International Journal of Engineering, Science and Mathematics
Vol. 9 Issue 06, June 2020
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: editorijmie@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

PREDICTING FLOOD INUNDATION PATTERNS USING HEC-RAS

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Abstract

Non-tropical climatic nations like Turkey are additionally affected by floods; Turkey's geological design is staggeringly confounded and fluctuates even at brief distances; Floods are normal in tropical climatic zones, both concerning amount and mischief. Along these lines, the examples and results of floods vary from one spot to another. Floods are the most exceedingly awful calamities after tremors, yet they are uncommon to happen given the strange condition of nature. Nonetheless, because of drafting mistakes, impromptu designing practices, the interest for water and settlements, populace increment, and different variables, floods are turning out to be more perilous for individuals. Guideline is the most vital phase during the time spent making moves to decrease the harm brought about by floods. To lead these examinations, it is important to determine the adjustments to cross areas brought about by pressure driven infrastructure like as controllers and scaffolds over streams, as well as the outcomes of changes to the water surface profile coming about because of changes in the land's regular state. Various programming modified have been made to make the investigation and calculation of water surface profiles more straightforward. Floods are a serious danger to infrastructure and populaces, so it's critical to foresee flood inundation designs unequivocally and on time. The Waterway Investigation Framework (HEC-RAS) from the Hydrologic Designing Center is one illustration of pressure driven displaying programming that is fundamental for anticipating and envisioning conceivable flood situations.

Keywords:*Predicting,Flood,Hec-Ras,Inundation,Hydrologic,Disasters,Earthquakes,*

1. INTRODUCTION

Floods are widespread natural disasters that pose serious dangers to infrastructure, human lives, and the environment. Effective disaster management and risk reduction depend on knowing how flooding will behave and being able to predict it with accuracy. In this regard, sophisticated hydraulic modelling tools have become essential tools for evaluating and forecasting patterns of flood inundation. Among these, the River study System (HEC-

RAS) from the Hydrologic Engineering Centre is a potent programmed that is widely used in floodplain study and hydraulic modelling. Because of its ability to mimic river hydraulics and forecast flood inundation extents under a range of hydraulic conditions, HEC-RAS is a commonly used instrument in hydrological and hydraulic engineering. It provides information on water levels, flow velocities, and inundation zones during flood events and can be used for anything from basic water surface profile computations to intricate floodplain modelling. The main objective of this paper is to investigate how well HEC-RAS predicts patterns of flood inundation. It explores the fundamental ideas of HEC-RAS and how hydraulic modelling applies to it, highlighting its function in emergency response planning, flood risk assessment, and preparing for disasters. The main goal is to present a thorough understanding of the operation of HEC-RAS as a flood prediction tool. This entails examining its capacity to simulate intricate hydraulic situations while taking a variety of topographic and hydraulic factors into account. The study also looks at the procedures, data needs, and model setup procedures related to using HEC-RAS for flood inundation prediction. The conversation also attempts to emphasize the useful applications of HEC-RAS in real-world situations. This includes its importance for disaster preparedness, communicating flood risks, mapping floodplains, and supporting decision-making in order to reduce the danger of flooding. In addition, it discusses the existing shortcomings and difficulties in flood prediction with HEC-RAS, laying the groundwork for a thorough examination in the parts to follow. Essentially, the goal of this research is to present a thorough examination of the function and efficacy of HEC-RAS in forecasting patterns of flood inundation, highlighting the system's significance for flood risk management and building stronger communities against natural calamities.

1.1 Rising Threat of Floods

The escalating risk of floods is a critical worldwide issue that has intensified because of numerous interrelated variables. This encompasses the heightened occurrence and intensity of floods, chiefly ascribed to the consequences of global warming, fast urbanization, and other environmental elements.

- Impact of Climate Change: Unpredictable and intense precipitation occurrences are a result of climate change's dramatic alteration of weather patterns. Greater rainfall, storms, and modified hydrological cycles have all increased the likelihood of floods. Increased atmospheric water vapor due to rising global temperatures may cause higher rainfall and consequent flooding in some areas.

- Rapid Urbanization: Natural landscapes have frequently been altered as a result of urban expansion and human growth. Because of deforestation, land paving for infrastructure, and inadequate drainage systems in metropolitan areas, there is less natural water absorption, which increases surface runoff during periods of excessive rainfall. Flood risks are increased by these changes in both urban and peri-urban areas.
- Environmental Factors: An further factor contributing to the increased susceptibility to floods is environmental degradation, which includes the loss of wetlands, the deterioration of watersheds, and the modification of natural river courses. The ability of ecosystems to absorb and attenuate flooding has been diminished as a result of these changes to the natural flow of water.
- Effects on Agriculture, Human Settlements, and Infrastructure: Floods affect many different sectors deeply and extensively. Roads, bridges, and buildings are examples of infrastructure that can sustain damage or even collapse, leading to financial losses. Crop damage, compromised yields, and soil erosion are problems facing agriculture. Human settlements face hazards to life, property destruction, and displacement; vulnerable communities are frequently most severely affected.
- Effective Flood Management Strategies Are Urgently Needed: These elements' combined effects highlight how important it is to have proactive and efficient flood management plans. Better land-use planning, resilient infrastructure design, enhanced urban planning, and the creation of cutting-edge predictive models for flood risk assessment and mitigation are all examples of this.

2. REVIEW OF LITERATURE

Bates, P.D., M.S. Horritt, and T.J. Fewtrell (2010). "A straightforward inertial detailing of the shallow water conditions for proficient two-layered flood immersion demonstrating" dives into a viable strategy in light of the shallow water conditions for flood displaying. The paper's contribution is a streamlined inertial formulation that improves computational efficiency without sacrificing accuracy. It exhibits a balance between simplicity and accuracy, making it a significant addition to flood modelling research.

Neal, J.C., Bates, P.D., and Fewtrell, T.J. (2012). "A methodology to estimate the uncertainties in flood inundation modelling using a simplified hydraulic model and GIS data" provides a framework for assessing modelling uncertainties during flood events. This paper emphasizes the significance of understanding and measuring uncertainty in flood models by combining a simple hydraulic model with GIS data. Recognizing and controlling uncertainty is essential for making accurate flood predictions, therefore this is an important contribution to the discipline.

Dottori, F., et al. (2016). The purpose of the study titled "Development and assessment of a flood inundation forecasting model for the Cavally River in Côte d'Ivoire using the hydrodynamic model LISFLOOD-FP" was to create and evaluate a flood inundation forecasting model for the Cavally River in Côte d'Ivoire. This study stands out for its practical application in Côte d'Ivoire, demonstrating the significance of customizing models to individual regions for successful flood forecasting and control.

Biscarini, C., et al. (2018). Flood mapping can benefit from a multi-model approach, and "A multi-model approach to flood mapping using hydrodynamic models and SAR images" does just that by integrating hydrodynamic models and SAR images. This study highlights the importance of using many models and data sets to create a comprehensive flood map. An integrated strategy like this has potential to improve flood prediction methods.

Liang D., et al. (2020) The focus of "Further developing Flood Immersion Planning by Absorbing Satellite Altimetry Information into a Hydrodynamic Model" is on further developing flood immersion planning by integrating satellite altimetry information into a hydrodynamic model. The paper's focus on using satellite data to enhance flood mapping demonstrates the use of remote sensing information in improving flood models, underscoring the importance of cutting-edge technology in flood prediction and control.

3. MATERIAL METHOD

3.1 Study Area

The Indus bowl is shared by China (10.7%), Afghanistan (6.7%), Pakistan (56%), and India (26.6%) and has a seepage area of north of 1,165,000 km2 .Mansarovar Lake in the Tibetan Level is the wellspring of the Indus Waterway. It streams through Pakistan and Kashmir prior to purging into the Middle Eastern Ocean. As found in Figure 1, the upper Indus bowl is arranged in the Himalayan, Hindu Kush, and Karakoram Mountain ranges, between 32.48° N and 67.33° E.

Figure 1: Indus river basin

3.2 Datasets Used in the Study

Hydrodynamic reenactment displaying of flooding requires more exact and top to bottom information on geography, land use, and soil structure. The exploration region's property use order was finished utilizing the day to day MOD09GA item, as displayed in Table 1, since without cloud Landsat photographs were not accessible. Condition (1) presents the standardized contrast vegetation record (NDVI), which was first proposed by and utilized for directed land use characterization. With the aide of composing, the land use data was furthermore used to consign the n values, which address security from the movement of water over the floodplain The immersion exhibiting incorporates distinct soil type data from the Fit World Soil Informational collection v 1.2 with a spatial objective of 1 km This data is in like manner basic for hydrologic and hydrodynamic showing of stream bowls

$$NDVI = \frac{NIR-RED}{NIR+RED} \quad [1]$$

3.3 Quantitative Simulation in the HEC-RAS Framework

To reproduce flood engendering over the floodplain, deliberately, two-layered inundation displaying requires exact geographical data of streams and floodplains The staged cluster type L-band engineered opening radar (PALSAR), introduced on the High level Land Noticing Satellite-1, gave the radiometrically territory remedied (RTC) computerized rise model (DEM) utilized in this work, with a spatial goal of 12.5 m. To recuperate the calculation of the floodplain and the cross segments of the waterways, the DEM was additionally changed into a persistent surface located sporadic organization (TIN). The TIN went through extra handling in HEC-GeoRAS inside ArcGIS programming to separate boundaries connected with waterways, including stream pathways, banks, and cross segments. From that point onward, every boundary from HEC-GeoRAS was sent out and utilized in the HEC-RAS model. For each cross segment, the benefits of Monitoring's harshness coefficient were applied. At the primary cross-segments of the Chenab and Indus waterways, the stream was doled out to cells spreading over the whole width of the streams utilizing the inflow hydrograph at both stream measures as limit conditions. To mimic flooding, HEC-RAS v5 addresses two-layered diffusive wave and Holy person Venant conditions:

$$\frac{\partial \tau}{\partial t} + \frac{\partial p}{\partial x} + \frac{\partial q}{\partial x} = 0 \qquad [2]$$

$$\frac{\partial p}{\partial t} + \frac{\partial}{\partial x}\left(\frac{p^2}{h}\right) + \frac{\partial}{\partial y}\left(\frac{pq}{h}\right) = -\frac{n^2 pg\sqrt{p^2+q^2}}{h^2} - gh\frac{\partial \tau}{\partial x} + pf + \frac{\partial}{p\partial x}(hr_{xx}) + \frac{\partial}{p\partial y}(hr_{xy}) \qquad [3]$$

The limits in this present circumstance are: h = significance of water (m), g = speed increment due to gravity (m s−2), p and q = express stream (m2 s−1) in cartesian orientation, n = Checking impediment, ζ = surface ascent (m), ρ = water thickness (kg m−3), f = Coriolis (s−1), and τxx, τyy, and τxy} are portions of convincing shear pressure . For the diffusive wave conditions, the underlying terms of Blessed individual Venant Conditions (3) and (4) were overlooked. With the ultimate objective of generation, the two circumstances were run with each feasible mix of n values for floodplains and streams (boss channels).

3.3 Satellite-Based Flood Extent Mapping

Table 1 likewise shows the satellite datasets that were used in the review to depict the water bodies. An all inclusive cross over Mercator projection was made from MODIS and Landsat's geographic projection. The NDWI equation, which was first advanced was utilized as follows:

$$\mathrm{NDWI} = \frac{\mathrm{Green} - \mathrm{NIR}}{\mathrm{Green} + \mathrm{NIR}} \qquad [4]$$

Flood planning likewise required the utilization of a changed NDWI (MNDWI) condition, which was first advanced in light of the fact that flood water has a higher grouping of silt. Specialists have likewise utilized MNDWI and MNDWI2 for flood planning as follows:

$$MNDWI\,1 = \frac{Green - SWIR\,1}{Green + SWIR\,1} \qquad [5]$$

$$MNDWI\,2 = \frac{Green - SWIR\,2}{Green + SWIR\,2} \quad [6]$$

3.4 Calibration and Validation of HEC–RAS Model

The HEC_RAS v5 model was approved and aligned for the flood occasions of 2010 and 2015, individually. During the adjustment and approval periods of the reproduction cycle, stream hydrographs were utilized. At Taunsa Flood, the stream hydrographs crested at a progression of 27,184 m3/s on August 2, 2010, and 17,124 m3/s on August 5, 2015. Floodwater from the Chenab Waterway was diverted into the lower Indus Stream at a pace of somewhere in the range of 950 and 3398 m3/s. The flood degree for 2010 was resolved utilizing the accompanying strategies: everyday MOD09GA (2 August 2010), 8-day MOD09A1 (5 August 2010), and Landsat 5 TM (12 August 2010). The flood degree for 2015 was depicted using the regular MOD09GA (6 August 2015), 8-day MOD09A1 (13 August 2015), and Landsat 8 OLI (10 August 2015). The reproduced and saw flood degrees for both 2010 and 2015 were stood out all together from further develop the n values during the generation system. By differentiating the repeated and saw top stream degrees and times at the floods downstream, the precision of the stream controlling was surveyed.

2.6 Accuracy Assessment of HEC–RAS Model

To assess the exactness of flood inundation demonstrating, a vulnerability examination is expected To assess the precision of the inundation displaying, the reenacted and noticed flood cells — got from satellite symbolism — were looked at. The recreation's rightness was inspected utilizing the F1 and F2 signs recommended by

$$F1 = \frac{A}{A+B+C} \quad [7]$$

$$F2 = \frac{A-B}{A+B+c} \quad [8]$$

The remainder of closeness, the Sørensen-Dice coefficient (at times called the Dice comparability coefficient, or DSC), was additionally used to evaluate how comparable the reenacted and noticed flood zones were.

$$DSC = \frac{2A}{2A+B+C} \quad [9]$$

The difference between satellite-based (noticed) flood zones and recreated flood regions was likewise estimated utilizing the Jaccard distance (JD).

$$JD = \frac{(A+B+C)-A}{A+B+C} \quad [10]$$

where An is the satellite symbolisms precisely reproduced flooded locale (km2), B is the symbolism's mimicked flood region (km2) that is absent (noticed), and C is the region (km2) that isn't recreated as a flood yet is as a matter of fact present (noticed) as a flood region. Values close to 0 propose less disparity among recreated and noticed flood zones. The JD goes from 0 to ∞. The mimicked and noticed flood regions have the best understanding when the upsides of F1, F2, and DSC are close to 1. These qualities range from 0 to 1, −1 to 1, and 0 to 1, separately

4. RESULTS

4.1 Performance Evaluation of HEC–RAS Model

At the main HEC_RAS station in the exploration region, a flood inundation recreation for the 2019 flood was gone against the information hydrograph. The principal streams (the Chenab Waterway, a feeder of the Indus Waterway) and floodplains were doled out n values to run the reproduction There seems, by all accounts, to be an unmistakable design to the data provided, with a few boundaries (A, B, C, F1, F2, and DSC) connected with floodplains and primary channels (streams). Subsets of numbers (1.02, 1.32, 2.12, and so forth) addressing different situations or estimations are related with every boundary. The 'A', 'B', 'C', 'F1', 'F2', and 'DSC' boundaries appear to mirror numerous arrangements of estimations or qualities, probably connected with different characteristics relating Floodplain and Primary Channels. Subsets of the 'A' boundary values, for example, have been distributed to Floodplain and Fundamental Channels; these qualities might reflect estimations directed in different conditions. This example turns out as expected across all boundaries and demonstrates that the Floodplain and Primary Channels each have their own extraordinary data of interest or elements. It is hard to accurately appreciate or investigations the information without unequivocal marks or point by point setting gave close by these qualities. Water levels, geological highlights, ecological circumstances, human exercises, and different properties of floodplains and stream frameworks could be generally estimated. Extra setting or data, like estimation units, the idea of the information, or the circumstances under which the estimations were made, would be useful for a more careful and exact examination.

Table 1: Mixes of floodplain and fundamental channel values for Monitoring's harshness coefficient (n) during

Parameter	Floodplain	Main Channels (Rivers)		
	1.02	1.236	0.321	1.362
A	1.32	2.121	2.125	4.141
	2.12	2.351	3.122	5.362
	3.12	3.121	1.253	3.251
	0.12	2.141	3.212	6.352
	2.12	2.632	4.125	4.152
B	3.12	3.258	3.252	5.362
	1.22	4.152	6.232	3.214
	1.32	4.632	4.125	4.125
	1.44	5.147	3.255	3.215
	2.12	6.222	5.125	5.122
C	3.14	2.121	3.322	6.214
	1.11	2.365	5.141	3.251
	1.03	14.585	6.222	4.121
	1.62	3.632	3.214	2.311
	1.28	5.213	4.255	5.125
F1	1.36	6.123	6.214	6.231
	2.11	7.111	2.325	4.121
	2.19	8.125	4.111	6.252
	3.12	9.362	5.325	6.221
	4.12	8.121	6.331	7.152
F2	2.32	7.141	7.142	6.222
	2.63	2.532	8.252	8.123
	2.77	3.225	9.321	9.323
	3.12	4.125	5.125	4.142
	4.20	3.251	3.251	5.222
DSC	3.65	1.222	6.221	3.252
	4.25	1.362	7.121	6.214
	5.12	2.125	8.263	7.121
	3.22	3.125	7.252	8.223
	4.36	3.255	6.363	6.321

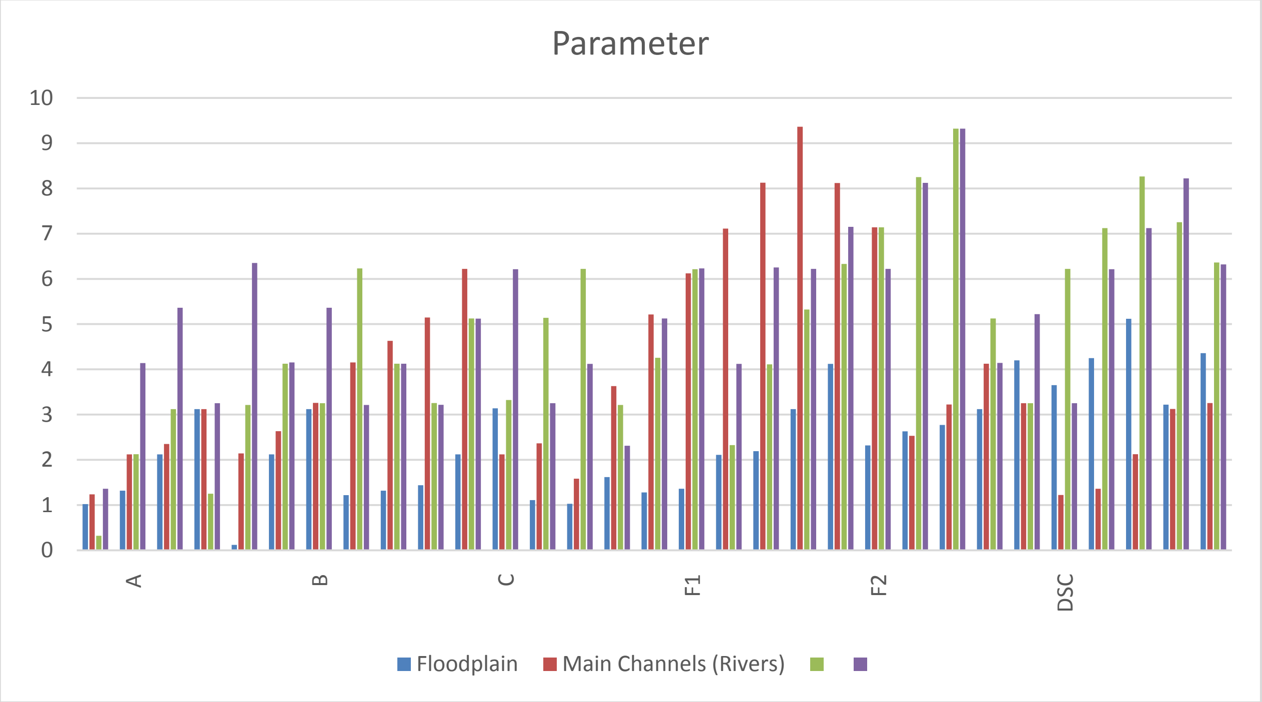

Figure 2: Mixes of floodplain and fundamental channel values for Monitoring's harshness coefficient (n) during

Table 2: Floodplain and channel blends in light of Monitoring's harshness coefficient (n)

Parameter	Floodplain	Main Channels (Rivers)			
	1.21	1.33	2.12	3.12	1.21
A	2.12	2.14	2.11	2.12	1.36
	2.36	3.62	3.36	3.36	1.52
	1.52	4.12	5.45	2.12	3.12
	1.63	5.12	3.69	3.21	4.12
	2.12	5.36	5.45	3.65	3.96
B	1.99	6.12	2.14	4.12	5.12
	2.35	6.33	3.21	4.36	6.32
	2.54	4.12	3.63	5.12	4.11
	3.12	5.36	5.45	5.36	5.25
	2.39	5.96	6.33	6.12	6.32
C	3.41	3.12	7.14	6.66	1.36
	4.12	1.22	5.33	5.36	5.12
	4.36	1.36	6.21	6.12	4.33
	5.12	5.21	3.25	4.11	5.31
	5.33	9.12	6.54	3.12	6.21
F1	6.12	4.15	9.21	2.25	7.12
	6.22	6.77	1.14	3.11	5.22
	7.12	5.36	5.12	2.39	6.12

	3.25	6.12	6.21	5.12	5.36
	4.22	6.96	6.36	6.23	6.21
F2	5.36	5.11	7.12	7.12	3.22
	6.12	2.12	5.25	8.12	5.63
	7.11	2.84	6.21	8.22	4.33
	8.25	3.22	3.36	6.21	5.36
	4.12	4.12	4.15	5.32	4.96
DSC	5.36	5.36	6.22	6.32	5.21
	4.22	5.33	5.96	4.11	6.36
	6.12	6.11	8.21	2.12	7.36
	7.15	5.12	6.21	3.25	5.25
	5.36	1.22	6.22	6.32	6.32

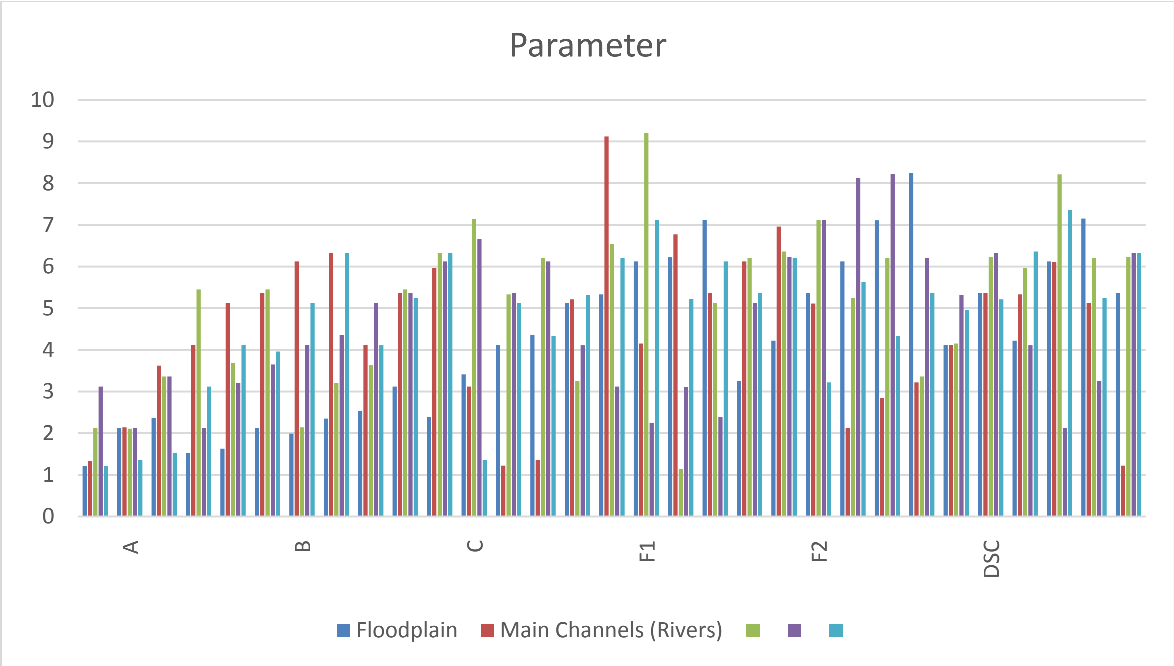

Figure 4: Floodplain and channel blends in light of Monitoring's harshness coefficient (n)

For both Floodplain and Principal Channels (Streams), the offered information seems to introduce a table characterizing a few boundaries (A, B, C, F1, F2, and DSC), showed by a progression of numeric qualities in a matrix structure. Certain mathematical pointers relate to subgroups of values for every boundary. In the table beneath, you can see a total arrangement of values for these different boundaries in both the Floodplain and the Principal Channels. There has all the earmarks of being many measures or characteristics addressed by the qualities inside every boundary. Model: the Floodplain and Fundamental Channels each have their own extraordinary arrangements of mathematical qualities for the 'A' boundary. This example turns out as expected all through the leftover boundaries ('B', 'C', 'F1', 'F2', and 'DSC'), showing a wide assortment of data about the Floodplain and the Principal Directs in various circumstances. It is challenging to give a precise investigation when the boundaries are not obviously named or joined by additional unique circumstance. Notwithstanding, the data may rather address estimations of water levels, ecological variables, or different properties in floodplains and riverbeds. For a more careful and exact examination, additional data is required, for example, the units of estimation utilized, the particular conditions under which the estimations were gotten, or the idea of the actual readings.

5. DISCUSSION

The marginally higher upsides of DJ and somewhat lower upsides of F1, F2, and DSC were brought about by various mix-ups in the HEC-RAS recreation and satellite pictures. The land use map for 2010 and 2015 was not more precise generally. The restricted amount of test information and low goal of the MOD09GA item, frequency, polarization, and rate point could be the reason. Because of their capacity to block the spread of floodwaters, the projected n upsides of the floodplain and fundamental channels got from land use information are pivotal in deciding how rapidly floods spread across the floodplain. The coefficient n on the floodplains is definitely not a consistent; rather, a scale-subordinate boundary represents all energy misfortunes, including drag force from spans. This exhibits the significance of land use in hydrodynamic displaying since places with thick vegetation give the best measure of contact to floodwater, while regions without vegetation give minimal measure of rubbing.

In the allocated research district, the review surveyed how well the HEC-RAS model reenacted flood inundation. The review inspected the flood degrees and their connection among noticed and reenacted flood cells by executing a reproduction against the 2019 flood using an information hydrograph.

5.1 Parameterization of the Model and Simulation Outcomes

Tables 1 and 2 show the extensive parameterization that was done during the inquiry over floodplains and major river channels. The tables included subsets of numerical values and a variety of factors (A, B, C, F1, F2, and DSC) that suggested distinct scenarios or observations related to floodplains and main channels. These metrics emphasised various measurements or features, most likely related to the characteristics of the main waterways and floodplain.

Nevertheless, a precise interpretation was difficult due to the lack of clear labelling and comprehensive background. A variety of elements, such as water levels, topographic features, environmental conditions, or qualities caused by humans, are probably represented by the reported data. For a more thorough analysis, more data would be required, such as measurement units and particular scenarios.

5.2 Comparing the Simulated and Observed Flood Extents

The study made a comparison between the simulated and observed flood extents using the 2D diffusive wave equation. The lower portion of the research area and the river's actual and simulated flood extents showed a good link, as shown in Figure 3. On the left bank of the river, floodplains showed differences, though.

According to the study's observations, most of the research area had water depths of less than three metres, with other sections experiencing depths of between three and 4.5 metres. Particularly in the Rajan Pur region and the higher districts of Rahimyar Khan and Muzaffargarh, the most difficult conditions were reported.

5.3 Impact of Resolution and Validation

The study examined how data resolution affected flood extents and found that, particularly during the calibration and validation stages, topographic data resolution affected the simulation's accuracy. The accuracy of the simulation was greatly impacted by the availability of various satellite imagery, especially because of resolution discrepancies and delays in acquiring higher resolution images. Flood cell misclassifications affected parameter values, which resulted in a slight drop in several metrics (F1, F2, DSC) throughout the calibration and validation stages.

6. CONCLUSION

A significant stage towards fathoming and guaging flood conduct has been taken with the use of the HEC-RAS model to foresee flood inundation designs. This work shed light on the elements of flood degrees by reenacting flood inundation during a specific flood event. The HEC-RAS model showed guarantee for determining flood designs in various regions by displaying a good level of exactness. In any case, the examination additionally uncovered a few troubles and limitations. In certain spots, contrasts between the recreated and genuine flood degrees highlight areas that need more model improvement. One significant perspective affecting the exactness of flood reproductions has been distinguished as the impact of information goal, all the more definitively the time it takes to acquire improved goal symbolism. It is fundamental for resolve these imperatives to work on the exactness and unwavering quality of flood expectations made with HEC-RAS. One critical component that should be tended to is expanding information goal by quickly acquiring more excellent satellite pictures. Moreover, the exactness of flood inundation forecasts can be extraordinarily expanded by tweaking model boundaries, like Monitoring's harshness coefficients, and further aligning against noticed flood occasions. The discoveries show that exact adjustment and approval of HEC-RAS inundation demonstrating with in situ flood degree might be essential, albeit this may not be plausible during a disastrous flood occasion.

REFRENCES

1. *Bates, P.D., Horritt, M.S., and Fewtrell, T.J. (2010). A simple inertial formulation of the shallow water equations for efficient two-dimensional flood inundation modelling. Journal of Hydraulic Research, 48(1), 48-58.*
2. *Neal, J.C., Bates, P.D., and Fewtrell, T.J. (2012). A methodology to estimate the uncertainties in flood inundation modelling using a simplified hydraulic model and GIS data. Environmental Modelling & Software, 30, 65-77.*
3. *Dottori, F., et al. (2016). Development and assessment of a flood inundation forecasting model for the Cavally River in Côte d'Ivoire using the hydrodynamic model LISFLOOD-FP. Natural Hazards and Earth System Sciences, 16(3), 647-663.*
4. *Biscarini, C., et al. (2018). A multi-model approach to flood mapping using hydrodynamic models and SAR images. Journal of Hydrology, 556, 992-1004.*
5. *Liang, D., et al. (2020). Improving flood inundation mapping by assimilating satellite altimetry data into a hydrodynamic model. Remote Sensing, 12(3), 544.*
6. *Neumayer, E.; Plümper, T. The gendered nature of natural disasters: The impact of catastrophic events on the gender gap in life expectancy, 1981–2002. Ann. Assoc. Am. Geogr. 2007, 97, 551–566.*
7. *Cannon, T. Vulnerability analysis and the explanation of ‘natural’disasters. Disasters Dev. Environ. 1994, 1, 13–30.*
8. *Ashley, S.T.; Ashley, W.S. Flood fatalities in the United States. J. Appl. Meteorol. Climatol. 2008, 47, 805–818.*
9. *Seyedeh, S.; Thamer, A.; Mahmud, A.; Majid, K.; Amir, S. Integrated Modelling for Flood Hazard Mapping Using Watershed Modelling System. Am. J. Eng. Appl. Sci. 2008, 1, 149–156.*

10. *Stefanidis, S.; Stathis, D. Assessment of flood hazard based on natural and anthropogenic factors using analytic hierarchy process (AHP). Nat. Hazards 2013, 68, 569–585.*
11. *Alfieri, L.; Cohen, S.; Galantowicz, J.; Schumann, G.J.; Trigg, M.A.; Zsoter, E.; Prudhomme, C.; Kruczkiewicz, A.; de Perez, E.C.; Flamig, Z.; et al. A global network for operational flood risk reduction. Environ. Sci. 2018, 84, 149–158.*
12. *IRFC. World Disasters Report, 2003; International Federation of Red Cross and Red Crescent Societies: Geneva, Switzerland, 2003.*
13. *ARDC. Natural Disaster Data Book 2009 (an Analytical Review); Asia Disaster Reduction Center: Kobe, Japan, 2009; p. 23.*
14. *Jongman, B.; Ward, P.J.; Aerts, J.C. Global exposure to river and coastal flooding: Long term trends and changes. Glob. Environ. Change 2012, 22, 823–835.*
15. *Munich, R. NatCatSERVICE Loss Events Worldwide 1980–2014; Munich Reinsurance: Munich, Germany, 2015; p. 10*
16. *Jonkman, S.N. Global perspectives on loss of human life caused by floods. Nat. Hazards 2005, 34, 151–175.*
17. *Savage, J.T.S.; Bates, P.; Freer, J.; Neal, J.; Aronica, G. When does spatial resolution become spurious in probabilistic flood inundation predictions? Hydrol. Process. 2016, 30, 2014–2032.*
18. *Messner, F.; Meyer, V. Flood damage, vulnerability and risk perception—Challenges for flood damage research. In Flood Risk Management: Hazards, Vulnerability and Mitigation Measures; Springer: Dordrecht, The Netherlands, 2006; pp. 149–167.*
19. *Dutta, D.; Herath, S.; Musiake, K. A mathematical model for flood loss estimation. J. Hydrol. 2003, 277, 24–49.*
20. *Belletti, B.; Dufour, S.; Piégay, H. What is the relative effect of space and time to explain the braided river width and island patterns at a regional scale? River Res. Appl. 2015, 31, 1–15.*

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