

PVC roof are available on local material market as the choice of gutters (Figure 62). Wood has been considered before since it's quite common material for construction in that region and cheap, but the whole cutting and installation process will take longer time and be more complicated. Eventually it is accepted by a local engineer's suggestion to choose PVC pipe and gutter to meet the expectation and budget.


Figure 62 Water test after the Installation of roof gutters


Figure 63 Renovation work

Figure 64 Construction of ditches and roof gutters

The ditch has been done almost as expected, but in a different shape without putting small stones inside comparing to the old design schemes (Figure 63,64) and without

Geofiber textile and asphalt for some reasons.
The problem is that these kids like to play in the area between office building and classroom building. So if the ditch is constructed in that place, kids can easily get fall down and it will be quite dangerous. Additionally, places for them to play will get smaller and smaller. Then the ditch has been laid to run on the backside of the office then there won't be any problems.
The left side of office building seems just possible for a narrow ditch to be located through the corner of left backside of office building. And it's better to make the water flow in this direction more than the right side. The reason is that there will be mushroom breeding plan room over there. A fence is immediately needed after the ditch work to prevent kids entering.
Moreover, soil and clay from slope have been doubted if they will fall down into the ditch to fill up the gaps between each small stones inside the ditch then block the water flow in rainy season then everything will become useless. At that time it was approaching the rainy season and sometimes a small rain came up which was pretty good for stabilizing the left side of the ditch. Then soil might not be easy to fall into the ditch and efficiently isolate the building wall. It looks ugly but worked well. Hopefully we will put asphalt this year as a water-proofing layer on back wall and right side of the ditch. Geofiber textile is not a common construction material in Uganda because of its high prices.
However, due to a mistake of the workers, the downpipe was installed on the middle of school building, forcing an outlet to the walk path in front of the building which is used to a playing ground for kids. In order to secure the safety of kids and passengers, a trapezoid shape trench has been dug with a width and depth of 50cm. Stones are going from big in the bottom and smaller on the top for example gravels. The big stones will allow for water to pass in between the gaps they create (Figure 65). The smaller stones will allow for easier maintenance and so that people can walk on it (Figure 66).

Figure 65 Ditch construction in the front

Figure 66 Front ditch with stones and gravels

There are always difficulties while doing renovation and working with local people in Africa, for example materials, quality, communication with local workers, building standard, but these are all meaningful and unforgettable experience for me to learn and get through.

5.2 New Resource Center

5.2.1 Water harvesting

This system is based on a large storage, designed to supply a household or school with domestic and productive water through major parts of the dry season and rainy season.

(1) Materials and construction
Tanks can be constructed of metal, polythene plastic, concrete, ferrocement and bricks in different types for example ground or underground. Metal tanks have low life span together with polythene and tarpaulin lined tanks. Houses will low capacity requirement often use plastic tanks. Reinforced concrete is usually the most expensive technology together with pre-manufactured plastic tanks. Concrete can though have a life span of hundred years. Bricks and ferrocement also suffer from low water quality since they are located below ground. Ferrocement is a great technology that can be comparably cheap but requires skilled artisans to be durable and efficient when it comes to material use. Brick tanks use local material, possibly making them cheaper than ferrocement, and can have long life span if correctly constructed.
Tanks are either above or below ground level. Above tanks are in general more expensive than underground tanks since they need extra reinforcement without the support from surrounding soil. They can neither be constructed in spherical shapes. For large tanks up to 100 m^3, costs can be significantly higher for above ground tanks. However, soil conditions needs to be established for underground tanks and not all locations are suitable. Excavation might not be possible. Inflowing ground water can carry pathogens from nearby latrines and some sort of withdrawal system is necessary which can reduce the quality of the water. Leaks are also harder to locate compared to an above ground tank where moist patches on the outside reveals any leakages.

(2) Volume design
The possible volume of stored water is limited by rainfall, roof size and consumption together with efficiency of the system. However economical resources often determine the design of the storage volume, which is the major cost. Since the climate is characterized by two distinct rain seasons in Uganda, a large storage is needed to provide water throughout the year.
Most people cannot afford such big investment but also smaller tanks can be helpful and reduce the time spent on fetching water during large parts of the year. Rainwater harvesting is the most appropriate when the rain that falls on the roof which is greater than the consumption. When these conditions apply, theoretically the demand can be met throughout the dry season and rainy season. If consumption exceeds supply, rainwater harvesting systems can only meet the demand during parts of the year. For such conditions one should not build large tanks which these tanks will not fill up.

For roofs the runoff coefficient is around 0.85-0.95.
Factors that need to be considered during water harvesting design:
- Horizontal projected area (Area) is the area perpendicular to vertical rainfall. The shaded area when sun is in zenith. This area is multiplied with rainfall to get volume of rainfall.
- Rainfall, usually in mm.
- Internal radius (r) of a tank is the distance from the center of a tank to the inner wall, in meters.
- Height (h) when determining storage volume is the vertical distance between the tap and the overflow pipe.
Equations used for volume design:

$$\text{Captured water } \left(m^3\right) = \text{Rainfall } \left(m\right) \times \text{Area } \left(m^2\right) \times Rc$$

Equation 2

$$\text{Total domestic use } \left(m^3\right) = \text{Usage per person and day } \left(m^3 / \text{day}\right) \times \text{persons} \times \text{days}$$

Equation 3

$$\text{Storage volume } \left(\text{cylindrical tank}\right) = r^2 \times Pi \times h$$

Equation 4

$$\text{Storage volume } \left(\text{half sphere}\right) = 2/3 \times r^3 \times Pi$$

The idea is to give a maximum size to avoid tanks being overdesigned, which has been a problem in some locations. The maximum volume is hard to estimate. Some years later, these tanks will overflow as the increasing users. But investing in a larger tank will be economically inefficient. Tanks are not able to be filled up during some seasons; however, it is likely that house owners will expand their house in the future. Then this should also be taken into account, as a larger tank could be built with the future expansion in mind. As long as there is a hard surfaced roof, a small tank of 1 m^3 could always be useful. But to build larger tanks than 3 m^3, the consumption needs to be compared with the captured water for sure.
Following aspects will determine the size of a tank:
- Rainfall, how much rain falls during the rainy months.
- Consumption of water per person.
- Future expansions that could be used for rainwater harvesting (hard surfaces vertically above and close by the exiting tank).
- Economy and objectives of the farmer.

It is important that the tank should be placed not far from the structures. Taps can be attached next the bottom but with a small distance in order to avoid drinking the ‘dead water’ volume.

A master plan of the site has been showed in Appendix 2.
Taking into account all the functions the new resource center needs to have including classrooms, theater, playroom, libarary, gathering room, dormitaries, toilet, workshop rooms, headteacher office, administration office, storages, first aid resting room, guard place, dining room, kitchen, etc. A whole roof area for water harvesting has been calculated with 797.94m^2, which can be estimated roughly with 800m^2.

Example, determining proper volume
If the new resource center has a roof area of 800 m^2 with a water consumer's number of 50, including students, teachers, workers, sewing girls and volunteers. Assuming the precipitation during a rainy season is 117mm/month in average distributed over the whole site with the largest rainfall 207.8mm. 0.95 has been selected as the runoff coefficient for metal roof. The domestic consumption is around 100L/day/family according to workshops with municipality people and school students, details are illustrated in Appendix 2. Over the month the consumption will be 3 m^3.
The captured precipitation during each rainy season (3 months) will be:

$$\text{Captured water}\left(m^3\right) = 0.117m \times 800m^2 \times 0.95 \times 3 = 266.8m^3$$

It is a huge amount of water by estimation for the best cases. If cylindrical tank is chosen, assuming a tank height of 3m, by Equation 3, a diameter could be calculated approximately as 10.6m.
Assuming one family has 5 people, then the average water consumption will be 20L/day/person, and this is the worst case for school students because most of them don't stay in school overnight and take showers there. Therefore, a total estimation for school water consumption per day will be:

$$50 \times 20L = 1000L = 1m^3$$

Then for a month, the consumption will be 30m^3. As for one dry season, if we consider 3 months, the water consumption will be 90m^3, which is much less than the water we can collect with 266.8 m^{3}during the former rainy season. Even it can also cover a water usage for another 3 months for the rainy season with 180m^3, too.
Thus the family will have water throughout the dry season also during the rainy season.
For the first phrase of master plan, a house with an area approximately 209m^2 will be constructed in the first place. Therefore, an estimation of 70m^3 of rainwater could be collected as a best result. The diameter for this tank will be 5.4m in cylindrical shape.

Instead of a huge water tank, taking account of the scattered building distribution in the master plan and their different functions, each building deserves to have their own small water tank for various usages.

5.2.2 Sanitation

After a comprehensive discussion with the design team members and local people, considering a practical situation at the site, dry latrine has been selected finally as a preliminary choice for sanitation solution. Due to a lack of site plan design details, latrine location can't be decided right now.

5.2.3 Slope Handling

Depending on how the architecture design type looks like, there are always various ways to handle this problem.

(1) Retaining Wall
A retaining wall could be combined with structural design of new resource center. One of the design proposals is shown in Figure 67 as the retaining wall version. Concrete material is suggested in this design for the retaining wall in order to consolidate the slope stabilization. But the reliability of retaining wall needs to be evaluated in reality.

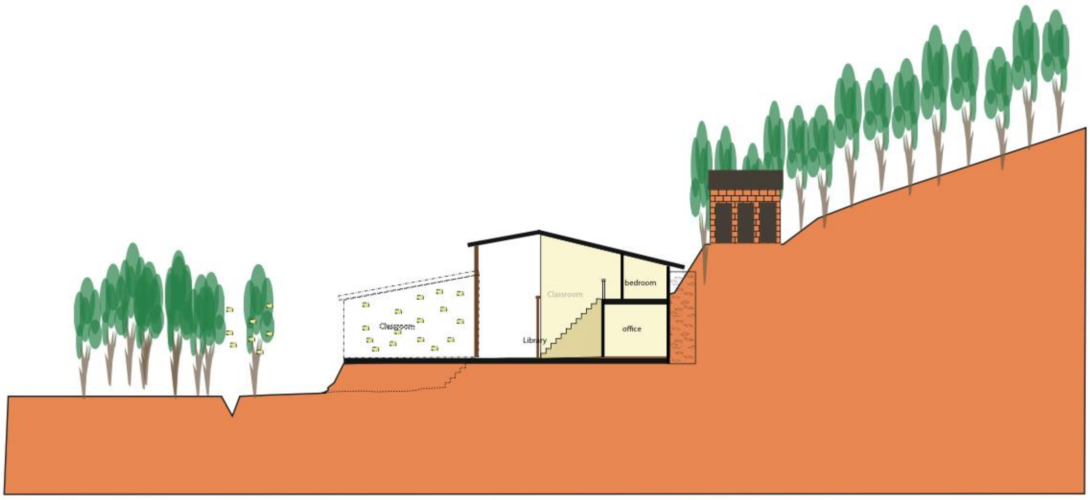

Figure 67 Retaining wall proposal

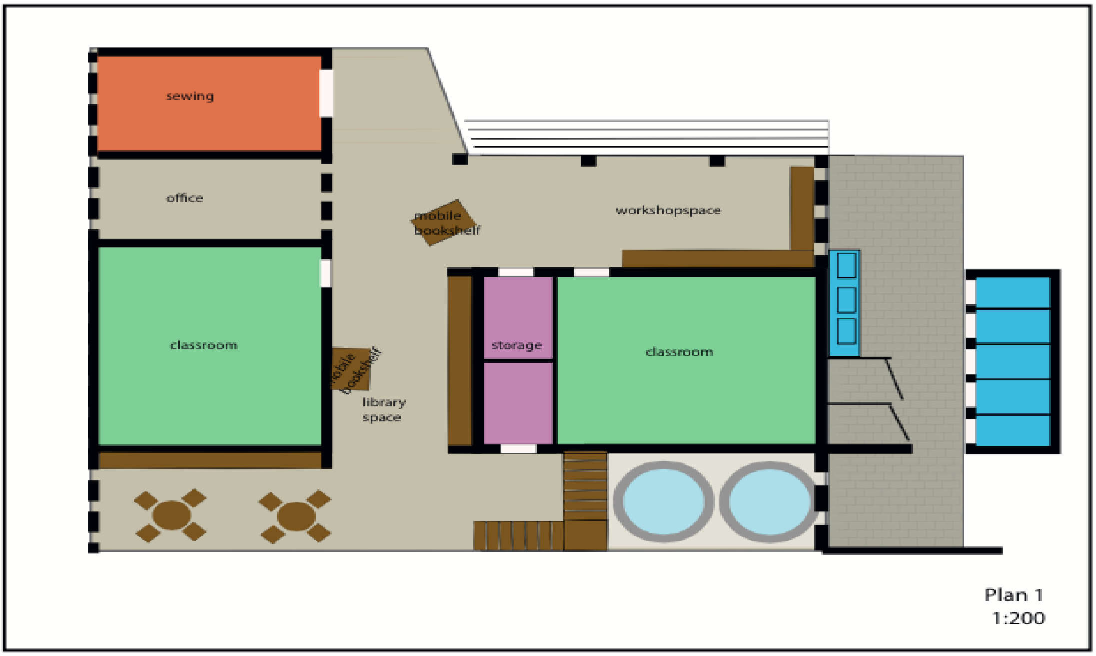

Figure 68 Plan view

In this proposal, water tanks are put behind the retaining wall solving a water shortage problem (Figure 68).

(2) Wood Structure

Another proposal handling the slope problem is to increase the level of foundation by using a wood structure. Therefore, the slope risk could be decreased by this design if a ditch can be dug on the bottom (Figure 69).

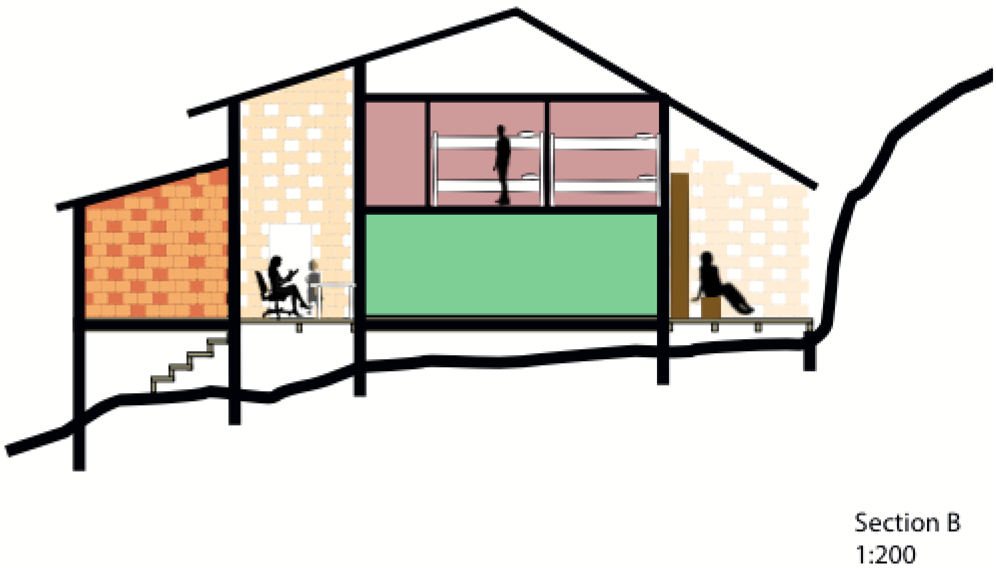

Figure 69 Wood structure proposal

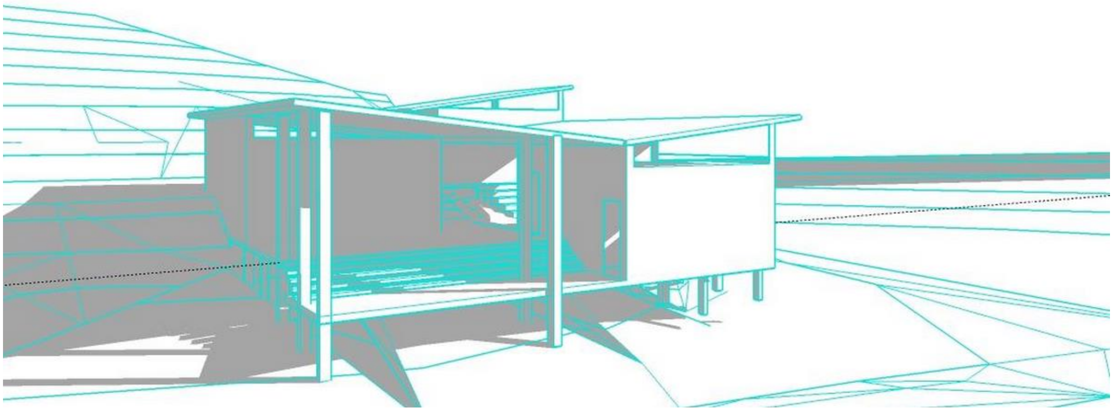

Figure 70 Wood proposal on the other side

However, even the risk of flooding and landslides have been reduced, this proposal also brings up to new problems for the building structure such as erosion by water, termite damage and foundation gap clogging (Figure 70).

(3) Vegetation

Vegetation must be the most sustainable method of dealing with slope issues (Figure 71).

Figure 71 Remediation of a slope failure/landslide in Germany

Figure 72 Example of slope stabilization in Germany

Nevertheless, there are a number of important aspects required to be considered for successful soil bioengineering works. Every time from the beginning, considering the planting season times for the different procedures, it requires long development period for reaching the full protective function; meanwhile, the existing vegetation is also the priority for protection. When the work is about to complete, protection of the growth and care for vegetation development for example stimulation of the plant efficiency are always needed.

6. Limitation of the Study

6.1 ArcGIS

The original DEM data, SRTM data, is a raw DEM data being derived from radar, represents the elevation of the first-reflected surface — quite often tree tops. So the data are not necessarily representative of the ground surface, but the top of whatever is first encountered by the radar. The limitation with the SRTM datasets is that they cover continental landmasses only, and it does not cover the Polar Regions and has void areas in some mountain and desert.
In general, this doesn't influence quite much for this study area close to the equator.

6.2 Field Study

Participatory rural appraisal has been conducted through the whole process of field study in Uganda. However, there could also be drawbacks by using this method.
It has taken so long for the author, the author, as an 'outsider' to have an idea of the knowledge of villagers and their creative and analytical abilities. In the theory of PRA, much of the mystery disappears if explanation is sought not in local people, but in outsider professionals. For the beliefs, behavior and attitudes of most outsiders have believed that their knowledge is superior and that the knowledge of farmers and other local people is inferior; and that they could appraise and analyze but poor people could not. Many outsiders then might interview by asking rapid fire questions, interrupting, and not listening to more than immediate replies, if that outsiders' reality could blanket that of local people. On one hand, as outsiders' beliefs, demeanor, behavior and attitudes are then self-validating; on the other hand, poor people whom are treated as incapable behave as incapable, reflecting the beliefs of the powerful, and hiding their capabilities even from themselves. Nor do many outsider professionals know how to enable local people to express, share and extend their knowledge. The ignorance and inabilities of rural people are then not just an illusion; they are an artifact of outsiders' behavior and attitudes, of the arrogant and ignorant manner of interacting with local people. For participatory approaches and methods to

take off, a stage has also to be reached when different conditions can come together and recognizing of past error and inadequacy. The most important element of all has been the insight that in facilitating PRA, the behavior and attitudes of outsiders matter more than the methods and their exact performance. Perhaps it is understandable that it has taken so long for these participatory approaches and methods, in many forms and with many labels to evolve, cluster and coalesce, and to spread, as philosophy, repertoire and practice.

In reality, the author has tried the best to avoid this situation without leaving any pressure or arrogant impression on the local people. However, sensitive words might come out by accident without any notice, which may result in conservative responses from the locals. In other words, inaccurate information could also be provided by them or unfaithful materials, so is the site estimation.

Therefore, this may increase the difficulty and reliability of carrying out PRA.

6.3 Funding

The limited project budget restricts the creativity and efficiency of the final implementation master plan. Even it worked quite well after the renovation; annually maintenance work is still required, which gives a huge inconvenience for the users at site. If the budget can achieve a certain level, then a more efficient plan and solution will be proposed in a better way with less maintenance.

7. Conclusion

This paper describes the process of looking for local solutions for storm water management in Muhanga shalom primary school, Uganda by using computer modeling with ArcGIS hydrology tool and participatory rural appraisal (PRA) field study methods, consequently come out with several feasible solutions for water problems on site.

A watershed area 56,700m^2 of storm water runoff has been modeled by ArcGIS hydrology tool which is the contributing area of flooding landslides at the backside of school building. Ditch proposal and roof gutter proposal have already been implemented on site this summer when I was in Muhanga. The whole rainwater system is functioning quite well in the coming rainy season. However, leaves clogging and water detention have become a new problem which needs to be considered in the future.

A water harvesting system has been designed in new resource center proposal by collecting 266.8m^3 rainwater which is sufficiently enough for school users during rainy season; dry latrine has eventually been selected as sanitation solutions after comparing with eco-san and decentralized wastewater system on account of the site situation; retaining wall, wood structure and vegetation proposals have been put

forwarded aiming to give rise to new flooding and landslides issues.
Nevertheless, limitations in methodology especially in computer modeling and field study still exist during my research by inaccurate raw data and site work process. Therefore, a number of recommendations are brought up for future works and researches with a purpose of solving water problems on site and making Muhanga people live in a better life.

8. Recommendations

8.1 Computer Modeling

In field study with ArcGIS, difficulties have been accompanying all the time. A long time has been spent in searching for high resolution DEM maps. However, there are only a few places in the world to get free DEM data and there are not any options. 90m grid length DEM map is one of the highest data that could be found for free. The higher resolution it is, the better simulation of hydrology situation there will be for hydrological analysis. Considering the site area is quite limited, smaller grids are strongly needed in modelling. Therefore, if there is a sufficient budget, more accurate and finer DEM map data is highly recommended in future works.
Additionally, ArcGIS hydrology model is still a model only considering geological map data as input in regardless of other influence factors such as soil types, vegetation, human activities, hydrogeology, climate, etc. Even a combined method with PRA for field study increases the reliability of computer modelling; a more comprehensive model is still suggested for similar study in the future if data collection can be achieved completely.

8.2 Field Study

Participatory Rural Appraisal has been described as a growing family of approaches and methods to enable local people to express, enhance, share and analyze their knowledge of life and conditions, to plan and to act. Nevertheless, due to the limited time of staying at the site, it was quite hard for people to prepare so well for every workshops and interviews with the local. Drawbacks and pities are still existed quietly among the field study.
As an outsider, in order to get as much information as possible in a short time, sometimes the author was in a hurry and inpatient during talking, chatting and data collecting process, which might create an unseen wall between the interviewee and interviewer, resulting in inaccurate instructions. Communication skills need to be improved in the future. In addition, a more structural plan for field study needs to be taken into account with much more detailed schedule, for example on which day to do

which work or interview which people with which theme and agenda, etc. Even though plans can never catch up with the changes, a full consideration of everything is always welcome.

8.3 Site Plan

8.3.1 Renovation Work

Ditch proposal and roof gutter proposal are working quite well according to some recent updated emails from the project coordinator in Uganda. However, leaves clogging in gutters and downpipes are becoming a new problem for water flow (Figure 73); Moreover, the permeability and productivity of earth soil on the ditch surface are lower than expected, plus a poor standard construction work of local workers for digging without a perfect gradient, sometimes after heavy rains, water could be retained inside for several time but never overflowing (Figure 74). Hence, regularly maintenance work of gutter and ditch is suggested for site guard after heavy wind and rain.

Figure 73 Roof gutter blocking

Figure 74 Water retained in ditch

8.3.2 New Resource Center

The whole design plan for the new resource center is still under discussion and hasn't accomplished yet. But a more feasible and simple new resource center and storm water solution is highly recommended as a person who has been to the site for a long time. The field group strongly understands how hard their life is and what kind of education they experience. It is not expected that they can construct a house or make any construction in a ‘Swedish’ way. Participatory construction work will be conducted according to our plan in order to assist and teach the locals a better way of doing constructions and maintenance. However, the Swedish group can’t stay in Uganda forever. Therefore, a site plan design and solution must be as simple as they can handle and understand, but function as well as a ‘Swedish’ resource center.

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10. Appendix

Appendix 1 Interviews with 6 school head teachers

a. Risorooza Primary School
The school is constructed in an uphill area and has no flooding problem because of a wonderful topography. There is a rainwater harvesting system in the school constructed by US AID in 2002. A concrete water tank around 10,000L. Even it was just early-August when I was visiting there, the head teacher said the tank started turning empty 2 month ago in June. The last rainy season in 2014 was the end of April. Water is not enough for them at all. After using up, they fetch water from a public well 500m away every day. And they always boil water before drinking instead of drinking it directly. There is a small agricultural field near the school building planting Irish potato and maize. The school has 168 students at that time and 9 staff. The head teacher didn't suggest eco-san in the school as the large volume they need and high requirement of maintenance. And it was costly around 2 million Ugandan shillings according to him.

b. Muhanga Primary School
The school is situated on the way to Risorooza Primary School. They have had a water harvesting system with a water tank. But right now the pipes were blocked for months. They stopped using it 2 year ago and they were fetching water 80L from a spring 250m away every day. They had a time table of all the students and staff doing it sequence. In rainy seasons, they collect water drops from the roof sometime for other purpose but they don't have gutters for it. Nowadays at the school, water are mostly used for drinking, cooking (for staff), washing (students). They only drink boiled water. There are 460 students and 10 staff in the school right now. There is no electricity in the school but the church has which is nearby. They don't have enough land for agricultural thing and no cost for eco-san. Traditional latrine has been used at the school but they have a VIP one which has a vent pipe down. No flooding problem in rainy season since it’s in half hill. The fund is from government since it's a public school.

c. Muhanga Modern School
This is the best school in Muhanga. It's a primary school with its boarding department funded by organization. They buy tap water from some place with 3300,000 Ugandan shillings every month for unlimited water. There are 330 students at the school and 169 of them are boarder students. Staff is around 20. They use water mostly for washing, bathing, cooking and drinking (boiled). They have a kitchen at the school for 3 meals every day. Depending on how much you pay for the tuition fee, you get different meals at school. This is the only school I've visited saying they have enough

water in any seasons. And it has a great position up in a small hill behind the trading center in Muhanga without any flooding problems. There is an agricultural field in the school planting cabbages and any other green vegetable. They don't use chemical fertilizer but composting product. Dry latrines are used. The head teacher didn't recommend eco-san for them because he thought it was too small amount of volume for all the students and staff. Sometimes they collect roof rainwater for washing. And they are planning to construct gutters for some building. The interesting part is that most school buildings are built by wood. The head teacher said they were temporary and they would have new plans for new buildings in the coming future.

d. Golden primary school

I didn't do interviews and workshops here, just got some information about the school. There are 198 students and 13 staff. What impressed us was the entertainment group with singing and dancing interest teams. They even have a drama group!

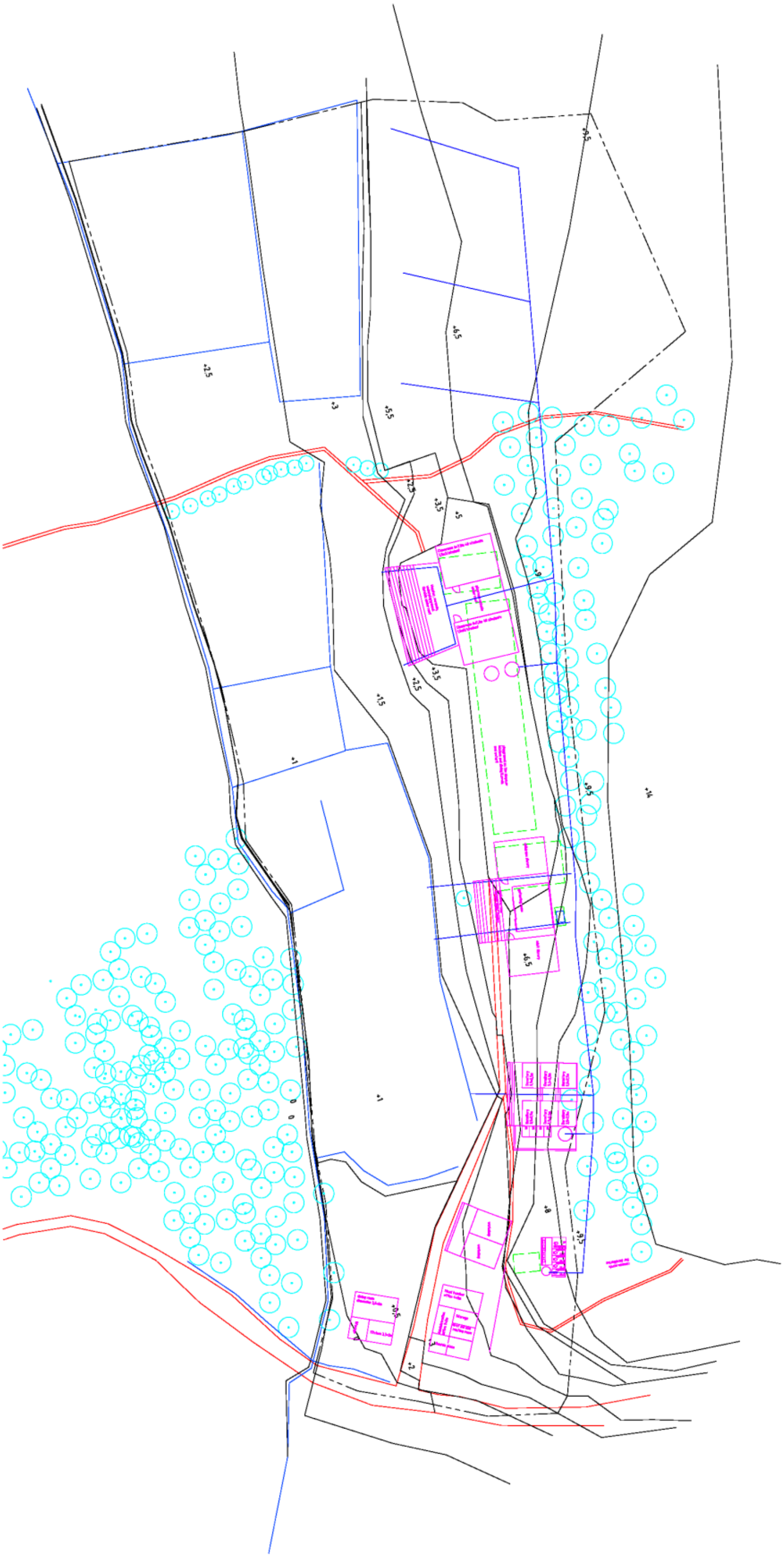
e. Step by step school

This is where Junice (The previous teacher) went to work. The school is located in a church in an up-hill next to Anne's brother's house which was opened up in May 2014. Right now they fetch water from a well 500m away every day with 20L. There are only 28 students who are ranging 4-7 years old. Junice is the only teacher there. They drink boiled water, and use it for washing hands and cleaning. The water is not enough for them and they are lacking of money for everything right now.

f. Nyakitabira Annex School

This is the farest school I've went to. It is on the road to Nyakitabire. It is a church school. The staff fetches spring water every day for 40L. There is a water harvesting system for the church building with a huge water tank. But it is not free. There are 70 students and 4 staff. They don't provide food for lunch. Just use water for drinking (boiled), washing, cleaning. The roof is leaking that I could even see the hole on it. Church shared traditional latrines have been used. No flooding in rainy season. No farmland.

Appendix 2 Masterplan of new resource center



Appendix 3 Water harvesting workshop with school students

a. Nyakitabira Annex School			
	Mugiimenka Desire	Byagaba Ben	Akanelwanaho Sunday
Age	10	10	12
Grade	P4	P3	P4
What is your water source at school	Gravity water	Gravity water	Gravity water
How much water do you drink every day at school (on average)	2L	2L	1L
How much water do you want at school (on average)	10 Jelecans	10 Jelecans	10L
What do you use water for at school	Cooking food,washing	Cooking	Cooking food
Do you have enough water during dry season at school	No	Yes	Yes
How many times do you go to toilet every day at school(on average)	2	2	2
Have you heard about water harvesting			
Have you heard about eco-san			
Do you have agricultural field at school; If you have, what plants do you plant.			
Can you describe or draw a picture about the school during dry season.			
Can you describe or draw a picture about the school during rainy season			

a. Nyakitabira Annex School	Nzeimaana Juliana	Ampeire Vivian	Anyikukire Rinah
	10	9	10
Age	P4	P4	P4
Grade	Gravity water	Gravity water	Gravity water
What is your water source at school	1L	1L	1L
How much water do you drink everyday at school (on average)	10 Jelecans	10L	10 Jelecans
How much water do you want at school (on average)	Washing, cooking food	Washing,cooking	Cooking food
What do you use water for at school	No	No	No
Do you have enough water during dry season at school	2	2	2
How many times do you go to toilet everyday at school(on average)			
Have you heard about water harvesting			
Have you heard about eco-san			
Do you have agricultural field at school; If you have, what plants do you plant.			
Can you describe or draw a picture about the school during dry season.			
Can you describe or draw a picture about the school during rainy season			

a. Nyakitabira Annex School			
	Owihoeere Kellin	Nyeturitze Evciline	Mwahereza Masiko
Age	10	12	11
Grade	P4	P4	P4
What is your water source at school	Gravity water	Gravity water	Gravity water
How much water do you drink every day at school (on average)	1L	1L	4L
How much water do you want at school (on average)	10L	10L	10L
What do you use water for at school	Washing hands	Washing hands	Washing hands
Do you have enough water during dry season at school	No	No	No
How many times do you go to toilet every day at school(on average)	2	2	2
Have you heard about water harvesting			
Have you heard about eco-san			
Do you have agricultural field at school; If you have, what plants do you plant.			
Can you describe or draw a picture about the school during dry season.			
Can you describe or draw a picture about the school during rainy season			

a. Nyakitabira Annex School			
	Busingye Allen	Turinawe Unity	Atukunda Joon
Age	9	10	13
Grade	P3	P3	P3
What is your water source at school	Gravity water	Gravity water	Gravity water
How much water do you drink every day at school (on average)	1L	1L	1L
How much water do you want at school (on average)	20L	3L	3 Juces
What do you use water for at school	Cook		
Do you have enough water during dry season at school	No		No
How many times do you go to toilet every day at school(on average)	1	2	2
Have you heard about water harvesting			
Have you heard about eco-san			
Do you have agricultural field at school; If you have, what plants do you plant.			
Can you describe or draw a picture about the school during dry season.			
Can you describe or draw a picture about the school during rainy season			

b. Risorooza Primary School	
	MuJuni Hirally
Age	13
Grade	
What is your water source at school	Rain tank
How much water do you drink everyday at school (on average)	2L
How much water do you want at school (on average)	2L
What do you use water for at school	Washing hands, cleaning classes, cleaning toilets,cooking
Do you have enough water during dry season at school;Reason	No;Too much sunshine, no rain no water
How many times do you go to toilet everyday at school(on average)	2
Have you heard about water harvesting	Yes
Have you heard about eco-san	No
Do you have agricultural field at school; If you have, what plants do you plant.	
Can you describe or draw a picture about the school during dry season.	
Can you describe or draw a picture about the school during rainy season	

b. Risorooza Primary School		
	Niwaherezo Nabolh	Kyasimire Rossete
Age	15	10
Grade		
What is your water source at school	Rain tank	Rain tank
How much water do you drink everyday at school (on average)	2L	1L
How much water do you want at school (on average)	2 cups	2 cups
What do you use water for at school	Washing hands,sweeping	Cooking
Do you have enough water during dry season at school;Reason	No;Too much sunshine, no rain no water	No;Too much sunshine
How many times do you go to toilet everyday at school(on average)	1	2
Have you heard about water harvesting	Yes	Yes
Have you heard about eco-san	No	No
Do you have agricultural field at school; If you have, what plants do you plant.		
Can you describe or draw a picture about the school during dry season.		
Can you describe or draw a picture about the school during rainy season		

b. Risorooza Primary School	
	Nimusiima Dareen
Age	13
Grade	
What is your water source at school	Rain tank
How much water do you drink everyday at school (on average)	2L
How much water do you want at school (on average)	1L
What do you use water for at school	Washing hands, toilet, sweeping classroom,drinking;Teacher cooking
Do you have enough water during dry season at school;Reason	No;Too much sunshine
How many times do you go to toilet everyday at school(on average)	2
Have you heard about water harvesting	Yes
Have you heard about eco-san	No
Do you have agricultural field at school; If you have, what plants do you plant.	
Can you describe or draw a picture about the school during dry season.	
Can you describe or draw a picture about the school during rainy season	

b. Risorooza Primary School	
	Katuehabe Emily
Age	13
Grade	
What is your water source at school	Rain tank
How much water do you drink everyday at school (on average)	1L
How much water do you want at school (on average)	2cups
What do you use water for at school	Washing hands, toilet, sweeping classroom,drinking;cooking
Do you have enough water during dry season at school;Reason	No;Too much sunshine
How many times do you go to toilet everyday at school(on average)	1
Have you heard about water harvesting	Yes
Have you heard about eco-san	No
Do you have agricultural field at school; If you have, what plants do you plant.	
Can you describe or draw a picture about the school during dry season.	
Can you describe or draw a picture about the school during rainy season	

b. Risorooza Primary School	
	Nankunda Faith
Age	14
Grade	
What is your water source at school	Rain tank
How much water do you drink everyday at school (on average)	2L
How much water do you want at school (on average)	2 cups
What do you use water for at school	Washing hands, toilet, sweeping classroom,drinking;cooking
Do you have enough water during dry season at school;Reason	No;Too much sunshine
How many times do you go to toilet everyday at school(on average)	1
Have you heard about water harvesting	Yes
Have you heard about eco-san	No
Do you have agricultural field at school; If you have, what plants do you plant.	
Can you describe or draw a picture about the school during dry season.	
Can you describe or draw a picture about the school during rainy season	

b. Risorooza Primary School	
	Akanawanaho Cranima
Age	12
Grade	
What is your water source at school	Rain tank
How much water do you drink everyday at school (on average)	2L
How much water do you want at school (on average)	2 cups
What do you use water for at school	Washing hands, cleaning classroom,cooking
Do you have enough water during dry season at school;Reason	No;Too much sunshine, No rain
How many times do you go to toilet everyday at school(on average)	3
Have you heard about water harvesting	Yes
Have you heard about eco-san	No
Do you have agricultural field at school; If you have, what plants do you plant.	
Can you describe or draw a picture about the school during dry season.	
Can you describe or draw a picture about the school during rainy season	

b. Risorooza Primary School	
	Atwijukire Anthony
Age	13
Grade	
What is your water source at school	Rain tank
How much water do you drink everyday at school (on average)	2L
How much water do you want at school (on average)	2 cups
What do you use water for at school	Washing hands, sweeping classroom,cooking
Do you have enough water during dry season at school;Reason	No;Too much sunshine,No water, Not enough
How many times do you go to toilet everyday at school(on average)	1
Have you heard about water harvesting	Yes
Have you heard about eco-san	No
Do you have agricultural field at school; If you have, what plants do you plant.	
Can you describe or draw a picture about the school during dry season.	
Can you describe or draw a picture about the school during rainy season	

c. Muhanga Modern School	
	Niwagaba Peter
Age	10
Grade	P5
Boarder student?	Yes
What is your water source at school	Taps
How much water do you drink everyday at school (on average)	3L
How much water do you want at school (on average)	
What do you use water for at school	Washing clothes, cooking food, drinking
Do you have enough water during dry season at school;	Yes
How many times do you bath at school everyday(on average)	2
Have you heard about water harvesting	
Have you heard about eco-san	
Do you have agricultural field at school; If you have, what plants do you plant.	
Can you describe or draw a picture about the school during dry season.	
Can you describe or draw a picture about the school during rainy season	

c. Muhanga Modern School	
	Ainembabazi Martha
Age	11
Grade	P7
Boarder student?	Yes
What is your water source at school	Taps
How much water do you drink everyday at school (on average)	2L
How much water do you want at school (on average)	
What do you use water for at school	Bathing, washing clothes and utensils,brushing teeth,cooking,drinking
Do you have enough water during dry season at school;	Yes
How many times do you bath at school everyday(on average)	2
Have you heard about water harvesting	
Have you heard about eco-san	
Do you have agricultural field at school; If you have, what plants do you plant.	
Can you describe or draw a picture about the school during dry season.	
Can you describe or draw a picture about the school during rainy season	

c. Muhanga Modern School	
	Kefeeza Stesher
Age	14
Grade	P7
Boarder student?	Yes
What is your water source at school	Taps
How much water do you drink everyday at school (on average)	2
How much water do you want at school (on average)	
What do you use water for at school	Bathing, washing clothes,irrigation,brushing teeth,cooking,drinking,mopping
Do you have enough water during dry season at school;	Yes
How many times do you bath at school everyday(on average)	3
Have you heard about water harvesting	
Have you heard about eco-san	
Do you have agricultural field at school; If you have, what plants do you plant.	
Can you describe or draw a picture about the school during dry season.	
Can you describe or draw a picture about the school during rainy season	

c. Muhanga Modern School	
	Asllmwe Grace
Age	11
Grade	
Boarder student?	Yes
What is your water source at school	Taps
How much water do you drink everyday at school (on average)	2
How much water do you want at school (on average)	
What do you use water for at school	Bathing, washing hands and utensils,mopping bathroom,drinking
Do you have enough water during dry season at school;	Yes
How many times do you bath at school everyday(on average)	2
Have you heard about water harvesting	
Have you heard about eco-san	
Do you have agricultural field at school; If you have, what plants do you plant.	
Can you describe or draw a picture about the school during dry season.	
Can you describe or draw a picture about the school during rainy season	

c. Muhanga Modern School		
	Awamani Lajab	Ampurira Treasure
Age	13	11
Grade	P6	P5
Boarder student?	Yes	Yes
What is your water source at school	Taps	Taps
How much water do you drink everyday at school (on average)	2	2 cups
How much water do you want at school (on average)		
What do you use water for at school	Bathing,washing clothes,cooking,drinking	Cooking food, washing clothes
Do you have enough water during dry season at school;	Yes	Yes
How many times do you bath at school everyday(on average)	2	2
Have you heard about water harvesting		
Have you heard about eco-san		
Do you have agricultural field at school; If you have, what plants do you plant.		
Can you describe or draw a picture about the school during dry season.		
Can you describe or draw a picture about the school during rainy season		

c. Muhanga Modern School	
	Ajuna Victor
Age	7
Grade	P2
Boarder student?	Yes
What is your water source at school	Taps
How much water do you drink everyday at school (on average)	2L
How much water do you want at school (on average)	
What do you use water for at school	Drinking, cooking, washing,bathing
Do you have enough water during dry season at school;	Yes
How many times do you bath at school everyday(on average)	2
Have you heard about water harvesting	
Have you heard about eco-san	
Do you have agricultural field at school; If you have, what plants do you plant.	
Can you describe or draw a picture about the school during dry season.	
Can you describe or draw a picture about the school during rainy season	

c. Muhanga Modern School	
	Akankunda Alexander
Age	8
Grade	P4
Boarder student?	Yes
What is your water source at school	Taps
How much water do you drink everyday at school (on average)	2L
How much water do you want at school (on average)	
What do you use water for at school	Washing clothes, cooking,brushing,bathing, washing utensils
Do you have enough water during dry season at school;	Yes
How many times do you bath at school everyday(on average)	2
Have you heard about water harvesting	
Have you heard about eco-san	
Do you have agricultural field at school; If you have, what plants do you plant.	
Can you describe or draw a picture about the school during dry season.	
Can you describe or draw a picture about the school during rainy season	

c. Muhanga Modern School	
	Orikirorn Innocent
Age	14
Grade	P6
Boarder student?	Yes
What is your water source at school	Taps
How much water do you drink everyday at school (on average)	4 cups
How much water do you want at school (on average)	
What do you use water for at school	Cooking,mopping bathroom, washing utensils,irrigating vegetable
Do you have enough water during dry season at school;	Yes
How many times do you bath at school everyday(on average)	3
Have you heard about water harvesting	
Have you heard about eco-san	
Do you have agricultural field at school; If you have, what plants do you plant.	
Can you describe or draw a picture about the school during dry season.	
Can you describe or draw a picture about the school during rainy season	

c. Muhanga Modern School	
	Nayebare Godwin
Age	12
Grade	P4
Boarder student?	Yes
What is your water source at school	Taps
How much water do you drink everyday at school (on average)	2L
How much water do you want at school (on average)	
What do you use water for at school	Bathing,washing plates,drinking,washing clothes,cups and basket
Do you have enough water during dry season at school;	Yes
How many times do you bath at school everyday(on average)	2
Have you heard about water harvesting	
Have you heard about eco-san	
Do you have agricultural field at school; If you have, what plants do you plant.	
Can you describe or draw a picture about the school during dry season.	
Can you describe or draw a picture about the school during rainy season	

c. Muhanga Modern School	
	Maria Patrah
Age	11
Grade	P4
Boarder student?	Yes
What is your water source at school	Taps
How much water do you drink everyday at school (on average)	2L
How much water do you want at school (on average)	
What do you use water for at school	Cooking,washing clothes,mopping homes,brushing
Do you have enough water during dry season at school;	Yes
How many times do you bath at school everyday(on average)	3
Have you heard about water harvesting	
Have you heard about eco-san	
Do you have agricultural field at school; If you have, what plants do you plant.	
Can you describe or draw a picture about the school during dry season.	
Can you describe or draw a picture about the school during rainy season	

c. Muhanga Modern School	
	Ainomujun Joram
Age	16
Grade	P7
Boarder student?	Yes
What is your water source at school	Taps
How much water do you drink everyday at school (on average)	3L
How much water do you want at school (on average)	
What do you use water for at school	Washing,bathing,drinking,water crops
Do you have enough water during dry season at school;	Yes
How many times do you bath at school everyday(on average)	1
Have you heard about water harvesting	
Have you heard about eco-san	
Do you have agricultural field at school; If you have, what plants do you plant.	
Can you describe or draw a picture about the school during dry season.	
Can you describe or draw a picture about the school during rainy season	

c. Muhanga Modern School	
	Ayebuzibwe Mack
Age	11
Grade	P4
Boarder student?	Yes
What is your water source at school	Taps
How much water do you drink everyday at school (on average)	4L
How much water do you want at school (on average)	
What do you use water for at school	Washing clothes, cooking,drinking,bathing, washing utensils
Do you have enough water during dry season at school;	Yes
How many times do you bath at school everyday(on average)	2 days once
Have you heard about water harvesting	
Have you heard about eco-san	
Do you have agricultural field at school; If you have, what plants do you plant.	
Can you describe or draw a picture about the school during dry season.	
Can you describe or draw a picture about the school during rainy season	

d. Muhanga Primary School	
	Mugisha Joseph
Age	14
Grade	P6
What is your water source at school	Well
How much water do you drink everyday at school (on average)	2L
How much water do you want at school (on average)	
What do you use water for at school	Teacher cooking;drinking,washing hands
Do you have enough water during dry season at school;Reason	No
How many times do you go to toilet everyday at school(on average)	1
Have you heard about water harvesting	
Have you heard about eco-san	
Do you have agricultural field at school; If you have, what plants do you plant.	
Can you describe or draw a picture about the school during dry season.	
Can you describe or draw a picture about the school during rainy season	

d. Muhanga Primary School	
	Agaba Miracle
Age	12
Grade	
What is your water source at school	Well
How much water do you drink everyday at school (on average)	2L
How much water do you want at school (on average)	
What do you use water for at school	Washing hands after latrines,washing plates,drinking
Do you have enough water during dry season at school;Reason	No
How many times do you go to toilet everyday at school(on average)	2
Have you heard about water harvesting	
Have you heard about eco-san	
Do you have agricultural field at school; If you have, what plants do you plant.	
Can you describe or draw a picture about the school during dry season.	
Can you describe or draw a picture about the school during rainy season	

d. Muhanga Primary School	
	Agaba Brian
Age	12
Grade	
What is your water source at school	Well
How much water do you drink everyday at school (on average)	2L
How much water do you want at school (on average)	
What do you use water for at school	Washing hands after latrines,drinking
Do you have enough water during dry season at school;Reason	No
How many times do you go to toilet everyday at school(on average)	2
Have you heard about water harvesting	
Have you heard about eco-san	
Do you have agricultural field at school; If you have, what plants do you plant.	
Can you describe or draw a picture about the school during dry season.	
Can you describe or draw a picture about the school during rainy season	

d. Muhanga Primary School		
	Twesigomwe Gilbert	Kukund Catherine
Age	14	9
Grade	P6	P4
What is your water source at school	Well	Well
How much water do you drink everyday at school (on average)	1.5L	4 cups
How much water do you want at school (on average)		
What do you use water for at school	Drinking, cooking,washing hands	Washing hands after eating,latrine
Do you have enough water during dry season at school;Reason	No	No
How many times do you go to toilet everyday at school(on average)	3	1
Have you heard about water harvesting		
Have you heard about eco-san		
Do you have agricultural field at school; If you have, what plants do you plant.		
Can you describe or draw a picture about the school during dry season.		
Can you describe or draw a picture about the school during rainy season		

d. Muhanga Primary School		
	Kyakundzire Claire	Akuheire Elizabeth
Age	9	9
Grade		
What is your water source at school	Spring	Spring
How much water do you drink everyday at school (on average)	1L	1L
How much water do you want at school (on average)		
What do you use water for at school	Washing, drinking, cooking	Drinking,washing hands,clothes
Do you have enough water during dry season at school;Reason	Yes	Yes
How many times do you go to toilet everyday at school(on average)	3	3
Have you heard about water harvesting		
Have you heard about eco-san		
Do you have agricultural field at school; If you have, what plants do you plant.		
Can you describe or draw a picture about the school during dry season.		
Can you describe or draw a picture about the school during rainy season		

d. Muhanga Primary School	
	Turyasingura Aloia
Age	11
Grade	P4
What is your water source at school	Spring
How much water do you drink everyday at school (on average)	1L
How much water do you want at school (on average)	
What do you use water for at school	Drinking,cooking food,washing clothes
Do you have enough water during dry season at school;Reason	No
How many times do you go to toilet everyday at school(on average)	2
Have you heard about water harvesting	
Have you heard about eco-san	
Do you have agricultural field at school; If you have, what plants do you plant.	
Can you describe or draw a picture about the school during dry season.	
Can you describe or draw a picture about the school during rainy season	

d. Muhanga Primary School	
	Nabwera Immaculate
Age	12
Grade	P5
What is your water source at school	Spring
How much water do you drink everyday at school (on average)	0.5L
How much water do you want at school (on average)	
What do you use water for at school	Drinking,cooking,washing clothes and toes,brushing teeth
Do you have enough water during dry season at school;Reason	No
How many times do you go to toilet everyday at school(on average)	5
Have you heard about water harvesting	
Have you heard about eco-san	
Do you have agricultural field at school; If you have, what plants do you plant.	
Can you describe or draw a picture about the school during dry season.	
Can you describe or draw a picture about the school during rainy season	

d. Muhanga Primary School	
	Akabinsinguza Rehema
Age	11
Grade	P4
What is your water source at school	Spring
How much water do you drink everyday at school (on average)	1L
How much water do you want at school (on average)	
What do you use water for at school	Drinking,washing hands,clothes and dences
Do you have enough water during dry season at school;Reason	No
How many times do you go to toilet everyday at school(on average)	3
Have you heard about water harvesting	
Have you heard about eco-san	
Do you have agricultural field at school; If you have, what plants do you plant.	
Can you describe or draw a picture about the school during dry season.	
Can you describe or draw a picture about the school during rainy season	

d. Muhanga Primary School		
	Tukahirwa Annha	Tuslime Hillary
Age	11	12
Grade	P4	
What is your water source at school	Spring	Spring
How much water do you drink everyday at school (on average)	2L	1.5L
How much water do you want at school (on average)		
What do you use water for at school	Drinking, washing hands and clothes, cooking	Cooking
Do you have enough water during dry season at school;Reason	No	Yes
How many times do you go to toilet everyday at school(on average)	3	3
Have you heard about water harvesting		
Have you heard about eco-san		
Do you have agricultural field at school; If you have, what plants do you plant.		
Can you describe or draw a picture about the school during dry season.		
Can you describe or draw a picture about the school during rainy season		

Appendix 4 Workshops with municipalities

Municipality Meeting 31st. July		
Name	Muheki Nkiine(female)	Peace Kisheija(single)
Age	30	35
Profession	Peasant	
Family member	5 (3 kids)	5
Water source;How far	Well, 3km away	
How much water do you use everyday	60L	40L
What do you used water for	Cooking,20L;irrigation,60L;washing,20L;drinking,2L	Cooking, washing(20L), bathing
Do you have enough water in dry season	No	No
Flooding problem	Yes	Yes
Water harvesting system	No	No
Eco-san; Reason	No; Expensive	No;Expensive,poverty situation
How many time do you go to toilet everyday	1	3
How many times do you shower	3	3
Do you have agricultural field	Yes	Yes
What fertilizer do you use; Have you heard about composting	Organic fertilizer, composting manure; Yes	Manure

Municipality Meeting 31st. July		
Name	Twezirikye Lybia	Rwantangare Fred
Age	54	76
Profession	Headteacher of Nyakitabira Annex School	
Family member		6 people(8 kids)
Water source;How far		Spring
How much water do you use everyday	40L	8 jellycan a day=160L
What do you used water for		Washing, cooking, bathing,animal,crops,flowers
Do you have enough water in dry season	No	No
Flooding problem		
Water harvesting system		
Eco-san; Reason	No;Expensive	No;Expensive
How many time do you go to toilet everyday		2
How many times do you shower	1	1
Do you have agricultural field	Yes	Yes
What fertilizer do you use; Have you heard about composting	Organic manure	Manure

Municipality Meeting 31st. July			
Name	Johanson Bkrutaro	Tktongyerwe Gilbert	Lydia Rubahimbya
Age	73		50
Profession	Peasant	Head teacher Mittle Angels	Peasant
Family member	8		1
Water source;How far	Spring; 0.25miles;30 min		Well;1km;30min
How much water do you use everyday	200L	40L	60L
What do you used water for			Cooking,drinking,washing
Do you have enough water in dry season	No	No	No
Flooding problem	No	No	Yes
Water harvesting system	No	No	No
Eco-san; Reason	No;Expensive	No;Expensive	No;Not able to make it
How many time do you go to toilet everyday	3		2
How many times do you shower	2	1	2
Do you have agricultural field	No	Yes	Yes
What fertilizer do you use; Have you heard about composting	Local manure	Organic manure	Local manure

Municipality Meeting 31st. July		
Name	Mugisha Gidron(Male)	Abarigye Mebivs
Age	28	45
Profession	Teaching	Headteacher Rwabvhimbira pls
Family member	3(1 kid)	6
Water source;How far	spring;30min	well
How much water do you use everyday	100L	40L
What do you used water for	washing(40L);bathing(20L);cooking(10L);watering(25L);drinking(5L)	washing,drinking,cooking
Do you have enough water in dry season	No	No
Flooding problem	No	Yes
Water harvesting system	No	No
Eco-san; Reason	No;Expensive	No;poor
How many time do you go to toilet everyday	3	2
How many times do you shower	1	1
Do you have agricultural field	No	Yes
What fertilizer do you use; Have you heard about composting		Organic mature

Municipality Meeting 31st. July	
Name	Bagumo Bermard(Male)
Age	54
Profession	Lay-reader
Family member	8(5 kids)
Water source;How far	spring;1km;40min
How much water do you use everyday	80L
What do you used water for	washing(30L),cooking(20L),bathing,drinking,crops,irrigation
Do you have enough water in dry season	No
Flooding problem	Yes
Water harvesting system	No
Eco-san; Reason	No;Expensive
How many time do you go to toilet everyday	2
How many times do you shower	once in 2 days
Do you have agricultural field	Yes
What fertilizer do you use; Have you heard about composting	Organic manure

Municipality Meeting 31st. July		
Name	Tumwijuke Inocent	Ngurusi Ida
Age	47	
Profession	Graduate teacher	Teacher
Family member	6(4 kids)	4(8 kids)
Water source;How far	spring;0.5km	well;20min
How much water do you use everyday	1000L	80L
What do you used water for	washing(40L),drinking(20L),cooking(40L),shower(20L）	washing(40L),bathing,cooking(20L),animals
Do you have enough water in dry season	No	No
Flooding problem	No	Yes
Water harvesting system	No	No
Eco-san; Reason	No;Expensive	No;Expensive
How many time do you go to toilet everyday	1	2
How many times do you shower	1	every night
Do you have agricultural field	Yes	Yes
What fertilizer do you use; Have you heard about composting	Manure	Local manure

Municipality Meeting 31st. July		
Name	Ecokyonuhouwe	Nahurira Agnes
Age	70	19
Profession	peasant	Teacher
Family member	5(7 kids)	7(0)single
Water source;How far	well;0.25 miles	spring;10min,500m
How much water do you use everyday	200L	40L
What do you used water for	cooking,washing,bathing	Cooking(5L),washing utencils,plates,cups(15L),bathing(10L),drinking(5L)
Do you have enough water in dry season	Yes	No
Flooding problem	Yes	Yes
Water harvesting system	No	No
Eco-san; Reason	No;money	No;Poverty;Too many people at home
How many time do you go to toilet everyday	2	3
How many times do you shower	2-3 days	2
Do you have agricultural field	Yes	Yes
What fertilizer do you use; Have you heard about composting	Local manure	Composting manure

Municipality Meeting 31st. July		
Name	Rubanza Florence	John Rwakiseete
Age	45	65
Profession	Teacher	Retired teacher
Family member	1 kid	10(6 kids)
Water source;How far	well;100m;5 min	spring;1km;45min
How much water do you use everyday	40L	100L
What do you used water for	Washing,drinking,cooking,spraying plants	washing,drinking and bathing(60L);animals(40L)
Do you have enough water in dry season	No	No
Flooding problem	Yes	Yes
Water harvesting system	No	No
Eco-san; Reason	No;Expensive;can't afford	No
How many time do you go to toilet everyday	Everyday	
How many times do you shower		
Do you have agricultural field	Yes	Yes
What fertilizer do you use; Have you heard about composting	Organic manure	Manure