

Flood Frequency Analysis of Chenab River for Predicting Peak Flows during Late Monsoon Period

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Abstract

The River Chenab is one of the main western rivers of the Indus River system in Pakistan, which undergoes intensive inundation almost every year during the late monsoon period. The present study performs flood frequency analyses for the river basin as well as simulates different levels of water flow in the system to speculate all kinds of inundation under different scenarios, *i.e.*, to predict flood hazard and flood extended areas. Flood frequency analyses were performed at MARALA Headworks to Khanki Headworks. Data were collected from the Punjab Irrigation Department, Pakistan and from USGS and ASTER GDEM. The peak discharge of MARALA Headworks had been analyzed for 25 years. The preprocessing was performed in HEC Geo-RAS after preprocessing model run in HEC-RAS. After analysis the data were exported in HEC-RAS to ARCMAP to generate a floodplain and inundation map. Our analysis generated the result that different areas would be under water in different return periods. Flood hazards maps for different return periods 10, 20, 50 and 100 years were conducted using annual peaks flow of 35 years from 1980 to 2016. The maximum discharges at up and down stream for different periods were obtained using Gumbel distribution model results which showed that different areas were predicted under water in different return periods and affected areas after five years' return period.

Keywords

ASTER GDEM, HEC Geo-RAS, ARCMAP, Gumbel Distribution Model

1. Introduction

Flooding in arid mountainous regions leads to serious catastrophic outcomes that affect a country's infrastructure. The governing factors are generally intensive rainfall and/or glacier melting [1] [2]. On a global scale, the impact of these extreme events is not even, and particularly developing countries in South Asia face higher damages compared to the rest of the world [3] [4] [5]. The fundamental reason behind these losses is lack of adaptation resources, *i.e.*, social, technical, and engineering facilities [6].

It is also important to drive an evaluation procedure to determine its predictive results [7]. The flood recovery cycle is used to re-establish flood attack area [8]. River floods often attack the river bank and take away huge farmland [9]. However, deposits also have disorderly effects on adjacent crops, which may increase crop fertility, or for a longer period of time to completely destroy farmland, as if sand were deposited as [10]. Pakistan is situated in a region which is highly prone to climate changes [11] possessing most of the rivers being shared by India as an upper riparian. River Chenab, being one of the three major western rivers, has an important contribution in water resources of Pakistan [12].

In the recent flooding of Pakistan in 2014, about four feet of sand was observed in the crop area of the Hafizabad region. Farmers were getting farmland from sediments, but still could not determine how much land was recovering from sand. The analysis and forecasting tools for agricultural development planning are observed before the results of various evolution decisions GIS data can be used [13]. Timely identification of flood affected areas can save living things and funds through early caution. Today GIS, GPS and remote sensing technologies prove helpful in that flood disaster managers develop exact flood maps at a lower cost and also provide hardware and software packages [14].

There are many frequency models which are now used for determining hydrologic frequency of flood. The probabilistic model relies on the use of existing data to forecast future scenario and deterministic model relies on different physical parameters to bring out the result and verify it with the existing data to develop a best fit model. Probabilistic approach is commonly practiced in hydrology [15]. Within probabilistic models, the two most popular are Gumbel maximum value and Log Pearson type III distribution.

The parameter estimation is done by using many ways, viz. by maximum likelihood estimators, method of moments (MOM) or by methods of L-Moments. L-Moments are based on probability-weighted moments (PWMs), for the data arranged in ascending order. The MOM technique is good for limited range of parameters, whereas L-Moments can be more widely used, and are unbiased [16].

Geographic Information System (GIS) and Remote Sensing are frequently and effectively used for flood hazard forecasting and mapping [17] [18]. Similarly, the applications of hydrodynamic models are also quite obvious in flood management studies and are used as a decision support tool. However, these models require proper characterization of the channel and adjacent floodplain. HEC-Geo RAS, an extension used in the ArcGIS, to process geospatial data for use with the

Hydrological Engineering Centre River Analysis System (HEC-RAS). HEC-RAS is a 1D hydrodynamic model, used to simulate river flood phenomena and the results can be presented in a geospatial format [19] applied HEC-RAS one-dimensional model in combination with the ASTER DEM for flood modelling in the Kalpani river reach in Khyber Pakhtunkhwa, Pakistan. Application of HEC-RAS for flood forecasting in perched river in Lingshi County, Shanxi Province of China [20]. Similarly, [21] also utilizes a hybrid approach of HEC-RAS and GIS to determine vulnerable localities along a 5 km long Nike river channel in northern Iran. With the developments in integrating capabilities of Remote Sensing (RS) (satellite imagery, Digital Elevation Models (DEMs)), GIS and Hydrodynamic modelling have provided opportunities for quantitative analysis of flood events, from local to regional scales [22].

[23] developed a simulation model for real time flood-control operation of river-reservoirs systems. Shahid *et al.* conducted in the Chenab River catchment, Pakistan, to develop and evaluate a hydrologic model using HEC-HMS for predicting flows based on TRMM rainfall data and found that capturing the hydrologic response of the catchment due to rainfall events.

Hydrologic engineering center-river analysis system (HEC-RAS), which was developed by the US army corps of engineers, has been applied extensively in calculating the hydraulic characteristics of rivers [24]. HEC-RAS calculates one-dimensional steady and unsteady flows, and the model equations are also described by [25].

The present study focused on the Chenab River is the main river in India and Pakistan. It is formed in the upper part of the Himalayas in the Latin America and the Kapur region of Jammu and Kashmir, and enters the plains of Punjab, Pakistan. According to the Indus River Treaty, Chenab's waters are allocated to Pakistan. The major objectives of the present study are flooding frequency analysis by hydrodynamic analyze the river, simulate different levels of water and water flow at different times and determine flood hazard, flood extended areas. This study will also be beneficial for flood extent prediction for future perspective. It also enables us to draw plan for mitigation and damages control.

2. Methodology

2.1. Study Area

First, Study area coordinates are Left 73.23455477863293, Top 33.25213418273533, and Bottom 31.62131683314346dd, Right 75.5195246098708dd as shown in **Figure 1**.

Current Study comprises over 42 cross sections will be used to map the interval of each important location along the 96 km river length. In the present study gives insight about the river modelling and assessment using the HEC-RAS model. Moreover the river's fluid dynamics with the different levels of water and water flow in different periods helps to draw extent of river and damage assessment. All the results will be calculated and drawn from the ArcGIS and HEC-RAS software for hydrodynamic modelling. In order to apply the t



Figure 1. Sialkot Area.

HEC-RAS model for the study area, the following necessary data sets will be se up to prepare and extract the geometric data and Manning's roughness at the flow cross-section and define the flow discharge input data method [26]. The whole process is explained in term of flow diagram in **Figure 2**.

2.2. Data Sources

Data collection process involves mainly from the secondary source. The study requires spatial and hydrological data, channel geometry, boundary conditions, and channel resistance for flow simulation through HEC-RAS. Organization addressed for data are an Irrigation department of Pakistan, Punjab, Lahore and Primary data collection from USGS and ASTER GDEM.

2.3. Tools and Technologies Used for Modeling

The purpose of this study is to use HEC-GEO HMS model to simulate and evaluate the flood in Chen cloth in Hebei Province, to model and analyze the river hydrodynamics, and to simulate the different water level and water flow in different periods. HEC-GEO HMS4.2 Software applied for hydrodynamic modelling. In order to apply the HEC GEO HMS model to the study area, the following necessary data sets will be set up to prepare and extract geometric data and Manning's rough coefficients in the stream and define the flow input data method.

2.4. DEM Data

The Digital Elevation Model (DEM) is a digital model or 3D representation of terrain surfaces that are typically used to create planets (including earth), lunar



Figure 2. Flow diagram.

or asteroids from terrain elevation data as expressed in **Figure 3**. DEM can be expressed as a raster (square grid, also known as elevation, when it represents elevation) or vector-based triangular irregular network (TIN). The TIN DEM dataset is also called the main (measurement) DEM. Surfaces are usually modelled with raster datasets. Rasters are cell matrices, also known as pixels, organized in rows and columns, covering some parts of the world (even the whole world). Each cell in the matrix represents a square of the unit area and contains a value that is the measure or estimate of the position.

2.5. Flood Frequency Analysis

Flood frequency analyses are used to predict design floods along a river. The technique includes using observed yearly peak flow discharge data to calculate statistical information. Rated curve (or stage-discharge curve) displays the relationship between the stage (water level) and the displacement of the point on the flow path. The flood frequency curve is a graph showing the relationship between the flood magnitude and the repeated interval of the specified location. Different formulas (e.g. Gumble Formula, Hazen Formula, Blom Formula etc.) were applied and different curves were obtained as shown in **Figures 4.1-4.7**.

Best fitted formula was only Gumbel formula, as shown in **Figure 4.6**. It proves that our data are consistent. We find the peak values of flow after 2 years, 5 years, 10 years, 15 years and 100 years return period and results are given below:



Gumbel Extreme Value Type-I Distribution, [MM method]

Recurrence	Peak		95% Cor	nfidence	Standard
Interval	Discharge		Limits		Error
(Years)	(cfs)		(cfs)		(cfs)
2	278311.4	{	255484.3	301138.6}	11646.51
5	457886.5	{	419186.6	496586.3}	19744.82
10	576780.8	{	524701.1	628860.4}	26571.24
15	643859.9	{	583882.9	703836.9}	30600.53
100	949069.5	{	851896.7	1046242.3}	49577.97

Gumbel Extreme Value Type-I Distribution, [MM method]

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Recurrence	Peak		95% Cor	nfidence	Standard
Interval	Discharge		Limits		Error
(Years)	(cfs)		(cfs)		(cfs)
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15	643859.9	{	583882.9	703836.9}	30600.53
100	949069.5	{	851896.7	1046242.3}	49577.97

Gumbel Extreme Value Type-I Distribution, [ML method]

Recurrence	Peak		95% Cor	nfidence	Standard
Interval	Discharge		Limits		Error
(Years)	(cfs)		(cfs)		(cfs)
2	278395.0	{	253172.4	303617.7}	12868.69
5	470840.1	{	432130.3	509549.9}	19749.88
10	598255.5	{	548597.6	647913.4}	25335.66
15	670142.2	{	614007.1	726277.3}	28640.36
100	997226.0	{	910399.8	1084052.3}	44299.09



Figure 3. DEM data.





Figure 4.1. Autoregressive model.



Observed Frequency Distribution









Figure 4.4. Hazen formula.





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Gumbel Extreme Value Type-I [Method of Moments]





Observed Frequency Distribution

Figure 4.7. Wiebell formula.

2.6. Cross-Section

The spacing is very close to the cross-section should be shown in each super bank and channel similar to the flow.

2.7. Cross-Section-Requirement

Cross sections are required at representative location along a river reach where:

>Slope changes.

>Cross section shape changes.

>Roughness changes.

>A levee starts and end.

>Bridge, Culverts, Weir and other control structures.

>Junction/Confluence.

>Where abrupt changes occur, several cross section should be used to describe the change regardless of the distance.

>Up to 500 ground points can be used to describe the cross section.

>HEC-RAS takes into account Cross section data with Distance taken on (X-axis)

& Elevation on (Y-Axis).

>Cross section should be defined perpendicular to the direction of flow as shown in **Figure 5**.

2.8. Processing

Required Data

The essential dataset required for HEC-Geo RAS, HEC-RAS and Arc GIS DEM, TIN, River Boundary of study area, Gauges Data

Required softwares are Arc GIS, DFW, HEC-RAS latest version, HEC-Geo RAS (Extension) with ArcGIS 10.x Compatible version

2.9. Methods of Data Processing

2.9.1. Study Area Boundary

Map of study area acquires from Google in JPG format. And also open in Arc Map to geo reference and make the feature class of study area boundary. Select the polygon to digitize the boundary of our study area. Note that before digitizing also set the spatial reference system of feature class Boundary of study Area is in the form of shape file. To validate the result of digitizing shape file convert in to KML. KML file can export into Google earth.

2.9.2. DEM

Dem is downloaded from ASTER GDEM.

2.9.3. Clipping

Extract by Mask tool is used for clipping. DEM is clipped with boundary shape-file.

2.9.4. TIN

Digital Elevation Model (DEM) is converted into Triangular Irregular network.

Drawing river. Digitize river on TIN. Drawing centerline. Digitize river central line on TIN. Drawing left and right banks. Digitize both left and right banks. Digitize flow path. Digitize river' flow path. Digitize flow path. Digitize flow paths.

2.9.5. Post Processing

All preprocessing is now ready for input HEC RAS model. Different tools of HEC-Geo-RAS as well as HEC-RAS are applied. At this stage we will run the model. This SDF File (model file) will import in ARC MAP and using tools of HEC GeoRAS We generate water surface.



Figure 5. Cross section on river stream.

2.9.6. Output

Finally, we obtained hazards maps on the basis for different return periods, e.g. 3 years, 5 years, 10 years etc.

2.9.7. ArcGIS Tools

ArcGIS is a Geographical Information System (GIS) for working with maps and geographic information. It is used for creating and using maps, compiling geographic data, analyzing mapped information, sharing and discovering geographic information, using maps and geographic information in a range of applications, and managing geographic information in a database. The system provides an infrastructure for making maps and geographic information available throughout an organization, across a community, and openly on the Web. For this purpose, we add the data in ArcGIS as shown in **Figure 6.1** and data layers are shown in **Figure 6.2**.

2.10. Add Data

2.10.1 Extract by Mask (Spatial Analyst)

Extract the cells of a raster that correspond to the areas defined by a mask. Input mask data defining areas to extract as shown in **Figure 7.1** and **Figure 7.2**. This is a raster or feature dataset.

2.10.2. Raster to TIN (3D Analyst)

Convert a raster to a triangulated irregular network (TIN) dataset. Converting a raster to a TIN will not, in and of itself, produce a better surface. You need ancillary data that's compatible with, and improves, the surface definition. Such data could be added to the TIN using the Edit TIN tool. The default maximum allowable difference between the height of the input raster and the height of the output TIN is 1/10 of the z range of the input raster (**Figure 8**).

2.10.3. HEC Geo-RAS

Using tool draw centerline, left and right bank lines and flow path Centerline as shown in following **Figure 9**.



Figure 6.1. Add data by this tool.



Figure 6.2. Chenab river, DEM, and boundary.



Figure 7.1. Image.



Figure 7.2. Extract by Mask.



Figure 8. Convert DEM into TIN by using RASTER TO TIN (3D Analyst).



Figure 9. Tool selection.

In following Figure 10, stream center line, bank line and flow direction is shown.

2.10.4. Construct XS Cut Lines

Tool bar is shown in **Figure 11** from which XS Cut line is selected. Then cross section layer is exported in the form of RAS data as shown in **Figure 12**. This RAS DATA is imported in HEC RAS.

2.10.5. HEC RAS Tools

Hydrologic Engineering Center's River Analysis System allows the user to perform one-dimensional steady flow, one and two-dimensional unsteady flow calculations, sediment transport/mobile bed computations, and water temperature/water quality modeling. <u>http://www.hec.usace.army.mil/software/hec-ras/</u>

For adding Geometry data we click on Ke import GIS DATA as shown in Figure 13. Results are shown in Figure 14 and Figure 15.

2.10.6. Option Tool

Assigning main channel MANNING'S n values or k values as shown in **Figure 16.1** and **Figure 16.2**. The k value or manning's n value of Chenab river is 0.03 and n#2 and n#3 values are 0.035.

2.10.7. SAVE Geometry File

Save Geometry Data as shown in Figure 17.

2.10.8. Enter Study Flow Tool

For adding Geometry data we click on $\underbrace{1}_{2}$. We can enter many numbers of profiles. Each Profile shows different return period .we enters peak flow data which we determine by DFW, as shown in Figure 18. Then we set Boundary Conditions.

Now we will set boundary Conditions as shown in **Figure 19** and **Figure 20**. For this we click on normal depth button and enter the value of Upstream and Downstream Chenab values. These values almost equals to 0.002. Click OK and save Study Flow.



Figure 10. Stream Centre line, bank line and Flow paths.



Figure 11. Tool bar.



Figure 12. Cross Section layer exported as RAS DATA.



Figure 13. Enter geometric data tool.

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Figure 14. Results.



Figure 15. Results.





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		normal depth co MARALA TO	mputation for reach: KHANKL_for all			
		DI	ofiles.			
	Steady Flow Reach-Storage Area			OK Can	ncel Help	
		OK				
١.	1					-
ų	y 0 10 100 100 100 100 100 100 100 100 1					

Figure 20. Up stream and down stream value setting window.

2.10.9. Run Model

We will run model by clicking on $\frac{\text{RAS 4.1.0}}{\text{jit Run Vi}}$ (RUN) and then compute after type our plan. As shown in Figure 21, the running result is shown in Figure 22.

<u>き</u> Steady Flow Analysis				23
File Options Help				
Plan : Plan 01		Short ID	plan1	
Geometry File :	geometrydatarabi			•
Steady Flow File :	STDFRABI			-
Flow Regime Plan D Subcritical Supercritical	escription :			
Mixed	Compute			
Enter to compute water surfac	e profiles			

Figure 21. RAS run window.

IN HEC-RAS 4.1.0	L L 24
File Edit Run View Ontions GISTools Help	
	loss India
Project: rabia C:\MARLA HEC RAS MODEL practice\ali\rabia.prj	
Plan: Plan 0 🔣 HEC-RAS Finished Computations	23
Geometry: geomeSteady Flow Simulation	
Steady Flow: STDFF River: RIVER CHENAB RS: 57100	
Unsteady Flow: Reach: MARALA TO KHANKI Node Type: Cross Section	
Description : Profile: PF 1	tomary Units
Simulation: 1/1	
Computation Messages	
Steady Flow Simulation Version 4.1.0 Jan 2010	
Finished Steady Flow Simulation	
Diana I Task Time	
Complete Process 1.58 sec	
Computation messages written to: C:\MARLA HEC RAS MODEL practice\ali\rabia.p01.comp_ms	<u>gs.txl</u>
(• Su	
Su Su	

Figure 22. Result.

2.10.10. Cross Section Tool

The following tool is used to view cross sections plot results after computing the model as shown in **Figure 23**.





2.10.11. Rating Curve Tool

By this tool we can see computed rating curves as shown in **Figure 24**.





2.10.12. Profile Plot Tool

This tool is used to view the water surface profile plot as shown in **Figure 25**.



Figure 25. Profile plot.

2.10.13. Detailed Output Table Tool (Figure 26)

iject: in: ometry: iady Flow:	rabia Plan 01 geometrydatarabi STDFRABI			C:VMARLA H C:VMARLA H C:VMARLA H C:VMARLA H	EC RAS MODEL prac EC RAS MODEL prac EC RAS MODEL prac EC RAS MODEL prac	itice\ali\rabia.prj tice\ali\rabia.p01 tice\ali\rabia.g01 tice\ali\rabia.f01	
File Ty	Section Output pe Options H	lelp					
River: F	IVER CHENAB	-	Profile	e: PF 1	-		
Reach N	1ARALA TO KHAN	KI 👻	RS:	5100 -	J 🛃 🚹 Pla	n: plan1	
	PI.	an: plan1	RIVER	CHENAB MARALA TO KHAI	NKI RS: 5100 Profi	e: PF 1	
E.G. Eler	v (ft)	72	8.22	Element	Left OB	Channel	Right 0B
VelHead	(f))		4.87	Wt. n-Val.	0.035	0.003	0.035
W.S. Ele	v (ft)	72	3.35	Reach Len. (ft)	5314.37	5249.34	6131.07
Crit W.S.	(ft)	72	3.35	Flow Area (sq ft)	28865.15	20237.70	17659.34
E.G. Slop	oe (ft/ft)	0.00	0071	Area (sq.ft)	28865.15	20237.70	17659.34
Q Total (cfs]	45788	6.50	Flow (cfs)	45417.66	388637.10	23831.80
Top Wid	th (ft)	821	0.40	Top Width (ft)	3434.54	2048.97	2726.89
Vel Tota	[ft/s]		6.86	Avg. Vel. (ft/s)	1.57	19.20	1.35
Max Chl	Dpth (ft)	1	7.97	Hydr. Depth (ft)	8.40	9.88	6.48
Conv. To	otal (cfs)	543417	20.0	Conv. (cfs)	5390144.0	46123240.0	2828345.0
Length V	√td. [ft]	528	3.47	Wetted Per. (ft)	3437.02	2050.38	2728.28
Min Ch E	1(R)	71	1.78	Shear (lb/sg ft)	0.04	0.04	0.03
Alpha			6.66	Stream Power (Ib/ft s)	16404.20	0.00	0.00
Froth Los	ss (ft)		0.23	Cum Volume (acre-ft)	8761.83	11431.52	5430.03
C & E Lo	ss (ft)		0.44	Cum SA (acres)	1254.31	1171.63	849.32
				Errors, Warnings and Not	es		
Warning:	The energy equa for the water surf-	ition could n ace and co	ot be b ntinuec	alanced within the specified nu on with the calculations.	mber of iterations. Th	e program used ci	itical depth 🔺
Warning:	Divided flow com	puted for th	is cros	s-section.			
Warning:	The velocity hea	d has chanc	ed by	more than 0.5 ft (0.15 m). This i	may indicate the need	for additional cro-	ss sections.
Warning:	The conveyance	ratio (upstre	am co	invevance divided by downstrea	m conveyance) is les	s than 0.7 or grea	ter than 1.4.
	This may indicate	e the need t	or add	itional cross sections			

Figure 26. Cross sections bridges.

2.10.14. Profile Summary Table Tool (Figure 27)

ſ	File Edit Run V	iew Opt	ions GIS	Tools H	elp								
CINESS CONTRACTOR CONT												Ind	
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											ш		
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Steady Flow STDFRABI C:\MARLA HEC RAS MODEL practice\alivabia.01											ш		
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	Unsteady Flow:					1							
ŝ	Desfile Output Tel	hin Chang	and Table	. 1									83
į	Prome Output Ta	ble - Stand											
	File Options Std.	Tables	Locations	Help									
HEC-RAS Plan: plan1 River: RIVER CHENAB Reach: MARALA TO KHANKI Profile: PF 1 Reload Date													
	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	11.4
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	-
	MARALA TO KHANKI	57100	PF 1	157886.50	788.78	798.98	798.98	801.43	0.000078	12.54	36500.89	7549.12	-
	MARALA TO KHANKI	56600	PF 1	157886.50	778.51	791.85	791.85	794.56	0.000075	13.21	36605.61	7203.06	
	MARALA TO KHANKI	55500	PF 1	157886.50	720.77	785.93		787.10	0.000019	8.70	53871.46	6908.85	
	MARALA TO KHANKI	54200	PF 1	157886.50	760.07	783.75	783.75	786.77	0.000080	13.95	32824.89	5844.98	
	MARALA TO KHANKI	52500	PF 1	157886.50	741.27	783.30		783.68	0.000005	4.97	01756.80	11868.16	
	MARALA TO KHANKI	51100	PF 1	157886.50	756.82	781.87		783.51	0.000029	10.31	48292.68	7138.45	
	MARALA TO KHANKI	49600	PF 1	157886.50	761.94	782.03		783.29	0.000015	9.18	68338.41	7143.17	
	MARALA TO KHANKI	48000	PF 1	157886.50	757.81	776.99	776.99	782.71	0.000059	19.30	27082.76	2404.36	
	MARALA TO KHANKI	46100	PF 1	157886.50	757.87	777.23	776.51	780.47	0.000051	14.52	37153.78	5031.60	
	MARALA TO KHANKI	45000	PF 1	157886.50	755.55	778.91		779.69	0.000005	7.17	94185.62	7870.22	
	MARALA TO KHANKI	43800	PF 1	157886.50	761.16	774.75	774.75	779.26	0.000067	17.54	42716.44	5373.38	
	MARALA TO KHANKI	42000	PF 1	157886.50	736.98	771.90	771.90	776.17	0.000063	16.73	34794.69	4559.61	
	MARALA TO KHANKI	40000	PF 1	157886.50	754.59	765.78	765.78	769.80	0.000067	16.64	50588.49	7360.36	
	MARALA TO KHANKI	38700	PF 1	157886.50	749.84	766.95		768.48	0.000018	10.15	79929.00	11124.26	-
			1										
	•												•

Figure 27. Output summary at multiple locations profile.

2.10.15. Export GIS Data (Figure 28)

K HEC-RAS 4.1.0							
File Edit Run View	Options GIS Tools Help						
)	ET oss I tall					
Project: MARALA 2D M	MODEL C:\MARLA HEC RAS MODEL practice\MARALA2D	OMODEL.prj 🗀					
Plan: GIS Export							
Steady Floy Export File: C.	MARLA HEC RAS MODEL practice/MARALA2DMODEL.RASexport.sdf	Browse					
Unsteady F Reaches and S	Reaches and Storage Areas to Export						
Description Select F	Reaches to Export Reaches (1/1)	nary Units					
Select Stor	rage Areas to Export Storage Areas (1/1)						
Results Export	Options						
🔽 🔽 Water Surf.	laces 🔲 Water Surface Extents Select Profiles to	Export					
Profiles to Export:							
Flow Distribut	tion (only averaged LOB, Chan and ROB values available) Additional Information						
E Velocity	Ice Thickness (where av	ailable)					
Shear Str	/ess /nwer						
- Geometry Dista	a Evport Options						
River (Stree	am) Centerlines						
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[all ×5's exc	d Cross Sections Levees	mapping)					
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2.10.16. HEC Geo-RAS Tools (ArcGIS Extension) (Figure 29; Figure 30)



Figure 29. Conversion to SDF to XML.

	Classification - Ktract_tif11	-
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	······	
Convert KAS Expo	rt SDF to XML	
RAS SDF File:	rt SDF to XML	
RAS SDF File: RAS XML File:	rt SDF to XML	

Figure 30. Conversion SDF file to XML file.

2.10.17. RAS Mapping Tool (Figure 31)

🔣 Layer Setup for HEC-	RAS PostProcessing
Analysis Type © Existing Analysis @ New Analysis	· · · · · · · · · · · · · · · · · · ·
RAS GIS Export File	
Terrain	
Terrain Single	Terrain Type () TIN () GRID
Terrain Single Multiple	Terrain Type TIN GRID Terrain
Terrain Single Multiple Output Directory	Terrain Type TIN GRID Terrain

Figure 31. Layer setup window.

RAS MAPPING TOOL then LAYER SETUP TOOL. It will be done when you saved your .mxd file.

2.10.18. RAS Data Import Tool (Figure 32)

	nport RAS Data								
RASE	File C:\MARLA HEC RAS	MODEL practice	\rabiaiiaz2.RASexport.xml						
Mess	ages								
	Start Time	Message Type	Message						
•	6/8/2017 4:08:43 AM	Informative	Starting format transformation						
	6/8/2017 4:08:44 AM	Informative	Transforming to internal format						
	6/8/2017 4:08:45 AM	Informative	Validation internal format						
	6/8/2017 4:08:45 AM	Informative	Transforming to GDB format						
	6/8/2017 4:08:45 AM	Informative	Creating Geodatabase						
	6/8/2017 4:08:49 AM	Informative	Importing data						
	C/9/2017 4-09-50 AM	Informativo	EasturaClass Profile Definition has been created						

Figure 32. Import RAS DATA.

2.10.19. Flood Delineation Tool

Flood delineation using grid tool is used to flood plain mapping as shown in **Figure 33**.

S 6/ 6/	tart Time /8/2017 4:20:38 AM /8/2017 4:20:38 AM	Type Information	Message
6/ 6/	/8/2017 4:20:38 AM /8/2017 4:20:38 AM	Information	Deside by defendent and a second seco
6/	/8/2017 4:20:38 AM		Floodplain delineation started
6/		Information	Reference to ArcMap document and focus map obtained.
	/8/2017 4:20:38 AM	Information	Configuration XML obtained.
6/	/8/2017 4:20:38 AM	Information	Spatial Analyst and 3D Analyst licenses validated.
6/	/8/2017 4:20:38 AM	Information	Starting floodplain delineation
6/	/8/2017 4:20:38 AM	Information	Verify if the RAS export file has already been read
6/	/8/2017 4:20:38 AM	Information	XS cutline and bounding polygon feature classes obtained.
6/	/8/2017 4:20:43 AM	Information	Floodplain delineation started for profile PF 1
6/	/8/2017 4:20:43 AM	Information	Checking if the water surface TIN for the current profile PF 1 exists.
6/	/8/2017 4:20:43 AM	Information	Water surface TIN for the current profile PF 1 exists.
6/	/8/2017 4:20:45 AM	Information	Constant GRID constructed.

Figure 33. Flood delineation using grid tool is used to flood plain mapping.

2.10.20. Flood Plain

A floodplain or flood plain is an area of land adjacent to a stream or river that stretches from the banks of its channel to the base of the enclosing valley walls and experiences flooding during periods of high discharge as shown in **Figure 34**.





2.10.21. Layer to KML

This tool converts a feature or raster layer into a KML file containing a translation of Esri geometries and symbology. This file is compressed using ZIP compression, has a .kmz extension, and can be read by any KML client including ArcGIS Explorer, ArcGlobe, and Google Earth.

3. Results

After evaluation obtained following results after flood frequency analysis by DFW.

Recurrence	Peak	95	% Confidenc	e	Standard	
Interval	Discharge		Limits		Error	
(Years)	(cfs)		(cfs)		(c1	is)
2	278395.0	{	253172.4	303617.7 }		12868.69
5	470840.1		432130.3	509549.9 }		1 9749 .88
10	598255.5	{	548597.6	647913.4 }		25335.66
15	670142.2	{	614007.1	726277.3}		28640.36
100	997226.0	{	910399.8	1084052.3}		44299.09

Gumbel Extreme Value Type-I Distribution, [ML method]

Results show 2, 5, 10, 15,100 years return period peak discharge value, these values indicates if flood accuracy in future that return period so peak flow discharge would be.

3.1. HEC RAS Model Results

After preprocessing in HEC Geo RAS model run in HEC RAS for steady flow analysis Geometric data and steady flow data are used to analyze the Subcritical Flow Regime. Flow regime: the condition of flow for the river. In our case this is Subcritical. This means that there are subcritical conditions at the downstream end, and that you can calculate the water surface upstream and downstream.

Similarly, we can find out different flood extent on the basis of different return time period e.g. 2, 5, 10, 15 and 100 using peak value of water flow as shown in **Figures 35-39** and **Figure 40** respectively. **Figure 36** shows that return the flood during the period of 5 years.

3.2. Inundation Mapping

Floods: The map library is a set of maps that show where a series of water levels in a local river or river flood.

The risk of flood is regarded as being the product of the probability of occurrence of risings and the consequences caused by these events [27]. By having a diagram total of the situation, it would be not only possible to manage the risk, to take the necessary measurements in order to eliminate the life losses and to



Figure 35. Profile plot of two years' return flood.



Figure 36. Profile plot of five years' return flood.



Figure 37. Profile plot of ten years' return flood.

limit the material losses, but also to have diversified possibilities to envisage an adapted dimensioning of the works water-supply engineering [28].

At present, GIS modelling for floods or delimiting some flood prone areas is very advanced, and numerous mathematical methods for calculating the extent of a river (according to its flow rate, the water infiltration rate into the soil, land use etc.) have been developed as shown in **Figure 41**. These mathematical



Figure 38. Profile plot of fifteen years' return flood.



Figure 39. Profile plot of hundred years' return flood.



Figure 40. Floodplain for 15 years.

models have been integrated into GIS software, whose purpose is to create a model that would replicate the shape of the landscape as precise, as possible. The flood risk maps have a clear purpose of identifying vulnerable areas and the population that is exposed in a certain region; they represent a useful tool during General Urban Plan creation, and intend to be used in the interdiction of



Figure 41. Year return period flood along Chenab.

constructing houses in the affected areas and creating management plans for emergency situations, as close as possible to the probabilities of certain events of this type [29].

Flood hazard maps for different return periods 10, 20, 50 and 100 years were conducted by Flood frequency analysis. Flood frequency analysis was used to predict design floods for sites along a river. We used annual peak flow of 35 years from 1980 to 2016. The technique used observed annual peak flow discharge data to calculate statistical information such as mean values, standard deviations, skewness, and recurrence intervals. Flood frequency curve were obtained which is a graph showing the relationship between flood magnitude and their recurrence interval for a specified site. Different formulas, *i.e.* Gumble Formula Figure 3.10, Hazen Formula, Figure 3.8, Blom Formula Figure 3.6, Relative frequency formula Figure 3.9, Wiebell formula 3.11 and Gingorton formula were applied. The best fitted formula for our data was Gumble Formula Figure 3.10. In the phase of Preprocessing we made HEC-RAS model and then this model imported to Arc GIS for post processing. This model results showed that different area is predicted under water in different return periods. Figure 6 shows affected areas after five years' return period.

Flood hazard and flood risk of losses mitigated by multiple risk characteristics combined into a meaningful spatial planning map [30] [31]. The forecast and the control of the damage caused by this type of disasters, particularly require the identification of the vulnerable areas and the determination of the factors

and the damages generated by these catastrophes [32][33]. Remote sensing and GIS application in Sindh Province for flood risk management provide an approach to access hazard of flood [34]. The results of the simulations carried out by HEC-RAS represent the result of a combination of several models brought into consideration. These results made it possible to inform about fluctuations in the appearance of the hydro-gram of rising.

4. Conclusion

The foremost spotlight of this study was on assessing the appropriateness of HEC-RAS model in simulating water surface profiles of river Chenab which was the main reason for river flooding in Punjab. The resultant outputs obtained from the use of one dimensional steady flow analysis using the HEC RAS model suggested assessing flood hazards maps for different return periods 10, 20, 50 and 100 years was conducted using annual peaks flow of 35 years from 1980 to 2016. The maximum discharges at up and down stream for different periods were obtained using Gumbel distribution model results which showed that different areas were predicted under water in different return periods and affected areas after five years' return period. However, further studies should be carried with HEC-RAS models that can be effectively utilized to improve and simplify the forecasts of areas likely to be inundated under a given flood. This method can only be best fit for limited areas of rivers.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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