Watershed Parameters to Flood Discharge Modeling at Wodeba River Newly Constructed Bridge in Wolaita Zone Damot Pulasa Woreda,Ethiopia

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Abstract

Urban river bridges are prone to flood risk as result of high flow from the upper part of Watershed. Watershed Length, shape, area and slope are very important parameters affecting the timing and magnitude of the flood discharge contributed from the watershed outlet .Flooding frequently occurs in Wodeba River due to large watershed draining to the location of newly Construction Bridge. This research has applying hydrologic modeling to determine the flooding discharge newly constructing bridge designed location. In order to determine the derive watershed parameters i.e. longest flow length [L], watershed centroid length [L_c], average slope of watershed slope [S_w] and area [A] of watershed, Geographical information system (GIS-10.4.1) by using digital elevation model has applied .Snyder's method of hydrologic method was applied and determined the peak discharge of 1564.75m^3/s at bridge location by suing watershed parameters of Longest flow length [L), Centroid distance (Lc) Area [A] and average channel slop are 30.77Km,17.25km, 142.25Km^2 and 30% respectively .The result of the study indicates that the area contributing the runoff to bridge location is high that result vulnerable to flooding during maximum probable precipitation and the steep slop of watershed resulted high response to peak discharge.

Key Words: Snyder's method, Peak discharge, peak time, Parameters, Time to base

1.0INRODUCTION

Construction of Bridge structure considering the effect of watershed hydrology is very important in order to have life of the bridge long lasting. Prior to construction of such expensive structure, simulation of the flood discharge by applying watershed the parameter is very important to necessary management and mitigation strategies of flood risk from the watershed because it is high cost incurring structure. Flood and scour represent the most frequent cause of bridge failures (>50% of all failures; Wardhana and Hadipriono, 2003. It is high cost incurring structure, however affected by different disruptive events. Man-made and natural events are a threat to bridge safety and network serviceability (Yang and Frangopol, 2020).Hydrologic modeling, the best means of tool planning, designing and management for such costive infrastrure to public utility. In most developing countries watersheds are ungagged or very poorly gauged with hardly any record of rainfall or stream flow data, as a result, establishment of rainfall runoff relation in such poorly gauged or completely ungagged catchments, planning of watershed is impossible. Hence in such case, Hydrologic models that rely on geomorphological parameters can be applied to derive synthetic unit hydrographs. The most common synthetic unit hydrograph techniques for ungagged basins are Snyder's SUH, SCS Dimensionless hydrograph, Instantaneous Unit Hydrograph (IUH) and Geomorphological Instantaneous Unit Hydrograph (GIUH).In this paper, a study has been has been carried out in the Wodeba watershed, and Snyder's Synthetic unit hydrograph technique has been used. The geomorphological parameters required are obtained using geographical information system [GIS].

2 Objectives

- ✓ To apply DEM and determine rainfall-runoff affecting area of the watershed.
- ✓ To determine geomorphological parameters of the watershed by using GIS
- ✓ To derive the peak discharge and distributed unit hydrograph.

3 Area Descriptions

The study area is located in Ethiopia, South Nation Nationally and Peoples Region in between Woliata and Hadiya Zone, Geographically Longitude 037^{0}55'6''and Latitude 07^{0}4'17''.

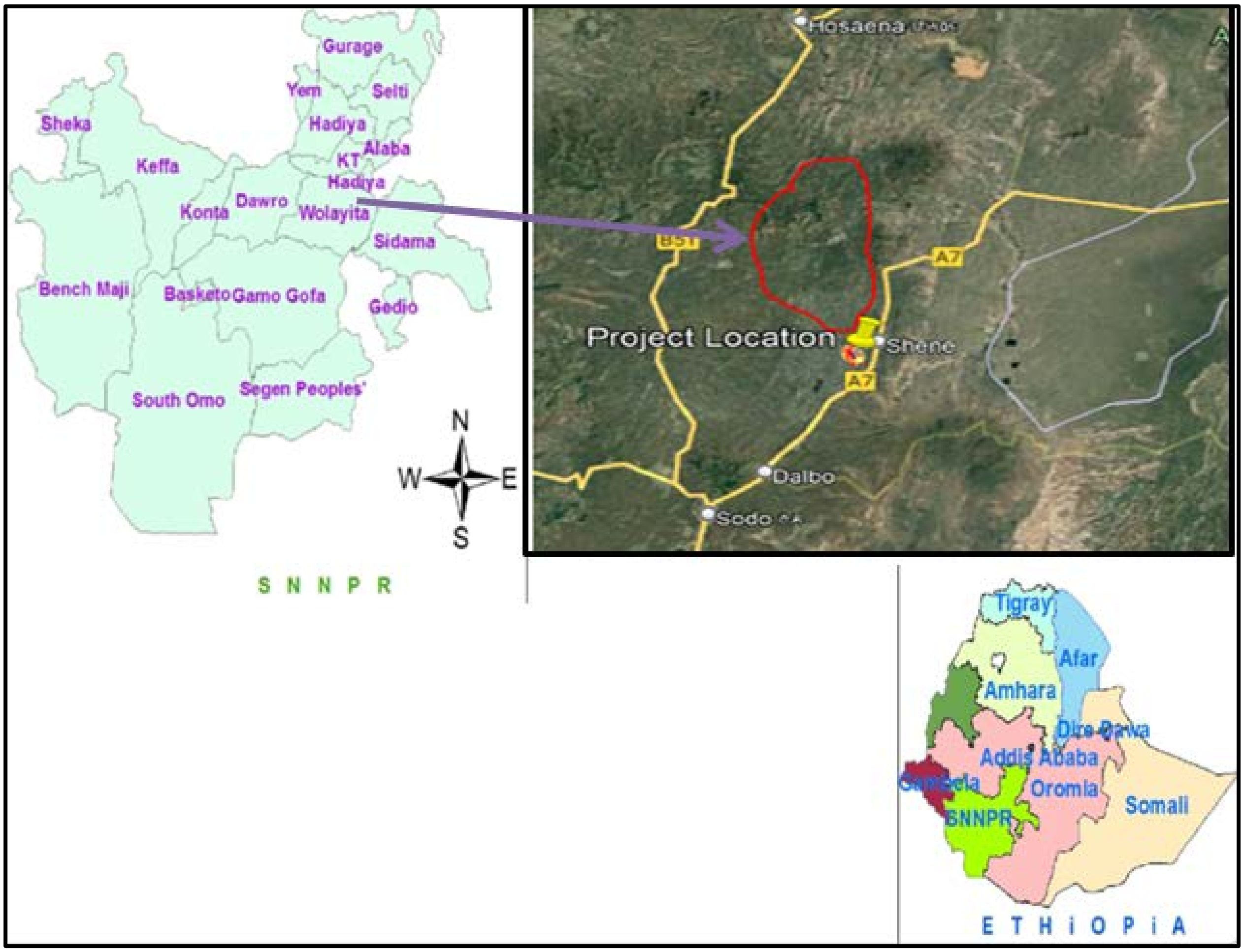

Figure 1: Research Study Area

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4. Methodology

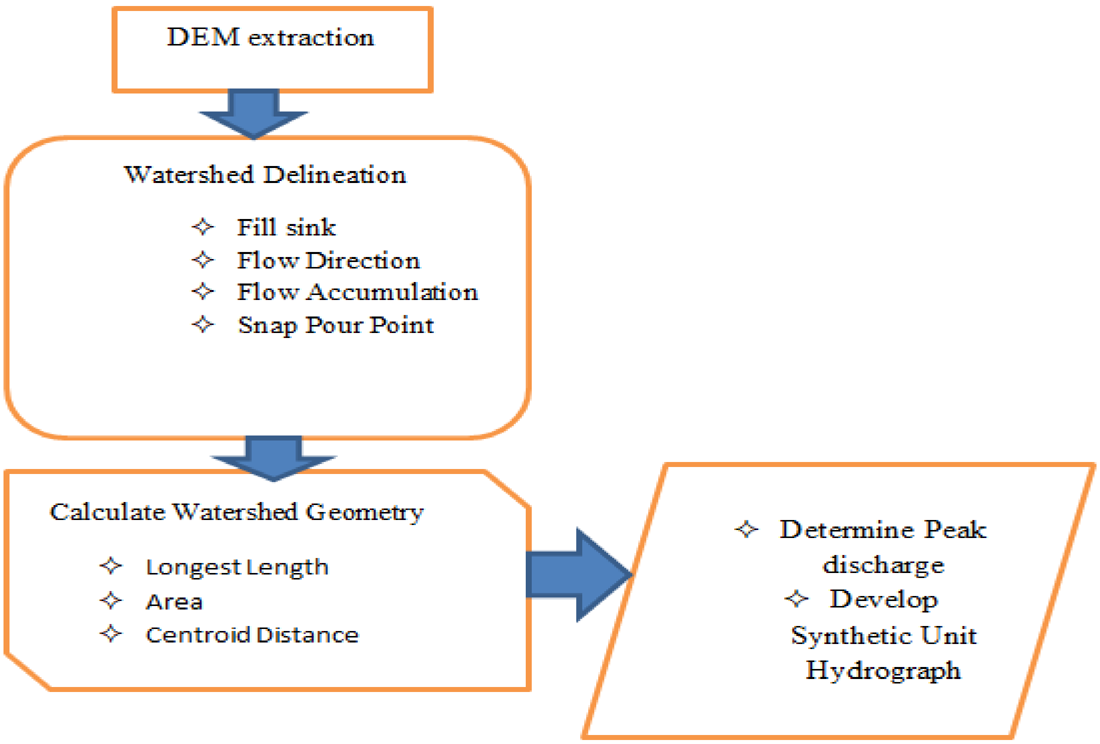

Figure 2 Research Methodology

5. Results and Discussion

5.1 Dem Extraction

DEM is the digital representation of the land surface elevation with respect to fixed point**.**Inorder to extract DEM data for the specific study area, USGS earth explorer, ASTER data [Advanced Space born Thermal and Reflection and Radiometer] base was used and downloaded for path and raw 054,168 respectively in rectangular polygon of latitude and longitude**.**

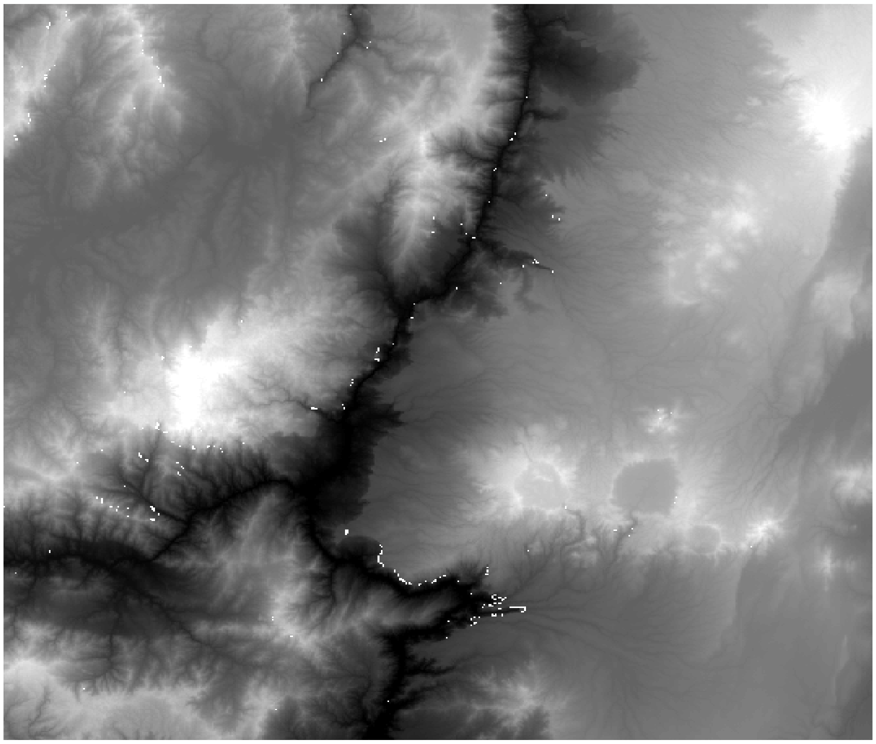

Figure 3 DEM downloaded [USG: path and row 054x168]

5.2 Fill Dem

Filling the DEM after getting the DEM, there is needed to fill the depressions .If cells with higher elevation surround a cell, the water is trapped in that cell and cannot flow. The fill sinks function modifies the elevation value to eliminate these problems.

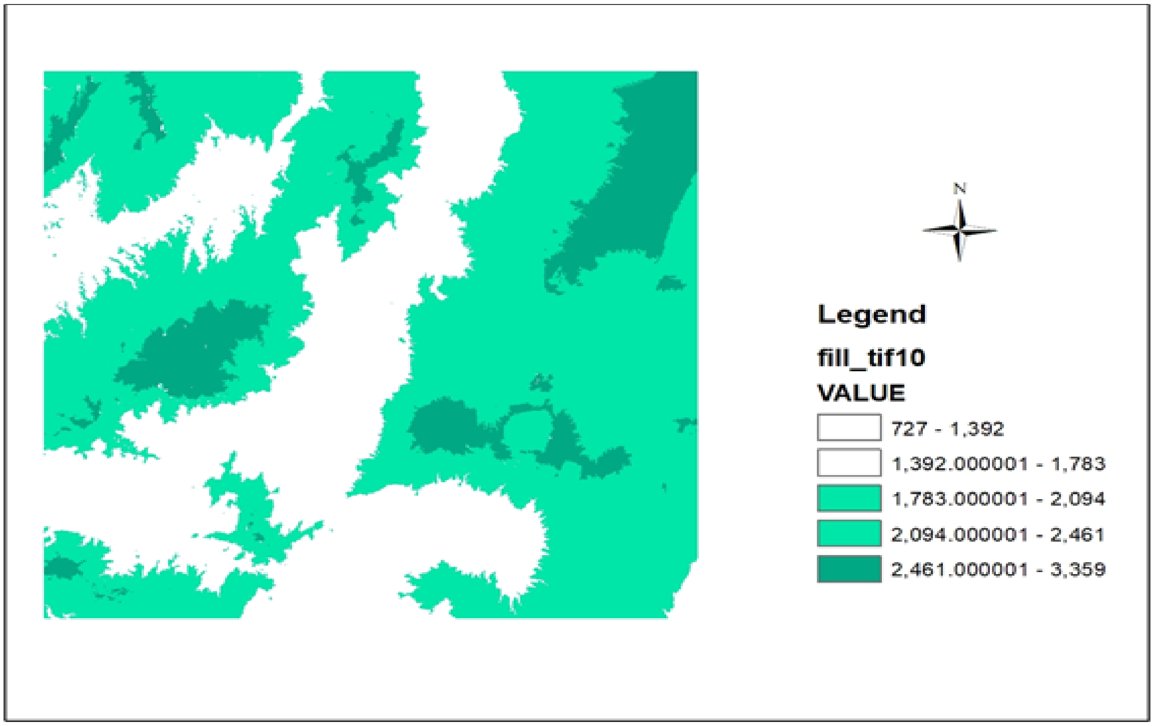

Figure 4 Fill DEM

5.3 Flow Direction

The filled DEM is used to prepare the Flow Direction map. Flow direction tool is available in the hydrology tool box in spatial analyst extension. It creates the raster with flow direction to the steepest neighboring cell down the slope. It is used to determine the direction of flow of water in the given topography the given topography. Direction of flow must be known for each cell, because it is direction of flow that determines the ultimate destination of water flowing across the surface

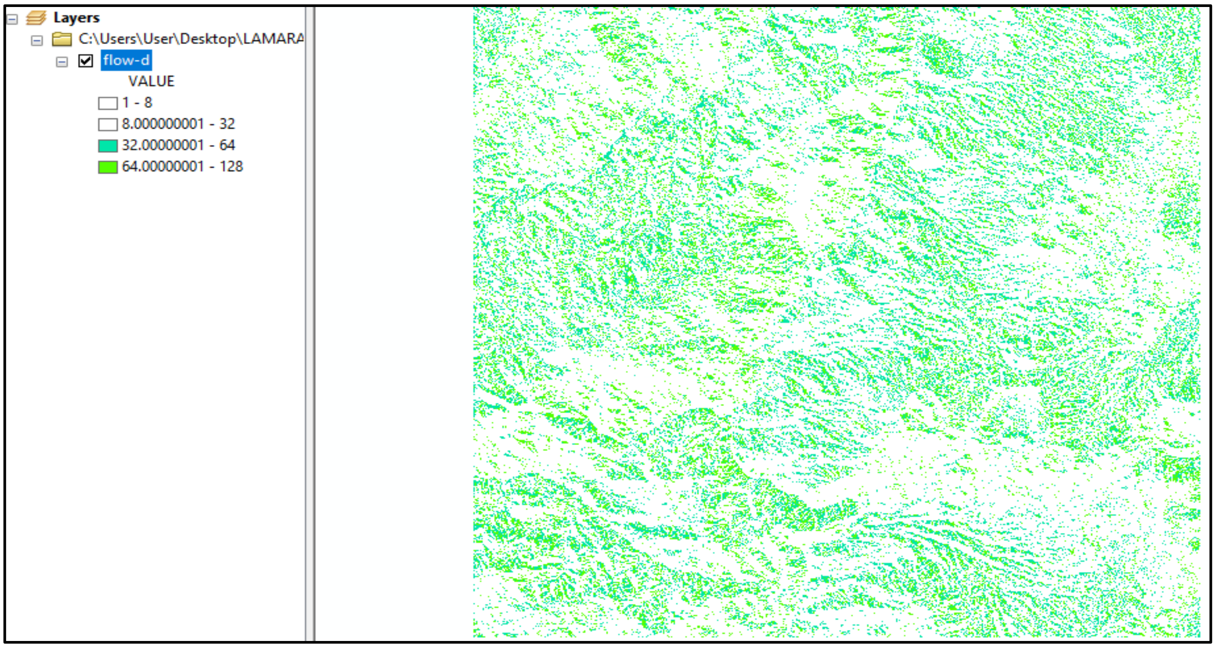

Figure 5 Flow Direction

5.4. Flow accumulation

The flow accumulation tool it shows the drainage path based on Fig-4.6 and calculates the flow into each cell by the flow into slope of each cell. The new flow accumulation raster will be added to your map. It means that each Cell with higher flow accumulation values should be designated in the area of low elevation, such as in valleys.

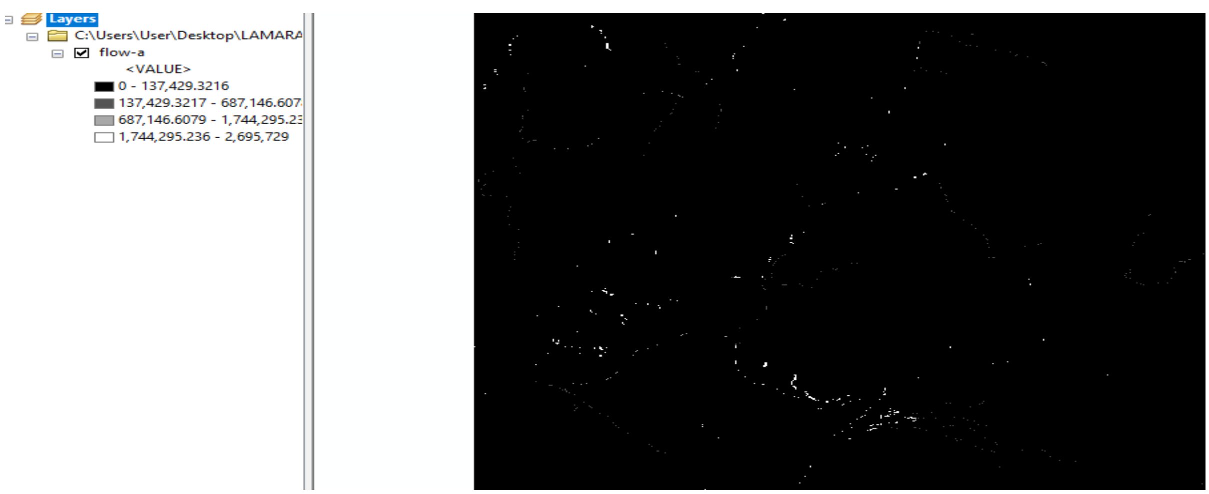

Figure 5 Flow Accumulation

5.5 Average Slop of Watershed

Flood magnitudes reflect the momentum of the runoff. Slope is an important factor in the momentum. Watershed slope reflects the rate of change of elevation with respect to distance along the principal flow path.

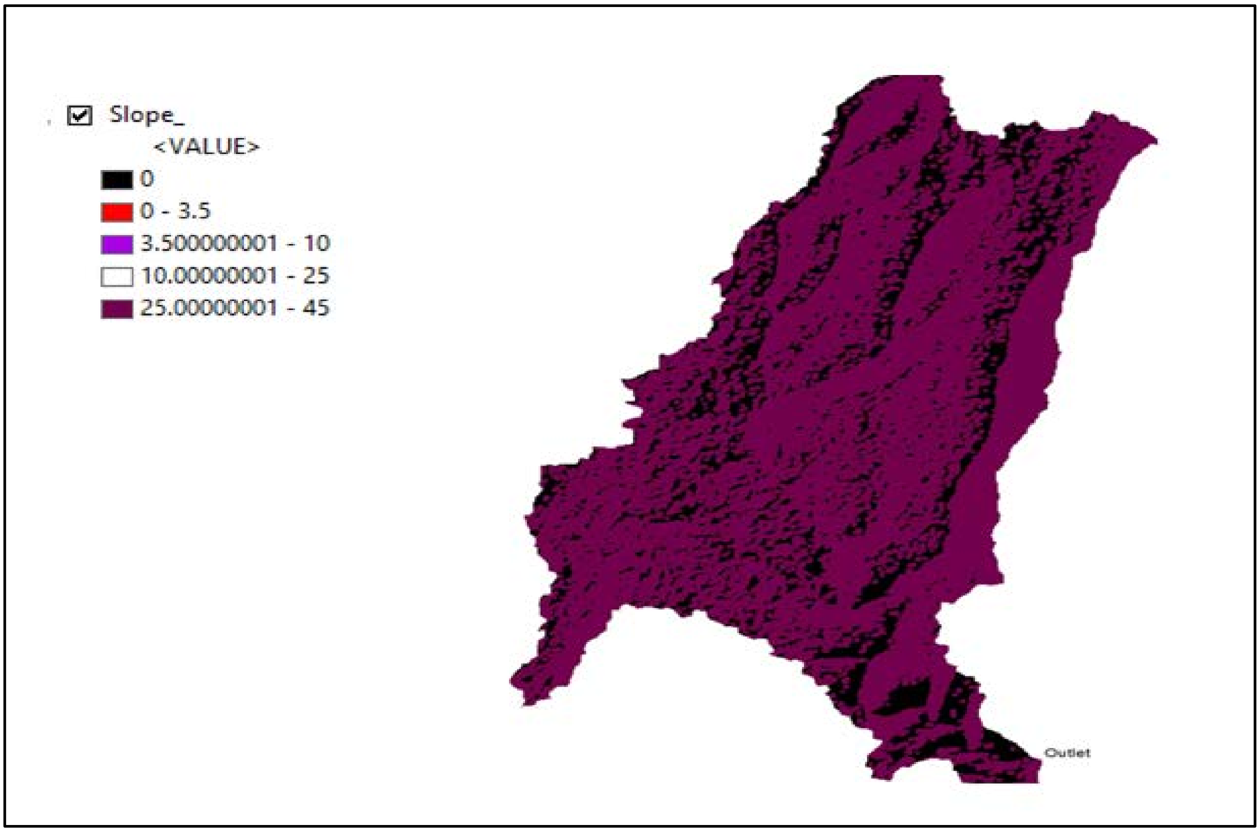

Figure6: Average Slop of the watershed

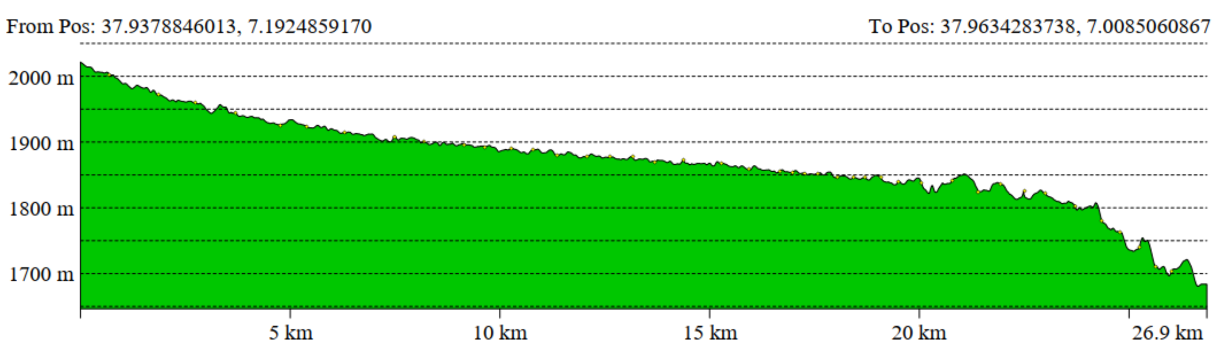

Figure 7 Slop Along the main course of the river

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5.6 Drainage Area (A)

Most important for hydrologic design; reflects volume of water - generated from rainfall. The volume of water available for runoff may be assumed– the volume of water available for runoff may be assumed as product of rainfall depth & drainage area. Drainage area input to all models.

5.7 Watershed length (L)

Increases as the drainage increases; L is important in hydrologic computations; L- defined as distance measured along the main channel from the outlet to the basin divide; L is measured along the principal flow path A & L- both measures of watershed size; they may reflect different aspects of size. A-indicate potential for rainfall to provide a volume of water; L- used in computing time parameter -measure of travel time of water through a watershed

5.8 Length to the center of area (L_{ca})

Distance in miles measured along main channel from basin outlet to the point on the main channel opposite the center of area.

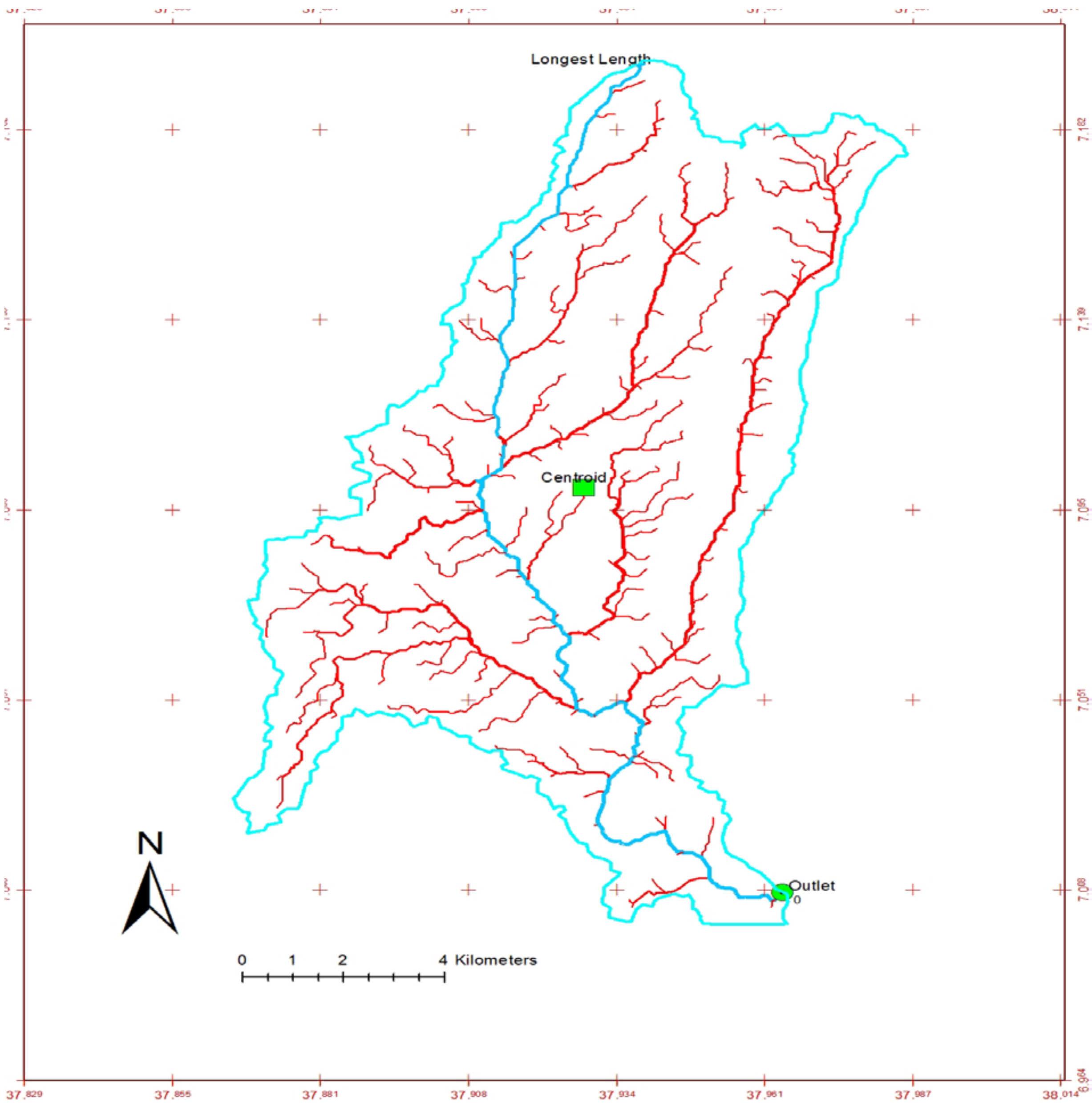

Figure 8 Watershed contributing to Wodeba River Bridge

Table 1: Watershed Parameters

Description	Unit	Value
Watershed length	Km	30.77
Centroid Length	Km	17.25
Area of watershed	$K.m^2$	142.25
Average Slop	%	30

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5.9 Snyder Synthetic Unit Hydrograph

The Snyder method is descriptor of basin morphology model based on relationships found between characteristics of a standard unit hydrograph. Peak discharge and time to it the peak is important parameters characterizing a unit hydrograph, the Snyder method employs factors defining these parameters, which are then used in the synthesis of the unit graph (Snyder, 1938). The basic assumption in this method is that basins which have similar physiographic characteristics are located in the same area will have similar values of Ct, the lag factor, and C_p, the peak flow factor. Ct = a regional constant representing watershed slope and storage. The value of [Ct] in Snyder's method ranged from 1 to 2.2. Cp =a coefficient ranging from 4 to 5 for Snyder's method. As the basin has steep slopes (the equivalent slope in the effective catchment is 30%) a value of Ct of 2 was adopted. Similarly, an average value of C_p was chosen as 4 and C1=0.75[1.0 for English units]

The hydrograph characteristics are the effective rainfall duration, $t_{r,}$ the peak direct runoff rate, Qp, and the basin lag time, tp. For a standard unit hydrograph, the basin lag, t_p, and the peak discharge, q_p, are given by

$$tp = C1 * C_t (L * L_c)^{0.3} = 9.85 hours \quad 1$$

A standard unit hydrograph is associated with specific effective rainfall duration, tr, defined by the following relationship with basin lag, t_p,

$$tr = tp / 5.5 = 13.13 / 5.5 = 1.99 hour = say = 2 hour \quad 2$$

The basin lag time of the standard unit hydrograph is in hours is the length of the main stream in kilometers from the outlet to the upstream divide, L_c is the distance in kilometers from the outlet to appoint on the stream nearest the centroid of the watershed area. The peak discharge of the standard unit hydrology is in m^3/s, A is the basin area in km^2, and if t_p is different from 5.5tr, then basin lag for the required unit hydrograph is calculated as for 2 –hour desired unit hydrograph

$$t_p' = tp - 1/4[t_r - t_R] = 9.85 = 10 hour \quad 3$$

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For a standard unit hydrograph unit hydrograph the basin lag, tp, and the peak discharge,q_p are given by for C_2= 2.75[640 for English units]

$$qp = [C_2 C_p A] / t_p' = 1{,}564.75 m_3 / s \qquad 4$$

The peak discharges of the standard and required UH are related as

$$Qp = \frac{qp * tp}{t_{p'}} = 1564.75 m^3 / s \qquad 5$$

For a triangular shape for the UH, and given that the UH represents a direct runoff volume of1 cm [1in], the base time of the required UH may be estimated by considering the steep slope of the river and watershed, T_B has been considered as 2.67 tp'

$$T_B = 2.67 tp' = 26.7 hours \qquad 6$$

The width in hours of the UH at a discharge equal to a certain percent of the peak discharge q_{pR} is given by chow et al [1988] as

$$W\% = CW * [qpR / A]^{-1.08}$$

Where, the constants CW are 1.22, for the75% width and 2.14, for the 50% width.

$$W75\% = CW * [qpR / A]^{-1.08} = 9.2 hours$$

$$W50\% = CW * [qpR / A]^{-1.08} = 16 hour$$

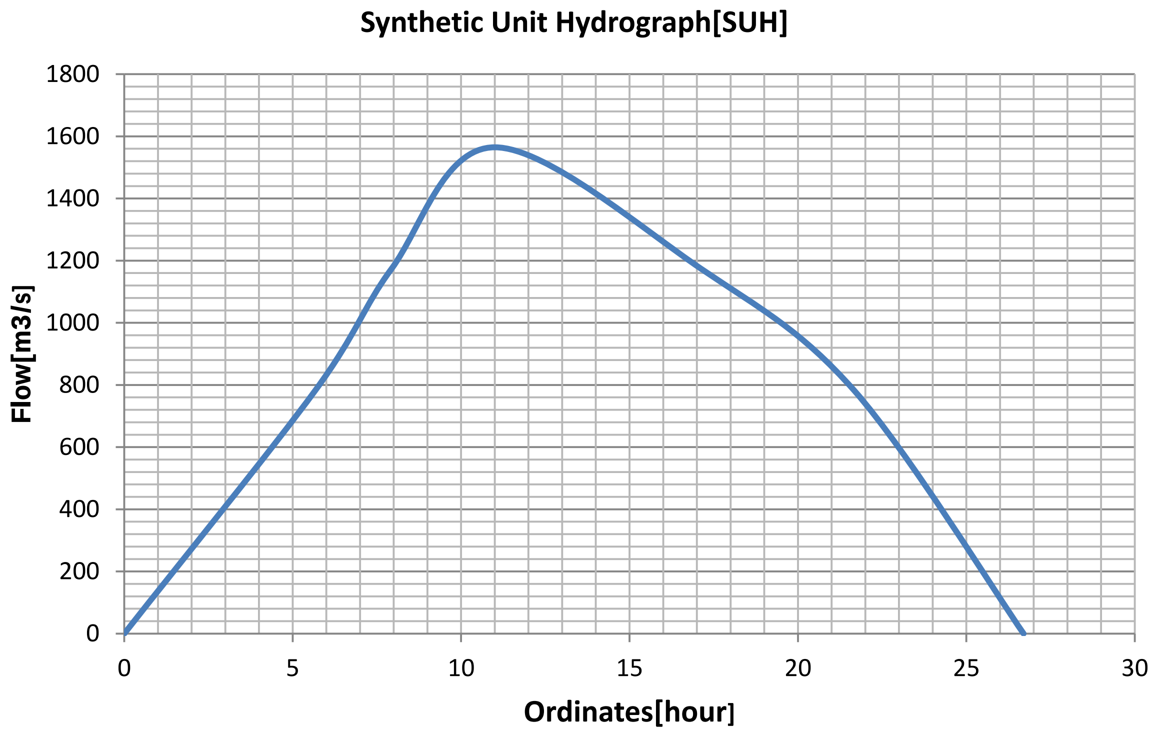

Figure 9 synthetic Unit Hydrograph of Wodeba River Bridge locations

Table 3: Modeled hydrograph parameters

Model	Time to peak[hour]	Peak discharge[m3/s]	Base time[hour]
SUH	10 hour	1564.75	26.6

The time to peak discharge is short as compared to the magnitude of the discharge which implies that the watershed steep slop has effect on response and area has the effect on magnitude of the peak discharge.

6. Conclusion

Watershed parameters modeled using GIS automated watershed tool are used to develop the discharge magnitude and response time to peak discharge. The area of the watershed 142.25km2 resulted large peak discharge of 1564.75m^3/s and compared to area of the watershed, length is smaller and resulted shorter time to peak discharge of 10 hour and similarly steep slop of the watershed modeled. The channel slop of the basin is milder than watershed overland flow that resulted broader hydrograph shape after time to peak discharge.

7. Recommendation

- Prior to construction of any infrasture that depends hydrology must develop have gauged data or develop by modeling.
- Wodeba River bridge site has high magnitude discharge with shorter response nature. Hence the watershed management should be applied to manage the project life

8. ACKNOWLDGEMENT

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9. REFFERENCE

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