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# Flood Hazard and Risk Assessment of Vulnerable Areas Downstream of Lower Usman Dam In Federal Capital Territory Abuja Nigeria

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**Abstract:** *Poor drainage systems, low capacity for storage and infiltration during heavy rainfall, lack of maintenance, and increase in urban growth are the main reasons for increase in flooding in urban areas. Also, future climate and land-use change also affect urban flooding and risks. Urban flood risk assessment and dissemination of this information are very important in urban flood management. Soil Water Application Tool is a hydraulic model used to asses flood hazard and risk assessment of vulnerable areas downstream of Lower Usman Dam Abuja and was also used it to predict the location of flood-prone areas using flood hazard maps. The SWAT model was interfaced with Map window GIS, the two modelssimulated the hydrology which predicted the sediment yield and surface runoff in the sub-basin of the watershed. Digital Elevation Model (DEM), digital soil map, digital land use and land cover map, climate and hydrological input data of study watershed were used. The result shows that Usman dam Reservoir falls within 7 sub-basin and 7 Hydrological Response Units (HRUs) with the area of 107.09292km2 and the average annual surface runoff estimated at 17.4069mm and the average annual sediment yield was estimated as 0.638452tons/ha. From the result, it was discovered that sub basin 6 has the highest sediment yield and sub basin 1 has highest surface runoff. Hence, to checkmate flooding hazard along the downstream area of the lower Usman dam, there should be proper vegetative cover to prevent surface runoff. Adequate and proper drainage construction will reduce the effect of flooding into the dam and downstream of the dam.*

**Keywords:** *Usman Dam, flood, vulnerable, SWART, MAP WINDOW Prediction.*

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## 1. INTRODUCTION

Dam is a hydraulic structure or barrier constructed against the downward flow of water for the purpose of holding and storing water for use afterwards. The major purpose of Dam is to store water for supply, irrigation, flood control, hydropower and navigation. It may either be constructed with earth, steel or concrete. There are four major dam types buttress, gravity, and arc and embankment dams. The choice of each type of dam is determined by the purpose for which it is to be used. However the construction of dams which has an advantageous economic values also has a negative economic and environmental values which includes water logging damp climate in the area, mosquitoes nuisance and erosion problems. The erosion problem is a major problem to dams because of the inflow of sediments into dam which hinders its primary functions of large water storage for supply, irrigation, flood control, hydropower and navigation. The continuous inflow of silt, debris and sediments into dams reduces water storage capacity of the dam. Sediment yield refers to amount of sediment exported by a basin over time and the amount that enters a reservoir as a result of soil erosion or wear away of the ground surface by water, wind, ice, and gravity while Sediment concentration on the other hand describes the ratio of the dry weight of the sediment in a water-sediment mixture. Suspended Sediment Concentration is generally transported within and at the same velocity as the surrounding fluid (water or wind).

To make a good and economic management of dams, accurate economic forecast of a planned dam, is important to be able to identify the vulnerable area around the dam environment. Identification of the vulnerable area with hydrological modelling base approach is an important step in the estimation of useful life of dam. Methods to identify the vulnerable area have been the subject of several practical researches. Prediction of dam useful lifetime is the ultimate aim of all dam designers making the problem as a substantial subject in water research. The overflowing of water onto dry land has adversely affected the environment in recent times. Floods happen during heavy rains, which may be a few inches of water, or it may cover a house to the rooftop. Floods can occur quickly or over a long period and may last for days, weeks, or longer. Floods are the most common and widespread of all weather-related natural disasters.One of the most devastating and expensive natural hazards in the world today is flooding and attempts have been made by different scholars and researchers across the globe and in Nigeria to study flood vulnerability. The multidimensional approach adopted and the results were aggregated not localized to specific areas of flood vulnerability assessment in Mokwa, Nigeria. Vulnerability explored through the lens of four dimensions (economic, environmental, physical, and social) and eighteen indicators, scrutinized and standardized for aggregation and comparability. Theindicators were weighted unequally using Analytical Hierarchical Process (AHP). Nine communities and 382 households selected from the downstream area of the Kainji dam revealed flood communities experiencing high flood vulnerability, from all dimensions; economic (0.71), physical (0.66), social (0.62), and environmental (0.57) and the flood vulnerability index of 0.65, which implies a high level of vulnerability to flooding downstream Kainji dam [1].The world has faced many disasters in recent years, but flood impacts have gained immense importance and attention due to their adverse. More than half of global flood destruction and damages causes losses of life, damage infrastructure, and creates panic conditions among the communities [1, 2]. Different approaches and methods to understand vulnerability assessment and how geographic information systems assess the flood vulnerability and their associated risk predicts the disaster trend and what mitigate the risk and damages. These methodologies were used to measure floods and their vulnerabilities by integrating geographic information system [2]. Flooding is a natural event that causes widespread destruction, adversely affects daily life and raises vulnerability, including physical, social, economic, and environmental exposure. About 350million people in the world are affected by floods. It is also predicted that the flood destruction will be double by the end of 2050. The ever-increasing population and the combination of properties in built-up areas also increased flooding potential. In the future, the impact of flooding will increase as the population increases [3].Dams in major rivers worldwide have been driven by the essential needs for flood control, power generation, water supply, irrigation and environmental enhancement but the vulnerability of these dams to external factors such as earthquakes, floods, landslides, wars, or natural dam-breaks poses a potential catastrophic consequence of dam-break floods. Studies to check this are mainly based on physical model tests and numerical simulation. In the aspect of numerical simulation, the shallow water model, diffusive wave model, and the three-dimensional Reynolds averaged model are used, there are also some studies based on the depth-integrated [4]. Outburst Floods (GLOFs) a major cryospheric hazard worldwide, especially in the Himalayas. GLOFs in the Himalayan region are mostly caused by moraine-dammed pro glacial lakes and ice-dammed lakes. The findings show that over this period, the PDGL has had a notable expansion of 78.7%, accompanied by a significant recession of 13.2% in its feeding glacier. The average, lowest, and maximum depth of the glacier were found to be 30.95, 14.30, and 50.57m, respectively and the average velocity of the glacier was estimated as 3.38m [5].Failure of dam structures could result in enormous losses in downstream areas due to unexpected floods. So, dam break study is important to reduce threats of flood in downstream areas during dam failure. The vulnerability of downstream and to estimate the time for peak discharge to reach at different sections of the river from

Kulekhani Dam to Bagmati River was studied. An equationwas used to calculate dam breach parameters and peak outflow respectively. The maximum flood discharge was calculated as 15,303.61 $m^3/s$. HEC-RAS two-dimensional unsteady flow analysis was performed from which approximately 2.03 $km^2$ of the downstream area was found to be inundated with maximum flood depth of 31.60 m. The cultivable lands, vegetation, roads, bridges, buildings, electric poles and other infrastructures are vulnerable during flood. The peak flood during the dam breach was estimated to reach different settlements in a time period between 60 and 100 min. The model was validated by comparing simulated flood depth and calculated flood depth using the coefficient of determination, Nash–Sutcliffe Simulation Efficiency, RMSE-observation for Standard Deviation Ratio and Percent BIAS were found to be 1.00, 0.81, 0.44 and −7.81% [6]. Risk analysis of dam breaks in the Wadi Al-Arab Dam in Jordan was carried out in Hydrologic Engineering Center—River Analysis System software was used to assess downstream areas, utilizing a Digital Elevation Model and design storms were employed to calculate the Probable Maximum Flood flow hydrographs using the Watershed Modeling System. River Analysis System—Mapper was utilized to create two-dimensional flow areas. The estimated maximum water depth for overtopping was 37.6 m, whereas that for piping failure was 26 m. The peak breach flow was estimated to be 10,800 $m^3/s$ for overtopping and 3234 $m^3/s$ for piping failure [7].Globally, floods are among the most devastating natural hazards. Among all flood types, riverine floods occur most frequently and often cause substantial damage to agriculture and infrastructure. Hydrological model combined with the CaMa-Flood model for the sub-basin level flood risk assessment in India considering the role of reservoirs. The CaMa-Flood model combined with the H08 model was used for several river basins globally. The CaMa-Flood model performs well in simulating flood dynamics. The CaMa-Flood model takes runoff as input simulated from any hydrological model and simulate flood depth and inundation. The model-simulated annual maximum stream flow against the observed annual maximum stream flow for the time periods for which observations were available. The mean annual maximum flooded area for the top flood-affected sub-basins ranged between 10 % and 15 %, their maximum flooded area varied between 30 % and 40 % [8].Floods possess great threats to the safety of human settlements and their sustainable development. Flood risk emerges from flood hazard and the probability of associated negative consequences for the environment, economic activity, and human health. However a significant flood risk occurs in a given area when there is a high flood hazard associated with a high probability of the occurrence of losses due to flooding [9]. Mountainous regions are highly hazardous, and these hazards often lead to loss of human life. The topography, geological processes, and hydrological character of mountainous regions provide water, resources, and ecosystem services to downstream areas, but also make the lives of mountain residents and their settlements vulnerable to multiple interacting natural hazards. Mountainous regions are hot spots for hazard mortality: over 70% of the more than 700,000 disaster-relateddeaths between 2005 and 2014 occurred in mountainous countries**.** Multi-hazard exposure from analysis shows nearly half (49%) of the region's population are exposed to multi-hazard risk and that high susceptibility to more than one hazard geographically concentrated in one-third of the region's land area [10].Dam sedimentation is the gradual accumulation of the incoming sediment load from a river. Sediments fill a reservoir within 50–200 years. At this point it is fact that reservoir sedimentation is just a symptom of erosion of the topsoil [11]. Sedimentation affects the sustainability of operations and projects established in the reservoir or runof the river projects. Overtime, sediments build-up in reservoirs and displace usable storage volume of water, which in turn negatively affects hydropower generation, reduces the reliability of the reservoir,irrigation,water supply, flood management services, and degrades aquatic habitat [12,13]. The increasing population and the building up properties of areas increase flooding potential. In view of this, the future, the impact of flooding in the areas down stream of lower Usman Dam need to study in other to predict the vulnerability of the area to flooding.

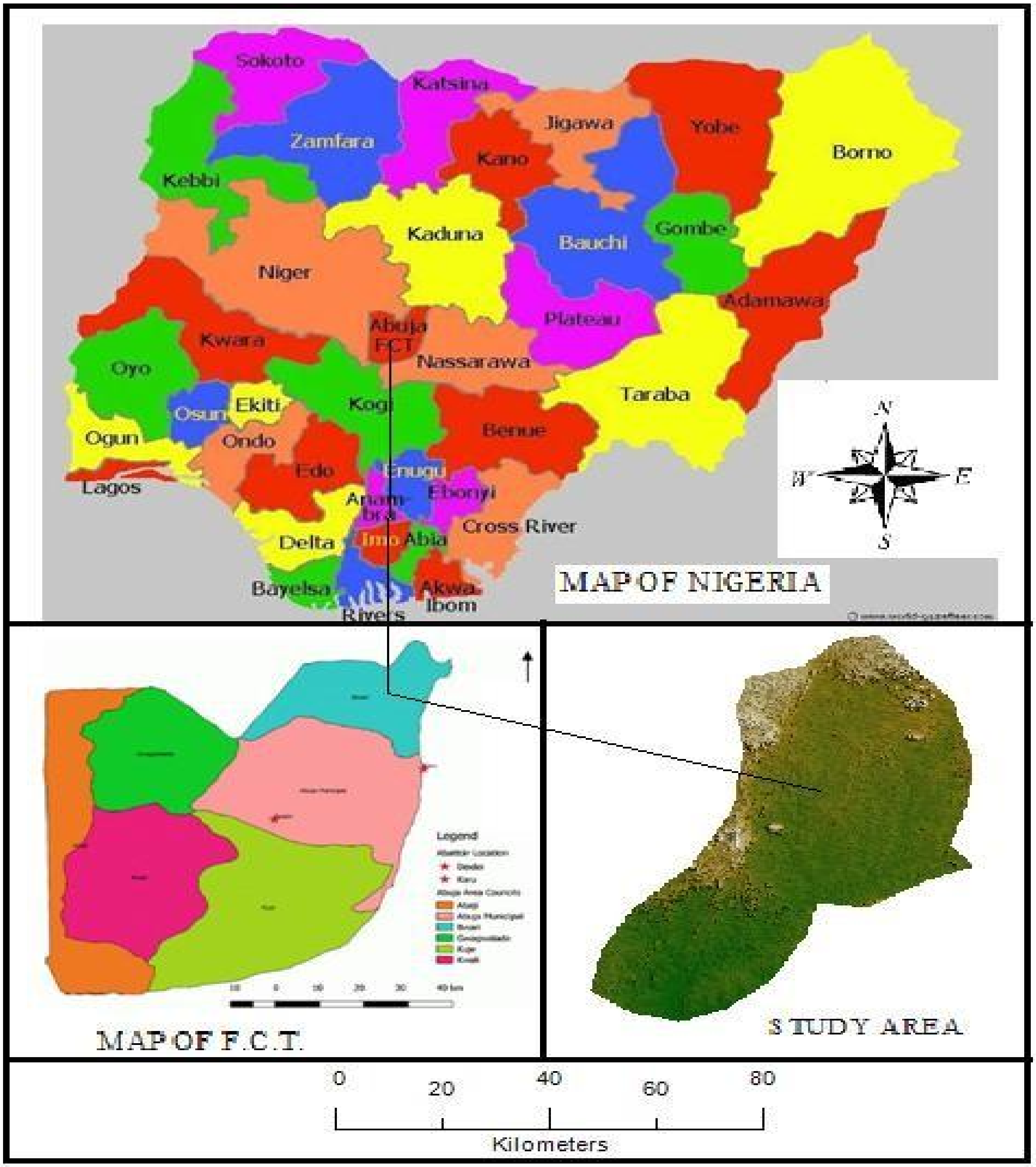


**Fig. 1.0 Map of Nigeria and F.C.T. Showing the Location of Watershed of the lower Usman Dam (Shuttle radar topography mission)**

**Fig.1.1: Lower Usman Dam Bwari Abuja**.

## II. MATERIALS AND METHODS

The study area covers the communities downstream of Usman dam near Ushafa of Bwari area council of the Federal Capital Territory, Nigeria,The study area is bounded by Bwari area council and some parts of Municipal council area of the Federal Capital Territory of Nigeria. The study area is located within longitudes [7°24'29.596" and 7°29'3.259"] East and latitudes [9°13'35.928"and 9°8'7.435"] North, and have the area of about 4401.7km$^2$. The area is characterized by a hill, dissected terrain and is the highest part of the FCT with several peaks that are 760 m above sea level [12]. Sediment yield is the amount of erosional debris from drainage basin deposited in reservoirs

### 2.1 SWAT Model

The Soil and Water Assessment Tool "SWATis a constant hydraulic simulation model that was developed to calculate the runoff and sediment load yield for watersheds and river basins. SWAT is a physically-based long-term simulation model designed for long-term yield. SWAT model was selected for this study because of the versatility and the ability to run the model on day by day till the number of projected years. The SWAT model was interfaced with Map window GIS to simulate the hydrology and predict the sediment yield and surface runoff (flooding) in the sub-basin of the watershed. The data was imputed in the SWAT model which has interface with MAPWINDIW GIS. The result was used to predict the sediment yield and sediment concentration of the 7 sub basins of the lower Usman dam.

### 2.2 SWAT Input Data

The SWAT model require the following data to run: the digital elevation model (DEM), land use, soil maps and climate data. The primary data was collected from Nigerian meteorological Agency (NiMet) and processed for daily rainfall, runoff and sediment discharge, maximum and minimum temperature for the watershed. The hydro-meteorological data was simulatedto find the hydrological behaviour of the watershed. Themeteorological data collected has the daily values for precipitation, maximum and minimum air temperature, wind speed, relative humidity and the sunshine (converted to solar radiation).The stream flow data were collected from Ministry of Water of resources from the hydrology and water quality directorate department. The first step in the SWAT model setup was watershed delineation, sub-watershed and naturally existing stream network determination using the lower Usman dam watershed DEM (Fig.3.0). The SWAT2005 was used to delineate the boundaries of the entire study area and its sub-basins. The model was calibrated using data in the catchment of lower Usman dam Bwari Abuja. During the simulation process the inflow and sediment yield was calibrated and then validated.

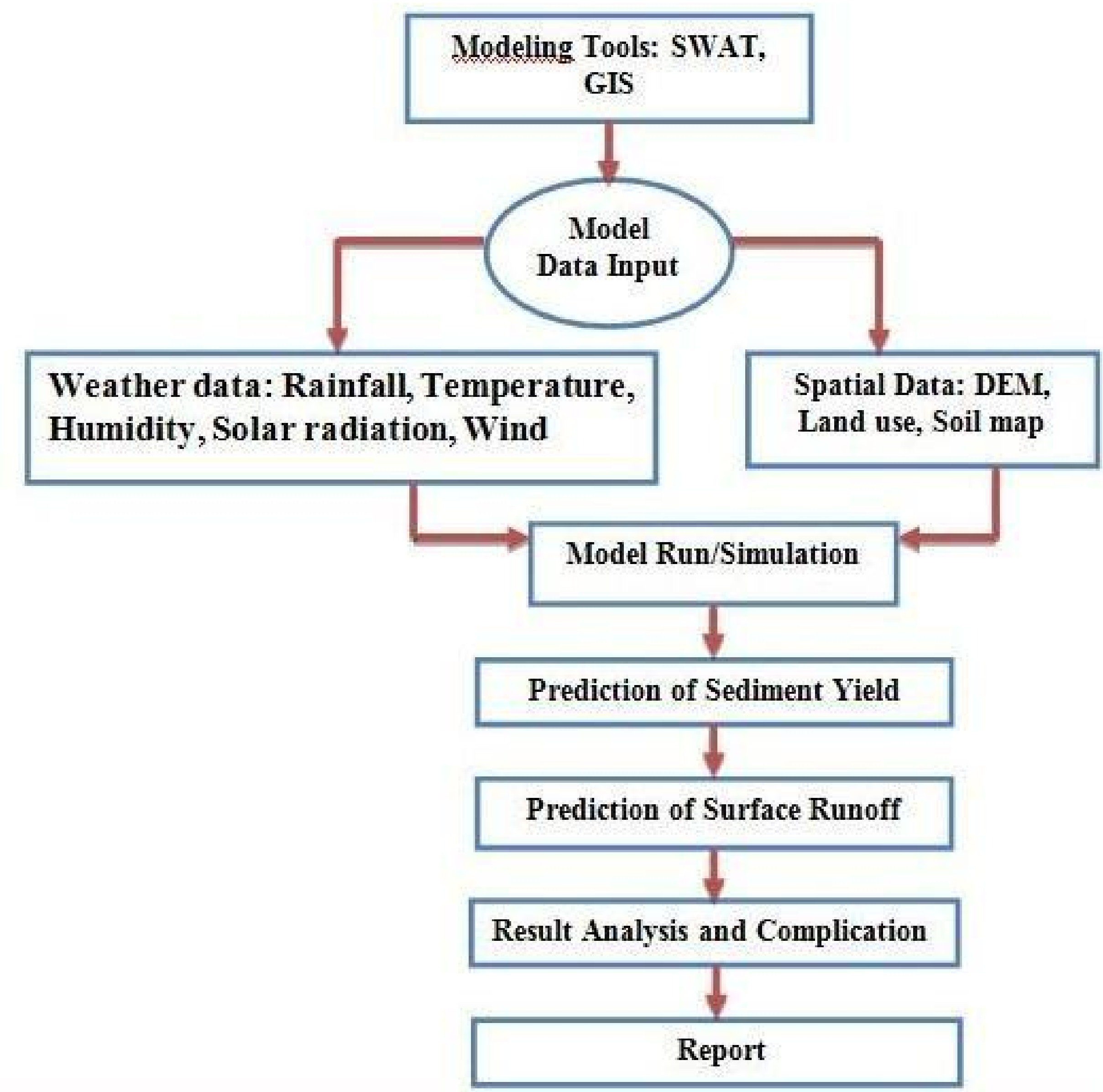


**Fig. 2.0 : SWAT-MAP WINDOW GIS Flow chart**

### 2.3 MAP window GIS

Map window GIS is a standard GIS data visualization features as well as data base files (DBF) attribute tables editing projections vectors operations, image operations, raster and spatial analyser.

**Table 1.0 : Model Data Input for Study Area**

| S/NO | DATA TYPE | DESCRIPTION | RESOLUTION | SOURCE |
|---|---|---|---|---|
| **1** | Topography Map | Digital Elevation model | 80m x 80m | Shuttle Radar Topography mission. |
| **2** | Land Use | Land use Classification | 1Km | Global land cover Classification Satellite Raster |
| **3** | Soil map | Soil type | 10Km | Digital soil map of the world. |
| **4** | Weather data | Daily precipitation min. and max, Temperature, Relative Humidity, Wind and solar radiation. | Daily | NIMET. Nigerian meteorological station. |

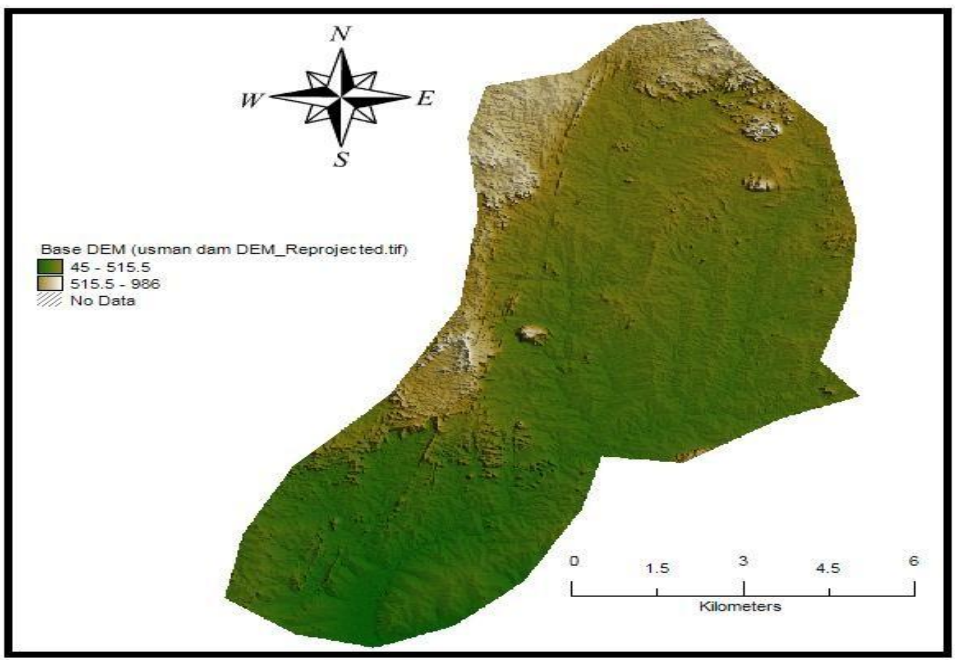


**Fig. 3.0: Digital elevation model of study area**

### 2.4 DIGITAL ELEVATION MODEL

The DEM of study area as shown in Fig. 1.0 and fig. 3.0 was downloaded fromAdvanced Space Borne Thermal Emission and Reflection Radiometer(ASTER) GDEM. Using the geographic positioning system (GPS) reading of the main outlet point (altitude 570 meters, Latitude - $9^0 12^l 27.34$” E and Longitude $7^0 25^l 10.35$” N) of the Bwari watershed; watershed boundary, stream network and drainage pattern of the watershed were developed. In addition, from DEM, the relevant flow parameters, flow accumulation, flow direction and slope were derived. The other spatial model input data were land use and land cover, soil map of the study area. The land use and land cover are one of the most important factors that affect runoff, evapotranspiration and surface erosion in any watershed. The digital 2008 land use and land cover and soil map of the lower Usman Dam watershed was obtained from the Federal Ministry of Agriculture of Nigeria. The digital elevation map was collected from the Ministry of Water, Irrigation, and Energy (MoWIE). Flat, undulating plains, rolling plains, Hills and mountainous landforms are the major topographic features lower Usman dam watershed. SWAT has predefined land uses identified by four-letter codes and it uses these codes to link land use maps to SWAT land use databases in the GIS interface.. The land uses were reclassified by 4-letter SWAT code and their spatial distribution was prepared.

**2.5 LandUseandLandCovers**

The land use and land cover map of lower Usman dam Abuja, Nigeria, was extracted, land use and land cover (LU/LC) map of the study watershed was reclassified using the SWAT model in order to correspond with the parameters in the SWAT database in the same manner the soil map was prepared. The LU/LC and the soil SWAT code was assigned to all map categories. These procedures were applied to determine the hydrologic parameters of each land and soil category simulated within each sub-watershed. The SWAT model requires different soil physical and chemical properties such as soil texture, available water content, hydraulic conductivity (permeability), bulk density and organic carbon content for different layers of soil. In this study, these parameters was obtained from the soil samples from Usman dam bank which were tested in the laboratory (Civil Engineering Laboratory, University of Abuja, Nigeria) to obtain the soil properties of the Usman dam watershed and environment. These were used in the analysis of Hydrological Response Units (HRUs)

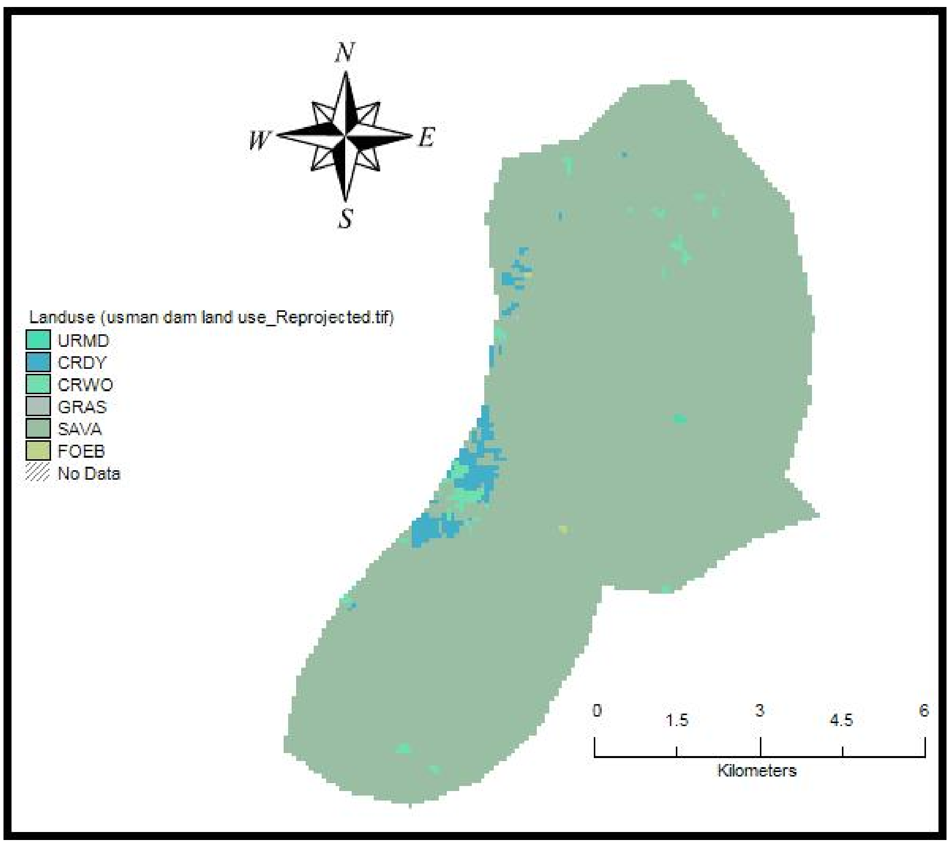


**Fig. 4.0: Landuse map of study area**

**Table 2.0 : Land Use Information of the Study Area**

| S/NO | SWATCODE | DESCRIPTION | AREA(HA) | %OF WATERSHED |
|---|---|---|---|---|
| 1 | SAVA | Savannah | 10422.13 | 97.38 |
| 2 | FOEB | Evergreen Broad leaf Forest | 66.40 | 0.62 |
| 3 | | | 214.33 | 2.00 |
| | CRDY | Dry landand Crop land Pasture | | |
| TOTAL | | | 10102.86 | 100 |

**2.6 SoilMap**

The soil map of this research area was obtained using the map of fig 4. It showed the soil types and soil properties like the PH, soil texture, organic matter content, and depth in the area downstream of lower Usman dam.Soil map also showed the end result of a soil survey inventory, i.e. soil survey which reveal the bearings of the dam.

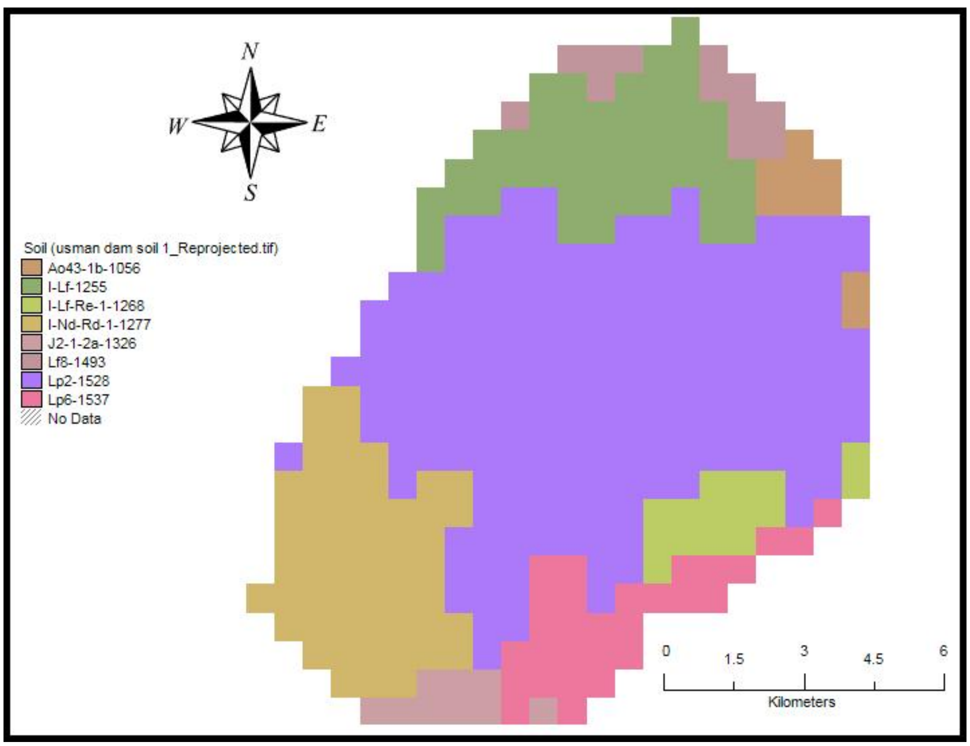


**Fig.5.0:Soil Map of the StudyArea**

**Table 3.0 : Soil Data Information of**

| S/N | SWATCODE | DESCRIPTION | AREA(HA) | %OFWATERSHED |
|---|---|---|---|---|
| 1 | Lp2-1528 | sandyclayloam | 10702.85 | 100.00 |
| | | TOTAL | 10702.85 | 100.00 |

### 2.7 Climate Data

Weather data were used in SWAT model to simulate the hydrological behavior of the watershed. The weather data that was suitable for this research were acquired from Nigeria Metrological Station inthe time ranges from1991-2021. Weather data accumulated dailyvalue for precipitation, maximum and minimum temperature, wind speed, relative humidity and the sunshine (converted to solar radiation) with the availability of data distribution of each weather. Weather datain this model contains estimates of atmospheric parameters such as rainfall, temperature, humidity, solar radiation and wind. The model utilizes the HRUs and the sub-basins during its running topredict the discharge inflows and outflows as well as the sediment yield from everysub-basin based on the data input into the model.

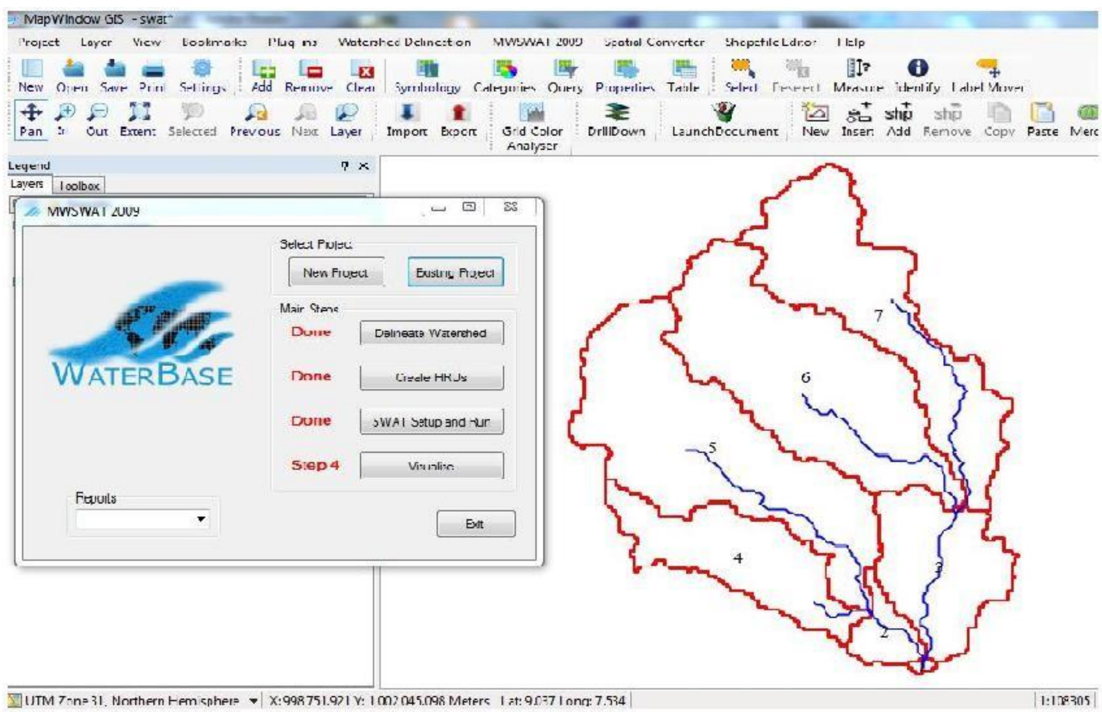


**Fig 6.0: Soil and Water Assessment Tool (SWAT) interface**

### 2.8 Watershed Delineation into Sub-basins and HRUs Creation

Watershed delineation generates the sub-basins, which is the first level of the subdivision of watershed area. The DEM was used to produce the stream network. The DEM generated from the GIS is in geographical coordinate system, it was re-projected using projected coordinate system. The final watershed delineation was done using the watershed delineation tool of SWAT which generated the flow direction and accumulation, outlet and inlet definition and calculation of sub basin parameters. Digital Elevation Model was processed to evaluate and delineate the watershed into sub-basins and sub-basins were later divided into smallest Hydrological Response Units (HRUs), Usman Dam watershed contains 7 sub-basins and 7 Hydrological Response Units (HRUs) with minimum elevation of 367m, maximum elevation of

883m, and mean elevation of 520.134992932307m and Standard deviation of 119.2318185497m. Fig. 7.

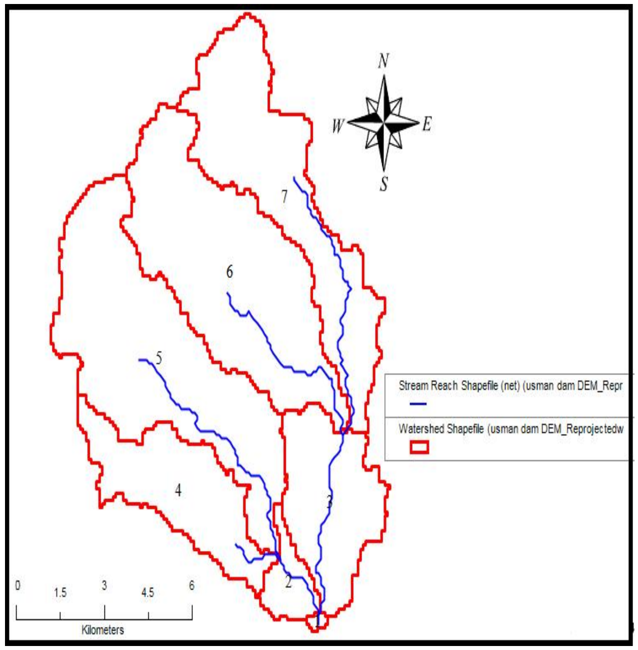


Fig. 7.0**:Delineation of Watershed into Sub-Basins of the Study Area.**

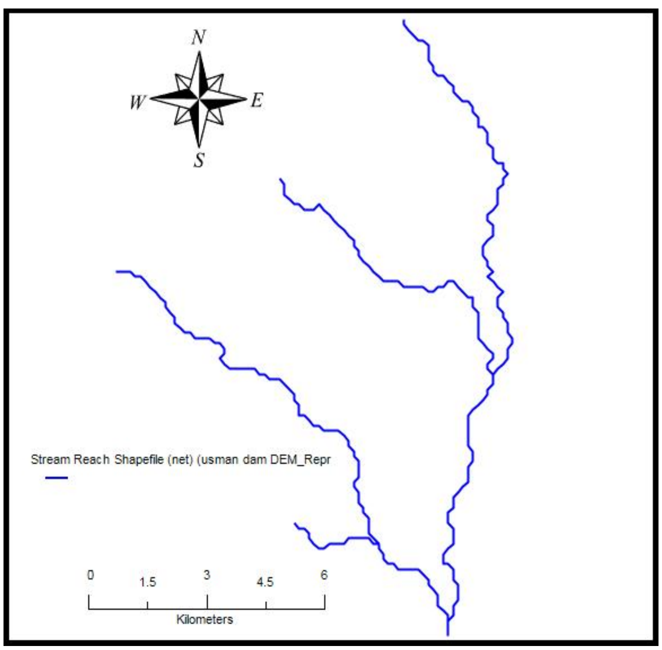


**Fig.8.0: Stream Flow of the Study Area**

**2.9 SWAT Model Process**

Watershed delineation was the first step in the SWAT model process and naturally existing stream network was determined using Usman Dam Watershed DEM Base on the concept of flow direction and accumulation; watershed was split into sub-watersheds and sub watershed were also split into smallest unit called HRUs that contains exceptional combination of homogeneous soil and land use properties and slope range, model was later set up and run, the last stage is visualization stage where sediment yield was predicted. The Fig. 6 shows the SWAT model interface.

**2.11 Visualization and Prediction of Surface Runoff**

The surface runoff was also predicted using the SWAT plug-in on map windows GIS software. This was done on the visualization stage. The year1991-2021(estimated years) was selected. SWAT output was selected as sub-basin. Two options were displayed under sub-basin which are static data and animation variable, static data was then selected. Surface runoff was selected under the options displayed, summary pattern was chosen as annual means (summary data can either be chosen as total or monthly) and model was saved. Annual and monthly surface runoff was differently calculated. Automatically by MWSWAT after the-model has been saved.

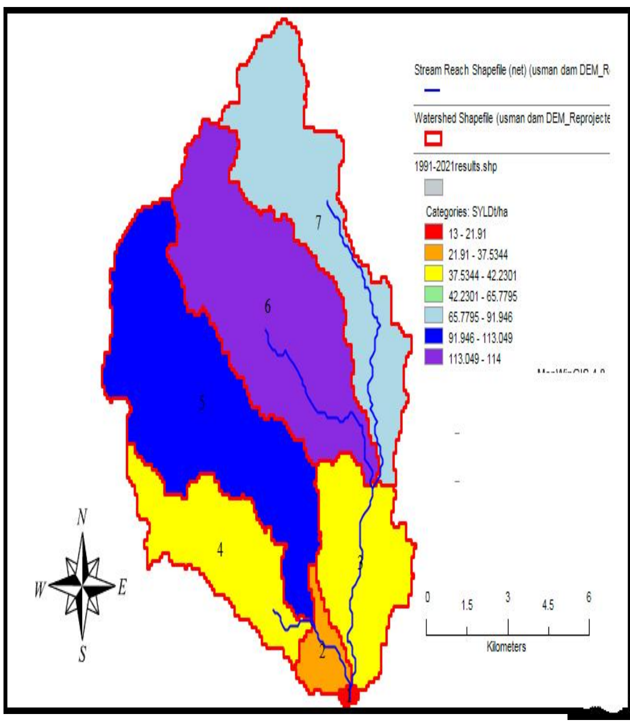


**Fig 9.0:Predicted Annual Sediment Yield in Sub-basins Area of the Watershed**

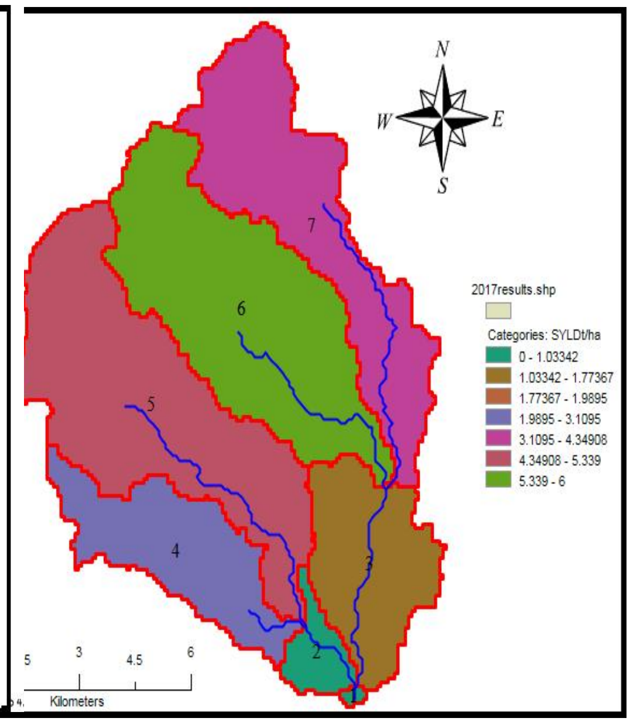


**Fig. 10.0 : Monthly Sediment Yield of the Study**

## III. RESULTS AN DISCUSSION

The MAPWINDOW interfaced with SWAT model was calibrated and evaluated the performance of the Flood combined models against the observed daily stream flow (Fig. 8.0). Due to the unavailability of daily observed stream flow for the seven Trans boundary sub basins, we used observed monthly stream flow to calibrate the model. In addition, we evaluated the model performance for daily live storage of the lower Usman dam against the observed flow (Fig. 8.0). The model exhibited that the sub basin 7 generated highest surface run off which stand at 30% of the total runoff of the seven sub basin flowing into the dam. Prediction from our results of sediment yield in sub-basins are shown in Table 4.0while Fig. 9.0 show the prediction of annual sediment yield of the study area and Fig. 10.0 Show the monthly sediment yield of the study area. The average annual sediment yieldwas estimated as 0.638452tons/ha. This analysis shows 30% of the sub basin 7 downstream of lower Usman dam are exposed to multi-hazard risk and that are high susceptibility to more hazard in the sub basin 7 region's land area.

**Table 4.0:Predicted Sediment Yield of the Watershed**

| | AREAS ($KM^2$) | SEDIMENT YIELD (t/ha) |
|---|---|---|
| 1 | 0.2353 | 13.6556 |
| 2 | 2.9249 | 21.9100 |
| 3 | 12.1620 | 37.5344 |
| 4 | 12.5740 | 42.2301 |
| 5 | 29.3250 | 91.9460 |
| 6 | 28.1400 | 113.0494 |
| 7 | 21.6680 | 65.7795 |
| 8 | 0.2353 | 13.6556 |
| 9 | 2.9249 | 21.9100 |
| **TOTAL** | **107.0292** | **386.1052** |

**Table 5.0 : Variation of Sediment Yield and Surface Runoff from 1991-2021**

| S/NO | YEAR | SURFACE RUN OFF (mm) | SEDIMENT YIELD (t/ha) |
|---|---|---|---|
| 1 | 1991 | 17.426 | 0.64 |
| 2 | 1992 | 17.352 | 0.634 |
| 3 | 1993 | 17.426 | 0.64 |
| 4 | 1994 | 17.426 | 0.64 |
| 5 | 1995 | 17.426 | 0.64 |
| 6 | 1996 | 17.352 | 0.634 |
| 7 | 1997 | 17.426 | 0.64 |
| 8 | 1998 | 17.426 | 0.64 |
| 9 | 1999 | 17.426 | 0.64 |
| 10 | 2000 | 17.352 | 0.634 |
| 11 | 2001 | 17.426 | 0.64 |
| 12 | 2002 | 17.426 | 0.64 |
| 13 | 2003 | 17.426 | 0.64 |
| 14 | 2004 | 17.352 | 0.634 |
| 15 | 2005 | 17.426 | 0.64 |
| 16 | 2006 | 17.426 | 0.64 |
| 17 | 2007 | 17.426 | 0.64 |

| | | | |
|---|---|---|---|
| 18 | 2008 | 17.352 | 0.634 |
| 19 | 2009 | 17.426 | 0.64 |
| 20 | 2010 | 17.426 | 0.64 |
| 21 | 2011 | 17.426 | 0.64 |
| 22 | 2012 | 17.352 | 0.634 |
| 23 | 2013 | 17.426 | 0.64 |
| 24 | 2014 | 17.426 | 0.64 |
| 25 | 2015 | 17.426 | 0.64 |
| 26 | 2016 | 17.352 | 0.634 |
| 27 | 2017 | 17.426 | 0.64 |
| 28 | 2018 | 17.426 | 0.64 |
| 29 | 2019 | 17.426 | 0.64 |
| 30 | 2020 | 17.352 | 0.634 |
| 31 | 2021 | 17.426 | 0.64 |
| | | | **0.6385** |
| **AVERAGE** | | **17.4069** | |

From the table 4.0and 5.0 respectively, it was deduced that sub-basin 6 has the highest sediment yield which was estimated to be 17.4069 mm surface run off and sub-basin 1 has highest surface runoff which was also estimated to 0.6385t/ha annually.

### 3.1 Soil Classification, Bearing Capacity and Strength Influence

From Table 1, the compressive strength of SDA–SGA concrete pad footings increased progressively from 22.40 MPa on clayey soil (ST1) to 25.28 MPa (+12.86%) on lateritic soil (ST4) and 24.78 MPa (+10.63%) on gravelly soil (ST5). This trend confirms that soils with higher bearing capacities and subgrade stiffness significantly improve structural performance by enhancing load transfer efficiency and reducing differential settlement risks. These findings are consistent with curing and testing standards specified in ASTM C511 (Standard Specification for

.

## IV. CONCLUSION AND RECOMMENDATIONS

The result of the increasing infrastructural development without codified urban planning in Bwari area council of federal capital territory Abuja causes urban flooding in areas downstream of the area council. It has caused many problems for residents and urban infrastructures. The SWAT modelling has identified the high-risk neighborhoods which will be vulnerable to flooding and other hazard if not properly guided and channeled out to a safe discharge. The sediment generated annually from the dam was estimated to be 0.638452 t/ha and **t**he average annual surface runoff of the dam was estimated to be17.40690323mm.The sub basin6 has the highest sediment yield and sub basin1 has the highest surface runoff.

### 5.0 Recommendations

- This study recommends the use of another multi-dimensional approach, sophisticated models, site-specific indicators, and fine-resolution satellite data to validate the prediction of vulnerability assessment of SWAT modelling.
- The predicted, developed hazard, and risk maps should be used for local and disaster management authorities to develop plans for quick response to recovery practices, emergency action plans (EAPs), and prioritize the wards and villages during the flood.
- This study also recommends enhanced flood management strategies, incorporating both rainfall forecasting and dam operation schedules, to reduce critical flood-related vulnerabilities in the lower Usman dam downstream area.
- Build and rehabilitate good drainage network systems that will convey excess water and prevent water-loggings whenever there is heavy rainfall.
- Regular cleaning of filled and blocked drains should be conducted in order to ensure that the drains function effectively.

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