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Preparation of flood Inundation Map for Dhora dam using HEC-RAS 2D

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Abstract: *The Dhora Dam is an earthen dam situated in the Rudrapur block of the Udham Singh Nagar District (Uttrakhand) in the hamlet of Najimabad. Its coordinates are 28°56'18" N and 79°34'56" E. The dam is 16.15 m tall and 9050 m long, with a reservoir capacity of 44.89 million cubic meters. This dam is mostly used to irrigate the area of Uttarakhand and Uttar Pradesh. If Dhora dam fails then it causes devastating consequences at the downstream areas. Therefore, the dam breach simulation and determine the flood impacts are crucial for reducing the negative impacts of dam failure. This research conducted a dam breach analysis considering overtopping failure at full reservoir level using HEC-RAS 2D software version 6.4.1. It provides specific information regarding flood characteristic such as flow depth, velocity of flow, flow rate and water surface elevation values. The main goal is to create an inundation map for the downstream areas of dam and it is prepared using QGIS. In times of emergency, these maps can aid local government and other stakeholders save lives by providing early warning.*

Keywords: *HEC-RAS 2D, flood inundation map, QGIS.*

1. INTRODUCTION

Dam breach studies are essential for understanding the potential consequences of a dam failure and assessing the associated risks to downstream areas. A dam breach occurs when the structural integrity of a dam is compromised, leading to the sudden release of stored water and the formation of a breach or opening in the dam. Such failures can result from natural disasters, design flaws, construction defects, or inadequate maintenance. The study of dam breach involves analyzing the hydraulic behavior of water during the breach formation, estimating the breach size and evolution and simulating the subsequent flood propagation downstream. These studies provide critical information for emergency response planning, risk assessment, and the design of mitigation measures to minimize the impacts of dam failures. There are several commonly used software programs for dam breach modeling such as FLO-2D, BREACH, MIKE 21 FM, HEC-RAS etc. This study utilizes Hydrologic Engineering Center- River Analysis System (HEC-RAS 2D, version 6.2.1) software due to its availability as freeware and widespread usage for modeling dam breaches.

OBJECTIVES

2. To determine fluid parameters such as depth of flow, Water stage elevation and velocity of flow in the event of dam failure.
3. To determine the peak of flood waves downstream between point of interest, time of arrival of peak flood and maximum water at point of interest.
4. To prepare the flood inundation map for the downstream areas of Dhora dam

METHODS

Dam breach analysis is conducted on Dhora dam using HEC-RAS 2D software and prepare flood inundation map using QGIS. In this work trapezoidal breach shape is considered and the modeling is conducted at full reservoir level considering overtopping failure.

2.1 study area

The Dhora Dam is a medium irrigation project situated in the Rudrapur block of the Udham Singh Nagar District (Uttrakhand) in the hamlet of Najimabad and having coordinates are 28°56'18" N and 79°34'56" E. The dam project was started in 1956 with the intention of supplying 1125 hectares of land with
dependable irrigation throughout the Rabi season. The height of the dam is 16.15 m and length are 9050 m. Its main purpose is to irrigate the areas of Udham Singh Nagar District of Uttarakhand and areas of Bareilly District of Uttar Pradesh. This data is taken by Dhora Dam authority and Location of Dhora dam is shown in Figure 1.

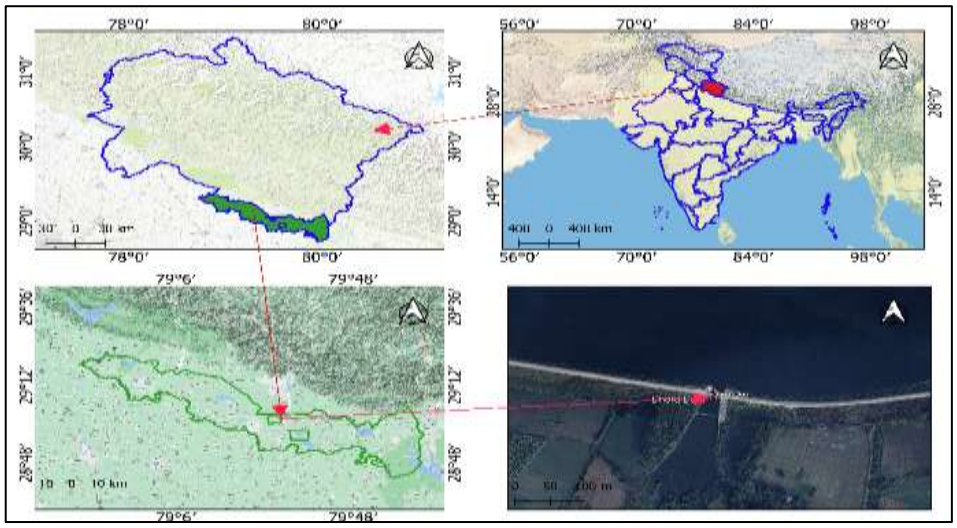

Figure 1: Location of Dhora dam (Source: https://www.qgis.org/en/site)

2.2 Software used

HEC-RAS (Hydrological Engineering Center- River Analysis System) is a widely used software tool developed by the U.S. Army Corps of Engineers for modeling and analyzing river hydraulics and floodplain inundation. It is freely available to the public for use in their research and analysis work. In the research HEC-RAS version 6.2 is used for the purpose of dam breach modeling. Quantum Geographic Information System (QGIS) is an open-source software that supports both raster and vector layers with vector data being stored as point, line or polygon features. In the current context, QGIS proves to be valuable for generating inundation maps by utilizing the shapefile data from HEC-RAS. In the research work QGIS version 3.8 is used for the preparation of flood inundation map.

2.3 Methodology Flowchart

The methodology flowchart for Dhora dam breach analysis is shown in Figure 2.

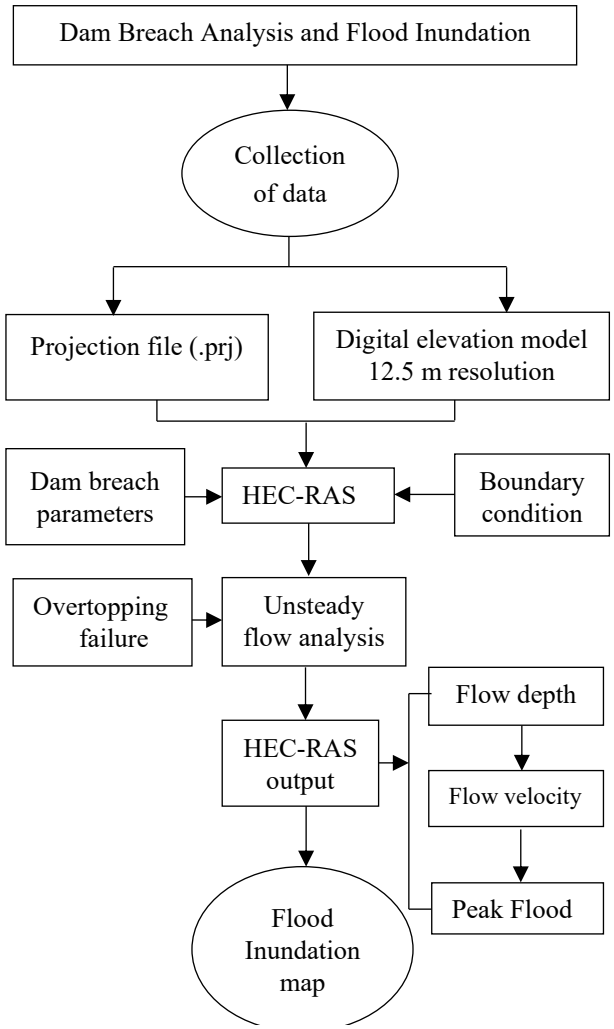

Figure 2: Methodology flowchart for dam breach analysis

2.4 Steps in dam breach analysis using HEC-RAS 2D

The steps followed in dam breach analysis using HEC-RAS 2D are given below:

- In HEC-RAS Mapper, a horizontal coordinate projection was established by utilizing a projection file sourced from an ESRI shapefile.
- A topographical model, essential for conducting 2D simulations, was generated. To perform any flood mapping within RAS Mapper, having a terrain model is a prerequisite.
- Incorporated an extra mapping layer to enhance visualization.
- Outlined a boundary polygon for every 2D flow area intended for modeling within the HEC-RAS Mapper. Established the 2D computational mesh for each respective 2D flow area through utilization of the 2D flow area editor.
- Employing the SA/2D Area hydraulic connection functionality, integrated internal hydraulic components, including a dam, to serve as the linkage connecting the 2D flow area with the Storage Area.
- Established a connection between the 2D flow areas and the 1D hydraulic components. (Storage area)

- Created external boundary condition lines surrounding the edges of the 2D flow areas utilizing the Geometric Data editor.
- Entered complete boundary and initial condition details for the 2D flow areas within the Unsteady Flow data editor. Configured essential computational options and parameters for the 2D flow areas within the Unsteady Flow Simulation window.
- Executed the unsteady flow simulation.
- Generated output in the form of map layers, comprising information such as depth, velocity and water surface elevation.
- Identified impacted regions and determined the extent of inundated areas.

2.5 Reservoir data

Understanding the correlation between elevation and storage for the reservoir is crucial for predicting the flood hydrograph. The data provided by the Dhora Dam Safety Authority is presented in Table 1. The storage elevation curve can be constructed based on this data

Table 1: Storage-Elevation Data

Storage (m)	Elevation (1000, m^3)
209.4	0
209.5	113
210	726
210.5	1725
211	2855
211.5	4375
212	6267
212.5	8563
213	11062
213.5	14350
214	18409
214.5	24689
215	31557
215.5	35458
216	39130
2.16.5	44895

2.6 Topographic data

Digital Elevation Model (DEM) of resolution 12.5 m was downloaded from the Alaska Satellite Facility (ASF) website was freely available and comprised Synthetic Aperture Radar (SAR) data obtained from the ALOS PALSAR satellite. In the research work a high-resolution DEM is used because it provided a finer level of detail, enabling a more precise analysis of the dam breach and aiding in better decision-making regarding safety measures and evacuation procedures.

2.7 Breach parameter selection criteria

Thoroughly assessing and comprehending breach parameters is crucial for minimizing uncertainties related to various facets of dam failure. The determination of breach parameters is influenced by multiple factors like soil properties, upstream dam discharge, compaction level and fill material geometry. As per the Dam Safety Report (USACE, 2014), breach parameters encompass breach characteristics, which involve breach width, breach depth, side slope factor of the breach and the time taken for breach initiation and development.

RESULTS AND DISCUSSION

The breach simulation of the Dhora dam is carried out utilizing the HEC-RAS model considering overtopping failure at full reservoir level. The outcomes present information regarding the maximum flow discharge, the maximum water surface elevation, maximum velocity and the timing of flood arrival at seven distinct downstream locations from dam section such as, Bakhpur, Shahdaura, Bahunagar Urf Sirsa, Piparia Ganesh, Jawaharpur, Shakras and Seekari during the modeling process.

3.1 Dam breach results for flood routing

The simulation time started from first day12:00 hrs and maximum flow rate, maximum Water Surface Elevation (WSE), Time and day of arrival and maximum velocity at seven locations from dam section to downstream of Dhora dam is shown in Table 3.

3.2 Inundation Mapping

The primary focus of the current study was to create inundation maps which played a crucial role in flood-related investigations such as submergence studies and inundation planning. Inundation map was generated using QGIS. These flood inundation maps depicted the highest water levels and provided valuable information about the extent of the areas impacted by the flood. Based on the calculations conducted during the study, the reservoir area of Dhora dam was determined to be 13 square kilometers. At full reservoir level, the maximum area that could be flooded in the event of overtopping failure was calculated to be 90 square kilometers. Moreover, the total population at risk downstream of Dhora dam was estimated to be 14,901. Most affected flood prone areas at downstream of Dhora dam as shown in Table 2. Flood inundation map is shown in Figure 3.

Table 2: Flood prone areas at downstream of Dhora dam

Locations	Distance from dam (km)	Population
Bakhpur	3	1289
Shahdaura	6	4930
Bahunagar Urf Sirsa	9	608
Pipariya Ganesh	12	427
Jawaharpur	15	1338
Shakras	18	5396
Seekari	21	913

(Source: https://www.census2011.co.in/district.php)

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Table 3: Maximum flow rate, Maximum water surface elevation, Maximum velocity and Time of Arrival of flood at seven locations of downstream of Dhora dam

Locations	Distance from dam (km)	Maximum Discharge Q_{max} (cumec)	Time and day of arrival of Qmax (hrs)	Maximum WSE (m)	Maximum Velocity (m/s)
Bakhpur	3	1311.8	18:00 (Day 1)	154.9	2.5
Shahdaura	6	990.3	20:00 (Day 1)	151.3	2.2
Bahunagar Urf Sirsa	9	797.7	23:00 (Day1)	146.7	2.1
Piparia Ganesh	12	605.2	09:00 (Day 2)	143.2	1.3
Jawaharpur	15	446.4	11:00 (Dya2)	139.9	1.1
Shakras	18	357.9	19:00 (Day 2)	136.9	1.2
Seekari	21	242.1	03:00 (Day 3)	135.4	2.1

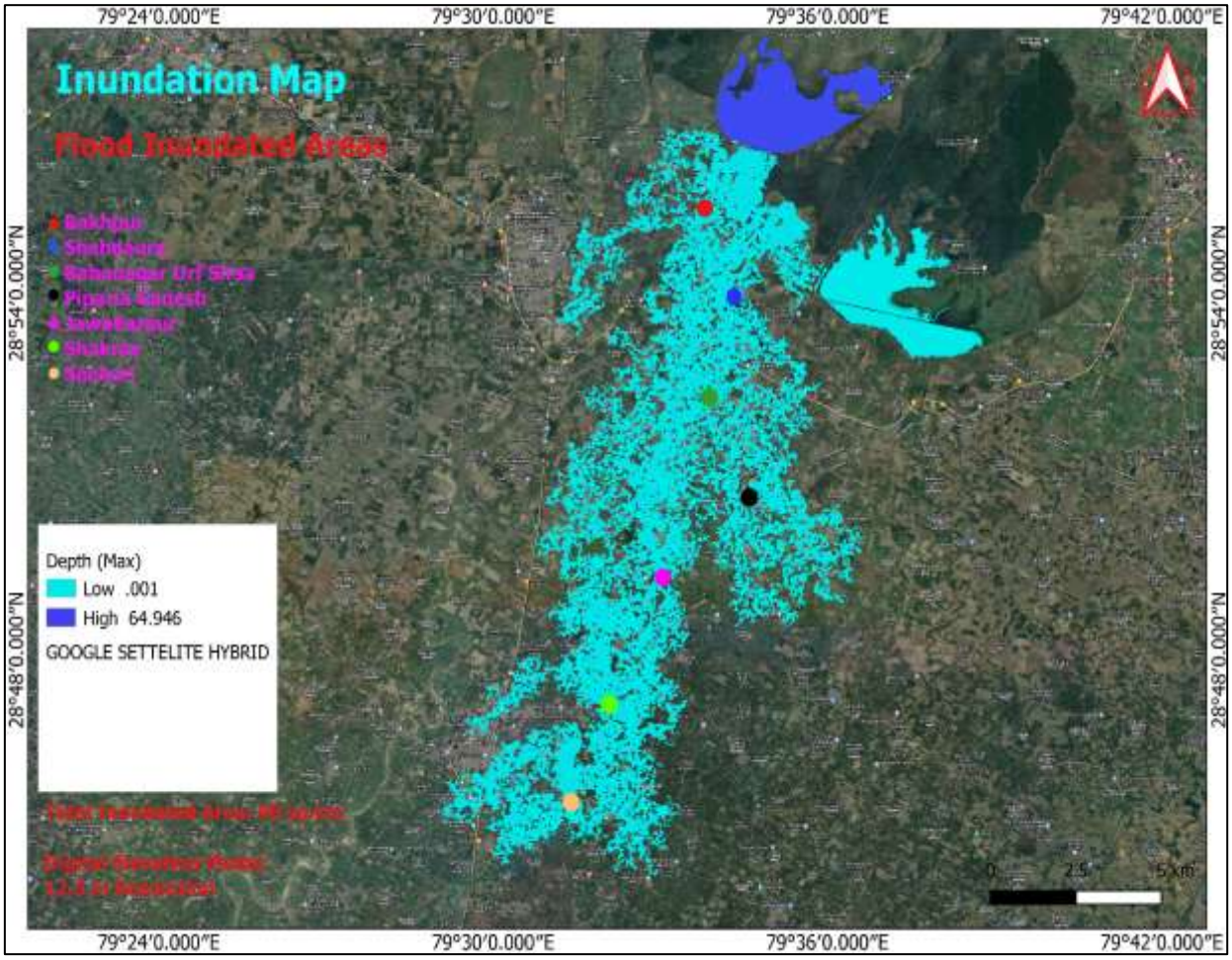

Figure 3: Flood inundation map at downstream of Dhora dam

CONCLUSIONS

- The study found that the maximum water surface elevation was154.9 m, 151.3 m, 146.7 m, 143.2 m 139.9 m, 136.9 m and 135.4 m for 12.5 m resolution at Bakhpur, Shahdaura, Bahunagar Urf Sirsa Piparia Ganesh, Shakras and Seekari. As a result, individuals living in close proximity to the dam site area needed to construct their houses above this water surface elevation level.
- Maximum flow velocity values at different locations of the valley gives an idea about the extent of flooding. Due to this the authorities should give sufficient warning to the downstream residents of Dhora dam as it is observed that about 14901inhabitants are at risk
- Preparation of flood inundation map in HEC-RAS is also essential for understanding and visualizing flood hazards, assessing potential impacts and supporting decision making processes.
- The total inundated area calculated for 12.5 m is 90 sq.km.

LIST OF ABBREVIATIONS

HEC-RAS	Hydrologic Engineering Center's River Analysis System
QGIS	Quantum Geographic Information System
RAS Mapper	River Analysis System Mapper.
WSE	Water Surface Elevation
USACE	United States Army Corps of Engineers
DEM	Digital Elevation Model
ESRI	Environmental Systems Research Institute
ASF	Alaska Satellite Facility
SAR	Synthetic Aperture Radar
FLO- 2D	Flood Simulation Model - 2D
BREACH	BREACH Model (Breach Erosion Prediction Model)
MIKE 21 FM	MIKE 21 Flexible Mesh
Km	Kilometer
m	meter
Sq. Km	Square Kilometer
m/s	Meter Per Second
m^3/s	Meter Cube Per second
Q_{max}	Maximum Discharge
m^3	Meter Cube
hrs.	Hours
1D	One- Dimensional
2D	Two- Dimensional

DECLARATION SECTION

- **Availability of data and material:** Not share because its confidential
- **Competing Interests**

I declare that there are no financial or personal relationships that could be perceived as having influenced the work presented in this research.

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