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Innovative Flood Mitigation Strategies for Urban Flood Managment

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1. INTRODUCTION

1.1. Introduction of the Project Work

Flood management has been facing many challenges presently due to frequent occurrence of floods with greater intensities & growth of rapid urbanization surrounding rivers. Though Maharashtra is not known as flood prone area, recent frequent floods & consequent losses necessitated to acquire better technical knowledge & work out remedial measures with the help of modernized techniques to mitigate floods.

During month of July & August 2019, heavy flood situation was created in Maharashtra due to occurrence of intense rainfall. Especially Kolhapur district in panchaganga basin experienced extreme floods of long durations. Heavy losses to life, property & crops etc. had been reported. Different opinions at various levels were put forth concerning these flood events. Kolhapur districts faced heavy flood situations in past also & floods of 2005 & 2006 were noteworthy. However, 2019 flood event was comparatively much more severe which lasted more than a week & losses experienced were also on higher scale,

For optimal use of water in Panchaganga basin & to mitigate flood situations, state of Andhra, Karnataka & Maharashtra have constructed number of major projects. Adjacent to Maharashtra, just below state boundary, Karnataka constructed Almatti dam & Hippargi barrage. Almatti dam is 269 km downstream of Sangli city & 211 Km form Rajapur KT weir at State border. Present FRL of Almatti dam is 519.6 m which is allowed to be raised to 524.25 m by KWDT, in future. Number of technical issues surfaced out concerning height of Almatti dam & possible submergence in Maharashtra during flood situations in the recent years.

It is thus necessary to find out causes of occurrence of floods with detailed technical analysis & overall in-depth studies, to ultimately forecast & mitigate floods impinging on different valleys. As such various experts related to this issue need to study and work out overall strategies, decide workable policies & pragmatic remedial measures in flood management. The group of experts from various organizations like Maharashtra Remote Sensing Application Centre (MRSAC), Indian Meteorological Department (IMD), Indian Institute of Tropical Meteorology (IITM), Indian Institute of Technology (IIT), Maharashtra Water Resources Regulatory Authority (MWRRA), Water Resources Department (WRD), Hydrologists, experienced flood management personnel and experienced officials executing Real Time Flood Forecasting System can certainly shoulder this responsibility.

1.2 Problem Statement:

In this project, in-depth technical analysis and investigate causes of 2019 flood situation experienced in Krishna basin using modern techniques. To clarify based on hydrological studies, whether due to Almatti & other reservoirs (back water effect) from Karnataka, create flood situation in Maharashtra. To propose strong overall remedial measures such as by diverging from t underground tunnels sensors & GIS technique to avoid such flood situation in future and or to reduce its severity.

1.3 Objectives:

- To study urban flood patterns and evaluate mitigation techniques.
- To analyze rainfall and flooding data for a specific case study area
- To propose and assess effective flood mitigation strategies

1.4 Scope of Project:

The term "disaster management" encompasses the complete realm of disaster-related activities. Traditionally, people tend to think of disaster management only in terms of the post- disaster actions taken by relief and reconstruction officials.

1.5 Details of Panchaganga Basin

The Panchganga River of Maharashtra flows through the borders of Kolhapur. It starts from Prayag Sangam (Village: Padali BK., Taluka: Karvir, Dist:Kolhapur). The Panchganga is formed, as has been noted already, by four streams, the Kasari, the Kumbhi, the Tulsi and the Bhogawati.Local tradition believes in an underground stream Saraswati which together with the other four streams make the Panchganga.

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The Prayag Sangam confluence marks the beginning of the Panchganga river proper which after receiving the waters of the four tributaries continues in a larger pattern with the flow of waters received from the rivers. From North of Kolhapur, it has a wide alluvial plain. After developing this plain the river resumes its course eastwards.

From Kolhapur the Panchganga River, as the river is now called, winds east about thirty miles tillit falls into the Krishna at Kurundvad. In the thirty miles of its course, to the east of Kolhapur the Panchganga River receives only one considerable stream the Hatkalangale or Kabnur which, rising from the Alta hills and passing Hatkalangale and Korochi joins the Panchganga near Kabnur about fifteen miles at Kolhapur. From Shiroli to its junction with the Krishna near Narsobawadi, it has an extensive Alaviya floor bordered by the large worn-out stumps of the Alta portion of the Panhala in the north and the Hupari part of the Phonda Sangaon range in the south. A characteristic feature of this basin is the contrast between the rounded worn out features locally known as Mals and the general entrenched nature of all the streams.

A further noteworthy aspect is the deeply incised course of the Panchganga itself. From Mangaon, the river flows 1n a deep bed that is well below 40 feet from the surrounding plain. Further downstream it develops an incised meander-core which includes the Narsobawadi area.

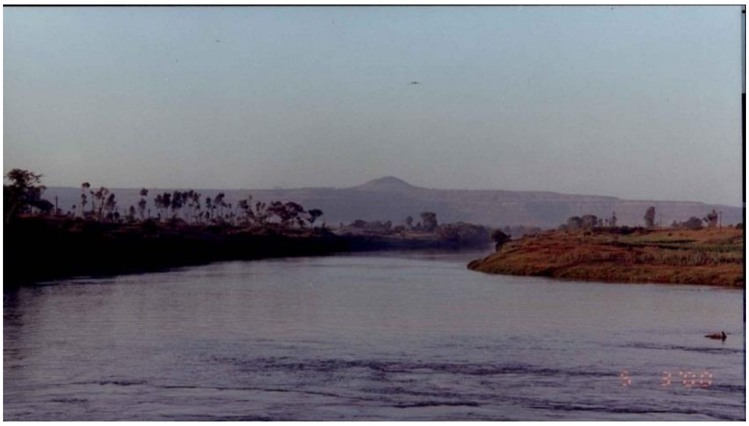

Fig 1.1 The valley of the panchganga

The valley of the Panchganga is reckoned the most fertile in Kolhapur and is famous for its hay. The bed of the river is shallow, and its sloping banks yield rich crops during the cold weather. At Kolhapur the Panchganga is crossed by two beautiful bridges one near the Brahmapuri hill on the north side of Kolhapur town on the road leading to the Amba pass and the other a few miles to the cast on the Poona Road. The Panchgnaga and its feeders are fordable in the hot season. In the rainy season large and small boats ply at twenty-three fords.

The waters of all the streams which join to form the Panchganga are much used for growing sugarcane In October, towards the close of the south-west rains, a series of fair- weather earthen dams are built across the riverbeds and the water is raised by lifts worked by bullocks.

Maharashtra being upper riparian state, maximum rainfall / runoff occurs (due to Sahyadri Ghat area) in comparison to other D/S States. Total available water at 75% dependability in the entire Krishna basin in India is around 58,328 Mm³ (2060TMC), whereas Maharashtra generate around 29,300 Mm³ (1035 TMC) and yearly allocation to Maharashtra is 15,856 Mm³ (560 TMC). It is thus pertinent to note that out of total available water nearly 50% volume of water is alone produced n Maharashtra. After using 27% share allocation, remaining 23% quantum i.c. 13,444 Mm³ (475 TMC) normally flow down to Kolhapur & Sangli town situated near state border causing occurrence of frequent floods around state border of Maharashtra. Intermittent very high rainfall of short durations also causes extreme floods.four administrative regions viz. Pune, Nashik, Aurangabad & Kokan.

1.6 Details of Krishna Basin Krishna

River is the second largest river in Peninsular India. It originates in the Mahadev range of the Western Ghats near Mahabaleshwar, at an altitude of 1337 m above msl (139.7" /N to 1920, N and 73° 22" /E to 8110 /E) and flows through Maharashtra, Karnataka, Andhra Pradesh and drops into the Bay of Bengal n Andhra Pradesh state. Krishna Basin is having a total area of 2.59 Lakh sq. km, which is nearly 8% of the total geographical area of the country. The total length of river is about 1400 km. Krishna Godavari Commission had divided entire Krishna basin into 12 subdivisions & they are designated as Kl to K12 spread in all states i.e. Maharashtra, Karnataka & Andhra Pradesh (now divided into Andhra & Telangana). $ basins K1, K2, K3, KS

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& K6 are spread in Maharashtra state. Water availability and allocation: Krishna Water Dispute Tribunal (KWDT-1) distributed 75% dependable basin flow of 58³28 Mm3 (2060TMC) among three riparian states namely Maharashtra. Karnataka & Andhra. Later Krishna Water Disputes Tribunal (KWDT-ID) reviewed& distributed 75% and 65% dependable flows among three states (Final decision of KWDT-Il has not been notified in gazette since the reports are challenged in Supreme Court by Andhra, Karnataka & newly formed Telangana state). State wise initially Maharashtra was allocated 16564 Mm³ (585 TMC) water at 75% dependability by K WDT-L. As per the analysis of different local authorities following is the status of state sectors irrigation project. Major area of Krishna basin in Maharashtra (82%) is spread over in Pune, Satara, Sangli, Kolhapur & Solapur district. Remaining 18% is spreaded in Ahmednagar, Osmanabad, and Beed & negligible in Sindhudurg district.

Table 1.1 State wise allocation of water

Dependability	75% (KWDT-I) In Mn3 (TMC)	65% Dependable Flow In Mn3 (TMC)			Average (KWDT) In Mn3 (TMC)	
		Additional	Minimum	Total	Additional	Total
Maharashtra	16564 (585)	1218 (43)	85 (3)	17867 (631)	991 (35)	18858 (666)
Karnataka	20783 (734)	1727 (61)	198 (7)	22708 (802)	2973 (105)	25682 (907)
Andhra Pradesh	22963 (811)	1217 (43)	170 (6)	24238 (856)	4106 (145)	28457 (1005)
Total	60310 (2130)	4162 (147)	453 (16)	64926 (2293)	8070 (285)	72996 (2578)

Table1.2 Region wise area

SrNo	Sub Basin	Total Area in Sq.Km.	Region wise area in Sq. Km			
			Pune	Nasik	Aurangabad	Kokan
1	Upper Krishna sub basin (K-1)	17128	17128	0	0	0
2	Middle Krishna Sub basin (K-2)	1388	1388	0	0	0
3	Ghatprabha (K-3)	2010	1893	0	0	117
4	Upper Bhima Sub basin (K-5)	45335	34598	6180	4557	0
5	Lower Bhima Sub basin (K-6)	3564	1997	0	1567	0
	Total	69425	57004	6180	6124	117

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1.6.1 Status of Irrigation Projects in Maharashtra

To create ultimate irrigation potential in Krishna basin from allocated water to Maharashtra, the details of completed & ongoing state sector projects.

As per the analysis of different local authorities following is the status of state sectors irrigation project

Table 1.3 Status of state sector irrigation projects

Sr. No.	Sub Basin	No. of Completed Projects				No. of Projects under construction				Total No of Projects
		Major	Med	Minor	LIS	Major	Med	Minor	LIS	
1	K-1	04	04	101	00	05	11	23	07	155
2	K-2	00	02	18	00	00	00	00	02	22
3	K-3	00	03	21	00	00	03	06	00	33
4	K-5	07	32	651	01	08	04	15	13	731
5	K-6	00	07	112	00	00	00	09	00	128
	Total	11	48	903	01	13	18	53	22	1069

Thus, in all 210 Major / Medium / Minor / L.S. Projects are in place in Krishna sub basin and 859 projects are constructed in Bhima Sub Basin.

1.6.2 Krishna sub-basin system

Terms of reference (TOR) relates to Krishna & Bhima sub basins in Maharashtra Initially, entire study is proposed to be undertaken for Krishna sub basin (K-1, K-2, K-3) as such all further chapters relates to Krishna sub basin in Maharashtra (K-1, K-2, K-3) having 20,526 Sq.km catchment area has following broad features.

Broad features of Krishna sub basin are shown below:

Upper Krishna K-1- The river Krishna from source to the confluence with it of the Dudhganga ; the sub-basin includes the catchment area of the river Krishna and of all its tributaries which fall into the Krishna in this reach up to and including the Dudhganga. Area of sub basin is 17128 Sq.km. Total area of this sub basin lies in Pune region.

Middle Krishna K-2- The river Krishna, from its confluence with the Dudhganga to its confluence with the Bhima; the sub-basin includes the direct catchment of the Krishna in this reach as well as of all its tributaries out falling in this reach, except that of the Ghatprabha and of the Malaprabha (K-3 & K-4). Area of sub basin is 1388 Sq.km. Total area of this sub basin lies in Pune region.

Ghataprabha K-3- The entire catchment of the Ghataprabha from source to its confluence with the Krishna, including the Catchment area of the Hiranyakeshi, the Markandeya and other tributaries of the Ghataprabha. Area of sub basin is 2010

Major area of this sub basin is from Pune region. Due to restriction on water use, major flow goes down to Karnataka state leaving hardly any scope for flood mitigation in Maharashtra.

1.6.3 Krishna River System in the Maharashtra and Karnataka State

From its source, the Krishna speeds south-wards skirting the castern spurs of the hills hrough the districts of Satara, Sangli & Kolhapur in Maharashtra. After passing the dam sites for the Krishna Projects at Dhom & Borkhal, the Krishna receives the water of the Venna on the right bank, 72 km from its source at Mahuli near Satara city. Lower down, the river is joined by the Urmodi and the Tarali on the right bank.

Flowing past the Khodshi weir from which the Krishna canal takes off, the Krishna is joined on the right bank by the Koyna of which the Wang is a tributary, at km 37 at an elevation of 760 mtrs Lower down, the Krishna receives the waters ofthe Yerala from the Ieft. About 244 km from its source near Sangli right bank by the Dudhganga of which the Vedganga is a tributary. About 306 km from its source and at an altitude of about $19 mtrs, the Krishna enters Karnataka State. L- Section of Krishna River showing various tributaries in Maharashtra is shown in Annexure "Maps".

The river leaves the heavy rainfall zone and turns cast. In the run of 300 km within Maharashtra, the bed fall is 2.86 m per km, the fall up to km 137 being steeper at the rate of 4.20 m per km. After flowing for some distance in Kamataka, the Krishna is joined by the Agrani on the left bank, the Ghataprabha on the right bank at 507 km and the Ma laprabha on the right bank at 542 km. The Junction of the Malaprabha is between

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Almatti and narayanpur, the dam sites of the Upper Krishna Project. At Jaldurga falls below narayanpur, the Krishna drops about 121.95m in about 5 km from the table land of the Deccan platue to the alluvial lands of Raichur district Lower down, the Krishna receivesthe waters of the Don on the left bank and at about 788 km, the waters of the Bhima on the leflt bank at an altitude of 342.98 m. in the run of 773 kms within Kamataka, the bed fall is 0.40 m per km. Annexure ""Maps"shows Krishna river from origin (Maharashtra) upto Almatti dam (Karnataka) which s 211 km D/S of Maharashtra State border. Geography of river system of Krishna sub basin in Maharashtra shows elevation of all river/ tributaries at their origin and confluence points. It is seen that Krishna, Koyna, Warna, Panchganga, Dudhganga, Vedganga & Ghatprabha rivers along with 22 tributaries are spread over in K-1, K-2, K-3 sub basins. Entire river system flows down from origin at 1395 m level till 519 m level at state border of Maharashtra. General slope of Krishna sub basin prepared using remote sensing techniques is also annexed for overall elevation view.

1.7 Flood Mitigation in Krishna Basin In Krishna basin,
Satara, Sangli & Kolhapur districts normally experience floods since their location is adjacent to Panchaganga rivers, which carry sizable flows due to frequent very high & intense rainfall in ghat areas above series of dams constructed. The rise in the flood is also attributed by heavy rainfall in free catchment below dams and U/s of these districts. The dam constructed in upper Krishna sub Basin (K1) and middle Krishna (K2) mainly play role for flood mitigation in Maharashtra while as flows from Ghatprabha basin (K3) mostly drains in Karnataka, hence not considered in this report. Major and 13 medium Irrigation Projects serving for flood. The list of 9 mitigation measures in the Krishna Sub Basin (K-1, K-2).
As per the analysis of different local authorities following is the status of state sectors irrigation project. Apart from conservation /power generation major dams namely, Koyna & Warna especially play major role during flood moderation process though other gated dams help to reduce intensity of flood in smaller proportion. Comprehensive report on various Terms of Reference is included in foregoing chapters.

Table 1.4 Detail of irrigation project

Type	Name of the Projects	River / Tributaries	Total Capacity (Mm3)	Spilling range m3/ see
Major	9 majors- Koyna, Dhom, Urmodi Kanher, Dhom balkawadi, Tarali, Tulshi, Warna, Radhanagari.	Krishna, Koyna, Warna, Urmodi, yerala, Tarali, Uttarmand, Wang Nandani, Panchganga, Kasari, Kumbhi, Jambhli, Tulshi, Bhogavati	Major 5520.57 Mm^3 194.97 (TMC)	Major 640 to 5743 M^3/sec
Medium	13 medium - Yeralwadi Ner, Wang, Morna(G), Uttarmand, Nagewadi, Mahu,Hatageghar, Yevti, Masoli, Kadvi, Morna, Kumbhi, Kasari.		Medium 448.76 Mm^3 17.15(TMC)	Medium 150 to 2083 M^3/sec

1.8 Advantages of flood management:

- Habitat creation, biodiversity and conservation
- Improving water quality and reducing erosion
- Agricultural management.
- Financial incentives and capital gains.
- Community spirit and improving green spaces.
- Resilient ecosystems

1.8.1 Disadvantages of flood management:

- Very expensive

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- Dams trap sediment which means the reservoir can hold less water
- Habitats are flooded often leading to rotting vegetation.
- This releases methane which a greenhouse gas.
- Settlements are lost leading to the displacement of people.

2. LITERATURE REVIEW

This literature review provides a review on a Disaster Management of Panchaganga Flood near Kolhapur Region

2.1 Introduction

Disaster Management as a subject essentially deals with management of resources and information as far as a disastrous event is concerned and also how effectively and seamlessly one coordinates these resources. Disaster management, at the individual and organizational level, deals with issues of planning, coordinating, communication and risk management The new approach proceeds from the conviction that development cannot be sustainable unless disaster mitigation is built into the development process. Another corner stone of the approach is that mitigation has to be multi-disciplinary spanning across all sectors of development. The new policy also emanates from the belief that investments in mitigation are much more cost effective than expenditure on relief and rehabilitation. Disaster management occupies an important place in this countrys policy framework as it is the poor and the under- privileged who are worst affected on account of calamities/disasters

Sachin Panhalkar and Amol Jarag published paper on a flood Risk Assessment of Panchaganga river using GIS technique, in 2017, Flood hazard causes great loss to lives and properties leading to disturbance in human society. Flood is the single most hydrometeorological hazard causing substantial losses. To gain better understanding of the flood phenomena especially for planning and mitigation purposes, flood risk analysis is often required. For the present study, the middle part of Panchganga river of Kolhapur district. Maharashtra was selected. Shubhendu S. Shukla presented a paper on Disaster Management: Managing the Risk of Environmental Calamity in September 2013. Describes severe damage to ecology and economy of a region due to disaster. With installation of new technologies and by adopting space technology as INSAT and IRS series of satellites, India has developed an operational mechanism for disaster warning especially cyclone and drought, and their monitoring and mitigation. Pramod Patil (2012) publishes a paper on disaster management in India in Feburary 2012.Highlighted disaster profile of India and Disaster Management in India. He concluded that there are some points on which we have to focus like effective warning system and effective communication system etc, Chen-Huei Chou et al (2013) presented a paper on disaster management system in 2013 Presented we focus on identifying the contents of a web based disaster management system from the perspectives of multiple stakeholders the needs the system should meet, and crisis behaviors that the system should anticipate. We propose two conceptual models to investigate how these categories of web-design elements could enhance victims' coping mechanisms and reduce impacts of natural disasters on individuals and businesses extending the theories of task-technology fit and self-efficacy, we propose the concepts of need-web element fit, behavior-web element fit, and disaster self- efficacy.Priyanka Banerji (2013) publish a paper on Comparative Analysis of Disaster Management between Japan & India 74.Studied a comparison between Disaster Management in India and Japan and concluded that There is fast recovery growth in Japan after disaster as compare to India. Vicky Walters et al (2014) presented a paper on Disaster risk at the margins: Homelessness in vulnerability and hazards, Presented focuses on the linkages between the multi-faceted marginalisation of homeless people and their various vulnerabilities to disaster associated with both everyday small scale hazards and large-scale natural hazards. Highlighting the complexity and acute vulnerability of homeless people to disaster from a multitude of man-made and natural hazards at different scales, it argues for more attention and integration of homeless people's needs and everyday hazards in disaster research and policy.Ben Wisner (2015) publish a paper on A review of the international literature on disaster social work and case management In his paper presented the challenges during disaster. There have been key events that have motivated people to seek IDRIM such as the Indian Ocean Tsunami and Haitian earthquake and their aftermaths. New institutions have been created that have the potential to move us toward IDRIM such as UN-ISDR. Finally, a series of concepts have emerged from many reports, evaluations, and research. These ideas are discussed, and the challenge for the next 5-10 years mapped out. Scott Manning et al (2016) presented a paper on disaster management Presented a review of the international literature on disaster social work and case management was conducted. These results shed light on the roles and processes of social work, the use of psychosocial interventions, and the barriers to service delivery in the international disaster context. Shohid Mohammad Saidul Huq (2016) publishes a paper on Community based disaster management strategy in Bangladesh: present status, future prospects and challenges Presented analysis on the disaster management by grassroots community. Participation in Bangladesh and concluded that the people should be participated for disaster management. To aware people the social workers should provide training and seminars to the people

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time to time. Deeptha V Thattai *et. al*. (2017) presented a paper on Natural disaster management in India with focus on floods and cyclones .Researches about two case studies cyclones and floods are taken up for comparison of disaster management strategies adopted in the country. Chandana S.A. Siriwardana *et al.* (2018) publish a paper on Investigation of efficiency and effectiveness of the existing disaster management frameworks in Sri Lanka .Investigated the efficiency and effectiveness of the existing disaster management frameworks in Sri Lanka and found that only minor alignments with the global standards are present, and that the existing framework has not been able to manage previous disaster incidents properly. There are considerable inefficiencies in the whole of government response, coherence and integration as well as in the resource allocation.

3. SCOPE OF STUDY

3.1 Floods Layer of Krishna Basin and Panchaganga Basin

Flood is a natural phenomenon, which occurs due to prolonged high intensity of rain. Flooding occurs when an extreme volume of water is carried by rivers, creeks and many other geographical features into areas where the water cannot be drained adequately. Often during times of heavy rainfall, drainage systems in residential areas are not adequate, or unchecked civil development severely impedes the functionality of an otherwise acceptable drainage system. This situation becomes hazardous when it causes colossal loss to human lives and property. Due to their peculiar locations Satara, Sangli and Kolhapur districts normally experience floods in upper Krishna Basin. Floods experienced in recent periods i.e. year 2005, 2006 and 2019 are noteworthy. During last 5-6 decades various major and medium projects were completed in Krishna basins which help to mitigate floods to certain extent.
As per the analysis of different local authorities following is the status of state sectors irrigation project

Table 3.1: Details of reservoirs on upstream of kolhapur City (Rajaram Bandhara)

Main River	Major tributaries	Districts covered	Major and Medium Project	Storage Capacity MM^3 (TMC)
Krishna	Kasari, Dhamni	Kolhapur	2 Major-	334.96
	Jambhali, Kumbhi,Tulashi,		Radhanagari, Tulashi.	(11.83)
	Bhogawati, Panchganga.		3 Medium- Kasari, Kumbhi, Morna(Shirala)	175.56 (6.20)

As far as floods of Kolhapur city is concerned, though Radhanagari dam is having high spillway capacity, there are automatic gates installed and comparatively some partial relief is only possible through operation of Tulshi, Kasari and Kumbhi reservoirs.

3.2 Catchment area

Catchment area above all dam in Krishna basin is 3317 Sq.km. and the same above Sangli town is 2710 Sq.km. and 197.2 Sq.km. above Kolhapur town. As per the analysis of different local authorities following is the status of state sectors irrigation project.

Table 3.2 Details of free catchment area

Sr. No	Free Catchment Area up to	River Name	Area in Sq Km
1	Krishna Bridge, Karad	Krishna	3131
2	Irwin Bridge, Sangli	Krishna	6646
3	Ankali Bridge, Sangli	Krishna	8252
4	Rajaram Weir, Kolhapur	Panchganga	1409
5	Rajapur Weir, State border.	Krishna	10953

3.2 Flood Prone Area

Krishna River originates in the Western Ghats near Mahabaleshwar at an elevation of about 1,395 meters, in the state of Maharashtra. Koyna River is a tributary of the Krishna River which originates in Mahabaleshwar, Satara district, Maharashtra. It rises near Mahabaleshwar, a famous hill station in the Western Ghats. Unlike most of the other rivers in Maharashtra which flows East- West direction, the Koyna River flows in North-South direction. The river meets Krishna River at Pritisangam, Karad. Krishna river average bed slope up to Karad is 1: 880 and from Karad to Bhilawadi Village average river bed slope is l: 4672 and Bhilawadi to Irwin Bridge Sangli average river bed slope is 1: 4113. And Further Irwin Bridge, Sangli to Rajapur village, average river bed slope is gentle_i.e. 1: 4338. L-section of river Krishna from Koyna Dam up to Rajapur weir (State border) is shown below in Graph 3.1.

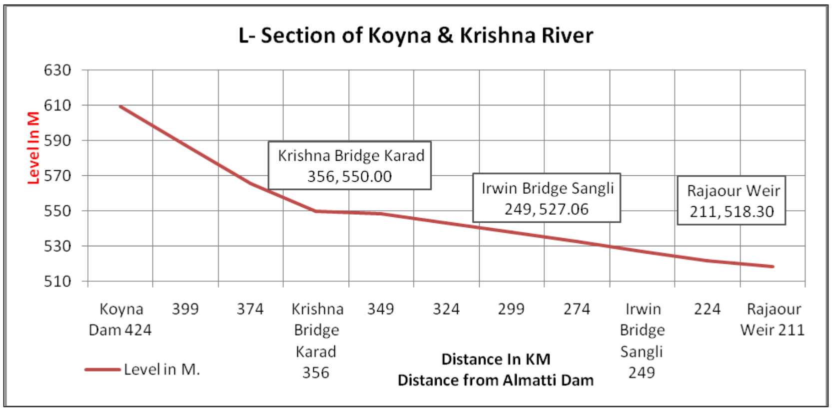

Fig 3.1 L -Section of Krishna river

Bhogavati River originates in the Western Ghats near Asane (Dajipur) in the Kolhapur district of Maharashtra state. At Radhanagari dam elevation is 553.90 m. Bhogavati river flows in south-north direction approximate 40 Km where river Tulashi meets at Bid (Tal. Karveer). Then, at Bahireshwar (Tal. Karveer) Kumbhi & Dhamani river meets and Kasari river meets at Prayag Chikhali. Then, after it runs as Panchganga river till confluence to Krishna river.

Average bed slope of Bhogavati River from Radhanagari to Prayag Chikhali is 1: 2529. Then, Prayag Chikhali to Rajaram K.T.weir average bed slope is 1:4641. Similarly, from Rajaram K.T.weir to shirol K.T.weir it is 1:7700. L-section of Bhogavati and Panchganga River is as shown Fig. 3.2 below.

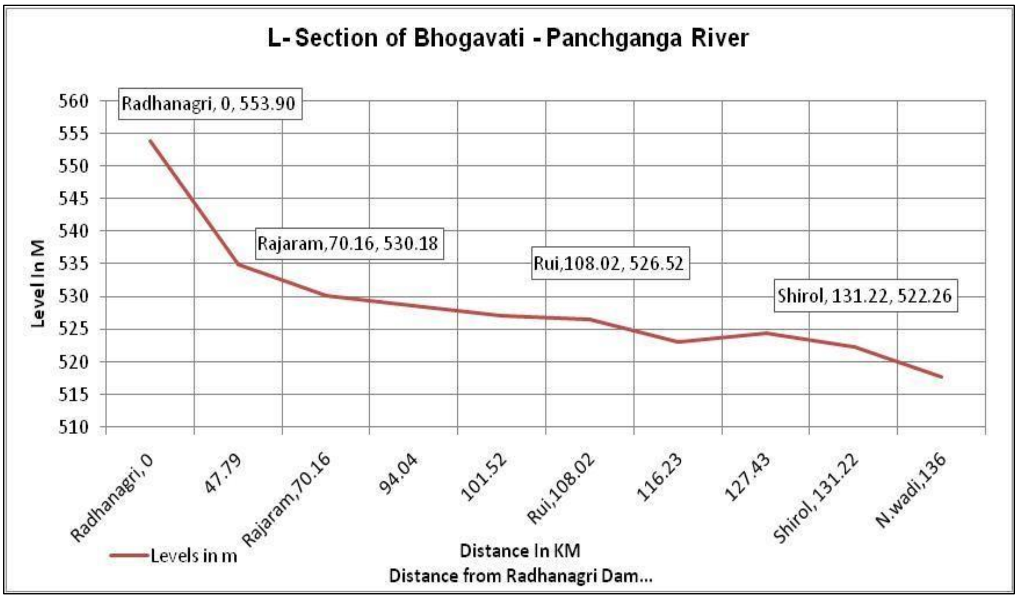

Fig 3.2: L -Section of river panchaganga

Flood is a natural disaster that often occurs in Satara, Kolhapur and Sangli districts during the rainy season. There are some areas always flooded but there are also new areas affected by floods so that citizens and local governments were unprepared for the disaster. This used great impact and losses including flooded settlements, destruction of agricultural land, damage to infrastructure, significantly disrupt economic activity, and the impact on public health. This aims to identify flood prone areas for natural disaster mitigation. This integrates geospatial data analysis including topography, rainfall data, mapping of land cover and field survey. The results show that generally flood-prone areas are distributed in low land, around Krishna river flows both in the middle and downstream of rivers, landform of floodplains and alluvial plains, and generally in areas with extensive settlements and farmland. The typical inundation area of Kolhapur districts as below

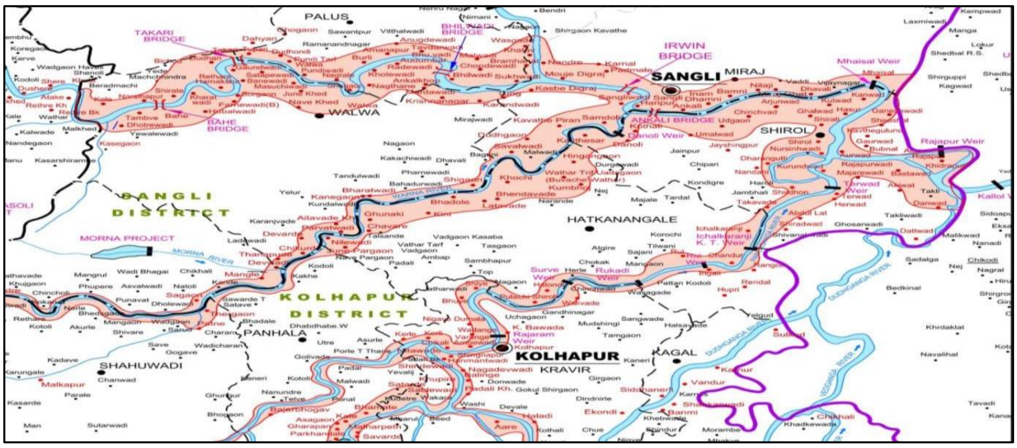

Fig. 3.3 Flood spread area of Kolhapur district

3.3 Flood

The flood level in the Krishna River Observation point at Irwin Bridge Sangli on 05/08/2019 exceeded the danger level 540.77m. The maximum flood level observed at this observation point was 544.57m (56 feet 5 inches) on 09/08/2019. The water level started receding below danger level from14/08/19.The flood level in Panchaganga river observation point at Rajaram K.T. weir Kolhapur had exceeded danger level i.e. 543.30 m on 03/08/2019. The Maximum level reached up to 546.97 m on 07/08/2019.

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3.3.1 Rainfall Pattern -3rd & 10th August, 2019:

Daily rainfall distribution during the flood period is shown in Figure 4.1.3. Figure indicates that during the entire period. In the beginning of the flood period from 27 July to 3rd Aug, the heavy rainfall events were localized in the northern part of the Konkan and adjoining North Madhya Maharashtra. Many stations in Pune and Nasik districts, recorded rainfall more than 150 mm/day during the period 3-5 Aug. Towards the latter part of the week, rainfall belt shifted towards south Madhya Maharashtra. It is also observed that Kolhapur district continuously experienced heavy rainfall heavy rainfall throughout the period with highest rainfall amounts on 6th Aug. 2019.

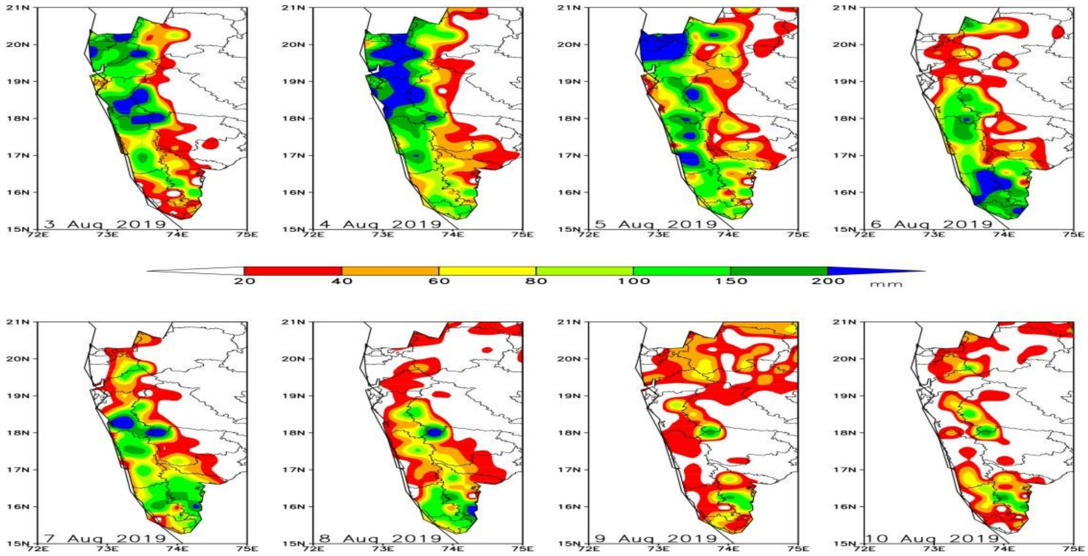

Fig. 3.4 Spatial distribution of rainfall over the region during peak rainfall activity period of 3-10 Aug 2019

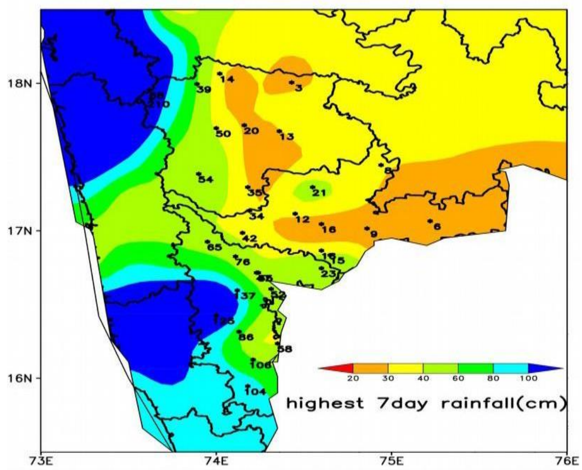

Fig. 3.5 Spatial Pattern of highest ever recorded 7 days' rainfall (cm) during 1951-2018 (indicated in different colors)

It is seen that during the heavy rain spell of Aug. 2019, many stations in Kolhapur district and western part of Satara district have crossed their previous record of 7 days rainfall. This indicates that compared to previous years, rainfall over the region was widespread and remained very intense for a long period during 27th July to 12th August 2019. ranges from 10-20 cm, which is nearly same as that of extreme rainfall. This is due to less variability in the extreme 1-day rainfall. For the ghat areas of Satara, where Mahabaleshwar is situated these values cross 40 cm. For Kolhapur district,50-200 year return period values are more than 20 cm. During the period 4-6 August 2019, many stations in Kolhapur district recorded rainfall of the orderof 100-year return period.

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4.1 INTRODUCTION:

One dimensional unsteady flow analysis is done using Version 5.06 of the HEC-RAS softvare developed by the Hydrologic Engineering Centre of the US ArmyCorps of Engineers. This software has ability to carry out:
Steady flow water surface profile computations. One- and two-dimensional un steady flow simulations.Movable boundary sediment transport computations; Water temperature and constituent transport modeling. The software has capabilities to solve 2D full Saint Venant shallow water equations (with optional momentum additions for turbulence and Coriolis effects) or the 2D Diffusion Wave equations, as chosen by the user. The 2D unsteady flow equations. Solver uses an Implicit Finite Volume Algorithm, allowing for larger computational time steps with improved stability and robustness i handling subcritical. Supercritical and mixed flow regimes. The ID and 2D solution algorithms are coupled through time steps Each cell and cell face are defined as table to have properties like elevation-volume, elevation- area, elevation wetted perimeter and roughness based on the resolution of the terrain model which is much smaller than the grid size of the mesh used for 2D computation. This allows much faster computation without losing details, It also has detailed flood mapping and flood animation capabilities. This software has following facilities: Modelling with geo-referenced geometry of the channel along with bends and Meanders. RAS mapper can be used to represent the river geometry modeling of the tributaries. Modeling inline structures. Superimposition with Google maps, to animate water surface profiles in various reaches at various time instances and over the cross sections. It makes easy to understand and observe. Animation of flood inundation with respect to time. If the geometry is geo- referenced, the Ras mapper (in built in HEC RAS) has facility to superimpose flood inundation on Google maps and animate unsteady flow results. Typical screen shot of inundation is shown in Fig. 5.1.Graphical representation of the velocity distribution along the reach of the rive r and also across the cross section. In the cross section, vertical as well as horizontal velocity distribution can be presented in color contours.

4.2 Flood Prone Area:
The river system comprising of River Krishna from Karad to Almatti along with its three tributaries Yerala, Warna and Panchganga is considered for modeling. The river system is developed on reach by reach basis. The river system is geo- referenced in order to have inundation mapping. Total length of the river system considered is 544.59 km. Meanders and curves are also modeled. The modeled geometry of the river system with terrain background, Following river reaches arc modeled with adequate number of cross sections.
As per the analysis of different local authorities following is the status of state sectors irrigation project.

Table 4.1 Reach wise cross sections modeled

River	Reach	Leng th (km)	Surveyed Cross Sections	Interpolated Cross Sections	Total Cross Sections	Year of Survey
Krishna	Karad Bridge to Yerala Confluence at Brahmnal	95	48	44	92	2012
Krishna	Brahmnal — Warna Confluence at Haripur	12.6	18	8	26	2012
Krishna	Haripur - Rajapur	48	19	27	46	2012
Krishna	Rajapur-Almatti	211	31	189	220	2008
Yerala		32.9	7	63	70	2012
Warna	National Highway — Confluence at Haripur	58.5	20	36	56	2012
Panchg-anga	Kolhapur-Confluence at Kurundwad	93.7	34	101	135	2012

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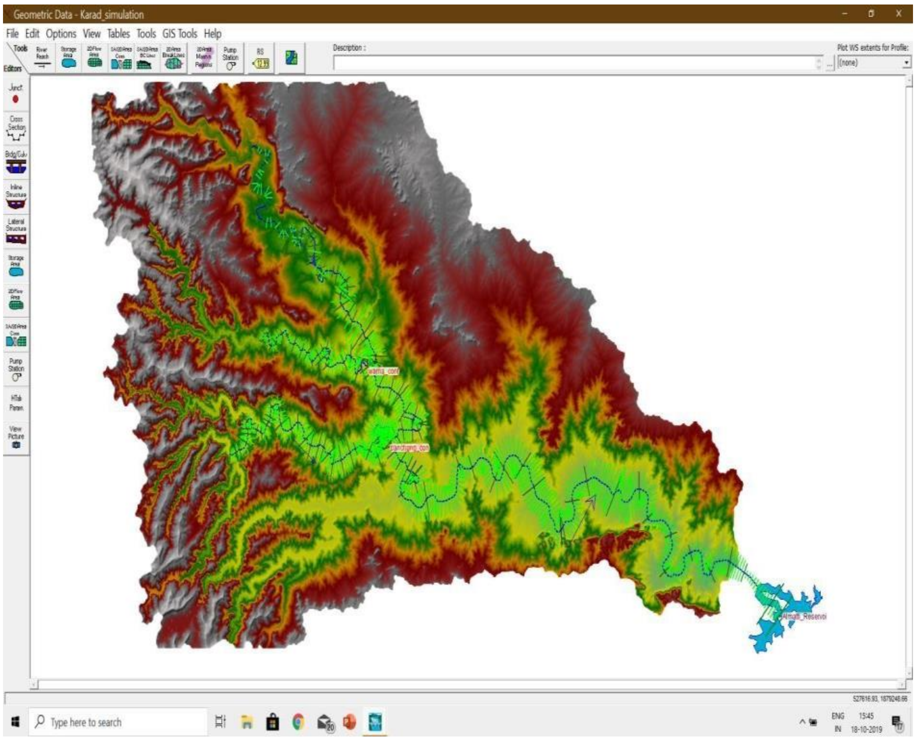

Fig. 4.2 River system

4.2.1 River Bed Gradient:

Table No.4.2: Natural river bed gradients

River	Reach	Length	From		From		Bed Gradient	01:X
			Station	RL	Station	RL		
Krishna	Karad to Sangli	102.1 km	1.36 km U/S of Karad bridge	548.65	Irwin Bridge	525.90	0.00022282	4487
	Sangli to Rajapu r	53.40 km	Irwin Bridge	525.90	Rajapur K. T weir	518.2	0.00014419	6935
	Rajapu r Hippar gi	91.50 km	Rajapur	518.20	Hippargi Barrage	509.00	0.00010055	9945
	Hippar gi Alamtti	119km	Hippargi Barrage	509.00	Almatti Dam	495.50	0.000113368	12185
Warna	NH to Conflu ence	58.506 km	Highway Crossing	536.50	Confluen ce	525.80	0.00018289	5467
Panchg anga	Kolhap ur - Conflu ence	93.478 km	Kolhapur U/S	532.44 km	Confluen ce	517.70	0.00015768	6341

Note: Due to sills of Hippargi and Almatti , the effective bed gradient between Rajapur to

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Hippargi and between Hippargi to Almatti reduce to about 1:16000.
4.2.2 Manning's roughness coefficient
Manning's roughness coefficient modeled for main channel portion is 0.031.For overbank portions higher value of 0.07 is adopted duly considering the standing crops (prominently sugarcane).

4.2.3 Hydraulic Structures:
Following inline hydraulic structures have been modeled. Typical sections are shown as Fig. 5.3, 5.4, and 5.5.

- Bridges: Karad, Sangli Bye pass, and Sangli (lrwin).
- Barrages: Tembhu, Takari and Hippargi.
- Kolhapur Type Weirs (submersible): Mhaisal, Sangli and Rajapur. During the flood, needles of the K.T. weir are out of span hence the hydraulic behavior of the structure is similar to that of the bridge.

Panchganga River near Kurundwad

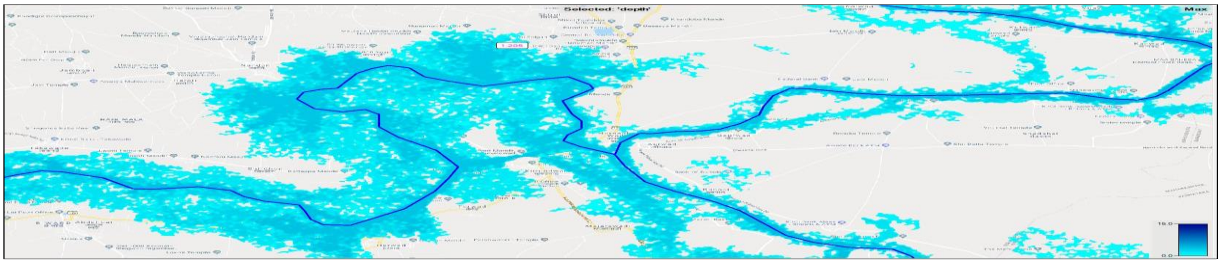

Fig 4.3 Member on panchaganga river

RESULT AND DISSCUSSION

5.1 Results and Discussion:
Flood risk is basically determined as a result of probability and consequences. Accurate information flood inundation and flood zonation is essential for sound planning and management of urban and rural land. It also provides the base line data required for proper under- standing of flood phenomena. Study will hopefully yield valuable information for analysis of flood hazard. It would be of great use to planners and administrators to resolve the conflict between human and functioning of river system Optical sensors are unable to penetrate through clouds Therefore, it is necessary to see an alternative way to tackle such problems. Synthetic Aperture Radar (SAR) is the most effective sensor as it can penetrate through clouds and detect the flood inundation area. In SAR, the calm water shows least backscattering values among the natural objects in microwave region. Calm water and completely submerged land covers under water have the same backscattering range. RADARSAT image.

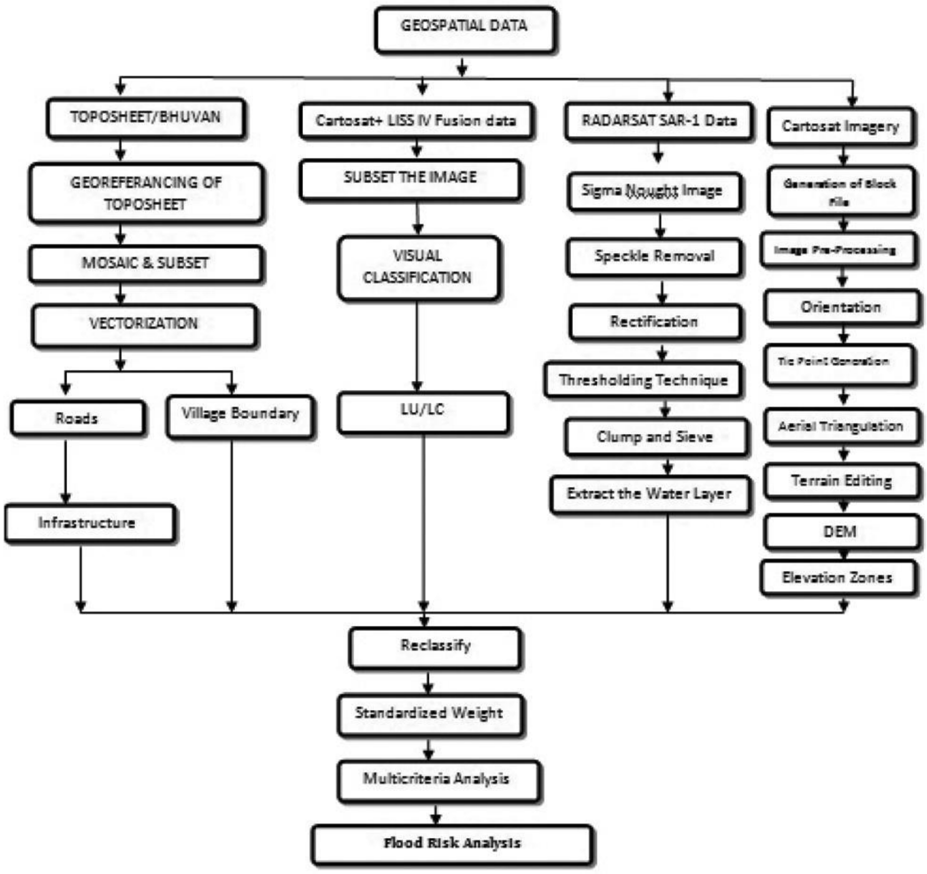

Fig. 5.1 Flowchart of radarsat

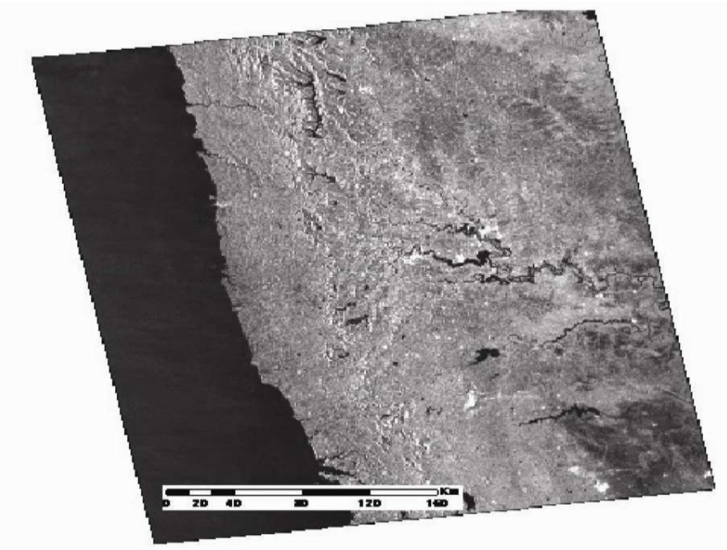

Fig. 5.2 RADARSAT-SAR Image

and radiometrically corrected. Then, DB values for land and water were observed for the image of 5 August 2005 was used to generate flood inundation map. RADARSAT image was geometrically Threshold values for water pixel ranges between -17 and -35 db which are being used to extract the water pixel. The erdas modeller was used to extract the water pixel to generate flood map.

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5.2 AHP Method

AHP calculates the required weights associated with the relevant criterion map layers with the help of a preference matrix in which he identified relevant criteria are com-pared with each other on the basis of preference factors'7. AHP is widely used in MCDA to obtain the required weights for different criteria' 18-20 It has been successfully employed in GIS-based MCDA since the early 1990s21-2s ,Preference structure of decision makers can be easily defined through pairwise comparison approach. This is the biggest advantage of this method. The present approach is helpful to identify and evaluate potential flood risk areas of Panchganga river. The weightage was obtained by pairwise comparisons and the consistency was evaluated among their relationship. As seen in Figure 1.3 the entire study area was broadly categorized as high, moderate and low flood risk areas. About 63 sq. km area of study area come under high flood risk area. This area includes about 17 villages such as Kolhapur, Rukadi, Pattan kodoli, Rangoli, Rendalm, etc.

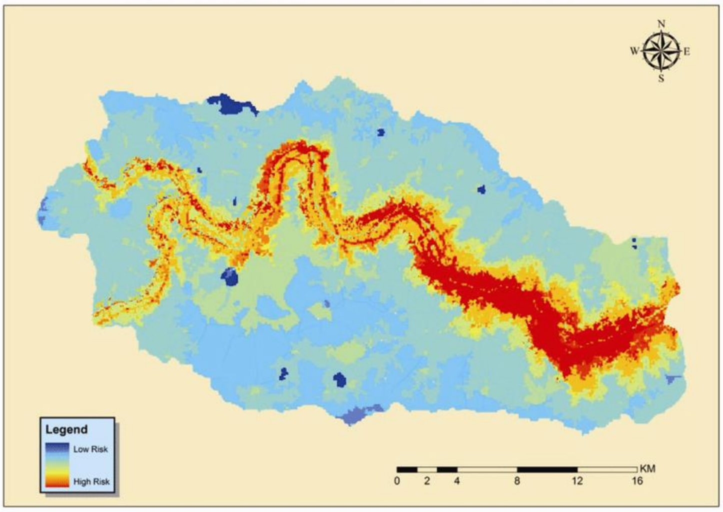

Figure 5.3. Flood risk map based on AHP method

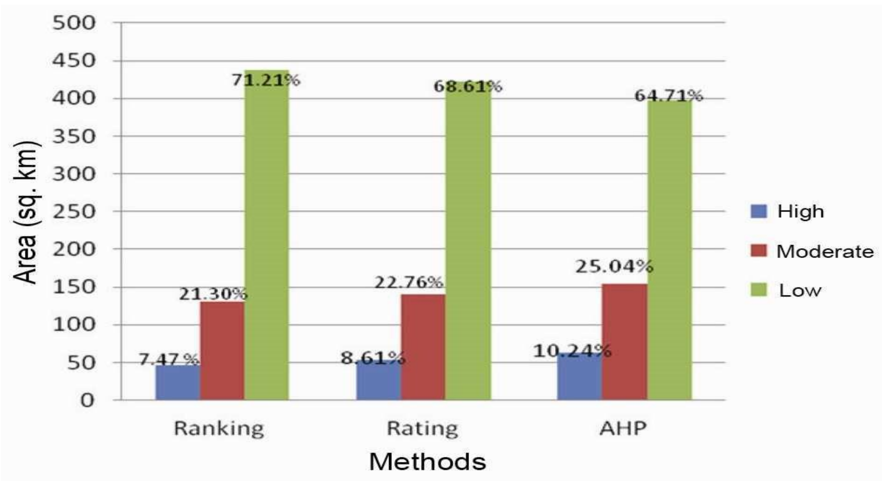

Fig. 5.4 Comparative analysis of result in different methods.

In the case of agricultural land, about 42 sq. km is flood vulnerable area. In addition, there were national highways (Mumbai-Bangalore and Ratanagiri) and three state highways. Sixteen district roads and some village roads were included in high flood risk zone. However, according to the result obtained from AHP, 154 sq. km area has moderate flood risk area. Moderate flood risk area includes nearly 127 sq. km agricultural land of 3 villages. Major national highways, state high- ways, district roads and some village roads were also included in moderate flood risk zone. The entire above mentioned infrastructure, agriculture and settlement areas are located in high flood risk zone, which immediately requires proper zonation and planning tc avoid the various kinds of losses during a flood. In this study, ranking, rating and AHP method were compared with each other, These form a promising and powerful tool, but an equally important ingredient of decision making process

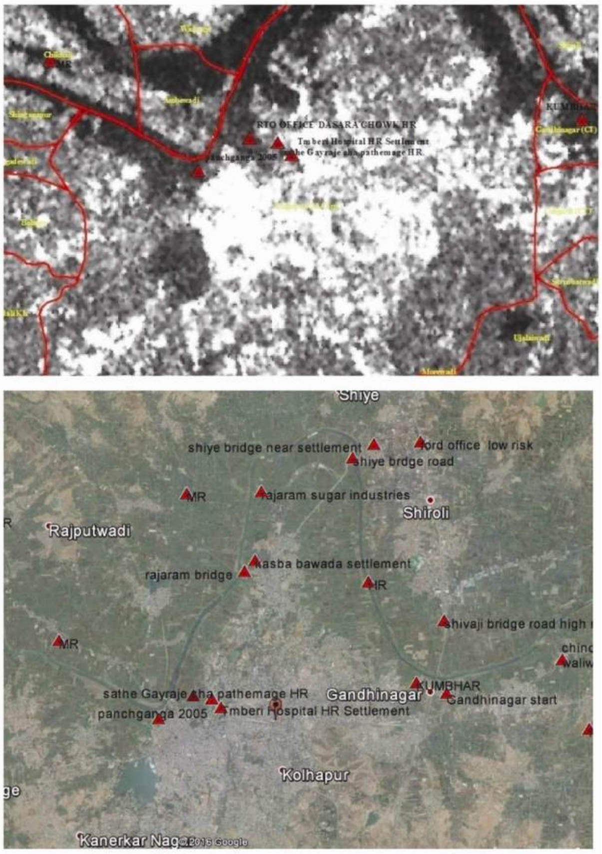

Fig. 5.5. GPS dataset for accuracy assessment.

is the ability of the decision maker to select and combine in the most appropriate way the several criteria, depending on the nature of the objective2%. The three methods have been assessed through GPS based field techniques and ancillary data of previous events. A total of thirty four points were collected from the study region by applying stratified random technique and each point categorized as high, moderate and low flood risk point as per geo-spatial conditions. Finally, accuracy assessment was performed in Erdas imagine software. The result shows that the overall accuracy of AHP method is quite higher with 79.36% as compared to other methods like rating and ranking. Sixteen district roads and some village roads were included in high flood risk zone. However, according to the result obtained from AHP, 154 sq. km area has moderate flood risk area. Moderate flood risk area includes nearly 127 sq. km agricultural land of 31 villages. Major national highways, state high- ways, district roads and some village roads were also included in moderate flood risk zone. All the above mentioned infrastructure, agriculture and settlement areas are located in high flood risk zone, which immediately requires proper zonation and planning to avoid the various kinds of losses during a flood. In this study, ranking, rating and AHP method were compared with each other. These form a promising and powerful tool, but an equally important ingredient of decision making process is the ability of the decision maker to select and combine in the most appropriate way the several criteria, depending on the nature of the objective26, The three methods have been assessed through GPS based field techniques and ancillary data of previous events. A total of thirty four points were collected from the study region by applying stratified random technique and each point categorized as high, moderate and low flood risk point as per geo-spatial conditions. Finally, accuracy assessment was performed in Erdas imagine software. The result shows that the overall accuracy of AHP method is quite higher with 79.36% as compared to be much more accurate and reliable for flood risk analysis for the present study. Other methods like rating and ranking. Therefore, analysis reveals that AHP method is much more accurate and reliable for flood risk analysis for the present study.

5.3 GIS Technique

Every year in India, one third of the area is inundated due to overflowing of rivers. As per the working group of Planning Commission on Flood Control Programme,the total flood prone area of our country is about4,56 lakh sq. km.Flood inundation in rural India is mainly _ associated with large scale loss in agriculture production, loss of livestock and sometimes loss of human lives. Human activities in the upstream section of the river system are mainly responsible for enhanced size and frequency of flood*. Flood risk is defined as the ' combination of prob- ability of a flood event and of the potential adverse con- sequences for human health, the environment, culture heritage and economic activity associated flood event'. Remote sensing and GIS are extremely useful and powerful tools in hazard management. Satellite data can provide hazardous footprints with greater accuracy which are useful for assessing or monitoring he impact of hazard and mitigate flood activities. Remotely sensed data (optical and microwave) can be used for quickly assessing severity and impact of damage due to flooding. In the past two decades, various studies have been carried out using remote sensing data to assess and detect flood inundation areas and to assess the dynamics behaviors of floods. Two distinctive areas of research, GIS and multicriteria decision making (MCDM) can benefit from each other. GIS techniques and procedure have an important role play in analysis of MCDM problems through automating, managing and analyzing spatial data for decision making. MCDM approach offers various techniques and methods to analyses end-users preference and to integrate them into GIS-based decision making. Otsubo et al. have used RADARSAT-SAR images for mapping inundated areas around the Lower Mekong basin. Hydrologic regimes of the flood and areal extent of flooding images. Sharma et al$ have prepared village-wise flood risk index map for the Naogaon district of Assam state by using multi-temporal satellite data. Flood hazard was integrated with land use/land over, infrastructure and population data by specifying weightage for individual class and by considering village as a reference unit. The analysis reveals that GIS environment is quite capable of generating flood risk maps. Sinha have used multi-parametric approach analytical hierarchy process (AHP) to assess flood risk of Kosi river basin. The hydro- logical analysis of the basin was integrated with a GIS- based flood risk mapping. Parameters like land cover, topographic social (population density) and geomorphological were integrated with analytical hierarchy process to generate a flood risk index (FRI). Finally, the flood risk map was validated with long-term inundation maps.

Flood devastation is increasing in this region due to rapid increase in population and human activities. In 2005, 107 villages were heavily affected by flood and 27villages completely marooned by flood water. During that period, 40,000 people were shifted to relief camps and 26 human casualties were reported. Agricultural area (520 sq. km) of Kolhapur district was also inundated as per state government report. The stream flow data and rainfall analysis of Panchaganga river for the last fifteen years (2000-2015) show that the rate of discharge on 9 September 2011with 68,109 cusec was the 2005, this region received highest at Rajaram river gauging station and on 26 July about 210 mm at the highest amount of rainfall within 24 h which was property, infrastructure and disruption to social and economic activities Wadange station. The main impacts of floods are damage to at present 133 villages are prone to flood. The problems related to flooding have greatly increased in Panchaganga basin, and there is a need for effective modelling to understand the problem and to mitigate its disastrous effects. The main limitation of inundated areas during the event. Cartosat stereo data with 2.5 m resolution can only flood risk analysis is the generation of accurate terrain in formation and identification of provide vertical accuracy up to 6 m. The main objective of the present study is to identify potential flood risk areas of Panchganga river using GIS and Multicriteria decision techniques.

5.4 Study area

The study area lies between 16925'-16955Nand 7405'-74930'E. This catchment area covers nart of Karveer. Hatkanangle and Shirol tahsils of Kolhapur district. The total area of the Study region was 615 Sq. km. The area has diversified physiography with a complex geological structure. Geologically, the region belongs to Deccan Trap Formation shich overlies Kaladgi beds. Underlying Kaladgi and Dharwar group of rocks may have been exposed because of large scale erosion of the lava-beds along river valleys.

Flood inundation maps based on the interpretation of Radar Sat 2 Satellite data-

The flooding in Krishna basin started from 5th of August, 2019, however, for ascertaining inundation, there was no satellite data available with ISRO, in optical and microwave region of Electro-Magnetic Radiations (EMR). The Disaster Management Support Division of National Remote Sensing Center (NRSC), ISRO, Govt. of India could acquire microwave satellite data for 9th August, 2019 (18.00 Hrs. IST), 13th & 15th of August 2019and generated near real time flood inundation map. The reported inundation includes wet area/ rain water accumulation and water in low-lying area on 9"h, 13th and 15h August, 2019. The inundation map along with area statistics for 9"h, 13th & 15th August2019, as referred in report as 4.4.1.1 Although, both the banks of Krishna, Warna, Panchganga, Dudhganga rivers of Sangli and Kolhapur districts were got flooded from 5th of August,2019 onwards, there was still extensive inundation over large area on9"hof August, 2019(as seen in inundation map) and slowly receded till 15" of August.

5.5.1 Inundation on 9th of August 2019

In Kolhapur District, a total of 215 Villages got affected in 9 Talukas, encompassing an area of 332.30 sq.kms, (21.20% of area) in these villages.

5.5.2Inundation on 13'h of August 2019-

In Kolhapur District, a total of 78 Villages got affected in 4 Talukas. Encompassing an area of 207.91 sq.kms, (24.47 % of area) in these villages encompassing an area of 36.1 1 sq.kms, (9.56% of area) in these villages In Sangli District, a total of 30 Villages got affected in 2 Talukas.

5.5.3Inundation on 15h of August 2019

In Kolhapur District, a total of 68 Villages got affected in 4 Talukas, encompassing an area of 133.59 sq.kms, (almost 19.28% of area) in these villages. • In Sangli District, a total of 4 Villages got affected in 1 Taluka, encompassing an area of 2.20sq.kms. (1.40% of area) in these villages. Limitations: The flooding in City area of Sangli and Kolhapur could 4.5.1.1 not be picked up due to mixing of digital signatures of urban area with water spread and course resolution (+50 to 100 m) of RadarSat 2.

5.5.4 Inundation up to Almatti

In order to study, the inundation up to Almatti reservoir of Karnataka. MRSAC has examined the web site of National Remote Sensing Agency (NRSA), Indian Space Research Organization (ISRO), Government of India - https://bhuvan- appl.nrsc.gov.in/bhuvandisaster/#flood where Disaster Management Support Division of NRSA has published inundation in Karnataka and Maharashtra for different period from 9" to 15" August, 2019.A combined snap shot of inundation in Karnataka and Maharashtra for 9h, 13th and 15th August 2019 have been captured and are attached with this report. The combined snap shots comparing with daily rainfall data indicate that even though the daily rainfall in Sahyadri hill range got receded from 8" of August, 2019, therc was extensive inundation upto 15" of August, 2019 on either side of Wamna, Panchaganga in Maharashtra and Krishna river in Maharashtra and Karnataka too.

5.5.5 Observed flood line 2019 for Krishna River and Flood Vulnerability map

To decipher precise flood lines of 2019. a detail survey has been done by WRD officials by collecting observed flood line 20 19 from the field level informatior and plotting it on the Village level map. These maps have been imported in GIS environment using Geo-referencing technique.(DEM) by extrapolating observed flood lines and corresponding elevation (m) in DEM. The Flood yulnerability map has layers like Observed flood 2019 lines (of WRD), flood inundation for 9th August, 2019 of NRSA, ISRO, Habitations/ Villages/ Taluka/ District boundaries, Transport network& Flood Vulnerable zone.

5.5.6 Encroachment/ Blocking in Rivers

For identification of encroachment / blocking in Rivers, namely Krishna, Warna, Panchganga and its tributaries (limited to those tributaries which are very nearer to main river), a visual scanning of satellite data available on Google site have been carried out in a "Google Map", a browser-based application. A detailed examination is a laborious& human intensive work& hence a rapid analysis has been done e in a limited area to identify demonstrate Encroachment pattern in the Krishna basin.

5.6 Encroachment/ Blocking in River & Tributaries in Rural Arca

- Blocking / Choking of Tributaries due to weed/ grass, mainly due to very flat surface, clayey and impervious soil
- Blocking of Tributaries due to encroachment by farm lands
- Meandering rivers affecting flow of water.

5.7 Encroachment/ Blocking in River & Tributaries in Kolhapur City

Panchganga River surrounds Kolhapur, forming an inverted "'U" shape. Rajaram barrage Panchganga has river-gauging mechanism. The terrain analysis reveals that the central part of Kolhapur city is at higher elevation than western, northern & eastern part of the city. Lot of urbanization has done in the western, northern & eastern part of the city, where the terrain is almost flat and tributaries are wide Such areas are observed to be at lower elevation than high flood level of 2019 particularly in low-lying areas in western, northern & eastern part of Kolhapur city. These areas have been extensively urbanized in last 10 years. Few snap shots, attached in the report, show changes in urbanization and flood inundation 2019, particularly in Padalkar colony, east of Nejdar Colony, KasbaBawda main road to Padalkar colony, Ranmala & new Shahupuri. Kadamwadi, Jadhavwadi, Kannagar, Mahavir College locality, etc. Local Urban body of Kolhapur needs to carry out a detail ground survey of such areas to remove encroachment in tributaries / storm water drains.

The main observations on encroachments/ blocking in the rivers are -

- In rural area, tributaries are blocked due to extended agriculture activity in tributaries.
- Tributaries are blocked / narrowed down due to presence of grass / weed in the river channels, thereby reducing water flow.
- Blocking of tributaries and ingress of urbanization on the flood plain in Cities in un-controlled manner in Sangli and Kolhapur cities.

6. CONCLUSIONS

6.1 AHP Method:

- According to AHP analyis, high flood risk area includes nearly 17 villages. In the case of agricultural land, about 42 sq. km is flood vulnerable area.
- Also, some major roads in the study area come under the high flood risk zone. All the above mentioned infrastructure, agriculture and settlement areas are located in high flood risk zone and it immediately requires proper attention to avoid sOcio- economic losses.
- The theoretical base of ranking leads to inaccurate weights but rating method required little effort. For more precise results, pairwvise comparison method is the ideal option.

6.2 GIS Technique:

- It is clear that with the help of GIS and multi criterion techniques, useful information • for flood risk analysis can be acquired.
- Comparative analysis shows that the area under high and moderate risk increases in • AHP as compared to other methods.

6.3 Sensors:

- The project contributes towards economy and the citizens. It envisions a safe, prepared. and |ess casualty community before, during and after typhoon devastation.
- The model also promotes the use of real-time monitoring system through him developed web-based application and SMS notification system as an easy medium in disseminating information particularly in the remote areas.
- By allowing the system in two-way communication, it gives more flexibility in providing important information to the community.

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