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FLOOD INUNDATION MAPPING IN GELANA IN ETHIOPIA

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Abstract: The flooded areas along the Gelana River have been mapped based on the exceedance of highest flows for different return periods using the hydrologic engineering center for river analysis system (HEC-RAS) model, Geographical Information System (GIS) for spatial data processing and hydrologic engineering center geographical river analysis system (HEC-GeoRAS) for interfacing between hydrologic engineering center for river analysis system (HEC-RAS) and Geographical Information System (GIS). The velocity of 100 years return period would be 13.2 m/s, the velocity of 50 years return period would be 15.6 m/s, the velocity of 25 years return period was 5.1 m/s, the velocity of 10 years return period was 5 m/s and lastly the velocity of 2 years return period was 5 m/s. Proper land use management, river training work and a forestation are significant to reduce the adverse effects of flooding particularly in the flood prone areas. The result of this research will help the concerned bodies like; NGOs, governmental organizations, stack holders of the catchment, researchers to formulate and develop strategies, considerations and awareness according to the available flood inundation to the area.

Key words: Gelana, HEC- GeoRAS, inundation mapping, GIS

1. Introduction.

1.1 Background

Flood Hazard Mapping is flood map illustrating the flood hazard, i.e. the intensity of flood situations and their associated excedence probability. Usually, flood hazard maps show synthetic events for the inundation area for a scenario with a certain return period, the spatial distribution of the water depth and distribution of flow velocity (Selina Begum, 2007). The hazard aspect of the flood risk is related to the hydraulic and the hydrological parameters. Flooding is a natural phenomenon. Maps will not prevent floods from occurring, but they are an essential tool in avoiding or minimizing the damage to property and loss of life caused by floods, and for communicating flood risk.

Without accurate flood maps, local officials face serious difficulties in guiding development away from the most hazardous areas or in ensuring that development in or near the hazard areas are properly built and protected. Without adequate, accurate, and current maps, neither construction nor the insurance regulatory elements of the program can be effective (Technical Mapping Advisory Council, 2000). All flood hazard areas need to be mapped in order to reducing the rate of flood-related disaster costs. (Technical Mapping Advisory Council, 2000)

In Gelana catchment the extensive deforestation resulted replacement of vegetation cover by cultivated land (Azeb, B. 2009). Agriculture is the main land use practice in the catchment. Thick bush lands, open woodland, forest, grassland with cultivated land are found on the floor of the catchment (Azeb, B. 2009).

1.2. Statement of the Problem

In the author of this research long time experience, in Gelana where the study conducted, unexpected huge amount of flooding happened and submerged large area repeatedly. Still no study was conducted specifically on maximum flood recurrence interval to warn and prepare the community across Gelana that could mitigate the problem of flooding. Due to this most of the time the flood results in destructing life and properties of the community. Mostly the occurrence of flood is sudden and due, the people cannot save their properties even life. The flood submerges houses, destruct properties of Gedeo people at Yirgachefe and Chelelectu, Guji oromia people at Como'lcha, Hidbira, Borre, and Koore people at Barbare, Dorbade and Pachato. At the vulnerable areas the flood close land transport (Amaro – Dilla, Dorbade – Borre), damage agricultural land (at yirgachefe, chelelectu, Como'lcha, Barbare, Dorbade, Pachato, Borre and Malka). All the communities of the affecting areas are almost farmers and they have no alternative way rather than farming. Once agricultural land damage means; loss of crop for a season. That is a great problem to lead their life. The flood also disturbs aesthetic value of the environment. Due, the community is vulnerable to disease, (Ethiopia floods flash update, 2018).

In Ethiopia, totally 210,600 people were affected and 105,300 people were displaced, in Gelana, 5000 people were affected and 2500 people were displaced due to unexpected flooding from November 2015 to January 2016, (OCHA, 2015 – 2016). To mitigate and resolve the problem, this study will analyze the frequency of the flood and maps the vulnerable area.

2. Objectives

2.1 General Objective

The aim of this study was to analyze flood frequency and mapping the inundation area in Gelana Catchment, which may serve as a basic input to aware and preparedness of the community.

3.2 Specific Objectives

- To relate the magnitude of extreme event to its frequency of occurrence.
- To analyze the rainfall runoff relationship of the watershed by HEC HMS model.
- To map the flood inundation of the floodplain.
- HEC-HMS model integrated with Arc-GIS was used to estimate the rainfall runoff relationship for Gelana watershed.

3. LITERATURE REVIEW

Enormous studies have been undertaken following an integrated approach of hydrological modeling with GIS application (Zoljoodi & Didevarasl, 2014); (Kebede et al., 2006); (Asfaw & Lindqvist, 2015); (Bewketu, 2010).

GIS could benefit from the temporal modelling capabilities of hydrological models and hydrologic models can benefit from the spatial modelling capabilities of GIS, (Singh & Fiorentino, 1996). GIS with its upcoming advanced technology has been a great asset to Hydrologic Modelling, and it has made an enormous contribution in the field of water resources engineering. The GIS technology has the ability to capture, store, manipulate, analyse, and visualize the geo referenced data. On the other hand, hydrological features are spatially and temporally distributed, thus producing large data requirements for hydrologic modelling. More specifically, it has become a powerful tool for supporting a number of hydrological modelling applications. In this research, HEC-GeoHMS software is worked in collaboration with GIS using it as a field for water shed delineation, stream line definition, flow accumulation, drainage line processing, etc.

V. Demir and O. Kisi,(2015) conducted flood frequency analysis research by using HEC-RAS, HEC-GeoRAS, and Arc- GIS to map flood hazard in turkey calculated flood frequency of Mert River for 5, 10, 25, 50 and 100 year return period flood in m^3/s were 508, 641.8, 839.7, 1011.6, 1207.6 respectively.

The model simulation used for various water resources management and development aspects. Studies that conducted in different parts of the country showed that similar results by using HEC-HMS model. For example, Brhane Hagos (2012), reported that the HEC-HMS model showed a good match of Gumera catchment for both calibration and validation periods with (NSE = 0.71 and R^2 = 0.758) and

(NSE = 0.7 and R2 = 0.744), respectively. Through HEC-HMS model Abayneh Alemu (2012), indicated that the model reasonable accurate with R^2 = 0.78 for calibration and R^2 = 0.81 for validation periods.

Flood Hazard Mapping is flood map illustrating the flood hazard, i.e. the intensity of flood situations and their associated exceedance probability. Usually, flood hazard maps show synthetic events for the inundation area for a scenario with a certain return period, the spatial distribution of the water depth and distribution of flow velocity. (Selina Begum, 2007) The hazard aspect of the flood risk is related to the hydraulic and the hydrological parameters.

Inundation mapping is considered as one of the most important steps in disaster risk reduction because it identifies areas vulnerable to disaster so as to plan for disaster risk management, (Ismail, M, and Opeluwa, I.S.2013).

4. MATERIAL AND METHED

4.1 Description of Study area

Gelana River originates from Yirgachefe area, Gedeo zone. This watershed is part of the Rift valley Basin that drains in to Lake Abaya which is situated on the South Western side of Lake Abaya. Due to the agro –forestry practice of the Gedeo people, especially the land cover of the upper catchments maintained well. The Gelana watershed is in a better condition in terms of land cover and environmental degradation. Because of better land cover, the flux of the sediment from the watershed would be relatively low.

The Gelana River contributes about 10% of the total inflow of Lake Abaya (WWDSE, 2006). Lake Abaya is the final receptor of Gelana watershed flow. It has diverse altitudinal difference which ranges from 1162 m to 3136 meters above mean sea level. The study covers area of 9339.7 Km^2

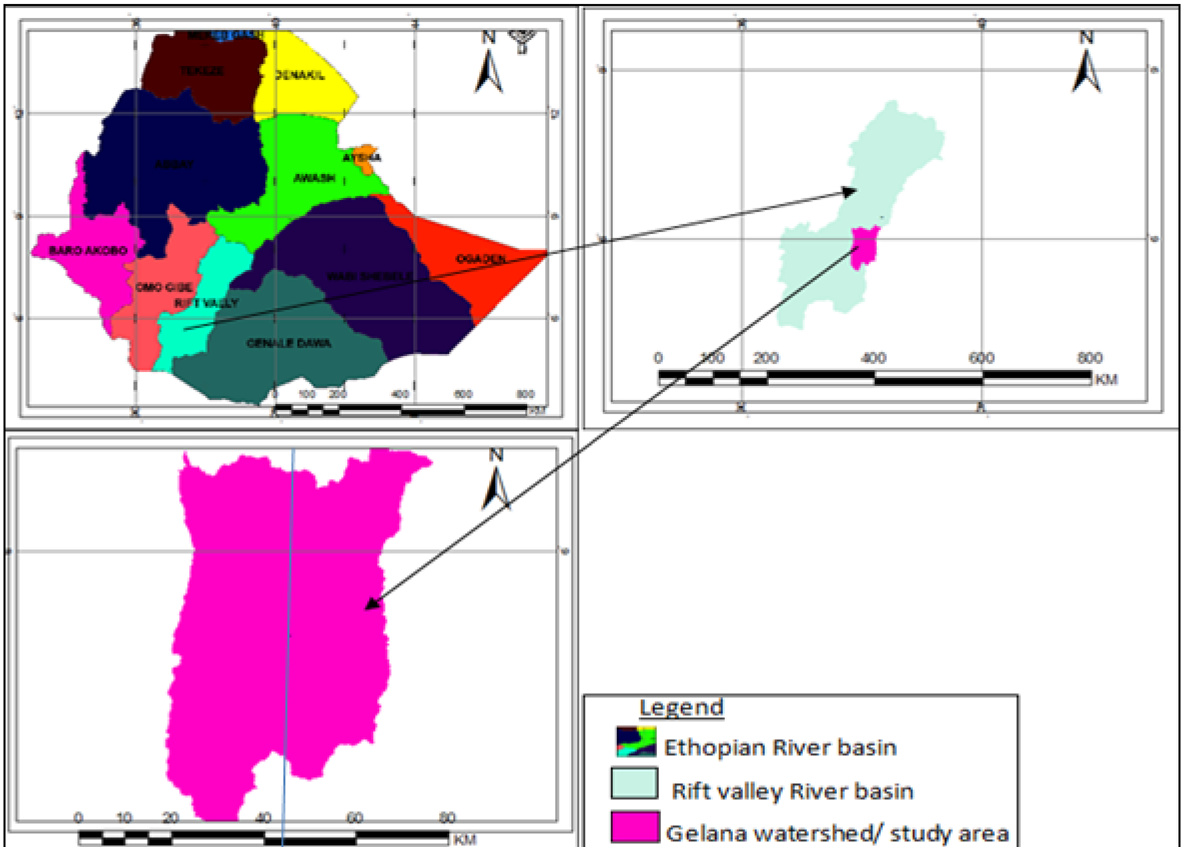

Figure 1: Study area

4.2 Materials used

4.2.1 Data Sources

In this section the datas used in this research are explained. Different data and soft wares were used to achieve the objective of the research.

The data and sources of the data used are; DEM data used as an input data for ArcGIS 10.2.1 software used to derive initial model parameters for watershed delineation and estimation of watershed characteristics. GIS data of the catchment such as land use, soil, and DEM of the basin are obtained from MoWIE data archive. The hydrological data used for the study were obtained from the MoWIE. Meteorological data was obtained from National meteorological agency (NMA) The soft wares used for this research are; ArcGIS 10.2.1 to obtain hydrological and physical parameters and spatial information of the study watershed. HEC-GeoHMS 10.2.1 used to delineate the sub basin of the study area for use of HEC-HMS for modeling. HEC-GeoRAS 10.2 for geospatial analysis of river for use of HEC-RAS modeling.

4.2.2 Land Use Analysis

The land use land cover of Gelana watershed had changed rapidly due to extensive deforestation as a result of increased number of population in the area. The extensive deforestation results in replacement of vegetation cover by cultivated land (Azeb, B. 2009). Agriculture is the main land use practice in the catchment. Thick bush lands, open woodland, forest, grassland with cultivated land are found on the floor of the catchment.

4.2.3 HEC-GeoRAS Model

HEC-GeoRAS is developed for the solution of geographic data with the HEC-RAS and is working on an extension to ArcGIS. This model can convert the format of HEC-RAS software and can read the obtained format. After determing the data with HEC-RAS, water surface profiles, water level, and water velocity can be obtained. The results obtained from hydraulic model can be converted to GIS format by using HEC-GeoRAS and thus flood mapping and flood depth map can be obtained [HEC-GeoRAS, 2009.].

HEC-GeoRAS is set of ArcGIS tools that designed to process geospatial data for use with the Hydrologic Engineering Center's River Analysis System (HEC-RAS). The extension helps users to develop an HEC-RAS import file containing geometric data from an existing digital terrain model (DTM) and complementary data sets. Results exported from HEC-RAS may also be processed.

4.2.4 Inundation area mapping

The DEM (digital elevation model) was processed to develop the TIN (triangular irregular network). After that, the river cross-sections, river centre line, stream bank lines, flow lines, and other river geometry information were extracted from the TIN for the HEC-GeoRAS model. After the RAS geometry data preparation, the HEC-GeoRAS model was used to create the RAS GIS import file (final river geometry file) that can be used as input for HEC-RAS (Figure 2). After checking the cross-section; editing the river geometry and making final correction of the river geometry file in the HEC-RAS model. After the generation of the final river geometry file, the flows imported from four gauging stations and the HEC-RAS generated water level for different return periods. The water surface level for each return period has been exported in HEC-GeoRAS for final inundation mapping along the river.

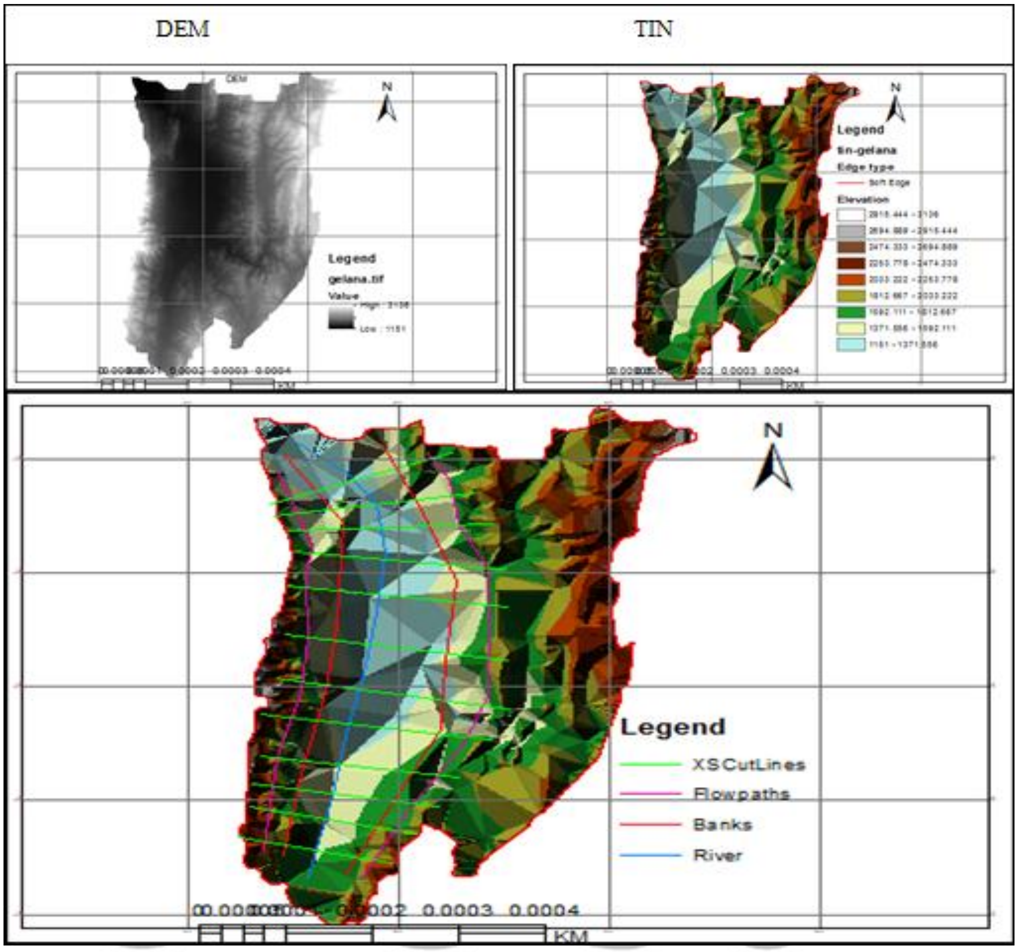

Figure 2: Gelana watershed Geometery data preparation Using HE-GeoRAS

5. Result and Discussion

The flood inundation map was produced by flood generating factors, such as slope, elevation, flow, and velocity and area type in the Gelana using HEC RAS. The figure 3 below shows that the area affected by flood.

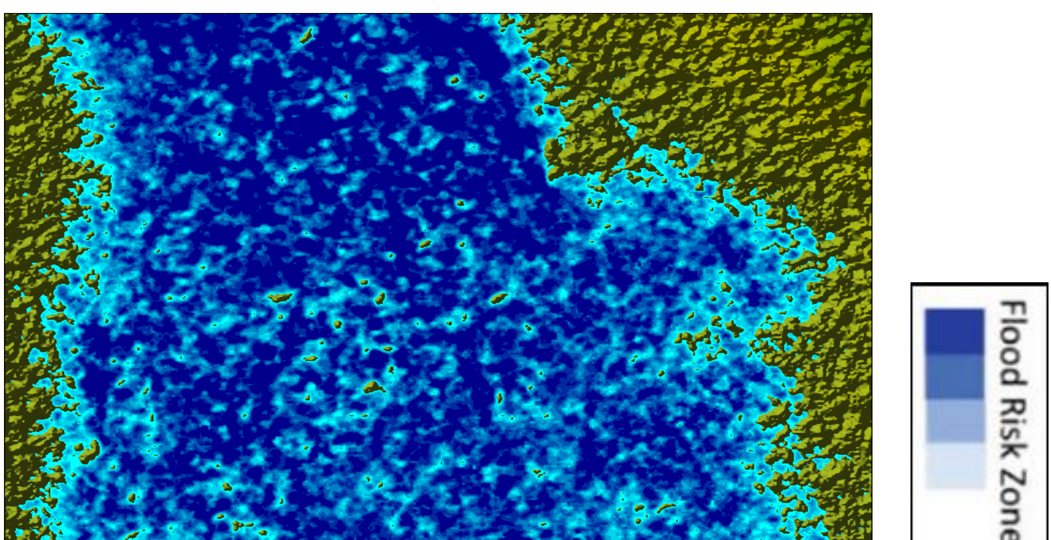

Figure 3: Inundation mapping

Table:1 flood hazard area

Flood Hazard area	status
3.99	Very High
2.32	High
2.21	Moderate
2.13	Low
2.04	Very low

The figure 3 and table 1 above shows the flood hazard area for Gelana. The flood hazard in the study area identified as 3.99, 2.32, 2.21, 2.13, 2.04 hectare of Gelana Catchment, were subjected respectively to very high, high, moderate, low and very low flood hazards.

The vulnerable area for Bantyeketu River in Adis ababa mapped by Elias Zeleke (The area of flooding for 10, 25 and 50 year return period was reported as 3.14, 3.93 and 4.47 hectares respectively) was higher than Gelana because the surface condition of adis ababa was impervious and most part of precipitation changed to surface runoff. However, in the case of Gelana, the area of flooding is minimum relative to adis ababa. The flooding area in Gelana is in the smaller in the Coast of Gelana River.

Water surface elevation

The first step in flood plain delineation process was to create water surface TIN from water elevation attached to each cross section.

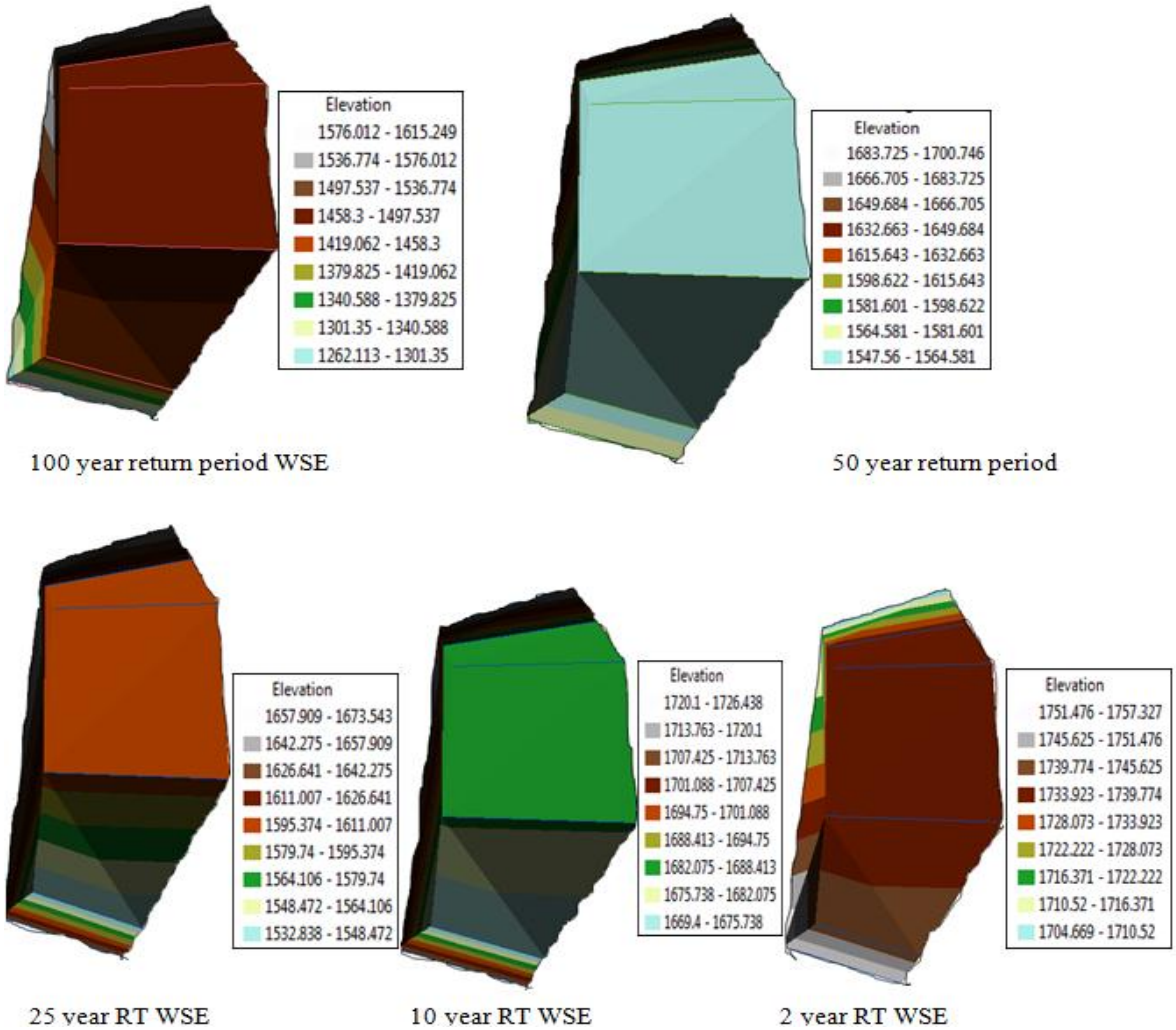

Figure 4: Water surface TIN for different return period

Table:2 flood depth

Return period	Flood depth
100	39.2
50	17
25	15.6
10	6.3
2	5.9

As figure 4 and table 2 above shows, the water surface elevation for 2, 10, 25, 50, and 100 years return periods are; 5.85, 6.34, 15.63, 17.02 and 39.2m above mean sea level respectively. This result indicates that the area is vulnerable to flood risk. The flood is capable to submerge and destruct properties.

Velocity mapping

The figure 5 below shows the 25 years recurrence interval velocity map. The red color is at the downstream and the blue color is the upstream side.

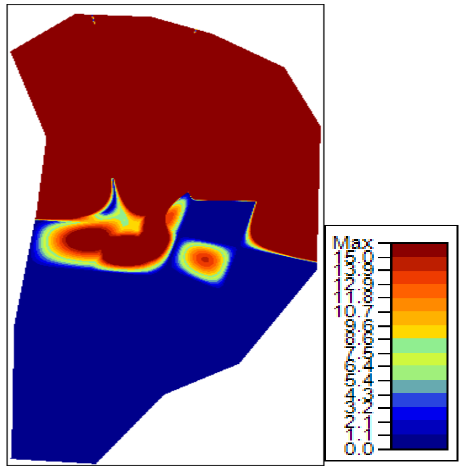

Figure **5**: flood velocity map

Table 3: flood velocity for different return periods

Return period	Water velocity(m/s)
100	13.2
50	15.6
25	5.1
10	5
2	5

The figure 5 and table 3 above shows the velocity of different recurrence interval. The velocity of 100 years return period would be 13.2 m/s, the velocity of 50 years return period would be 15.6 m/s, the velocity of 25 years return period was 5.1 m/s, the velocity of 10 years return period was 5 m/s and lastly the velocity of 2 years return period was 5 m/s. As a result indicates, the velocity 100 years of flood is smaller than 50 years return period. This is due to that the amount of flood is high for 100 years and it inundates large area rather than the flood having 50 years return period. The flood discharge per area coverage of flooding area is the velocity.

6. CONCLUSION AND RECOMMENDATION

6.1. CONCLUSION

In this study, HEC-HMS model integrated with Arc-GIS was used to estimate the rainfall runoff relationship for Gelana watershed. The work was conducted using a basin model generated by the Arc-GIS extension of HEC-GeoHMS. Frequency analysis was analyzed depending on data's are gathered from 1986-2015. Based on this it is to be known that there was a calibrated out flow using the model. The main components that played a significant role in the **analysis** of the flood were precipitation data, flow data, digital elevation data, land use and soil data.

The SCS CN loss method was a useful tool to simulate the rainfall runoff relationship. The curve number grid was generated from the union of land use and soil data of the catchment that ranges from 71 – 100. The dominating soil group of the catchment is clay soil which covers 78.72 % of the area categorized under HSG of "D" and loam soil which covers about 21.28 % of the catchment under HSG of "C". The land use of the catchment was re classified under four as; agriculture, medium residential, water and forest for the generation of curve number grid.

The flooded areas along the Gelana River have been mapped based on the exceedance of highest flows for different return periods using the HEC-RAS model, GIS for spatial data processing and HEC-GeoRAS for interfacing between HEC-RAS and GIS. The areas along the Gelana River simulated to be inundated for 2, 10, 25, 50 and 100 years return periods. The velocity of 2, 10, 25, 50, and 100 years are; 5, 5, 5.1, 15.6, and 13.2m/s respectively.

7. Reference.

1. C.Y., & Singh, V. P. (1998). A monitoring on monthly water balance models for water resources investigations. Water resources management, 12(1), 20-50.
2. Kebede, S., Alemayehu, T., Travi, Y., & Marc, V., (2006). Tana Lake Water Balance and its sensitivity to fluctuations in rainfall, Blue Nile basin,Ethiopia. Journal of Hydrology, 316(1), 233-247.
3.Yuan, Y. & Qaiser, K. (2011). Floodplain Modelling in the Kansas River Basin Using Hydrologic Engineering Center (HEC) Models: Impacts of Urbanization and Wetlands for Mitigation: US Environmental Protection Agency, Office of Research and Development.
4. Zhan, X. and M.-L. Huang (2004). "ArcCN-Runoff: an ArcGIS tool for preparing the curve number and runoff maps." Environmental Modelling & Software 19(10): 875-879.
5. Zoljoodi, M., & Didevarasl, A. (2014). The fluctuation of water level in Urmia Lake: Relationship with the Long-Term Changes of Meteorological Variables (Solutions for Water-Crisis Management in Urmia Lake Basin). Atmospheric and Climate Sciences, 2014.
6. V. Demir and O. Kisi,(2015), Flood Hazard Mapping by Using Geographic Information System and Hydraulic Model: Mert River, Samsun, Turkey
7. Venkatesh, M. (2009), Watershed and stream network delineation. School of Civil Engineer-ing Purdue University.
8. Verma, A. K., Jha, M. K., & Mahana, R. K. (2010). Evaluation of HEC-HMS and WEPP for simulating watershed runoff using remote sensing and geographical information system. Paddy and Water Environment, 8(2), 131-144.
9. Woubet G. Alemu (2014). Risk Assessment and Flood Hazard Using GIS and Remote Sensing in Fogera Woreda, Northwest Ethiopia.