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Morphometric Analysis of middle Kaligandaki Sub Basin and Flood Mapping using HEC-RAS

Kalyan Paudel
kalyanpaudel19@gmail.com
Tribhuvan University, Kirtipur, Nepal

Kaushal Chandra G. C.
kaushal@wrc.edu.np
Tribhuvan University, Kirtipur, Nepal

ABSTRACT

Watershed analysis based on morphometric parameters gives an idea about the basin characteristics regarding slope, topography, soil condition, runoff characteristics, surface water potential, etc. These characteristics are very important for watershed planning and management. The potential disaster of flash flood and soil erosion is anticipated by studying morphometric parameters of Kaligandaki basin. In Middle Kaligandaki Sub-basin, Kaligandaki river from Tatopani to Modibeni has human settlements concentrated along its sides like Beni bazzar. They are always in risk of erosion and flood inundation. In monsoon, due to heavy rain fall, the Kaligandaki river erodes and inundate the lands near its bank. From the analysis of morphometric parameters, the erosion and inundation of land near river bank is justified. The study of flood inundation map obtained by processing discharge of river in HEC-RAS indicates the settlement and structures near the river are very prone to flood disaster. This study can be referenced for flood planning and disaster reduction measures in Beni bazzar.

Keywords: *Morphometric Parameters, Flood Inundation, Erosion*

1. INTRODUCTION

1.1 Background

Morphometric analysis is a quantitative measurement of landforms and its mathematical analysis. It plays an important part in understanding the geo-hydrological characteristics of a drainage basin in connection to terrain feature and its flow patterns. It also aids in the estimation of infiltration and runoff, as well as other hydrological characteristics of a watershed such as erosion and sediment transport, all of which have a significant impact on natural resource conservation. The most commonly used morphometric parameters include stream number, stream order, stream length, mean stream length, stream length ratio, bifurcation ratio, mean bifurcation ratio, drainage texture, drainage density, form factor, stream frequency, relief ratio, circularity ratio, elongation ratio, and length of overland flow.

The Nhubine Himal Glacier in Nepal's Mustang region serves as the source of the Kali Gandaki River, which lies at an elevation of 6,268 meters. In Kagbeni, Kaligandaki river meets a major stream named Kak Khola. It unites with Rahughat Khola at Galeshwor, Myagdi Khola at Beni bazzar and Modi Khola at Modibeni in Kushma. It flows from north to south in the higher Himalayas before turning eastward through the lower Himalayas, entering Nepal's Terai plains and connecting with the Narayani River, which eventually merges with the Ganges River in India.

Figure 1: Study Area (Source: ("Valuing Green Infrastruct.," 2019))

1.2 Study area

The study area is of the Kali Gandaki Basin from Mustang up to Modibeni (Parbat District). The sub-basins morphometric parameters are studied to find various information related to flood, sediment transport, geomorphology of basin etc. For Flood Mapping, the focus will be on Beni bazzar as it is relatively densely populated area that lies very near to river and is particularly vulnerable to water-induced hazards during the monsoon season.

1.3 Statement of problem

Flash floods have become more common in the Kali Gandaki region of Mustang as a result of heavy snowfall and rapid melting. The impact of water-induced disaster is a major concern in the midstream (Fort, 2015).

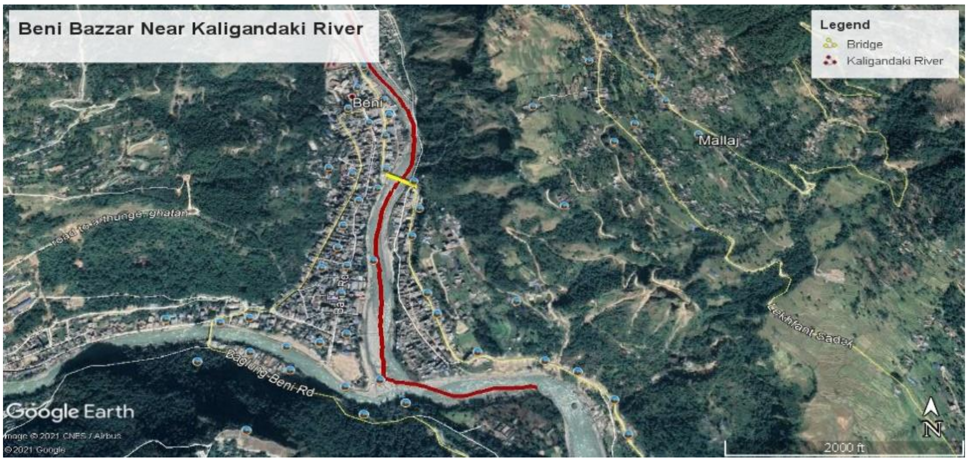

Figure 1: Beni bazzar near Kaligandaki River

Figure 2: A road near Beni Bazaar at risk due to erosion caused by the flood in Kaligandaki River, in Myagdi, on Thursday, September 13, 2018. (Photo: THT)

1.4 Objectives of the study

The main objective of the study is to morphometric analysis of basin focusing on Middle Kaligandaki Sub-basin. The other specific objectives of the study are as follows:

a) To find the morphometric parameters of the sub-basins.
b) To predict potential disaster on the basin/sub-basins by studying morphometric parameters.
c) To prepare flood inundation map of Beni-bazzar for different return periods.

1.5 Scope of the study

The morphological study can help in proposing watershed-based structures and decision making in policy making of Water and Energy related fields. Stream classification is helpful in determining the vulnerability of a stream to increased stream bank erosion and widening of the channel or entrenchment of the bed. Flood forecasting and risk management against flood disaster can be useful to save lives and properties.

1.6 Limitations of the study

The flood analysis will be focused on Beni bazzar only and the encroachment of land by human settlements and other structures near Kaligandaki river bank will not be studied in detail.

2. RESEARCH METHODOLOGY

2.1 Methodology

For Morphometric Analysis, rastar data sets collected from Digital Elevation Model (DEM) were analyzed by GIS tool to calculate Morphometric Parameters like Flow length, Stream Length Ratio, Bifurcation Ratio, Drainage area and Perimeter, Drainage density etc.

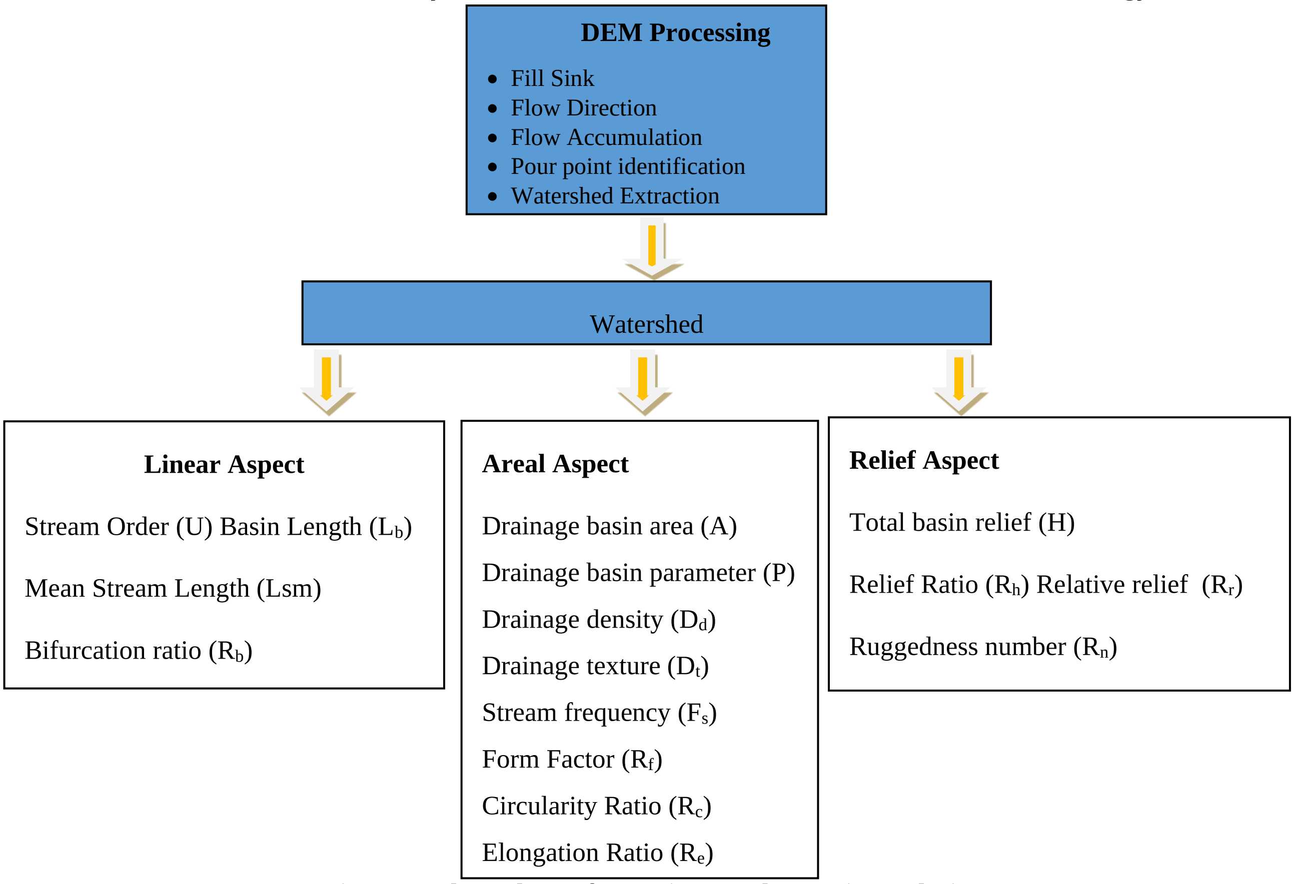

Figure 4: Flow Chart of Steps in Morphometric Analysis.

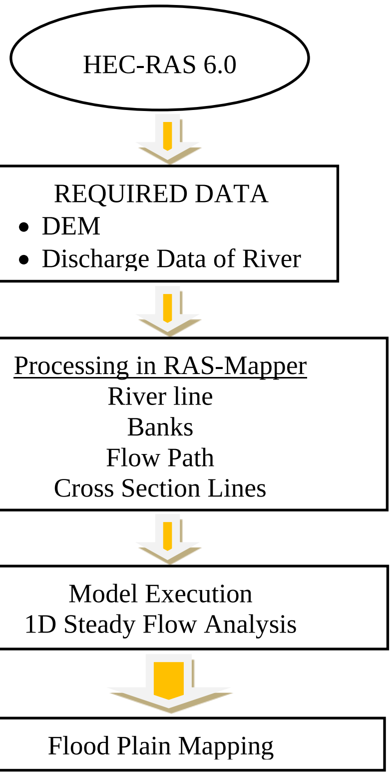

Figure 5: Flow Chart of Steps in Flood Mapping.

2.2 Downloading and Processing of Digital Elevation Model

The Digital Elevation Model (DEM) downloaded from the source: https://search.earthdata.nasa.gov were taken to ArcGIS 10.2 version. The DEM was then clipped for Kaligandaki basin till modibeni (Figure 6). DEM reconditioning was used to refine the input terrain data DEM. The steps in the Terrain Pre-processing menu were completed in sequential order. Filled sinks, flow direction, flow accumulation, stream definition, stream segmentation, catchment grid delineation, catchment polygon processing, drainage line processing, and adjoint catchment processing were all part of the process.

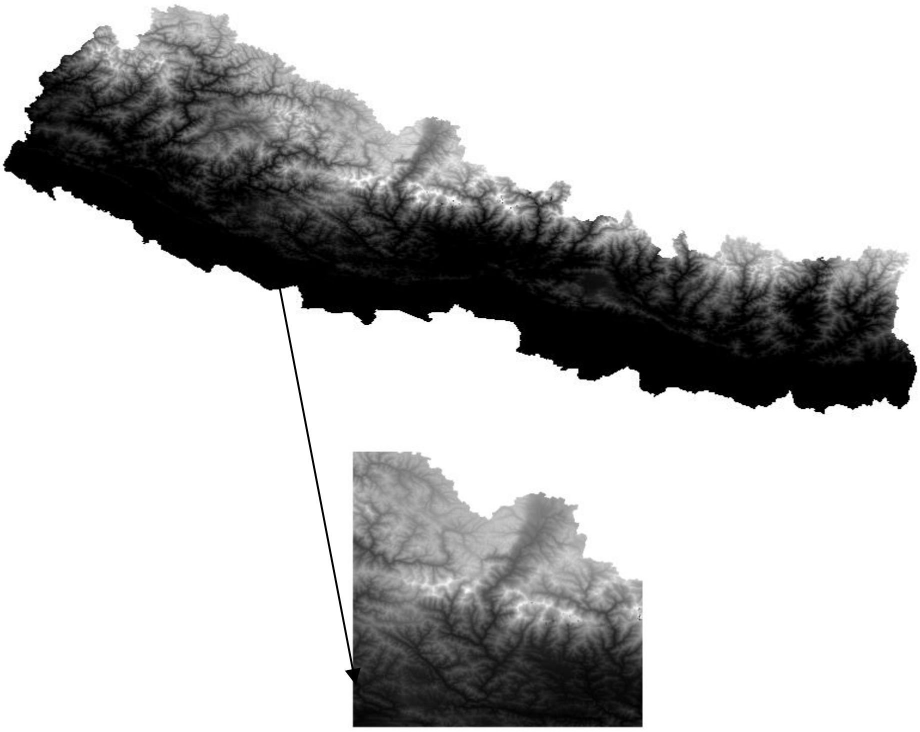

Figure 6: Clipped Kaligandaki basin DEM for Morphometric parameters study.

2.3 Flood Study

The Discharge data collected from Department of Hydrology and Meterology (DHM), Nepal were used to study flood inundation probability of Beni bazzar. The Station Index: 403 at Jomsom, 404.7 at Myagdi khola, and 420 at Kotagau were useful for the study. From the available data of discharge, flood mapping at Beni Bazzar with the help of HEC-RAS 6.0, with different return period was possible.

The prediction for the future floods is made on the basis of available past extreme floods using theoretical probability distribution method (Gumbel). The flood frequency analysis was conducted with the extreme discharge. Considering the specific extreme discharge events of the river, and determining the required statistical parameters, the flood magnitude for 50, 100 and 150 years return period was calculated. The extreme values of flood computed from Gumbel extreme value distribution method was adopted. In Steady state modelling, the model calculates water levels at discrete cross-sections as according to the flows prescribed by the user. The one dimensional energy equation is used to compute the unknown variable (stage). Once the hydraulic computation was done, the automated delineation of flood plain was output in RAS mapper.

3. RESULT AND DISCUSSION

3.1 Results

The five sub basins namely Mustang, Upper Kaligandaki, Middle Kaligandaki, Myagdi and Modi were studied and the Morphometric Parameters of the basin were found out as in table as below.

Table 1: Linear Morphometric Parameters of Mustang Sub-basin

Linear Parameters (Mustang)						
S.N	Stream Order(u)	Numbers (Nu)	Stream Length (Lu) in Km	Mean Stream Length(Lm), Lm=Lu/Nu in Km	Stream Length Ratio (Rl)=Lu/(L(u-1))	Bifurcation Ratio (Rb)=Nu/(N(u+1))
1	1	115	482.820	4.198		1.916
2	2	60	211.232	3.520	0.437	2.142
3	3	28	105.027	3.750	0.497	1.120
4	4	25	59.387	2.375	0.565	

Table 2: Linear Morphometric Parameters of Upper Kaligandaki Sub-basin

Linear Parameters (Upper Kaligandaki)						
S.N	Stream Order(u)	Numbers(Nu)	Stream Length(Lu) Km	Mean Stream Length(Lm), Lm=Lu/Nu Km	Stream Length Ratio (Rl)=Lu/(L(u-1))	Bifurcation Ratio (Rb)=Nu/(N(u+1))
1	1	34	102.576	3.016		2.833
2	2	12	40.906	3.408	0.398	12.000
3	3	1	3.795	3.795	0.092	0.045
4	4	22	45.347	2.061	11.946	

Table 3: Linear Morphometric Parameters of Middle Kaligandaki Sub-basin

Linear Parameters (Middle Kaligandaki)						
S.N	Stream Order(u)	Numbers(Nu)	Stream Length(Lu) Km	Mean Stream Length(Lm), Lm=Lu/Nu Km	Stream Length Ratio (Rl)=Lu/(L(u-1))	Bifurcation Ratio (Rb)=Nu/(N(u+1))
1	1	30	84.153	2.805		2.142
2	2	14	47.938	3.424	0.569	2.333
3	3	6	28.295	4.715	0.590	1.000
4	4	6	19.287	3.214	0.681	1.000
5	5	6	21.137	3.522	1.095	

Table 4: Linear Morphometric Parameters of Myagdi Sub-basin

Linear Parameters (Myagdi)						
S.N	Stream Order(u)	Numbers(Nu)	Stream Length(Lu) Km	Mean Stream Length(Lm), Lm=Lu/Nu Km	Stream Length Ratio (Rl)=Lu/(L(u-1))	Bifurcation Ratio (Rb)=Nu/(N(u+1))
1	1	37	122.234	3.303		2.055
2	2	18	63.986	3.554	0.523	3.000
3	3	6	29.203	4.867	0.456	0.500
4	4	12	36.154	3.012	1.238	

Table 5: Linear Morphometric Parameters of Myagdi Sub-basin

Linear Parameters (Modi)						
S.N	Stream Order(u)	Numbers(Nu)	Stream Length(Lu) Km	Mean Stream Length(Lm), Lm=Lu/Nu Km	Stream Length Ratio (Rl)=Lu/(L(u-1))	Bifurcation Ratio (Rb)=Nu/(N(u+1))
1	1	22	81.952	3.725		2.200
2	2	10	33.156	3.315	0.404	0.909
3	3	11	46.876	4.261	1.413	

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Table 6: Aerial Morphometric Parameters of Mustang, Upper Kaligandaki, Middle Kaligandaki, Myagdi and Modi Sub-basin.

Aerial Parameters																
S.N	Subbasin Name	Area (A) Sqkm	Perimeter (P) Km	Number of Streams(N)	Length of Streams (L) Km	Length of Basin (Lb) Km	Drainage Density in Km/Sqkm(Dd)=L/A	Stream Frequency per Km (Fs)=N/A	Drainage Texture(Dt)=Dd*Fs	Length of overland Flow (Lg)=1/(2*Dd)	Constant of Channel Mintenace ('C)=1/Dd	Form factor(Ff)=A/Lb^2	Circulatory Ratio (Rc)=(4*pi*A)/(P^2)	Elongation Ratio(Re)= 2*(sqrt(A/pi))/Lb	Shape index(Sw)=1/Fs	Infiltration Number(If)= Dd*Fs
1	Upper Kaligandaki	780.950	184.508	69	192.626	55.224	0.246	0.088	0.021	0.010	91.772	0.256	0.288	0.571	11.318	0.021
2	Modi Khola	676.085	202.180	43	161.985	65.935	0.239	0.063	0.015	0.007	131.246	0.155	0.207	0.444	15.722	0.015
3	Middle Kaligandaki	839.873	250.164	62	200.813	71.137	0.239	0.073	0.017	0.008	113.311	0.165	0.168	0.459	13.546	0.017
4	Myagdi Khola	1094.082	264.421	73	251.579	82.392	0.229	0.066	0.015	0.007	130.356	0.161	0.196	0.452	14.987	0.015
5	Mustang	3160.168	420.055	228	858.469	95.192	0.271	0.072	0.019	0.009	102.044	0.348	0.225	0.666	13.860	0.019

Table 7: Relief Morphometric Parameters of Mustang, Upper Kaligandaki, Middle Kaligandaki, Myagdi and Modi Sub-basin.

Relief Parameters								
S.N	Subbasin Name	Maximum Elevation(H) in m	Minimum Elevation(h) in m	Basin Relief (R)= H-h in m	Relief ratio (Rr)=R/Lb	Ruggedness Number (Rn)=R*Dd	Melton Ruggedness Number (MRn)=R/(sqrt(A))	Basin Slope (Sb) = H/Lb
1	Upper Kaligandaki	7994	1195	6799	0.123	0.030	0.243	0.144
2	Modi Khola	8000	602	7398	0.112	0.026	0.284	0.121
3	Middle Kaligandaki	8147	649	7498	0.105	0.025	0.258	0.114
4	Myagdi Khola	8148	781	7367	0.089	0.020	0.222	0.098
5	Mustang	6870	2699	6799	0.071	0.019	0.120	0.072

Table 8. Area inundated and Maximum Water Level in Kalipul of Kaligandaki river in 50, 100 and 150 years' return period.

Return Period (year)	Inundated area (m2)	Max. Water level in Kalipul (m)
50	231925.62	9.42
100	234681.81	9.71
150	238123.42	9.87

The flood values for different return periods were calculated using the maximum instantaneous flow from Kaligandaki and Myagdi River. The flow value was obtained from Gumbel distribution method. The inundation map of Kaligandaki and Myagdi River in Beni Bazzar due to 50, 100 and 150 year return flood is shown in the Fig. 8. The greater depth is symbolized by dark blue color in Fig. 8. The inundated area and maximum water level given by HEC-RAS during 50, 100 and 150-year flood is tabulated in Table 8. The highest value of water depth during 50, 100 and 150-year flood in this river are 9.42 m, 9.71 m and 9.87 m respectively.

Figure 7: Google Satellite Map of Beni Bazzar

(a) (b) (c)

Figure 8: Inundation areas of Beni Bazzar by Kaligandaki River and Myagdi Khola: Flood Hazard Mapping for Return Periods : (a) 50 year, (b) 100 year, and (c) 150 year.

The results from the flood analysis show that the Beni-Jomsom Highway, Buspark area near Kalipul and Human settlements along both banks of Kaligandaki River as well as Myagdi Khola are vulnerable to flood as demonstrated in Fig. 8 (a), (b), and (c). The inundation area seems to be increasing with increase in flood years' return period.

3.2 Discussion

The results obtained by ArcGIS modulation can be discussed as below:

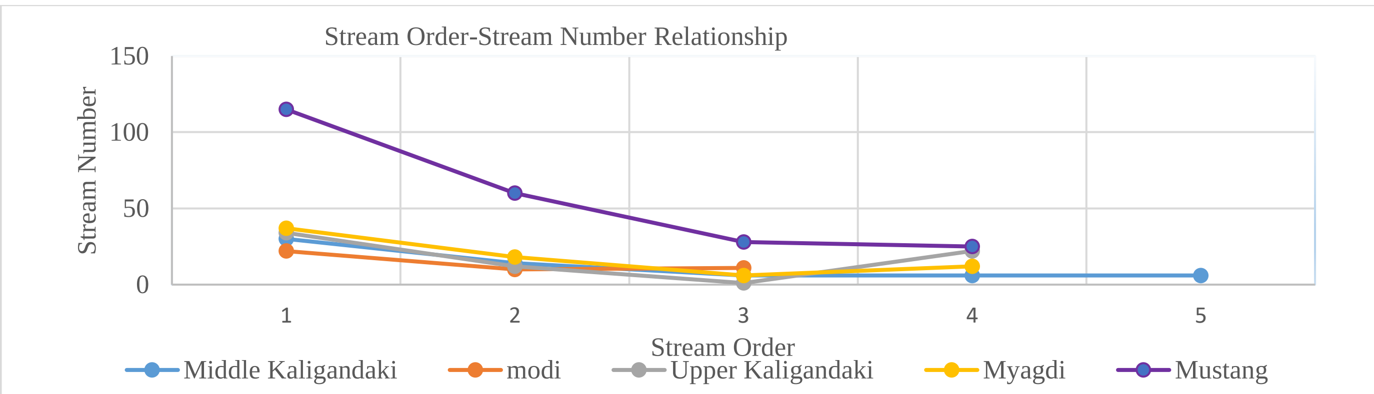

Figure 9: Relationship between Stream Number and Stream Order of Mustang, Upper Kaligandaki, Middle Kaligandaki, Myagdi and Modi Sub-basin.

The above figure shows negative correlation between Stream number and stream order in all sub-basins. It means that several streams usually decrease in geometric progression as the stream order increases.

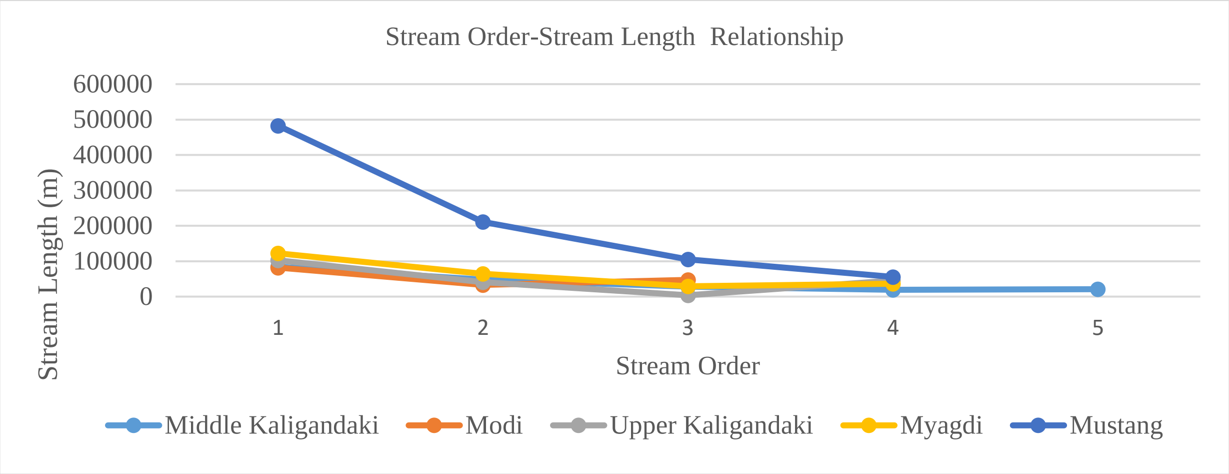

Figure 10: Relationship between Stream Length and Stream Order of Mustang, Upper Kaligandaki, Middle Kaligandaki, Myagdi and Modi Sub-basin.

- It demonstrates that as stream order increases, the total length of stream segments decreases.
- All basins have elongation ratio (Re) less than 0.7, which indicates steep slope and high relief. All the sub-basins are very prone to soil erosion because high relief watershed has a high susceptibility to erosion.
- Also, all basins have form factor <0.78 (elongated), thus low peak flow for long duration is indicated.
- Length of over land flow is very low (<0.2) which indicates high relief, short flow path, more runoff, and less infiltration making the area greater vulnerability to flash flooding.
- From the hydraulic analysis from HEC-RAS, there is increase in inundation area as the return period of discharge increases. The inundation area involves human settlements near river bank, bridge above Kaligandaki river, Kaligandaki Corridor in Beni Bazzar etc.

4. CONCLUSION

4.1 Conclusion and Recommendation

All the sub-basin namely Mustang, Upper Kaligandaki, Middle Kaligandaki, Myagdi and Modi are elongated type, thus are prone to soil erosion. There is also a chance of flash flooding as the length of overland flow is very low. In Middle Kaligandaki Sub-basin, where relatively large population resides near river bank of Kaligandaki and Myagdi river, there can be catastrophic flash floods. The study of flood at Beni bazzar, which lies in Middle Kaligandaki Sub-basin is of significant importance.

The results of hydraulic analysis for different return period shows inundation in very sensitive places of Beni bazzar which involves human settlements near river bank, bridge above Kaligandaki river and some parts of Kaligandaki Corridor. In Kaligandaki river, the discharge has been obtained as 915.98 m^3/s, 1058.10 m^3/s, and 1140.98 m^3/s for 50, 100 and 150 years' return period flood and in Myagdi Khola, the discharge has been obtained as 495.73 m^3/s, 550.35 m^3/s, and 582.20 m^3/s for 50, 100 and 150 years' return period flood, for which the inundation area was observed as 0.231 km^2, 0.234 km^2 and 0.238 km^2 respectively. The human settlements and other structures near river bank is at high risk of flood and the huge loss of life and property can be anticipated.

It is recommended to make public aware of the potential risk associated in living near river bank of Kaligandaki and Myagdi river in Beni-bazzar. The settlements on the flood prone area may be discouraged by law. Flood control measures and Early Warning System may be adopted so as to minimize the potential disaster from the flood.

REFERENCES

[1] Basnet, K., Paudel, R. C., & Sherchan, B. (2019). Analysis of Watersheds in Gandaki Province, Nepal Using QGIS. *Technical Journal*, *1*(1), 16–28. https://doi.org/10.3126/tj.v1i1.27583.

[2] Fort, M. (2015). Natural hazards versus climate change and their potential impacts in the dry, northern Himalayas: focus on the upper Kali Gandaki (Mustang District, Nepal). *Environmental Earth Sciences*, *73*(2), 801–814. https://doi.org/10.1007/s12665-014-3087-y.

[3] Manandhar, S., Pandey, V. P., Ishidaira, H., & Kazama, F. (2013). Perturbation study of climate change impacts in a snow-fed river basin. *Hydrological Processes*, *27*(24), 3461–3474. https://doi.org/10.1002/hyp.9446.

[4] Pokharel, N., Basnet, K., & Paudel, R. C. (2019). Morphometric Analysis of East Seti Watershed in Gandaki Province, Nepal using GIS. *Proceedings of IOE Graduate Conference, 2019-Winter Peer*, *7*(December), 149–155.

[5] Sukristiyanti, S., Maria, R., & Lestiana, H. (2018). Watershed-based Morphometric Analysis: A Review. *IOP Conference Series: Earth and Environmental Science*, *118*(1). https://doi.org/10.1088/1755-1315/118/1/012028

[6] USACE. (2016). HEC-RAS River Analysis System Hydraulic Reference Manual Version 5.0. *Hydrologic Engineering Center*, *February*, 547.

[7] Valuing Green Infrastructure. (2019). *Valuing Green Infrastructure*. https://doi.org/10.1596/32757.

