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Establishment of Floodplain Map in Urban Area of Swat

Sajjad Ali
Lecturer,University of Enginnering &Technology Peshawar,Campus III Bannu,Pakistan
Engr.sajjad@yahoo.com

Muhammad Tahir
University of Enginnering &Technology Peshawar, Campus III Bannu,Pakistan
Muhammadtahir188@yahoo.com

Mahmood Ahmad
Lecturer,University of Enginnering &Technology Peshawar, Campus III Bannu,Pakistan
engrkhattak@hotmail.com

Waheed ur Rehman
Lecturer,University of Enginnering &Technology Peshawar, Campus III Bannu,Pakistan
swrehman@hotmail.com

Shah Room
Lecturer,University of South Asia, Lahore, Pakistan
Shahrome313@yahoo.com

Abstract

Floods are the nation's greatest natural disaster. According to the U.S. Geological Survey, Floods cause an average of $6 billion of property damage, claim 140 lives and prompt more Presidential disaster declarations per year than any other hazard. Similarly, the severe floods, resulting from heavy monsoon rains and freak weather systems commenced in July, 2010, in the high altitude, northern parts of Pakistan. The rains, which broke a long standing,100 years record flood in early 1900s, rapidly became devastating for the provinces of Khyber Pukhtunkhwa, Punjab, Gilgit-Baltistan and Azad Jammu and Kashmir. They also inflicted heavy damage in some districts of Sindh and Baluchistan.

Keeping in view the damages, it is required to have a proper alarming and management system to minimize the chances of destruction. In this perspective, accurate estimates of probable future floods should be worked out as planning, design and construction of engineering infrastructure projects often requires consideration of the potential flood risks. Similarly the estimation of different engineering parameters like shear, flow graphs, top width of water plots, water surface profiles at cross section of rivers are required in many civil engineering projects such as design of bridge openings and culverts, drainage networks, flood relief protection schemes and the determination of flood risk. This research work is mainly focused to find these parameters at every cross section in tabular and graphical form to locate the line of hazards at every point in the study area. The research is carried out on three tributaries of river swat that run through urban area of main Swat city of KPK Pakistan. The devastating Flood of 2010 is taken as the peak discharge for analysis.

It was aimed to collect geometric data and flow rates of 2010 flood on these tributaries using HEC-RAS (Hydrologic Engineering Center-River Analysis System) and GIS (Geographic Information System) software as the basic tools to find hydraulic parameters and the probable boundaries up to which the flood can reach in future.

Keywords Geographic Information System (GIS), Water Surface Profile

1. Introduction

Accurate and updated floodplain maps can be the most valuable tools for avoiding severe social and economic losses from floods. Accurately updated floodplain maps also improve public safety. Early identification of flood-prone properties during emergencies allows public safety organizations to establish warning and evacuation priorities. Builders and developers would have access to more detailed information for making decisions on where to build and how to construct a structure.

A few commercial software companies have capitalized on this opportunity. RIVER CAD software allow user to display HEC-RAS outputs in CAD (Computer Aided Design). However, Geographic Information Systems (GIS) offer a superior environment for this type of work. Although CAD is a good environment for visualization, GIS provides tools for more complex queries, storage, mapping, analysis, and visualization of the spatial data.

GIS and HEC-RAS are ideally suited for various floodplain management activities such as, base mapping, topographic mapping, and post-disaster verification of mapped floodplain extents and depths. HEC-RAS is extensively used in model development and model results are applied in floodplain management and flood insurance studies (Davis CA smith, 1995). It gives a detailed output of different parameters at every cross section like shear, water surface profile, energy losses, rating curves, flow hydrographs, velocity distributions, Froude number, hydraulic depth and top widths.

2. FloodPlain Analysis

Typical floodplain analysis involves three major steps, Data Collection, Model Development and Execution and Final Flood Plain mapping.

2.1 Data Collection and Preparation

Geometric data describe the geometry of the river by cross sections; reach lengths, hydraulic structure data. These data can be obtained from a variety of sources like Digital Elevation Model (DEM), Remote sensing imagery and Manual survey. In manual survey, Lateral and elevation coordinates for each terrain (unfolded) point describes the geometry of the river in HEC-RAS. These coordinates can be taken by level machines, theodolite and total station. Flow data can be obtained by gauges installed at the obstructions in the waterway and from the clear marks after flood. In this research work, required flow data were collected from regional Irrigation department, Swat, KPK, Pakistan.

2.2 Model Development and Execution

Floodplain modeling involves two aspects: hydrology and hydraulics (H&H). Hydrologic analysis determines peak flood flows and hydraulic analysis determines peak water surface elevations. A hydrologic model, such as HEC-RAS, can be used to model storm water runoff. This calculation is based on physical characteristics of a drainage area. The runoff information from the hydrologic model can then be combined with stream cross-section information in a hydraulic model, such as HEC-RAS, to determine the depth of flooding (Maidmain, 1999).The same technique was adopted to work out three tributaries, Marghuzar, Jambil and Mingora running to the left bank side of main river Swat which cover approximately 70% of the urban area of the district.

2.3 Floodplain mapping

The collected Cross section data and reach lengths were entered in HEC-RAS for final model development. Flow and boundary conditions were specified for every cross section, a gateway to find normal depth, critical depth, rating curve and water surfaces.

Flood plain mapping is done by HEC-RAS as well as in GIS. HEC-RAS has a GIS tool called RAS Mapper and in that window there is floodplain mapping environment, which requires the geometric file of modeled and floating point grid(*.flt) format file. The modeled water surface profiles (elevations) can be imported from HEC-RAS in to a GIS and overlaid upon the terrain surface to create flood maps and determine which areas will be inundated (Prasuhn, A.L, 1997).These steps were followed in the present research approaching towards the final floodplain map development.

3. Graphical and Tabular Results

Several output options are available from the view menu bar on the HEC-RAS main window to view the results like water surface profiles, General surface profiles, velocity distribution, Cross section plots, rating curves at every cross section, X Y Z plots, Stage and flow hydroghaphs, profile summery table, detailed tabular outputs and floodplain mapping.In the following figures and tables, the step by step procedure to develop an automated flood plain map in the congested area of the city on the left bank of river Swat is explained in detail including hydraulic depth and shear distribution at left, center and right bank at a selectedd section for a specified flow rate of 2010 flood .

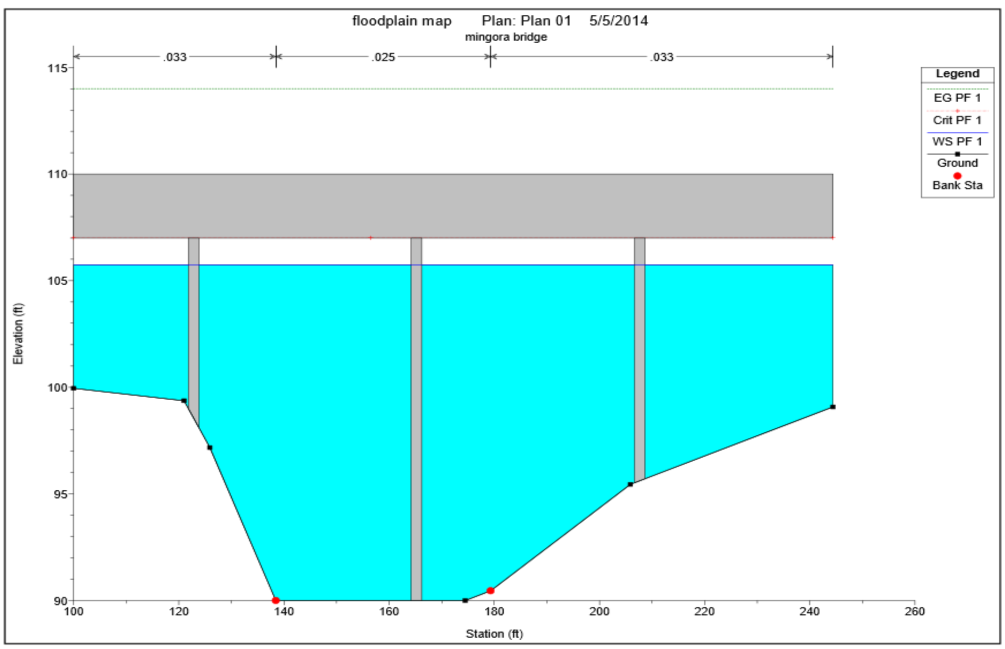

Figure 1: Cross section plot at Mingora bridge section

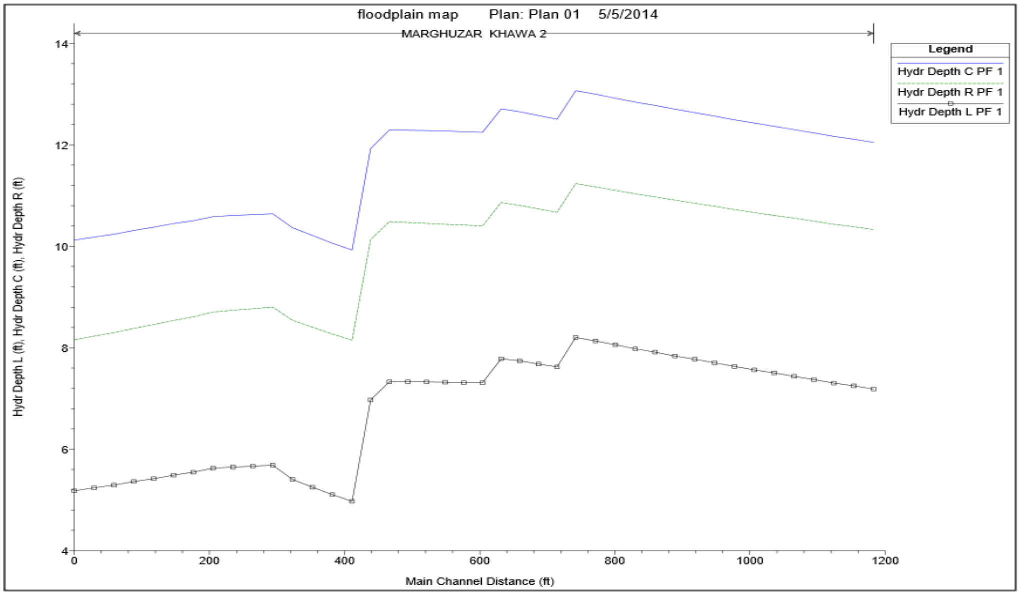

Figure 2: Hydraulic depth plot of Marghuzar tributary

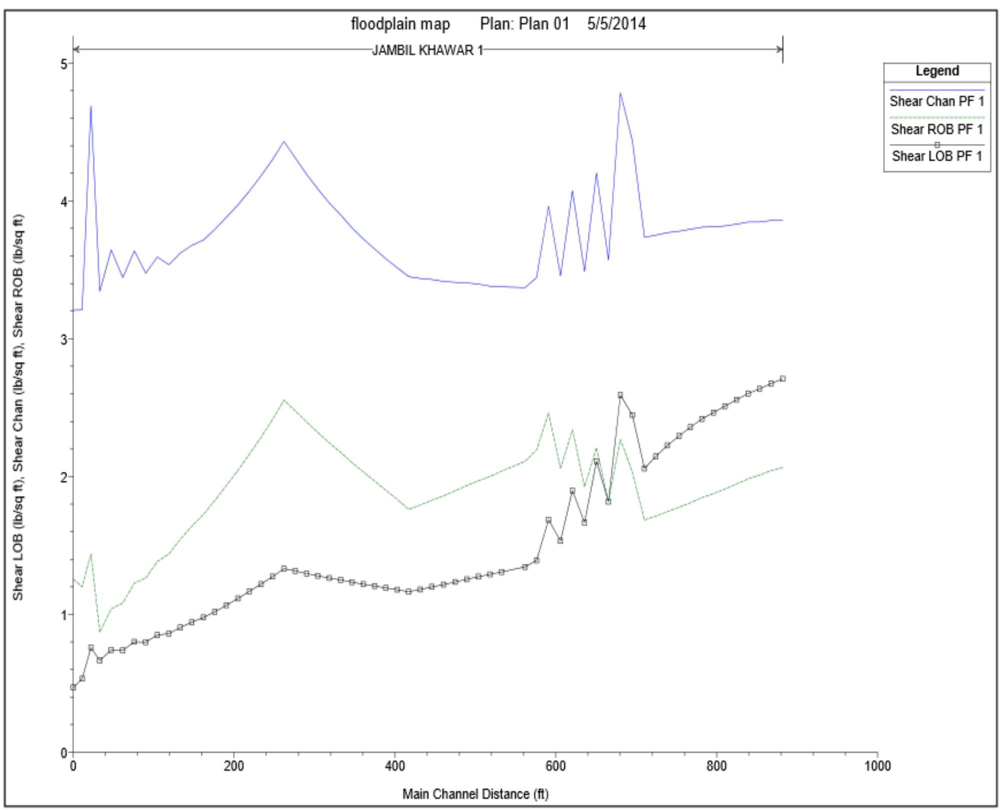

Figure 3: Shear plot of river of Jambil tributary

In the diagram given below, the velocity distribution is plotted at bridge section. Velocity is greater at center because of less friction and lower at sides because of more friction. (Beavers, M.A, 1994).

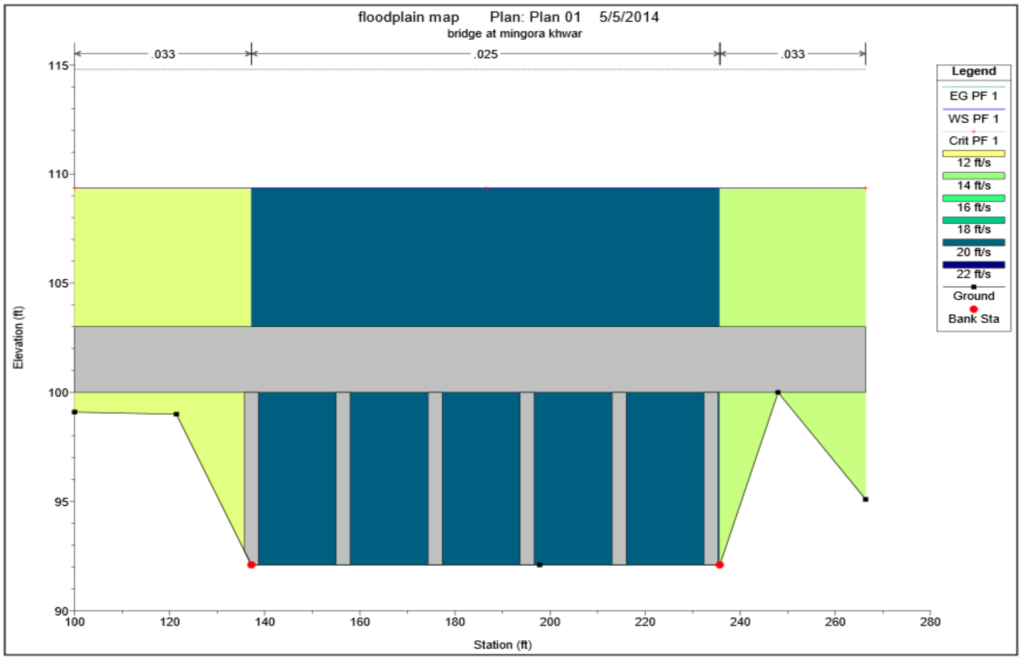

Figure 4: Typical Velocity distribution plot at bridge section

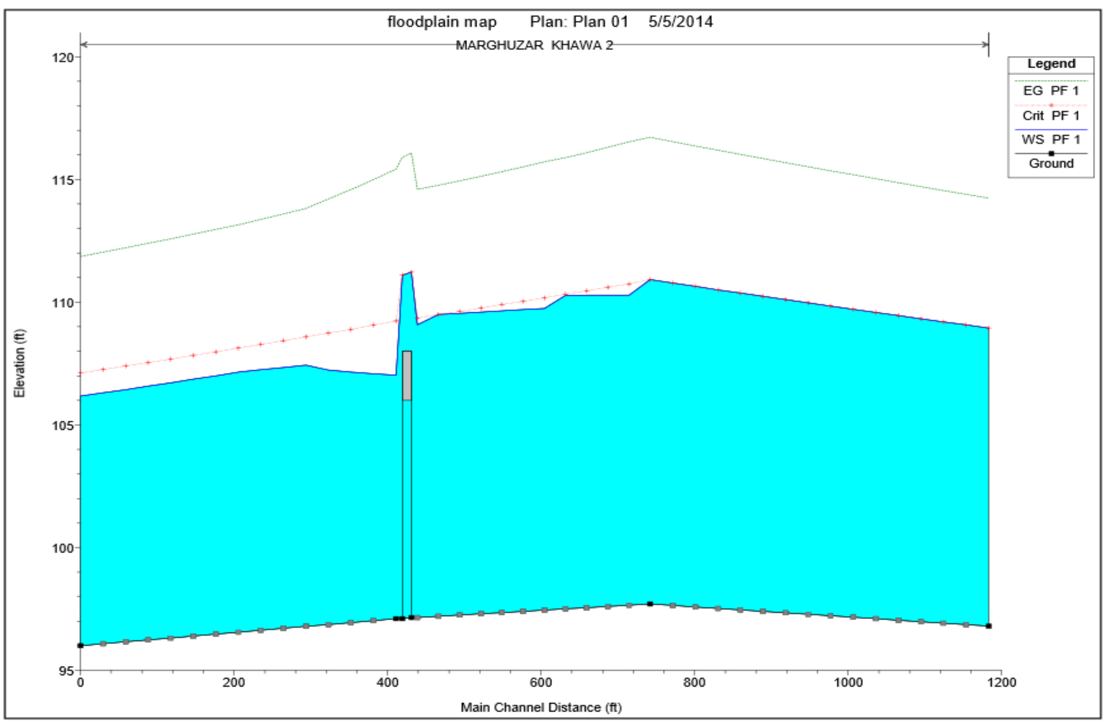

Figure Error! No text of specified style in document.**: Water surface profile plot**

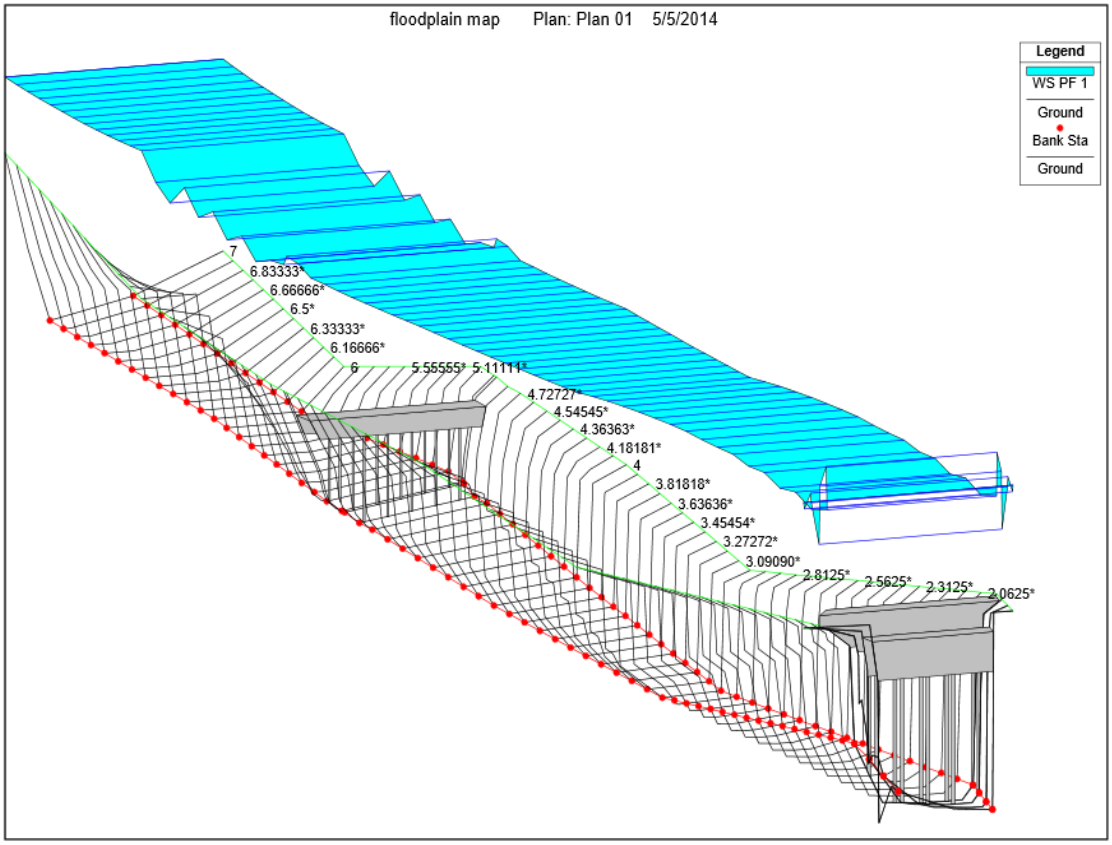

Figure 6: X, Y, Z plot of Jambil tributary of river Swat with two bridges

Table 1: Detailed output table of Jambil tributary of river swat

HEC-RAS Plan: Plan 01 River: JAMBIL KHAWAR Reach: 1 Profile: PF 1

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	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	7	PF 1	16600.00	96.30	108.85	108.85	114.39	0.005114	22.39	982.10	91.15	1.13
1	6	PF 1	16600.00	95.60	109.51	109.51	115.52	0.004302	22.55	987.74	84.66	1.07
1	5	PF 1	16600.00	94.80	107.28	107.42	113.10	0.004603	21.12	950.04	88.02	1.07
1	4.75		Bridge									
1	4	PF 1	16600.00	93.40	107.90	107.90	113.79	0.003877	21.76	1000.17	86.53	1.02
1	3	PF 1	16600.00	92.50	108.39	108.39	115.13	0.004482	25.09	953.51	72.74	1.11
1	2	PF 1	16600.00	92.70	107.97	108.11	114.80	0.003655	21.51	874.29	70.88	0.99
1	1.833		Bridge									
1	1.19		Bridge									
1	1	PF 1	16600.00	93.00	109.39	109.39	115.33	0.003230	21.36	1022.02	87.58	0.94

Table 1 : Cross Sections Details at a Particular Section of Jambil tributary

Plan: Plan 01 JAMBIL KHAWAR 1 RS: 7 Profile: PF 1

E.G. Elev (ft)	114.39	Element	Left OB	Channel	Right OB
Vel Head (ft)	5.54	Wt. n-Val.	0.033	0.025	0.033
W.S. Elev (ft)	108.85	Reach Len. (ft)	14.28	14.32	14.55
Crit W.S. (ft)	108.85	Flow Area (sq ft)	401.37	421.96	158.77
E.G. Slope (ft/ft)	0.005114	Area (sq ft)	401.37	421.96	158.77
Q Total (cfs)	16600.00	Flow (cfs)	5375.58	9449.30	1775.12
Top Width (ft)	91.15	Top Width (ft)	37.52	34.88	18.75
Vel Total (ft/s)	16.90	Avg. Vel. (ft/s)	13.39	22.39	11.18
Max Chl Dpth (ft)	12.55	Hydr. Depth (ft)	10.70	12.10	8.47
Conv. Total (cfs)	232130.8	Conv. (cfs)	75171.0	132137.0	24822.8
Length Wtd. (ft)	14.33	Wetted Per. (ft)	47.32	34.89	24.54
Min Ch El (ft)	96.30	Shear (lb/sq ft)	2.71	3.86	2.07
Alpha	1.25	Stream Power (lb/ft s)	191.15	0.00	0.00
Frctn Loss (ft)		Cum Volume (acre-ft)	3.41	11.98	5.47
C & E Loss (ft)		Cum SA (acres)	0.32	0.73	0.51

Plan: Plan 01 JAMBIL KHAWAR 1 RS: 6 Profile: PF 1

E.G. Elev (ft)	115.52	Element	Left OB	Channel	Right OB
Vel Head (ft)	6.01	Wt. n-Val.	0.033	0.025	0.033
W.S. Elev (ft)	109.51	Reach Len. (ft)	15.34	14.89	14.67
Crit W.S. (ft)	109.51	Flow Area (sq ft)	226.29	508.32	253.12
E.G. Slope (ft/ft)	0.004302	Area (sq ft)	226.29	508.32	253.12
Q Total (cfs)	16600.00	Flow (cfs)	2597.63	11460.53	2541.84
Top Width (ft)	84.66	Top Width (ft)	17.60	36.55	30.51
Vel Total (ft/s)	16.81	Avg. Vel. (ft/s)	11.48	22.55	10.04
Max Chl Dpth (ft)	13.91	Hydr. Depth (ft)	12.86	13.91	8.30
Conv. Total (cfs)	253086.1	Conv. (cfs)	39603.9	174728.9	38753.3
Length Wtd. (ft)	14.92	Wetted Per. (ft)	29.53	36.55	40.37
Min Ch El (ft)	95.60	Shear (lb/sq ft)	2.06	3.74	1.68
Alpha	1.37	Stream Power (lb/ft s)	184.66	0.00	0.00
Frctn Loss (ft)	0.06	Cum Volume (acre-ft)	2.16	10.15	4.65
C & E Loss (ft)	0.00	Cum SA (acres)	0.21	0.59	0.41

Plan: Plan 01 JAMBIL KHAWAR 1 RS: 5 Profile: PF 1

E.G. Elev (ft)	113.10	Element	Left OB	Channel	Right OB
Vel Head (ft)	5.81	Wt. n-Val.	0.033	0.025	0.033
W.S. Elev (ft)	107.28	Reach Len. (ft)	15.04	14.46	14.43
Crit W.S. (ft)	107.42	Flow Area (sq ft)	103.21	611.23	235.60

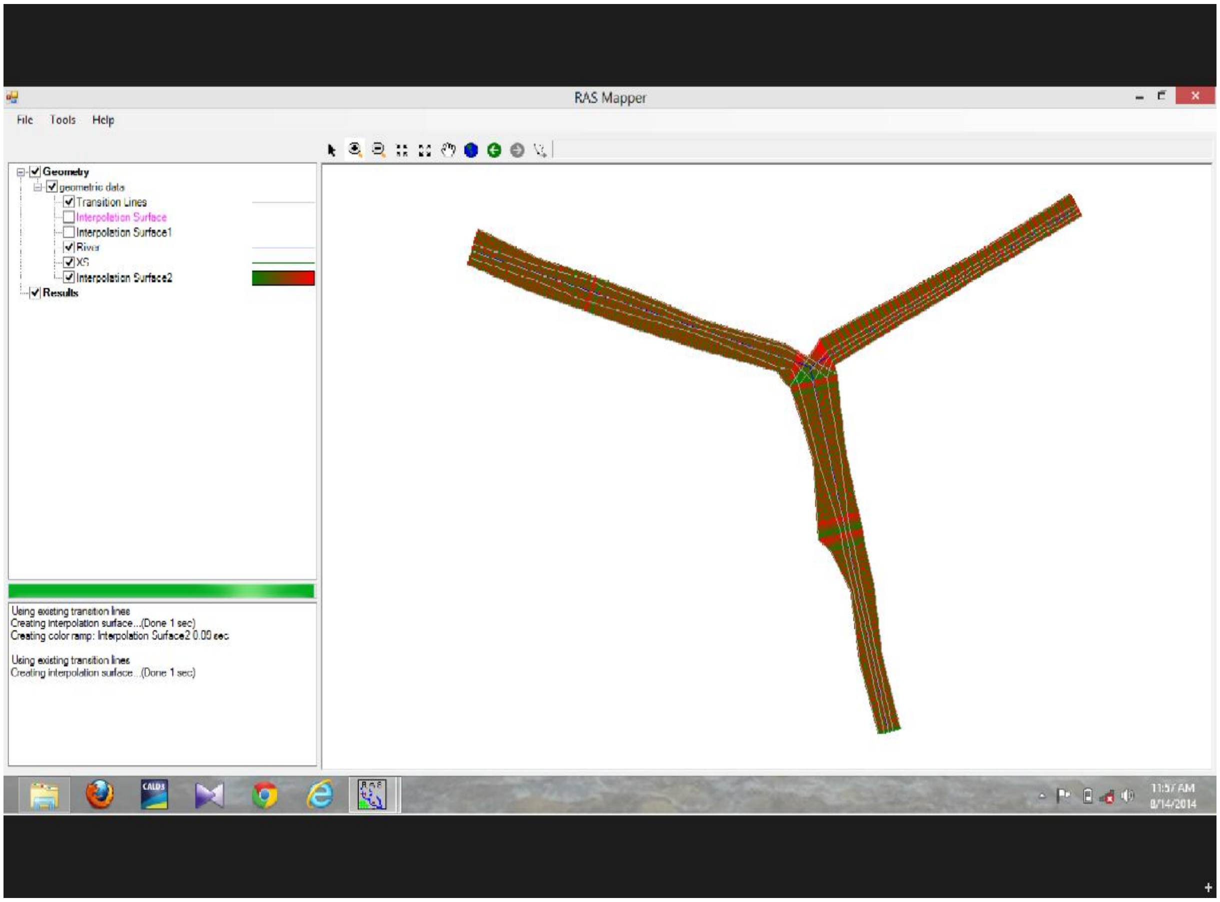

Figure7: Final Floodplain map of Mingora, Marghuzar and Jambil tributaries of river swat

4. Conclusion

It can be concluded that many floodplain maps need to be revised because they are outdated. The automated mapping approach developed for this research saves time and money versus conventional floodplain delineation on paper maps. Thus, floodplain maps can be updated more frequently, as changes in hydrologic and hydraulic conditions warrant.

Community planners and local officials will gain a greater understanding of the flood hazard and risk and can therefore improve planning before peak flows. Builders and developers will have access to more detailed information for making decisions on where to build and how to construct a structure. Residents and business owners throughout the region will have the facility to make better financial decisions about protecting their properties.

The developed flood plain map of river Swat in urban area will provide proper data base for any team working on the flood mitigation issue.

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