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Technical Analysis to Investigate Causes of Flood Situation Occurred in Krishna Basin

S. K. Patil [1], V. S. Sherekar[2], V. D. Sakhare[3]

[1]Assistant Professor, Civil Engineering Department, D.K.T.E. Society's Textile and Engineering Institute, Ichalkaranji, Maharashtra, India
[2] Assistant Professor, Civil Engineering Department, D.K.T.E. Society's Textile and Engineering Institute, Ichalkaranji, Maharashtra, India
[3] Assistant Professor, Civil Engineering Department, D.K.T.E. Society's Textile and Engineering Institute, Ichalkaranji, Maharashtra, India

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Abstract - The present paper attempts to analyse causes of floods occurred in recent years in upper Krishna basin of southern Maharashtra. Flood situation has become disastrous during recent years mainly part of July and early August in upper Krishna basin. It is also important to note that floods are serious phenomena by human and natural activities. About 27.72%of the geographical area of the upper Krishna basin of southern Maharashtra is affected by floods of which about 2.12% of total population of Upper Krishna basin has suffered in 2006. Since, the floods of rivers are responses of both natural and anthropogenic factors, the relative effects and causes vary from place to place. To analyse the causes of flood situation in the region under study, the statistical data and concerned information have been collected through personal visits and records available at Tehsil headquarters of Sangli, Kolhapur and Satara districts.

Key Words: Flood, Catchment, Rainfall, Runoff, Infiltration, Groundwater.

1.INTRODUCTION

Design flood is the discharge adopted for the design of a hydraulic structure and it is obviously very costly to design any hydraulic structure so as to make it safe against the maximum flood possible in the catchment. During the months of July & August 2019, Sangli & Kolhapur districts in Krishna sub basin experienced extreme floods for long durations. Heavy losses to life, property & crops etc. had been reported. Different opinions at various levels were put forth concerning these flood events. Sangli & 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. The floods of rivers are the responses of both natural and anthropogenic factors. The causes of floods of alluvial rivers are highly complex and their relative importance changes from place to place. The present paper aims to find on the probable causes of flood situation in upper Krishna Basin of Maharashtra.

2. OBJECTIVES OF STUDY

1. To carry out in-depth technical analysis using modern techniques and investigate causes of flood situation occurred in upper Krishna basin.

2. To specifically clarify based on hydrological studies, whether any downstream dam reservoirs (back water effect) from, create flood situation in Maharashtra.

3. METHODOLOGY

In order to accomplish the objectives of the study, various spatial and non-spatial (historic as well as contemporary) data were used. This section deals with the collection, processing, and analysis of the different datasets used in the present project. Required data and information have been collected from various sources. The vast statistical data and concerned information have been collected through personal visits to tehsil headquarters of Sangli, Kolhapur and Satara districts. Number of affected villages have been visited to have discussion with the affected people and Government officers. The secondary data have been taken from socio-economic reviews and district statistical abstracts, census handbook and district gazetteer of Satara, Sangli and Kolhapur districts. Various articles published on flood situation in daily newspapers, journals, magazines, S.O.I. toposheets and reference books were also referred. To find out causes of floods in upper Krishna Basin, the relative information regarding the rainfall, area under irrigation, bridges on Krishna and other rivers, statistical information about flood affected area, population and other aspects were collected through primary and secondary sources of data.

4. STUDY AREA

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 (13°.7‟/N to 19°20 „/N and 73° 22‟/E to 81°10‟/E) and flows through Maharashtra, Karnataka, Andhra Pradesh and drops into the Bay of Bengal in 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. The basin is roughly triangular in shape and is bounded by Balaghat range on the north, by the Eastern Ghats on the south and the east by the Western Ghats on the west. Map of Krishna Basin of India is shown in Annexure "maps" (Map No.1) Krishna Godavari Commission had divided entire Krishna basin into 12 sub divisions & they are designated as K1 to K12 spread in all states i.e., Maharashtra, Karnataka & Andhra Pradesh (now divided into Andhra & Telangana). 5 basins K1, K2, K3, K5 & K6 are spread in Maharashtra state.

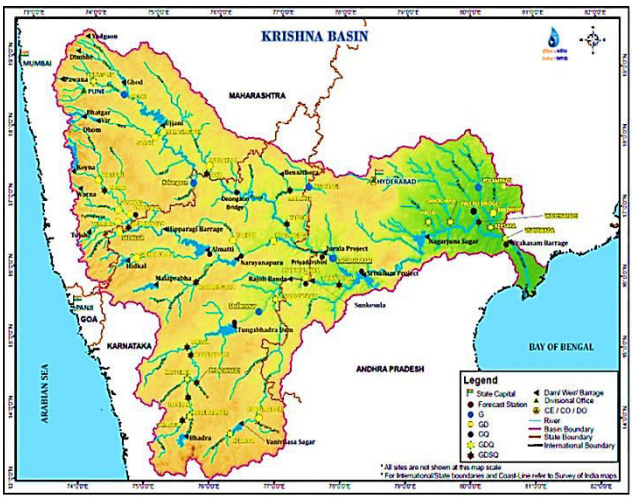


Fig -1: Index map of Krishna Basin

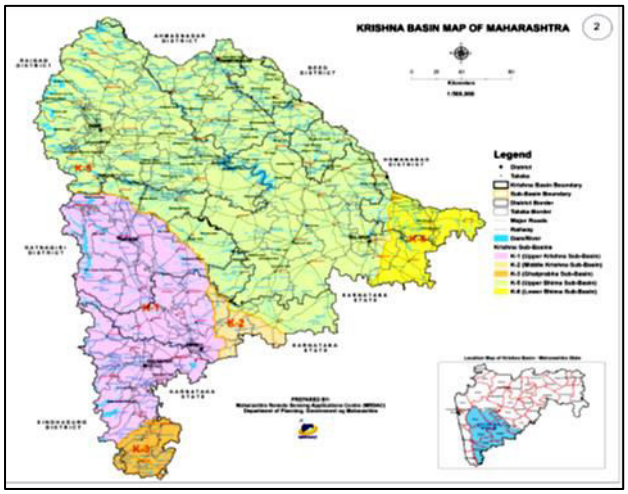


Fig 2: Index map of Krishna Basin in Maharashtra state

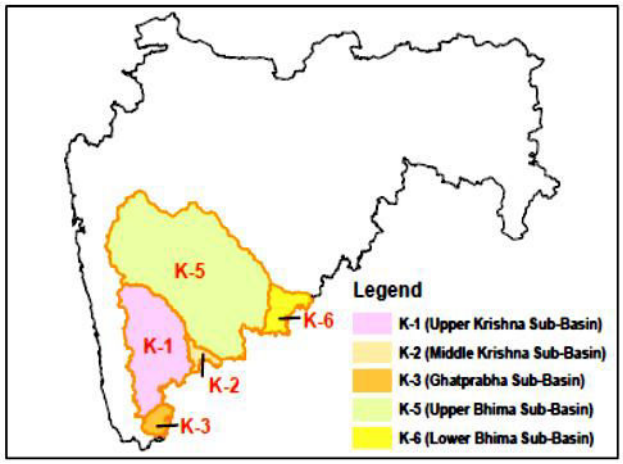
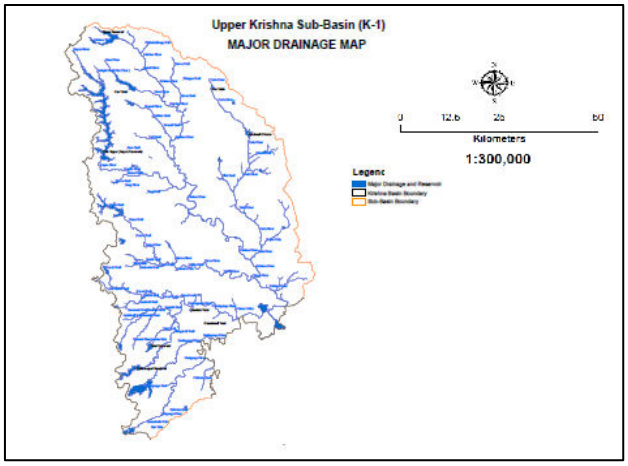


Fig 3: Location map of Krishna Basin



Fig, 4: Major Drainage map of Krishna Basin in Mah.

5. STATUS AND VULNERABILITY OF WATER RESOURCES SECTOR IN MAHARASHTRA DUE TO CLIMATE CHANGE

Out of 6 river basin systems, only 55% of the dependable yield is available in the four river basins (Godavari, Krishna, Tapi and Narmada) east of the Western ghats. The rest drains out in the westward flowing river basins into the Arabian Sea. Over dependency on ground water in a state where its recharge capacity is low, escalates vulnerability of systems dependent on the same such as irrigated agriculture, industries and drinking water. Maharashtra is prone to drought and floods. Out of the total geographical area of Maharashtra, 40% of the area is drought prone and 7% is flood prone. Rainfall trends indicate that Maharashtra could face an increase in rainfall variability, including droughts and dry spells, as well as increased likelihood of flooding in the future. This has direct bearing on ground water as heavy intensity rainfall gets lost as runoff while low intensity rainfall which contributes to recharge decreases in frequency. Climate change vulnerability assessments are necessary for designing targeted adaptation actions. The vulnerability analysis was carried out for different sectors at various levels of governance, on the basis of Macro Level Vulnerability Indices, estimated using the Indices of Exposure, Sensitivity and adoptive capacities to climate changes. This was done by the Department of Environment, Government of Maharashtra while preparing the Maharashtra State Action Plan on Climate Change in 2014. The Action Plan has also presented climate projections for future at 25km x 25 km resolution using the Hadley Centre regional climate model. Some of the projected changes in climate over Maharashtra are:

- Increase in mean temperature from 1.2 to 1.6 degree centigrade in 2030s.
- Rainfall is also projected to increase during the same period, with more rainfall projected as we progress from 2030 to 2050 to 2070 but it will be highly variable spatially.
- Annual rainfall shows highest increasing trend for Satara, Mumbai, Kolhapur and Sindhudurg and highest decreasing trend for Bhandara and Latur in 2030s.
- Extreme rainfall events with longer dry spells are projected to increase in all districts of Maharashtra.
- Numbers of dry days are likely to increase by minimum 3 to maximum 9 days in the state by 2030s.

• The sea level is expected to increase by 24 cm to 66 cm along the coastline in sync with the projections for global sea level rise, accompanied by an increase in wave heights, wind speeds, greater storminess and storm surges.

6. ABOUT THE EVENTS

During the year 2019, eight cyclonic storms were developed over Indian Seas. Arabian Sea contributed 5 out of these 8 cyclones against the normal of 1 per year, which equals the previous record of 1902 for the highest frequency of cyclones over the Arabian Sea. Out of 5 cyclones developed over Arabian Sea 2 were very severe, one was extremely severed and one was super cyclonic storm. Active spell of South West monsoon started from 27thJuly, 2019 and before it is fully dissipated; low pressure area was formed on the Bay of Bengal, which intensified into deep depression on 7th August. During the first spell catchment was fully saturated. Hence, during second spell almost all the rainfall converted into runoff causing severe inundation. During South-West Monsoon season over the country, rainfall over Maharashtra shows significant spatial and temporal variability. The state experiences extremes of rainfall ranging from 6000 mm over the Ghats to less than 600 mm in the interiors. Western coast of Maharashtra, the Konkan belt is often prone to heavy to very rainfall during active monsoon conditions due to favorable orography. The Western Ghats act as obstruction to the eastward-moving Monsoon cloud forcing it to rise ultimately leading to the heavy downpour on the windward side, while the leeward side forms the rain shadow area receiving less rainfall. Climatological records of the Satara, Sangli and Kolhapur districts indicate that, there is a large variation in space of rainfall. The western portions of these districts adjoining the Western Ghats and neighborhood get very high rainfall while near the eastern borders of the districts, receive very less rainfall

7. RAINFALL PATTERN

Rainfall data indicates that Konkan and adjoining Madhya Maharashtra experienced very heavy rainfall. In the beginning of the flood period i.e., from 27th Jul 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 3rd to 5th Aug. Towards the latter part of the week, rainfall belt shifted towards south Madhya Maharashtra. Mahabaleshwar recorded highest rainfall of 380 mm on 5th Aug. 2019. It is also observed that Kolhapur district continuously experienced heavy rainfall throughout the period with highest rainfall amounts on 6th Aug. 2019. Gaganbawda recorded its highest rainfall of 340 mm rainfall on 6th Aug. It is also seen that though heavy rainfall occurred in the western part of the districts in Madhya Maharashtra, their eastern parts were devoid of rainfall. It is further 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 13th August 2019. Sangli, Kolhapur and Satara district received very heavy rainfall of 1918 mm in comparison to 333 mm normal rainfall during 27th July to 13th August. This was about 6 times the normal and at the same time, in the free catchment, downstream of the dams, it was about 18 times the normal. Such high range of continued rainfall in short duration resulted in extreme heavy flooding mainly in Sangli, Kolhapur town and few talukas situated near Krishna and Panchganga rivers. It is observed that, the Flood affected districts of Satara, Sangli and Kolhapur continuously received excess to large excess rainfall during the first fortnight of August. It was seen that the observed actual rainfall in various catchments to the upstream of dams varies from 5 to 19 times the normal. Average actual rainfall was about 6 times the normal rainfall in all these catchments bringing abnormal flood to downstream areas. The actual rainfall during the first 56 days of the monsoon (starting from 1st June 2019) was measured at 6 rain gauge stations, situated in the free catchments of these three districts. It is observed that the total rainfall during the peak period of 18 days (27th July to 13thAugust) measured at the same stations, was about 1.6 times the total rainfall during the previous 56 days (1st June to 26th July). Also, the actual rainfall during the event in free catchments was varied from 13 to 29 times the normal rainfall. The overall observed rainfall over the normal was about 18 times. Such abnormal high occurrence of rainfall even in free catchments also aggravated floods in Sangli & Kolhapur districts.

8. ANALYSIS & REASONS:

To carry out in-depth technical analysis using modern techniques and investigate causes of flood situation occurred in Krishna basin

The flood disasters occurred during the monsoon of the year 2019, along river Krishna was primarily due to:

a) Persistent and simultaneous occurrence over large spatial areas, of heavy precipitation in short duration. Climatological records of the Satara, Sangli and Kolhapur districts indicate that, there is a large variation in space of rainfall. The rainfall in the belt, roughly 25 to 35 kms wide parallel to the crest of the Sahyadri Range, is considerably higher than in the rest of the district. While Mahabaleshwar at an elevation of 1372 metres gets an average annual rainfall of 5886.9 mm, other stations in this belt get annual rainfall ranging between 1684 and 2195 mm. Compared to Kolhapur and Satara, district of Sangli has relatively lesser average annual rainfall of about 670mm. The persistent intense rainfall activity over the region was in association with an active spell of monsoon started over Maharashtra from 27th July 2019 and resulted in flooding in many parts of Konkan and North Madhya Maharashtra. This was followed by another active monsoon spell from 3rd August 2019, in association with the formation of a low pressure over North East Bay of Bengal and its subsequent intensification into deep depression and westward movement in the subsequent days causing severe flood conditions in South Madhya Maharashtra. This movement of deep depression system (an active low-pressure system with wind speed ranging between 52 to 61 kmph) across central India, resulted in enhancement of rainfall over west coast and in the ghat areas of Madhya Maharashtra with heavy to very heavy rainfall and extremely heavy rainfall events for more than a week period over these places, resulting in severe flood situations. Maharashtra State has an average annual precipitation of about 741mm.The rainfall in the state is controlled by south west and north east monsoon. About 90%

of rainfall occurs during monsoon months from June to October, every year. The high intensity storms prevailing during the monsoon months result in heavy discharges in all the rivers. The continuous and heavy precipitation that occurs in the steep and undulating terrain, finds its way into the main rivers through innumerable streams and water courses. Flood event 2019 in Krishna basin is an example. Basin experienced an abnormally very high rainfall between 25th July to 13th August, resulting in severe flood in Sangli, Kolhapur, Satara districts. Average actual rainfall was about 6 times the normal rainfall in all dam catchments bringing abnormal flood to downstream areas. The overall observed rainfall over the normal was about 18times. Such abnormal high occurrence of rainfall even in free catchments also aggravated floods in Sangli & Kolhapur districts. It can be seen that the contribution of free catchment, in the discharge observed in river Krishna, at Irwin Bridge at Sangli, was 49%. Similarly, the contribution of free catchment, in the discharge observed at Rajaram weir on river Panchganga, was 84%. The discharge from free catchment, which was substantial and had no control.

b) Typical Topographical features and river meandering

By study of topographical features of the Krishna sub-basin including its tributaries in Maharashtra, it was found that the River Krishna originates at the highest altitude of 1310 m at Mahabaleshwar, and also the Koyna at the same place, they reach at Pritisangam, the confluence of Krishna and Koyna at Karad at the altitude of about 550 m. thereafter, there is sudden change in the river bed slopes in the Krishna River upto Sangli. While negotiating the Sangli city, the rivers Yerala and River Warna meets Krishna and thereafter within few kilometers there is confluence of River Panchganga leading Krishna to state border. The Krishna River reach from Sangli city to state border is only 30-40 kms long, having very flatter bed slopes and many meanders. This, typical topographical set-up plays major role in slowing down the flood dissipation beyond Sangli city. It was found that, in this reach of river, while there is drastic reduction in the velocities of the flow, the backwater effects of various confluences of its own tributaries further aggravate the problem. While the floods in main Krishna River are yet to dissipate this particular reach, the floods coming from tributaries by simultaneous raining cannot even enter in the main river course of Krishna. The situation was further aggravated as these tributaries could not drain out their own discharge, when river Krishna was already flooded, which was spread on the side banks of the tributaries. This peculiar situation resulted in long term inundation alongside the flood plains of tributaries like Warna and Panchganga, while increasing the backwater effect near confluences resulting in the higher flood levels at Sangli, Kurundwad and Kolhapur cities. The problem is further aggravated by the meanders in the same reach, because of which very large flood plains are created, submerging huge areas with almost stagnant waters for prolonged periods. During this time, the flood water even tends to create shortcuts, bypassing the meanders straight into the next stretch of the Krishna River, as an effort to dissipate the floods early.

c) Large Encroachments in Flood Plains and Reduction in flood discharge capacities of the rivers, due to many Structures built across Rivers

Due to the heavy developments around the river stretches and in city areas, there have been large encroachments, of building constructions, retaining walls, roads etc. in prohibited and restricted flood plains/zones and also in the natural drainage system. At many places, the debris in huge quantum is thrown in the river courses (or its tributaries), reclamation of lands, leveling of plots have been done, thus choking the waterways of natural drains. Many huge structures like Bridges, Barrages, weirs have been built across the main Rivers, in very unscientific way, which obstruct the flood discharges at every such location, thereby creating an afflux and reduction in the velocities. The cumulative effect of all such structures may be in increasing the flood levels and stagnation of water for prolonged period.

d) Sedimentation in main rivers – at confluences, along meanders

Due to sudden changes in the river bed slopes and stagnation of floods for prolonged periods, sedimentation occurs in the river courses and also in natural drainages. This results in raising the river bed levels, thereby raising the flood levels and extended inundation areas. At the meanders, the sedimentation occurs in the inner side of the curves, thus deflecting the floods further to the outer sides.

e) Absence of flood absorption capacities in reservoir planning of existing dams

At the time of project planning, the reservoirs are never planned with the provision of special cushion for flood absorption neither in consideration of river regime in downstream. The dead storage is designed to accommodate the silts and live storages are planned for complete utilization of the water stored for the objectives planned throughout the year. The Reservoir Operation Schedules are designed to assure for full storages by the end of the monsoon period to fulfill these objectives. With this background and keeping in mind the historic drought prone area, the dams are not designed for the flood mitigation too. For ungated spillways or dams having fully automated gates, there is no manual control to moderate the incoming floods. However, considering all these facts, and after reviewing the reservoir operations of all the major dams during the flood event, it can be concluded that, having many constraints and in such a severe situation, the dam operators of Maharashtra tried to mitigate the flood in proper way, by keeping the outflow from the spills on lower scale.

9. ANALYSIS: To specifically clarify based on hydrological studies, whether due to any other reservoirs (back water effect) from Karnataka, create flood situation in Maharashtra.

One dimensional unsteady flow analysis, of the River Krishna from Karad to Almatti, along with its three tributaries in the State of Maharashtra viz. Yerala, Warna and Panchganga, has been done using Version 5.0 of the HEC-RAS software. Analysis has been done for the period of 25th July, 2019, 8.0 am too 17th August, 2019, 8.0 am. Steady state analysis for PMF condition was also done.

The important conclusions of this hydrodynamic analysis are:

a) Although this mathematical model study, has certain limitations, the study indicates that Almatti and Hippargi reservoirs in Karnataka and its flood operations, during the Flood Event of 2019, has not adversely affected the flood situation in the State of Maharashtra.

b) The discharge carrying capacity of the river Krishna was inadequate to accommodate the releases of Koyna dam, the contribution of tributaries and the runoff of the free catchment

c) The river Krishna flows, a near plain land, between Sangli and the State border. It is a general phenomenon that the river

takes meandering course, while traversing on a plain land. Thus, River Krishna has so many curves and meanders. The velocity of the river is comparatively less while traversing curves and meanders, causing thereby more inundation on inner as well as outer sides of the curves and meanders as compared to straight reaches of the river. The Sangli city is on one of the curves of River Krishna and Kolhapur city is on the curve of river Panchganga

d) Flow stagnation in River Krishna from Sangli city to the State border, due to confluence effect. There exists series of confluences, Yerala-Krishna, Warna Krishna, Panchganga-Krishna and Dudhganga-Krishna within a reach of about 50 to 55 km length. At confluence points due to formation of stagnation zone velocity is reduced.

e) Generation of backwater effect in the tributaries and nallas meeting the River Krishna. Due to comparatively higher discharge in the River Krishna, the backwater effect is generated in the tributaries. The flooding in tributaries viz. Yerala, Warna, Panchganga and other nallas like Bhilwadi, Nagthane was primarily due to backwater effect of the river Krishna. The situation was further aggravated, as these tributaries could not drain out their own discharge, till the flood in the river Krishna was receded. Water was spread on the side banks of the tributaries due to pounding effect. The river Krishna was flooded for a long duration from 5th August up to 13th of August. Consequently, the backwater spread in the tributaries and on floodplains could not return back to the river course. Thus, the floodplains were under water for a prolonged time.

f) The lateral slope of the flood plains is very gentle. The flood plains are almost flat. This has resulted into spreading of flood on larger area on both the banks of the river

10. CONCLUSION

Basin experienced an abnormally very high rainfall between 25th July to 13th August, resulting in severe flood in Sangli, Kolhapur, Satara districts. Average actual rainfall was about 6 times the normal rainfall in all dam catchments bringing abnormal flood to downstream areas. The overall observed rainfall over the normal was about 18times. Such abnormal high occurrence of rainfall even in free catchments also aggravated floods in Sangli & Kolhapur districts. Although this study based on mathematical model, has certain limitations, the study indicates that Almatti and Hippargi reservoirs in Karnataka and its flood operations, during the Flood Event of 2019, has not adversely affected the flood situation in the State of Maharashtra. Generation of backwater effect in the tributaries and nallas meeting the River Krishna. Due to comparatively higher discharge in the River Krishna, the backwater effect is generated in the tributaries. The river Krishna was flooded for a long duration from 5th August up to 13th of August. Consequently, the backwater spread in the tributaries and on floodplains could not return back to the river course. Thus, the floodplains were under water for a prolonged time.

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