Agony of Floods: Flood Induced Water Conflicts in India

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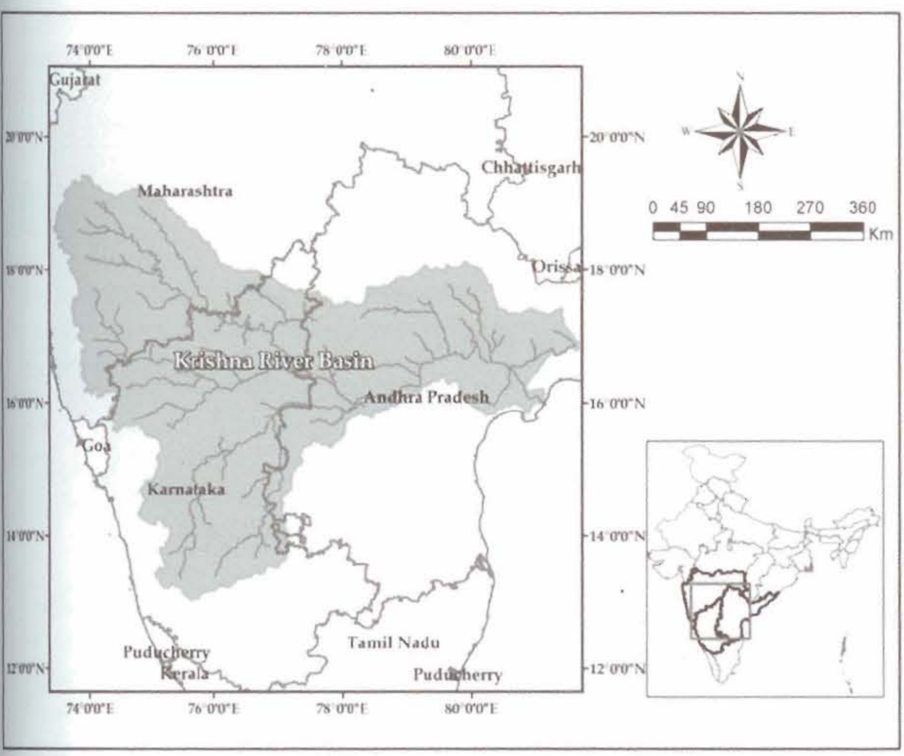
Introduction

The October 2009 flood in Krishna river basin is one of the worst disasters that we have seen in the recent past. Several districts in the States of Karnataka and Andhra Pradesh were severely affected by this flood, which primarily was a result of heavy, unprecedented rainfall over the entire basin from 29th September to 3rd October 2009. The high intensity of rainfall resulted in flash floods in several smaller catchments and sub-basins of the Krishna river. Fifteen districts in Karnataka and thirteen districts in Andhra Pradesh were severely affected by the flood, which took the toll of 319 lives[1], flattened more than a million houses, and destroyed vast areas of standing crops. There was severe damage to public infrastructure including roads, culverts, bridges and embankments leaving several villages stranded and hindering rescue operations.

Fig. 1: Location of Krishna Basin in India



[1] 229 deaths were reported in Karnataka and 90 in Andhra Pradesh. 21.92 Lakh hectares of crop land was damaged in Karnataka and 22.6 lakh hectares in Andhra Pradesh. 6,55,484 houses were damaged in Karnataka and 2,59,095 in Andhra Pradesh. The damage to livestock was also very high with 7,882 cattle deaths in Karnataka and 48,686 in Andhra Pradesh. The total damage in Karnataka was estimated at INR 18,568.25 Crores and INR 12,455.75 Crores in Andhra Pradesh (GoK, 2009 and GoAP, http://disastermanagement.ap.gov.in/website/history.htm, accessed on 30 December, 2011).

The three riparian States of Maharashtra, Karnataka and Andhra Pradesh, through which Krishna flows, have built small, medium and large reservoirs across the catchment to tap the water for irrigation, power generation and domestic water supply. It was pointed out that the intensity of floods could have been reduced if the reservoir levels were managed effectively. The downstream State of Andhra Pradesh argued that the upstream Almatti and Narayanpur reservoirs in Karnataka released water without adequate notice (Hegde, date unknown), resulting in the backwaters of Srisailam reservoir in Andhra Pradesh extending into the town of Kurnool, which had never before seen a flood of that magnitude nor was prepared to deal with it. Observers have, on the contrary, questioned why the release from Srisailam reservoir in Andhra Pradesh to the downstream Nagarjuna Sagar reservoir was delayed in the aftermath of the rainfall (Ramachandraiah, 2011: 435). Thus, on the one hand, storage and release of water from the reservoirs remain a contested issue where multiple economic and political interests overlap and on the other, it is important that the institutions, governance structures and the local communities in the region prepare for and adapt to flood events in the future.

While this debate has been controversial with political connotations sparking the inter-state water sharing debate, there has been little attempt to look at available data on what actually happened during the five days of the disaster, reflect on what went wrong and think forward to introducing specific measures for disaster preparedness. This case study attempts to do this using empirical analysis, field visits and interviews with affected communities, government agencies, local formal and informal institutions and offer some insights on the institutional aspects of dam operations and flood management. Even though the flood might not have been completely averted, we argue that a timely and proactive response would have reduced the severity of flood, both in terms of magnitude and duration, and its impact on the affected communities. In this article, firstly, we provide a brief overview of the events that led to the flood. We then examine the operation of reservoirs and compare it with an empirical simulation exercise involving an alternate strategy of reservoir operation. Finally, we discuss the complexities of reservoir management and flood control, and the need for disaster risk reduction strategy by combining results of our simulation exercise with field observations and assessment of institutional responses.

The Chronology of 2009 Floods

The geographic setting of this case study is best represented and demarcated by the major dams built across Krishna and Tungabhadra in Karnataka and Andhra Pradesh. The map (Figure 2) shows the major dams including Almatti and Narayanpur (Tungabhadra dam) in Karnataka, and Srisailam, Nagarjuna Sagar and Vijayawada (Prakasam barrage) in Andhra Pradesh.[2]

The entire Krishna basin, particularly the lower parts of the basin, constituting the Northern Interior Karnataka[3] and South-western Andhra Pradesh received extremely high rainfall from 28th September to 3rd October 2009. The region is typically characterized by frequent droughts and the average annual rainfall in most of the districts varies between 600 - 800 mm. Sudden downpour of

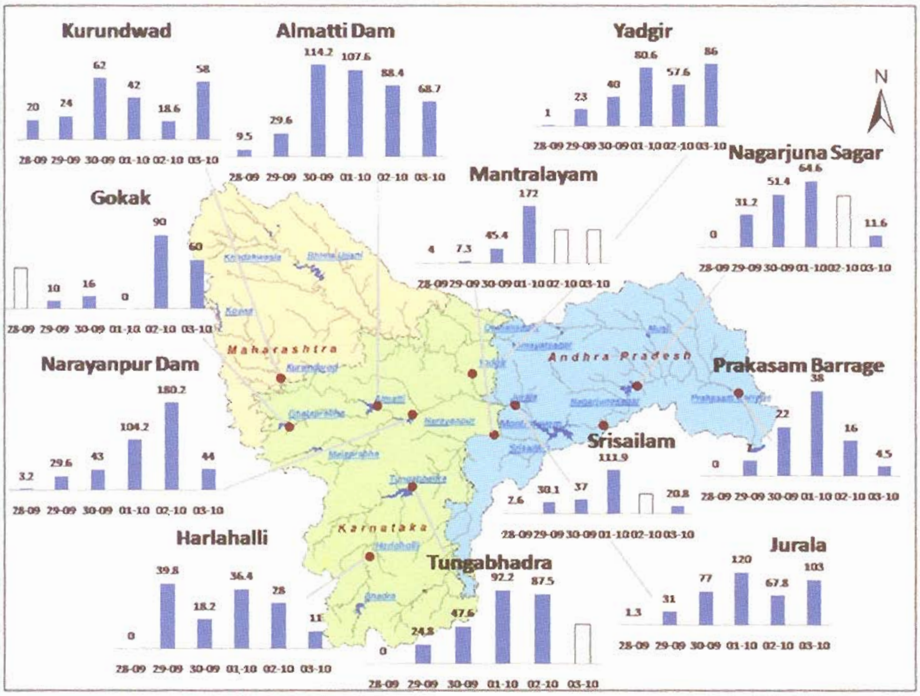
[2] We have used the popular nomenclature instead of the official nomenclature for the convenience of the readers.

[3] Northern Interior Karnataka region covers several districts including Bidar, Bellary, Dharwad, Bagalkote and Bijapur.

intense rain storms began on 28th September and took the form of cloud burst resulting in heavy and high intense rainfall from 29th September to 3rd October. The observed cumulative rainfall in the catchments of these reservoirs during these six days was much higher than even the normal monthly average rainfall (GoAP, 2009; GoK, 2009).

Fig. 2: Map of Krishna basin with major dams and rainfall from 28th September to 3rd October, 2009

(Source: (1) Rainfall data: Bulletins of Central Water Commission, Lower Krishna Division (GoAP, 2009). (2) Map: Adapted from the map produced by International Water Management Institute (IWMI) http://krishna-basin.iwmi.org/ (accessed on 30 December, 2011)).



The average annual rainfall for Mehboobnagar and Kurnool districts in Andhra Pradesh was 603 mm and 670 mm respectively. Several mandals[4] in both the districts received rainfall ranging from 300 mm to 560 mm over four days between 30th September and 3rd October (GoAP, 2009). The six days' rainfall from 28th September to 4th October in Northern Interior Karnataka when compared with the week's rainfall from 1970 showed a +555% departure from the normal (GoK, 2009). The previous event of highest departure occurred in 1994, which was +221%. Raichur district in Karnataka received the highest rainfall of 403 mm during this period and it was about nine times the normal. However, rainfall of this high magnitude is not totally unfamiliar to this region as several places received even higher rainfall at least once in the previous century[5] (GoK, 2009).

The heavy rains resulted in rapid swelling up of the entire stream network because of which even smaller streams and rivulets carried high inflows into the major river bodies. Tungabhadra river carried an inflow of 900,000 cusecs[6] against its maximum discharge capacity of 400,000 cusecs on 2nd October (Ramachandraiah, 2011). Hundri river which joins Tungabhadra on the

[4] A 'mandal' is an administrative sub-division of a district that comprises of a number of villages.

[5] For instance, Hungund in Bagalkote district recorded 163 mm rainfall in 24 hours on 2nd October, 2009 which is the second highest recorded in a day, highest being 182.8 mm recorded on 8th April, 1937 (See, GoK, 2009).

[6] Cusec or cubic feet per second, is the most commonly used unit for measurement of flow.

outskirts of Kurnool town carried an inflow of 200,000 cusecs, four times greater than its maximum discharge capacity of 50,000 cusecs on 2nd October between 10 am to 1 pm (Ramachandraiah, 2011).

Fig. 3: Flooded streets in central Kurnool
(Source: Authors)

Fig. 4: Local NGO volunteers rescuing flood victims in small fishing boats
(Source: Authors)

Fig. 5: Damaged weir of a local tank (Source: Authors)

All the reservoirs received very high inflows in an increasing trend till 3rd October. Srisailam reservoir received record inflows of the order of 2,500,000 cusecs from 8 pm on 2nd October to 4 am on 3rd October which created havoc as the maximum discharge capacity of the reservoir at Full Reservoir Level (FRL) is only 1,110,300 cusecs (GoAP, 2009). The available storage in reservoirs, if created, could have greatly helped in moderating the flood by providing the storage cushion for peak inflows. To create this storage, releases from the reservoir should have been initiated immediately and increased gradually after the forecast warnings of heavy storms across the basin were communicated. However, there was no storage available in all the reservoirs except at the Nagarjuna Sagar to facilitate such flood moderation, as all of them stored water very close to the FRL. Table 1 shows the reservoir levels of the major dams from 29th September to 4th October.

Table 1: Reservoir Levels at Various Dams from 29th September to 4th October, 2009

Dam/Reservoir	FRL (meters)	29 September	30 September	1 October	2 October	3 October	4 October
Almatti	519.68	519.60	519.60	519.56	519.35	518.70	518.80
Narayanpur	492.25	492.11	492.17	491.55	490.44	490.68	490.00
Tungabhadra	497.74	497.74	497.72	497.73	497.65	497.63	497.48
P.D. Jurala	318.52	317.70	317.75	317.75	317.15	317.60	316.65
Srisailam	269.75	269.50	269.55	269.63	268.70	272.70	272.83
Nagarjuna Sagar	179.83	162.95	163.46	165.20	172.76	176.17	178.16

Source: Bulletins of Central Water Commission, Lower Krishna Division (GoAP, 2009)

Maintaining the reservoir very close to FRL at Srisailam proved to be fatal with severe flooding in Alampur mandal, Kurnool town, and surrounding villages as a result of gradual and prolonged flow accumulation in the reservoir immediately downstream. A total area of 11.5 sq km which is about 30 per cent of the total geographic area of Kurnool town was submerged by flood waters (Ramachandraiah, 2011). This submerged area falls between elevation contours of 271 and 284 meters much above the FRL of the reservoir. The reservoir level at Srisailam increased beyond 271 meters from 7 am on 3rd October to 7 am on 4th October (the maximum reservoir level recorded was 273.32 meters[7] at 1 pm on 3rd October), which is clear evidence that the backwaters of Srisailam reached up to Kurnool town. The backwaters not only flooded parts of the town, but also prevented flows from Hundri and Tungabhadra rivers entering the reservoir, and diverted them into Kurnool town which coincidently has an antiquated storm drainage system. The combined effect of both these factors had a severe impact on Kurnool town, pockets of which were inundated by more than 13 meters deep water for several days. The villages in Alampur mandal faced a similar situation, particularly, the temple town of Alampur at which Tungabhadra merges with Krishna before flowing into Srisailam reservoir.[8]

The discharges from Srisailam reservoir were far lower compared to the inflows until 2 am on 1st October (GoAP, 2009). The discharges were eventually increased but were still lower than the heavy inflows which were of the order 1,200,000 cusecs received by 9 pm on 1st October. As noted earlier the peak inflows increased to 2,575,000 cusecs by 10 pm on 2nd October, and in response the reservoir discharge was increased to 1,410,800 cusecs, much higher than the reservoir's design peak discharge capacity of 1,320,000 cusecs at the maximum water level of 271.8 meters by 10 am on 3rd October. The twelfth gate of the reservoir was only opened on 3rd October at 1 pm after 20 years, which enabled a higher outflow of 1,480,000 cusecs.[9] The outflows were maintained above 1,000,000 cusecs until 6 pm on 5th October. Nagarjuna Sagar reservoir received inflows greater than 1,000,000 cusecs from 9 pm on 1st October which had also been gradually releasing water into Prakasam barrage from 1 pm the same day. Prakasam barrage received the maximum inflow of 1,110,404 cusecs at 11 pm on 5th October, which is the highest since its construction, creating havoc in Vijayawada town and the villages in the river delta situated further downstream. An important observation from Table 1 is that the reservoir level at Nagarjuna Sagar was around 14 meters, far less than the FRL until 1st October, which in terms of storage is half the reservoir storage capacity. Diverting the flood water from Srisailam early enough into the Nagarjuna Sagar reservoir and then downstream would have been a logical decision and would have greatly reduced the impacts on the catchment of Srisailam.

Numbers Count: A Closer Look at Reservoir Inflows and Releases

Results of the analysis of the rainfall, reservoir inflows and discharges at Srisailam reservoir suggest serious lack of flood regulation mechanisms even under such extreme flood events. As noted earlier, the releases from the

[7] We have used the conversion factor 1 ft = 0.3048 meters to represent reservoir levels throughout the article.

[8] During field visit to Alampur town on 6th November, 2011, two flood affected households who were still living in temporary flood camps were interviewed. They had lived in houses along the temple embankment prior to the floods, which were damaged due to submergence for more than ten days. Similar references to the backwater effect were made by residents of Kurnool town as well during interviews.

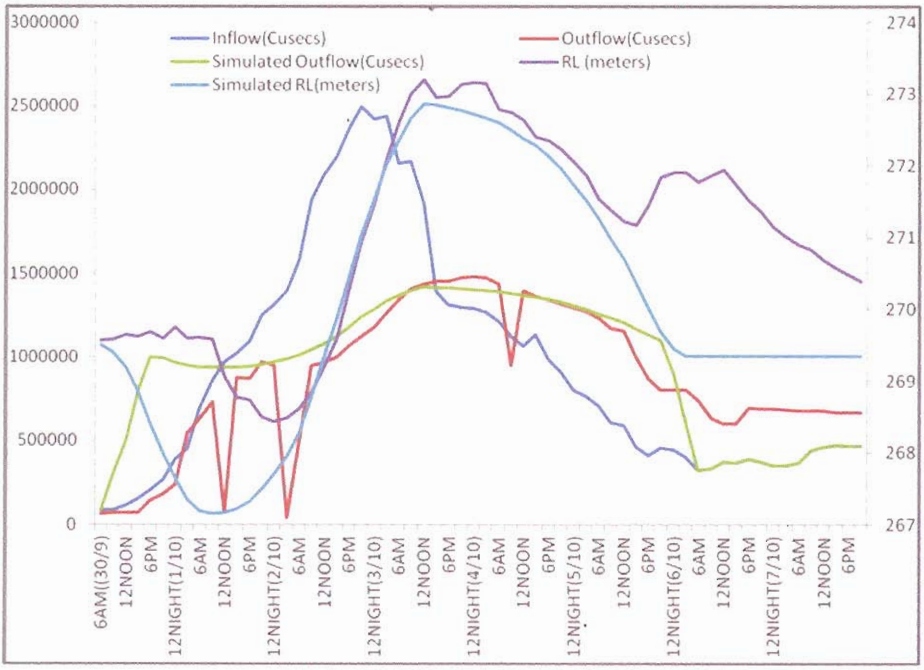
[9] Information gathered from the then Chief Engineer of Srisailam dam (interviewed on 1st November, 2011).

reservoir were significantly low on 29th and 30th September pointing to deficiencies in the emergency response by the reservoir authorities despite forecasts of heavy downpour in the entire Krishna basin. The delay of more than 24 hours in responding to the heavy downpour and reservoir inflows was a primary reason for exacerbating the flood and its impact in the Alampur mandal, Kurnool town and surrounding villages.

To arrive at an alternate real-time reservoir operation scenario, empirical simulations (Figure 6) with the observed inflow and reservoir discharges (estimated) were carried out starting from the morning of 30th September, which was when the depression in the Bay of Bengal and a possible cloud burst was forecast. Reservoir outflow data and the reservoir levels available in GoAP, 2009 were used to establish a simple linear relationship between the reservoir stage and discharge (the actual relationship is a polynomial of the order 1.5). Using this relationship, revised reservoir operations including discharges, observed inflows and resulting reservoir levels were simulated. Reservoir discharges were gradually increased to the maximum discharge capacity and subsequently maintained at maximum possible discharges at the prevailing reservoir level to create the necessary storage space for accommodating incoming flows to the Srisailam reservoir. The fact that more than half of the storage was available in Nagarjuna Sagar was also considered in parallel to facilitate these discharges from Srisailam.

Fig. 6: Results of simulation compared with the actual outflows and reservoir levels from 30th September to 7th October, 2009

(Source: The outflows and corresponding reservoir levels were simulated using the data available in GoAP, 2009)



With this simulation exercise, we were able to create a storage cushion of 40 TMC (Thousand Million Cubic feet) on an average from 12 am on 1st October to 12 am on 2nd October. If this storage cushion had been created in reality, it would have allowed the flood water to flow into the reservoir and subsequent releases downstream would have reduced the severity of flood in the upstream submerged areas by reducing the area under high and moderate submergence. Also, the duration of flood in which the reservoir water level crossed the dangerous level of 271 meters would have reduced by at least two days.

In the simulation, we have taken care to provide for realistic operational issues such as delays that would have happened between events, emergency consultations and decision making. We have also accounted for dam safety by making sure that the outflow simulated did not exceed the maximum discharge capacity, which it did in the real case on 4th October as a response to drastic increase in the inflows to the reservoir.

Discussion

While the 2009 floods in Krishna basin was an extreme event that could not have been fully averted, reading the chronology of events together with the alternate reservoir operation scenario built from the simulation exercise above clearly shows that there was scope for a more timely response to the extreme rainfall. However, some experts who reviewed the situation after the floods recommended that there was no need to reschedule the regular reservoir operations based on a 'freak and isolated' event (Basheer, 2010) as it might lead to shortage of water for irrigation and power generation (Subba Rao, 2010). There is increasing concern among the research community and policy makers backed by scientific evidence that such extreme events are expected to be no longer 'freak and isolated' events, but more frequent and probably worse under the changing climate scenario. It would be a very risky policy choice to prioritize water for irrigation over loss of lives. Hence, the design of the reservoir operations urgently require an effective flood management protocol and disaster risk reduction strategy which can respond in real-time to rain and flood forecasting, and manage the floods both in the upstream and downstream more effectively.

Absence of Pre-depletion and Politics of Water Control

The analysis clearly suggests that the absence of pre-depletion of reservoir, if implemented, would have decreased the risk of inundation of low lying areas situated both in the backwaters as well as downstream. Pre-depletion would help in absorbing the peak inflows by facilitating storage of flood water in large quantities and then releasing gradually into the river course downstream. Andhra Pradesh state water policy 2008 had identified several structural and non-structural measures for flood management, one of which was provision of appropriate flood cushion in water storage infrastructure (GoAP, 2008). The well-drafted policy statement, however, never got translated into action during the floods. Pre-depletion process was not initiated till 1st October as all the reservoirs, except Nagarjuna Sagar, stored water close to the FRL (GoAP, 2009). The outflows from the reservoirs just matched or at some sites were significantly lower than the inflows showing that there was no pre-depletion. If pre-depletion of the reservoir had been done, the magnitude of the flood as well as the duration of inundation, particularly in Kurnool town and Alampur, would have been greatly reduced. These areas would nevertheless have been affected by floods but the degree of impact would have been reduced significantly. This can be seen in Figure 6 where the reservoir level could have been brought down to 267.15 meters by the afternoon of 1st October. Reservoir discharge at Srisailam in the simulation exercise was initiated only in the morning of 30th September, possibly due to administrative delays in decision making. Ideally, with dependable weather forecasts in hand the process should have been initiated gradually from the morning of 29th September itself.

It is intriguing why pre-depletion was not initiated, and the authors suspect whether the decision, not to release water from the reservoir was due to communication delays between the forecast system and the reservoir staff or motivated by political compulsions to retain as much water as possible for irrigation and hydro-power generation. Interview with the Chief Engineer of Srisailam seemed to suggest that since there was no certain and accurate knowledge of the behaviour of unpredictable events such as a cyclone, emptying the reservoir in anticipation might have put the dam managers (as well as the political leadership) in trouble[10]. Irrigation, particularly in South Indian States, is a major manifesto point in political campaigns. The risk of miscalculating the weather and the consequent water shortfall from pre-depletion of reservoir is one which the political leadership in the command areas cannot afford to or is not willing to take. The dam has to cater to the irrigation and power needs of millions of users, and the reservoir may not be emptied to a safe level as an early response to a cyclone or an extreme rainfall given the record of inaccurate predictions. It appears that this mix-up of political and regional interests with the techno-administrative structures led to the dams not serving the crucial flood control functions.

The fact that Krishna basin falls in three States presents the complex overlap between State administrative boundaries, with associated regional and political interests, and the hydrology of the catchment. The tendency to group the reservoirs in each State into a 'political' entity complicates flood prevention and mitigation. The inferences drawn from our field visits point to the complexities in the information flow between different dam offices situated in Karnataka and Andhra Pradesh. An unequal power structure has been created based on geographic position and political boundaries. While there could be disagreements and disputes in releasing and sharing water in normal conditions, confrontation should be avoided during such emergencies. Instead the agencies involved in these project offices across the States and in the State should collectively share crucial information on actual releases and predictions on the runoff responses of the intermittent catchments.

Technical and Administrative Laxity

While technological advances in India have made use of satellite technology to collect meteorological data and Geographic Information Systems for river basin planning, the country still seems not to have achieved the required degree of certainty in weather predictions and forecasts and its subsequent stream flow generation. This is all the more surprising as India has specially

[10] Interviewed on 1st November, 2011.

dedicated organisations, namely, Central Water Commission (CWC) and Indian Meteorological Department (IMD) to provide necessary forecasts and information. After the devastating floods that occurred in Krishna Basin in 1998, a study was commissioned by the Andhra Pradesh State (Basheer, 2010) to estimate the pre-depletion required to keep the Srisailam reservoir level at the Maximum Water Level (MWL) of 271.88 meters if there was an event of the design flood of 1,955,000 cusecs. The results also highlighted the need for an advance forecast mechanism that would provide information more than a day in advance. Due to constraints posed by manual operation of the spillways it would be extremely difficult to limit the water level to MWL if the forecasts were available in less than a day in advance. The 2009 floods illustrated that the forecast apparatus and spillway operations through mechanisation for emergency response has not improved much in the eleven years since the 1998 study.

The resolution of data and information on rainfall as well as stream flow, both spatial and temporal, is also very coarse despite high variability of rainfall in the region. A major reason is also the density and positioning of these gauges. Further, manual operations make these stations inaccessible in the event of a flood. Many of these stations were submerged or marooned during the days of floods in 2009. The inflow and outflow forecasts were not presented in CWC bulletins for Srisailam dam for the period 2nd October to 4th October. Similar was the case with rainfall data at several rainfall stations (CWC bulletins in GoAP, 2009). The lack of reliable forecast is a major hindrance to real-time decision making on flood management. There is also ambiguity in CWC bulletins regarding the magnitude of the disaster (Ramachandraiah, 2011).

There is also a lack of adequate assessment of the runoff from the intercepted catchment of the Srisailam reservoir. The runoff generated by this intercepted catchment flows into the reservoir directly without being stored in any other storage structure. The CWC measuring gauges are located at an interval of 100 km which does not adequately capture the flow processes at times of high intensity localized rainfall. The Chief Engineers who monitored the flood in real time at Almatti and Srisailam dams pointed to the lack of scientific and technical support to estimate the runoff and peak discharge generated from the intercepted catchments[11]. These dams have been functioning for several decades and the lack of such a decision support system even now is a matter of serious concern. The Committee on Integrated Operation of Krishna River Irrigation Projects (CIOKRIP), comprising of senior irrigation engineers, advisors to government in irrigation department and other experts, that monitored the floods in Andhra Pradesh has recommended the installation of automatic recording of rain and river gauges to transmit data to enable informed decision making without any loss of time, especially in the intercepted catchment of Srisailam (GoAP, 2009).

We must, however, also ensure that the data generated is utilized for prompt and proactive decisions, without being influenced by the political pressures discussed earlier. The storage buffer which was available at Nagarjuna Sagar

[11] From interviews with the then Chief Engineers who monitored the dam operations at Srisailam (1 November, 2011) and Almatti (24 November, 2011).

was not utilized until 2nd October (GoAP, 2009), even though there were no technical constraints to release water from Srisailam dam. The storage buffer if created could have acted as a cushion to absorb the peak runoff and later regulated to flow into the downstream. This would have been a better strategy for downstream areas as well since the delta regions downstream of Prakasam barrage have a low threshold to flood. The Government Order to maintain the reservoir level at FRL on 1st October every year could have been a reason for not releasing water[12]. While the decision not to irrigate the command area of Nagarjuna Sagar during the Kharif season was based on inadequate quantity of water in the reservoir, the inflows from pre-depletion in Srisailam could have helped irrigation in the command area of Nagarjuna Sagar for Rabi or summer cropping season. In effect, the command area of Nagarjuna Sagar was irrigated in that Rabi season from the releases of Srisailam stored during the flood.

Final Remarks

The case of 2009 Krishna basin floods illustrates the unintended consequences of purportedly rational choices of the State and the latent conflict of interest between citizen welfare and safety. The challenge, however, lies in pre-emptive and real-time response to disasters by the State even under situations where little information exists. Our analysis suggests that citizen safety seems to have been compromised through the interplay of political interests and technical inefficiencies in decision making during the flood event.

While some of the measures to this end such as flood risk identification, providing storage cushions in reservoirs, modernising current forecast systems and preparing the vulnerable communities were suggested in the State Water Policy of 2008, none of these seem to have taken effect in the case of Krishna basin floods. Further, the politics of water control and the tacit pressure by interest groups often stand in the way of building adaptive and resilient social-ecological systems. A participatory decision making process should be set in by the three States in the Krishna basin bringing together representatives of key political parties, water resource experts, regional interest groups and the concerned government departments. Extreme and unpredictable events are increasingly becoming part of the social-ecological system, due in part to the changes in global environment including climate. Identification of risks and deployment of adaptive management systems are crucial for responding to such events.

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[12] Interview with a CIOKRIP member on 2 November, 2011.

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