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Flood Inundation Mapping And 2-D Hydrodynamic Modeling Using GIS And HEC-RAS Technique: A Case Study Of Machhu-II Reservoir

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Abstract: Climate change, rapid population growth, and damaged soil all contribute to flooding, which causes harm to people and property. This can be mitigated by applying flood prevention measures. One of these approaches is submerging flood-prone areas. As a consequence, this study employed GIS and HEC-RAS to map the flood-prone sites along the Machchu-II River. When a stream's release surpasses the bank-full stage along a river, flood inundation mapping is used to identify the flood-prone zones. In addition to topographical data, historical information on river banks and prior flood releases were utilized to construct maps that depicted the areas that were most likely to flood for various releases. These extreme floods had a devastating impact on the Machchu-II River region, threatening social and economic growth due to property loss and mortality. Agricultural fields and urban areas are located near rivers and are especially prone to floods. This study generated flood hazard maps for Machchu-II using the Hydrologic Engineering Centers River Analysis System (HEC-RAS) and GIS. During the preceding thirty-one flood, this river basin suffered significant property and human damage. A basic technique for processing the output of the HEC-RAS hydraulic model is also provided to aid with 2D floodplain mapping and analysis in the ArcView geographical information system.

Keywords: flood inundation, flood mapping, 2-D modelling, GIS, HEC-RAS.

I. INTRODUCTION

Flooding is a natural phenomenon that occurs during rainy period season in tributaries, ponds, and seaside areas when water levels increase & overflow the banks. Floods can be caused by heavy rainfall, snowmelt, dam collapses, cyclones, tidal effects, and tsunamis. Riverine floods can lead to loss of life, infrastructural damage, and a negative impact on the socioeconomic status of inland regions. Proper flood control is crucial for river floodplain regions, which are particularly prone to floods. Flooding is difficult to prevent, but it can be controlled with effective flood management techniques and innovative technology. Flood catastrophes can be life-threatening because to high rainfall intensity during the monsoon season and catchment area topography.

Plain terrain decreases the velocity of flow, which minimizes surface runoff, whereas sharp slopes increase the velocity of flow, increasing surface runoff and generating flood-like conditions in coastal places. Sedimentation of rivers occurs when the sediment load in the river raises the river bed level every year during the monsoon season, reducing the overall capacity of the river c/s to cover the flow, causing the surplus flow to overtop the river's banks and cause floods in low-lying floodplain areas.

Obstructions in river flow can potentially generate a flood on the upstream side owing to a sudden cessation of the flow, raising the water level upstream. Obstructions in the river section, such as the building of flyover bridges or railway bridges, restrict the river's natural cross-sections, causing the water level to rise, resulting in flood-like conditions. The inappropriate size of the cross-drainage systems design is enough only for natural flow and not for large flood flow, which may result in flooding in low-lying regions. Other factors include the melting of snow or ice glaciers, which can create devastation in downstream areas. A dam breach, which releases a large volume of water and sends it rushing downstream, creates hazardous flood catastrophes. A sudden rise in river bed level caused by an earthquake may result in floods in low-lying areas.

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II. STUDY AREA

Machhu River rises in the hills of Jasdan near village Khokhara in Chotila taluk of Surendranagar districts at an elevation of 220m above m.s.I. This is one of the North flowing rivers of Saurashtra in Gujarat state. The Machhu basin is situated between 22° 10’ to 23°10’ North latitude and 70° 40’ to 71° 15’ East longitude.

The river Machhu originates from the hill ranges of Jasdan Sardar and Mandva in Rajkot district and Chotila in Surendranagar district and flows in North Westerly direction along the district boundary of Surendranagar and Rajkot up to village Beti and then flows mostly towards North in Rajkot district and finally disappears near Malia in the little Rann of Kachchh. Machhu along with its tributaries flows 52% in the hilly area and 48% in plain region.

The river fertilizes Malia, Morbi, Wankaner, Jasdan and Rajkot talukas of Rajkot districts and part of Chotila taluk in Surendranagar district. Machhu drains an area of 2515 sq.km out of which more than 75% lies in Rajkot district. Basin map of Machhu Basin is enclosed. The district wise distribution of area is shown in the below table:

Name of district	Drainage area Sq.km	% of total
Rajkot	1924	76.51
Surendranagar	591	23.49
total	**2515**	**100.00**

Table 1 The District Wise Distribution of Drainage Area

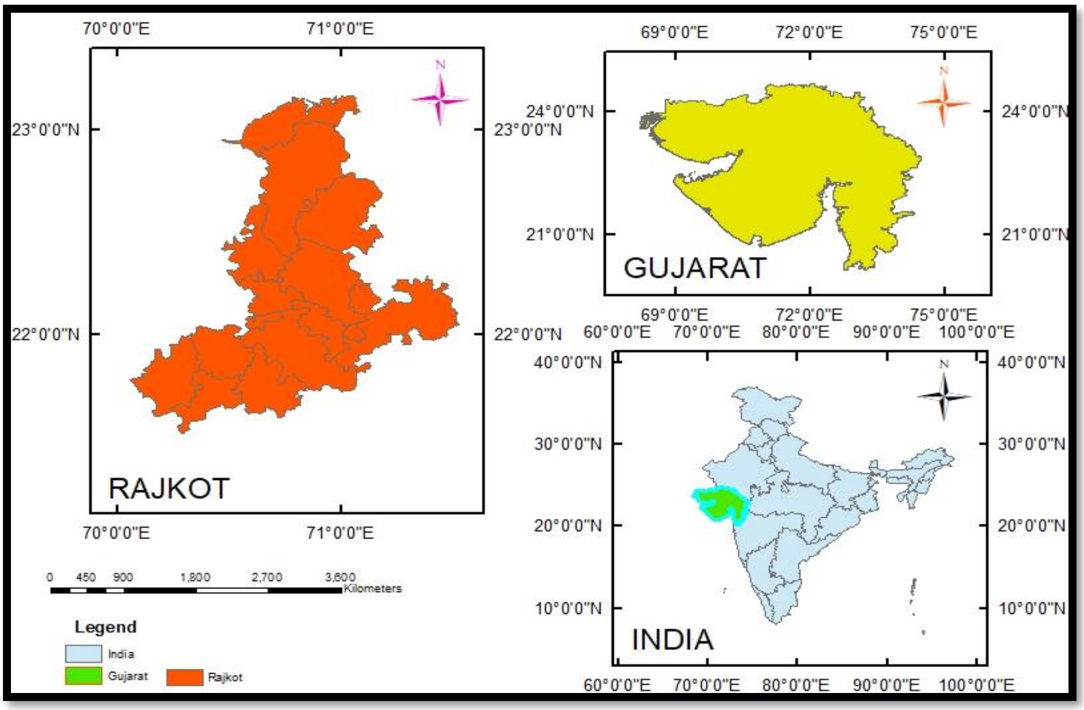

Fig. 1 Study Area Map

III. DATA COLLECTION

The various data acquired for this study are; Index map of MACHHU-II dam has been acquired from the sectional office, machhu-II irrigation scheme Morbi.

The Discharge data and other relevant data from last 31 years has been collected. Also, Capacity table and has been acquired from the sectional office, machhu-II irrigation scheme Morbi. DEM files from EARTH DATA (NASA), Other relevant data

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YEAR	MONTH					TOTAL
	JUNE	JULY	AUG	SEP	OCT	
1991	0	162	24	0	0	186
1992	37	181	174	30	11	433
1993	13	160	0	93	43	309
1994	80	536	181	365	0	1162
1995	10	314	77	25	17	443
1996	131	103	26	0	0	260
1997	325	122	106	170	9	732
1998	81	50	44	197	245	617
1999	57	30	25	0	205	317
2000	0	287	35	35	0	357
2001	54	311	117	0	0	482
2002	217	0	61	0	10	288
2003	131	286	178	5	0	600
2004	101	224	255	60	0	640
2005	148	108	116	217	0	689
2006	93	397	76	77	0	643
2007	195	126	200	94	0	615
2008	44	61	154	282	0	541
2009	3	230	182	0	0	415
2010	26	379	241	74	12	732
2011	0	197	378	112	0	687
2012	0	63	31	176	0	270
2013	186	298	51	372	21	928
2014	10	203	97	70	0	380
2015	129	360	0	53	0	542
2016	50	10	274	00	59	393
2017	115	475	194	11	00	795
2018	10	210	50	11	00	281
2019	09	69	329	276	35	718
2020	145	135	731	44	20	1075
2021	40	185	0	260	45	530
2022	23	300	157	120	00	600

Table 2 Machhu-II Dam: Monthly Discharge Data Of Last 31 Year

IV. METHODOLOGY

A. HEC-RAS 6.4.1

HEC-RAS is a widely used software system for computations related to water surface profiles, flow analysis, sediment transport, and water temperature modeling. Developed by the U.S. Army Corps of Engineers in 1995, it is part of the Institute for Water Resource and is available for free download. The software is designed for use in a multi-tasking, multi-user environment and includes a graphical user interface, separate analysis components, data storage, graphics, and reporting capabilities. The HEC-RAS system includes four one-dimensional river analysis components for stable and unstable flow, sediment transport, and water quality analysis. It also offers features like 2D channel modeling, floodplain modeling, dam breach analysis, and mixed flow regime modeling. Overall, HEC-RAS is a comprehensive and versatile tool for hydraulic engineering, offering a range of features for analysing and modeling various aspects of water flow and sediment transport in rivers and other water bodies.

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B. QGIS

Quantum GIS is an open-source GIS application developed using C and Qt toolkit. Originally designed for presenting GIS data, it has now become a full GIS software package under the GNU free documentation license as an official project of OSGeo. Compatible with all operating systems, Quantum GIS can handle various raster, vector, and database functionalities. It also provides access to other open-source GIS packages like SAGA, GRASS, and Post GIS. With easy access to tools and plugins, Quantum GIS is a versatile geospatial tool. Download the installation file from the QGIS webpage.

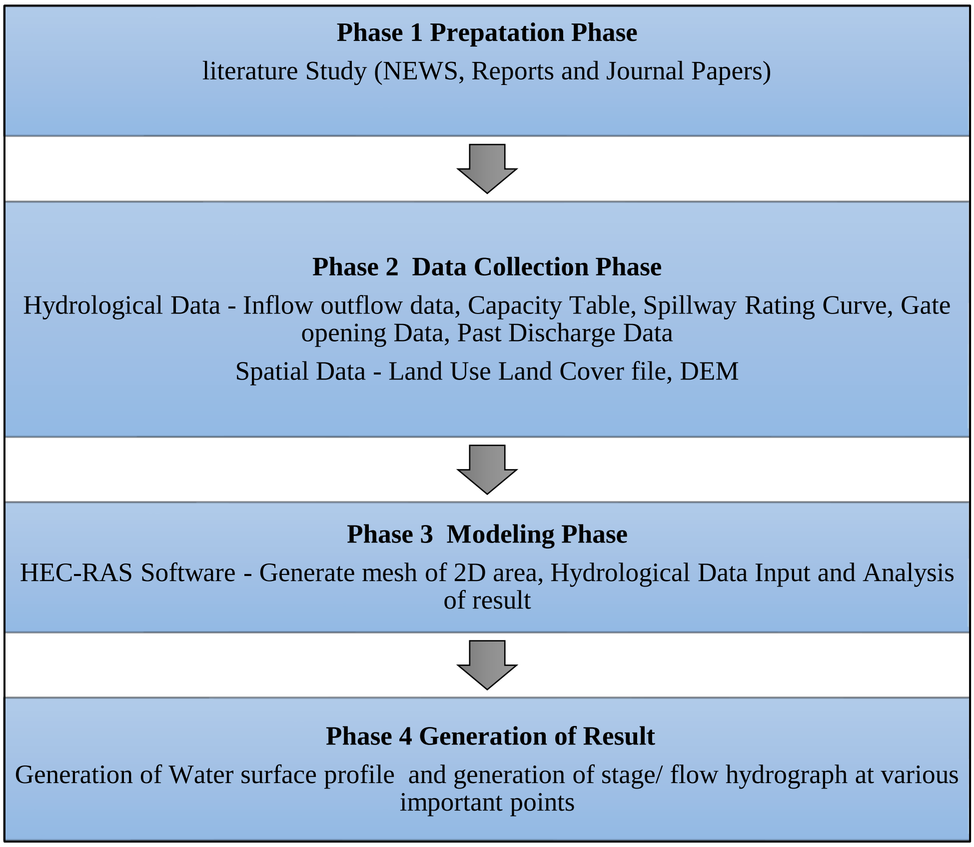

Fig 2 Flow chart of a method applied throughout the research

V. RESULT AND DISCUSSION

In the present study 2-d model is generated using GIS and HEC-RAS. Floods depth, flood velocity, flood water surface elevation were simulated using discharge data from 1991 to 2022. The flow hydrograph of the corresponding year of Machhu-II Dam and the normal depth were used to determine the upstream and downstream boundary conditions, respectively.

a. Flood depth:

flood depth at 2 different cross section have been collected. The model findings indicated a flood depth close to zero as the lowest, with a critical height of 4.57 m for the research region. In a general sense, high water depth rises significantly due to the small gorge in the river's lower segment.

This might be attributed to the fact that the river upland area contributes to a large influx into the main channel. As a result, the greatest flow depth occurs in the center of the main River and gradually extends to the floodplains. Fig. 3 shows flow, elevation, time wise flow graph depth of upstream side machhu-II river. Also, Fig. 4 shows flow, elevation, time wise flow hydrograph depth of downstream side of machhu-II river.

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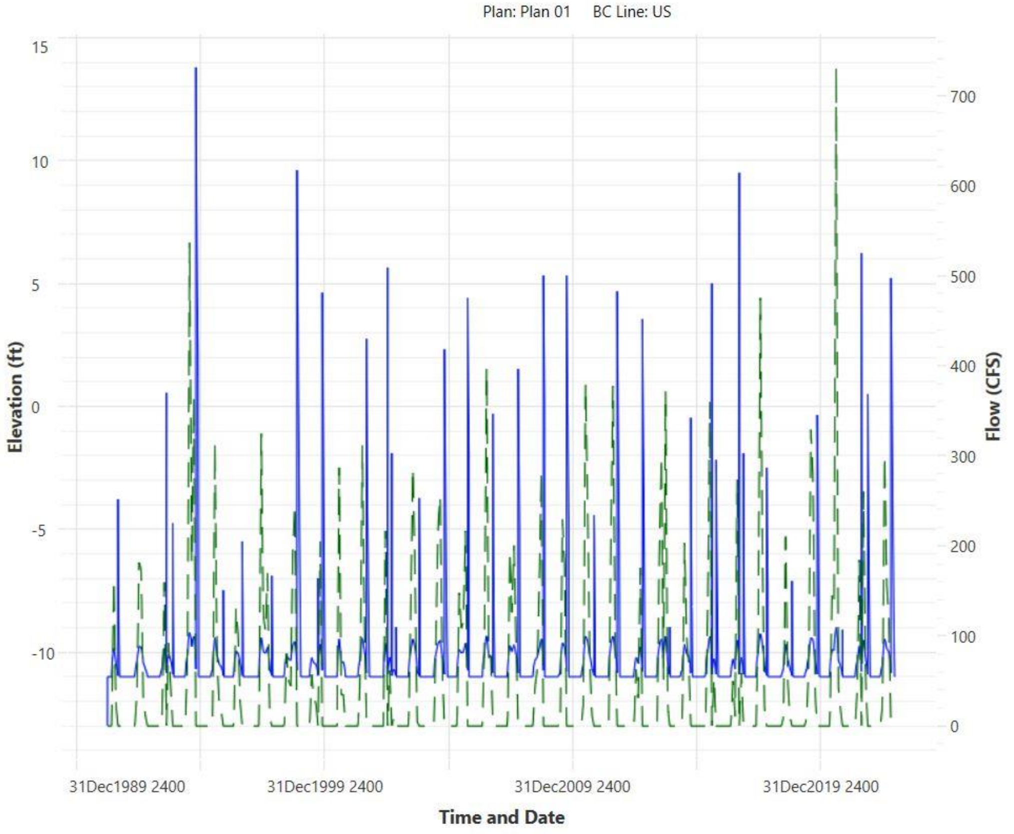

Fig. 3 Upstream Flow Hydrograph

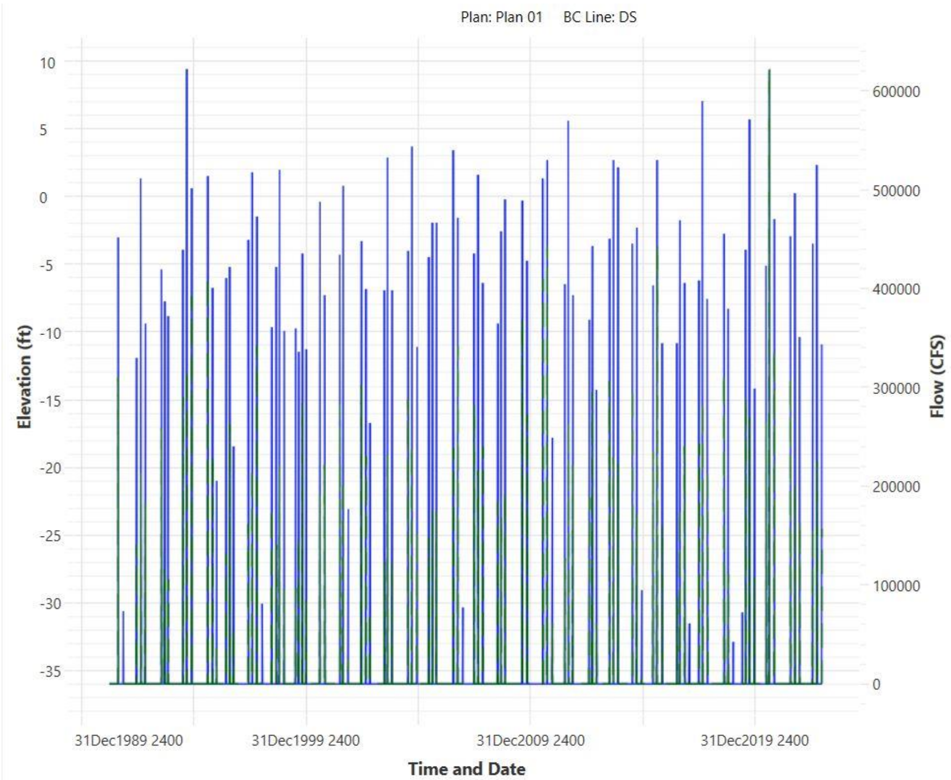

Fig.4 Downstream Flow Hydrograph

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Fig. 5 is graph which is one of the first cross section of machhu-II dam. In which station wise depth occurring during the flood were indicated. Also, this graph indicated maximum flood depth during last 31 year data.

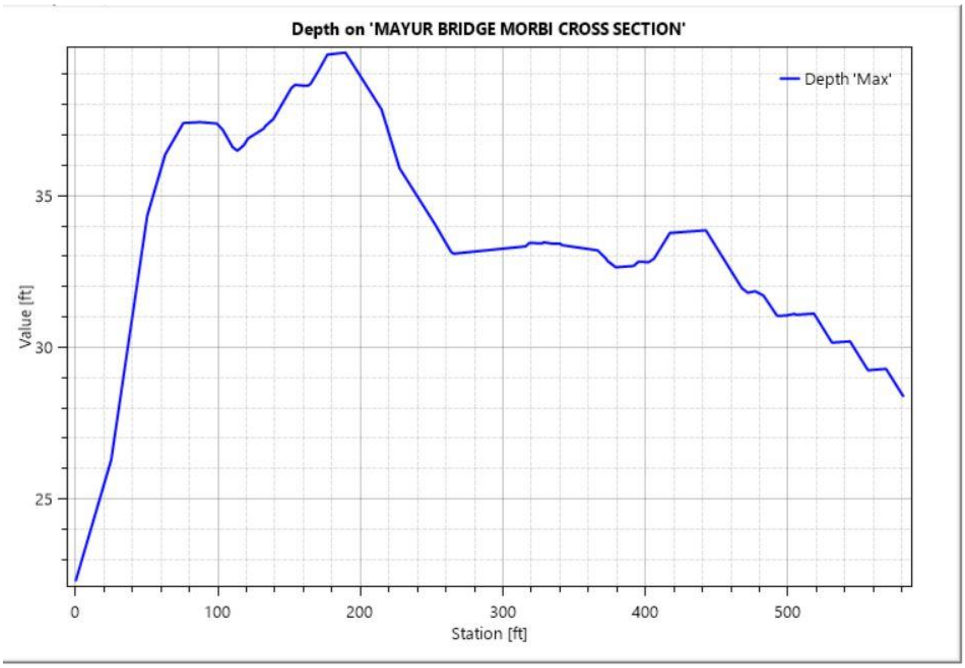

Fig.5 Depth At Mayur Bridge Morbi Cross Section

Fig. 6 indicate the graph which is one of the cross section of machhu-II dam. This cross section is close to machuu-II reservoir. In which station wise depth occurring during the flood were indicated. Also, this graph indicated maximum flood depth during last 31 year data.

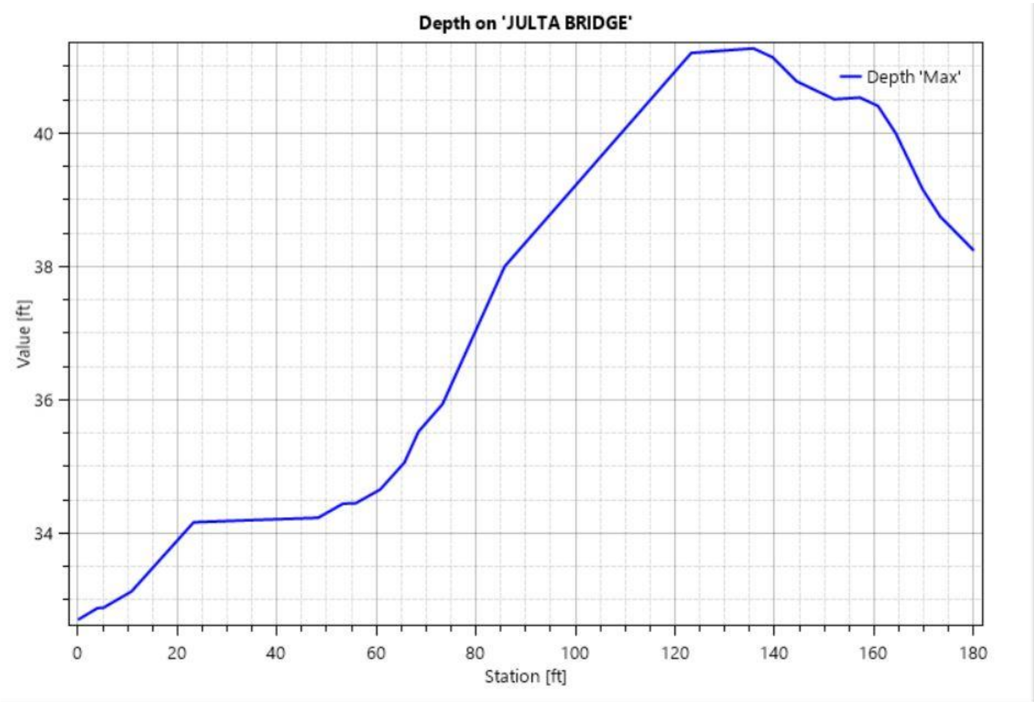

Fig.6 Depth At Julta Bridge

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b. Water Surface Elevation

Also, flood water surface elevation at 2 different cross section have been collected. In a general sense, high water surface elevation rises significantly due to the small gorge in the river's lower segment. This might be attributed to the fact that the river upland area contributes to a large influx into the main channel. As a result, the greatest flow depth occurs in the center of the main River and gradually extends to the floodplains.

Fig. 7 indicates the water surface elevation at mayur bridge morbi cross section. It is clearly shows that terrain wise water surface elevation. As a result form is determined that higher that the 3.04 m.

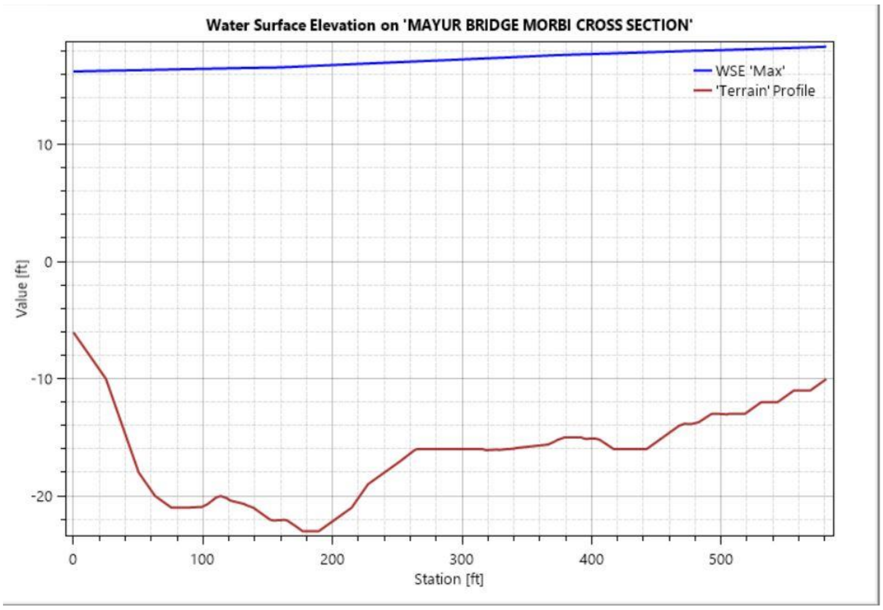

Fig. 7 WSE At Mayur Bridge

Fig. 8 indicates the water surface elevation at julta bridge cross section. It is clearly shows that terrain wise water surface elevation. As a result form is determined that higher that the 6.0 m.

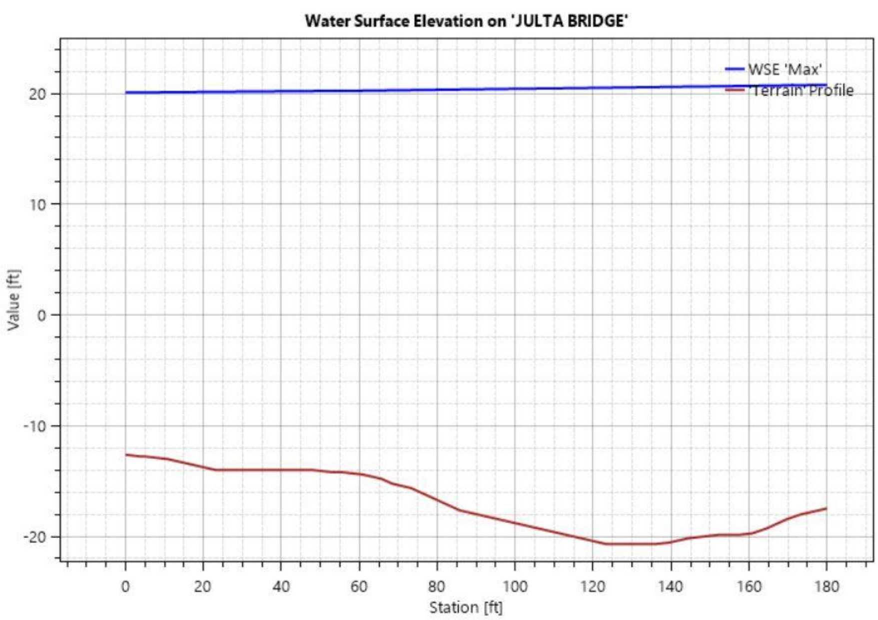

Fig. 8 WSE At Julta Bridge

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As per the results of model in form of flood depth and flood elevation, it clearly indiacted the four villages are goes to submergence. So, the highly recommended to mitigate the flood in flood prone region. As a mitigation techniques, there will be two suggestion to restrict flood is structural mitigation techniques and non-structural mitigation techniques.

VI. CONCLUSION

In present work, 2-D model is generated for the Machhu-II dam which is situated on Machhu river. For generation of 2-D model HEC-RAS and GIS both techniques used. From that water depth, flow velocity and water surface elevation maps generated as a results formate.

Command area of Machhu-II mainly consist six villages : jodhpur, lilapar, bhadiyad, morbi, Amreli, juna sadurka. From the study it is observed that four villages are almost likely to be submerged. To mitigate the flood , construct the dikes or diaphragram wall which has minimum height is 4.75 m.

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