Tehri Dam – A Savior from Climate Change Led Extreme Events

Himalayan region is prone to rapidly changing weather at micro levels due to its topography, geology, tectonic activities and ecological fragility. In recent years, anthropogenic factors such as population, deforestation, land-use change and emissions due to urbanization have been implicated in extreme weather events in the Himalayas. The extreme events of cloud bursts, glacial lake formation and their outbursts, and significant changes in distribution of rainfall over space and time are common. Large reservoir based hydro projects are need of the hour in each and every Himalayan river basin to regulate the highly unevenly distributed runoffs for sustenance of dependent civilizations. Tehri dam project is built as a mega project on river Bhagirathi in one of the largest river Ganga Basin of India. It is a multipurpose scheme designed for storing surplus water of river Bhagirathi during monsoon period in its reservoir and releasing the stored water after monsoon period from the reservoir through power house to fulfill the irrigation and drinking water requirements of population in the downstream while providing 1000MW peaking power to Northern grid. It is not only providing the water for consumptive use of downstream population but also safeguarding them from the fury of recurrent floods. It is providing irrigation support to 8.74 Lac Ha. Land in UP by way of additional irrigation to 2.70 Lac. Ha. area and stabilization of 6.04 Lac. Ha. already irrigated area. It has created biggest reservoir in this region which has vast potential for saving the downstream population from extreme events happening due to climate change. THDC India Ltd., as a responsible owner of Tehri project, is in pursuit of new technologies and methodologies for continual improvements in its reservoir management program for ensuring safety of downstream population from recurrent floods, and safety of beneficiaries from droughts and water scarcity.

Atul Singh(DGM), Muhar Mani (Exec. Dir.) and Rajeev Vishnoi (Dir. Tech.)
THDC India Limited, Rishikesh, Uttarakhand, India

1.0 Context

India has a portion of its territory drought prone and some obligated to flooding. Around 80% of the surface water of the rivers goes to the sea unutilized while nation reels under the flood-drought syndrome. In our country significant lump of rainfall takes place amid around 90 days. This water needs to be stored for drinking, irrigation, generating power throughout the year along with the provisions of mitigating flood issues. Further, the inflow in the streams amid the lean time frame is extremely less when contrasted with storm and storage of water is additionally required to be done to enlarge the flows during lean period.

Sudden high-intensity rainfall (exceeding 100mm per hour) over a small area is termed as cloudbursts which mainly depend on geography of the area. Himalayan region is prone to rapidly changing weather at micro levels due to its topography, geology, tectonic activities and ecological fragility. It is being reported by scientists that cloudburst-like events in the Himalayas saw a steep increase from an average of five days per year between 2001 and 2005 to over 15 days per year between 2006 and 2013. While high-intensity rainfall events have increased, there has also been a fall in the annual number of days with rainfall in India. The average number of rain days has fallen from around 80 per year in early 2000s to 65 in the past 10 years.

In recent years, anthropogenic factors such as population, deforestation, land-use change and emissions due to urbanization have been implicated in extreme weather events in the Himalayas.

The Intergovernmental Panel on Climate Change says glaciers in the Himalayas are receding faster than in any other mountain range. Glacial lakes formed by melting glaciers are constrained by ice dams. Since the Indian summer monsoon coincides with the melting of glaciers, ice dams are weakened by the additional stress of the monsoons and are prone to bursting. A flash flood in Kargil in May 2016 was attributed to this.

While global temperature is recorded to have increased by about 0.8°C in recent decades, the increase has been greater in regions at higher altitudes. This is especially ominous considering that mountains are not only affected by climatic patterns but also contribute to the changing climate owing to the enormous deposits of water they hold in the form of glaciers, ice and snow. Nowhere is this situation truer than in the Himalayan-Tibetan massif, the world's highest region, where warming of 0.15-0.6°C per decade has been observed in the past three decades. The warming, according to some scientists, has wreaked havoc on the monsoonal patterns in the Himalayas.

In such a scenario when distribution of water over time and space is becoming highly uneven, large reservoirs could play an important role. One of the important roles of Tehri dam is to store flood water in the reservoir and safeguarding the downstream population from its devastating effect. Tehri dam, even in the worst scenario is capable to store the highest peak of Bhagirathi flood and thereafter passing the same to the downstream in a regulated manner to mitigate the impact of flood.

2.0 Introduction to Tehri Dam Project

Tehri dam project (Tehri HPP) is a multipurpose scheme designed for providing water for irrigation and drinking purposes along with generating 1000 MW of peaking power. At Tehri, a 260.5 M high with its crest at EL 839.5m, Earth and Rockfill Dam has been constructed across river Bhagirathi, just downstream of its confluence with river Bhilangana. The gross storage of dam is about 3540MCM at Full Reservoir Level (FRL, EL 830m). The live storage i.e. usable storage between FRL and Minimum Draw Down Level (MDDL, EL 740m) below which no power generation takes place is 2615MCM. The basic purpose of constructing such a big dam at Tehri is to store surplus water of floods during monsoon and thereafter releasing the same during non monsoon for irrigation and drinking purposes through power plant when river flow becomes lean. River Bhagirathi while traversing down joins river Alaknanda at Devprayag after 42 kms and river Ganga is formed. Thereafter, river Ganga traverses down towards Indian Ocean through Gangetic plains having major cities like Rishikesh and Haridwar in Uttarkhand; Kanpur, Allahabad and Varanasi in UP; Patna in Bihar, and Kolkata in West Bengal. So, the consequences of river Ganga floods could be disastrous for millions of people living along the river.

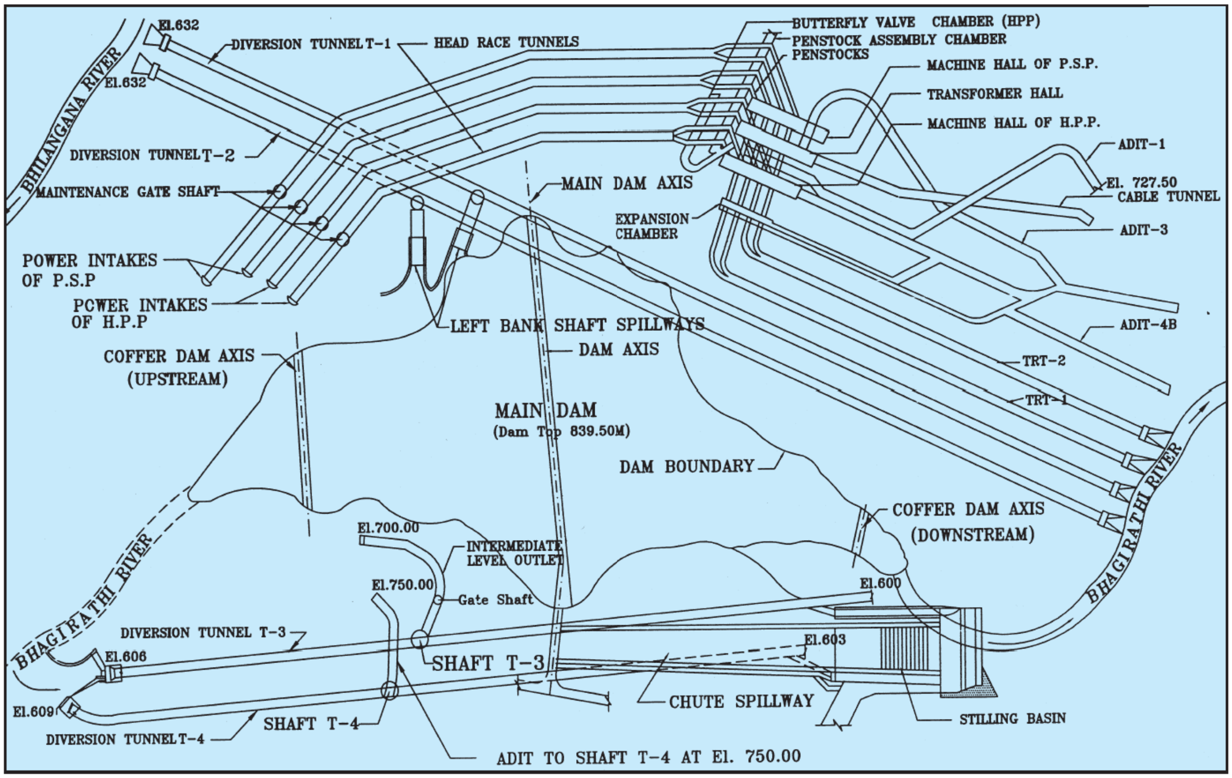


Fig. 1 : Layout of Tehri Dam Project

Fig. 2 : A View of Tehri Dam Project

3.0 Reservoir Management at Tehri Dam

The hydrology year in the Central Himalaya starts from 21st June. Around this time the reservoir level is brought down to its minimum at EL 740.00 i.e. MDDL. From 21st June to 31st October, which is monsoon period, excess water of floods is allowed to fill in the reservoir in such a manner that it reaches FRL by the time monsoon is over. From 1st November to 20th June, water stored in the reservoir between MDDL and FRL is allowed to be released thus touching MDDL by 20th June.

4.0 Release of Water for Irrigation, Drinking and Other Purposes

Water stored in the Tehri dam is for the intended use of population living downstream of Tehri dam and it is capable to irrigate 2.70 Lac hectares additional area and stabilization of 6.04 Lac hectares of already irrigated area in the Gangetic plains of Uttarakhand and Uttar Pradesh apart from providing 300 cusecs of water for drinking purposes of Delhi and 200 cusecs for UP states. As an estimate, it fulfills the drinking water requirement of 40Lacs population in Delhi and 30Lacs in UP. During lean months, discharge of river Bhagirathi at Tehri becomes as low as 40-50cumecs whereas minimum 150 cumecs is released from Tehri dam which increase availability of water in river Ganga.

5.0 Arrangements for Flood Regulation

The spillway system of Tehri dam has been designed to cater a PMF (1 in 10,000 years return period flood) of 15540cumes whereas the peak flood discharge of about 7500 cumecs has been observed so far in river Bhagirathi at Tehri. Its flood regulation system consists of gated chute spillway having 3 bays of 10.5m each with crest at EL 815m, gated left bank shaft spillway (LBSS) having 2 bays of 10.5m each with crest at EL 815m and 2 nos. un-gated right bank shaft spillways (RBSS) with crest at EL 830.2m. The routed flood discharge of complete spillway system (Chute Spillway, LBSS & RBSS) is 13043cumecs by allowing a lift of 5m in reservoir level above FRL (i.e water level rises to MWL EL 835m).

6.0 Operation of Spillways for prevention of flood

The operation of reservoir is governed by the reservoir rule curves which help reservoir operation team in taking decision about the regulation of discharge through power plant and spillway system. As per sequence of the spillways operation, Chute Spillway on the right bank goes into operation first by simultaneous lifting of all the three gates in case the water level in the spillage zone of reservoir tends to rise above the desired level followed. If the rate of rise is still not controlled, the Left Bank Shaft Spillway (LBSS) is operated by simultaneous lifting of both the gates. If the reservoir level continues to rise and reaches EL 830.2m with full opening of all the gates of chute spillway & left bank shaft spillway, the Right Bank Shaft Spillway (RBSS) start discharging the flood water automatically.

Fig. 3 : Chute (U/s & D/s), Right Bank & Left Bank Shaft Spillways (clockwise from top)

7.0 Prevention of Flood

One of the important roles of Tehri dam is to store flood water in the reservoir and safeguarding the downstream population from its devastating effect. Tehri dam, even in the worst scenario (1 in 10,000 years return period flood) is capable to store the peak of flood and thereafter passing the same to the downstream in a regulated manner when the flood recedes in river Alaknanada to mitigate the impact of flood. Since Tehri dam came into operation, maximum observed outflow has been about 1400 cumecs whereas maximum observed inflow has been about 7500 cumecs. Tehri dam has stored water of almost every flood event so far. It is not out of context to mention here that during the floods of 2010 and 2011, Tehri dam played a crucial role in averting the flood of higher order in the river Ganges by storing high flood inflows of Bhagirathi and Bhilangana and mitigated flood impacts on habitation along river Ganges in Rishikesh and Haridwar towns.

In the year 2010, when all the major rivers were running at their highest on 19-20 Sep, the discharge of river Bhagirathi went above 3500Cumecs (1,22,500Cusecs) at Tehri whereas only 800-900cumecs (28,000-31,500Cusecs) was released from the Tehri dam at the time of peak discharge. At this point of time discharge from Alaknanda and other tributaries of Ganga were also heavy and flood situation at Rishikesh and Hardwar was grim and water was much above danger level. Tehri dam by storing the most of the flood water of river Bhagirathi in its reservoir, mitigated the flood discharge in the river Ganges which otherwise would have further increased the water level at Rishikesh and Hardwar 1.5-2.0m. In the year 2011 on 16th Aug also, Bhagirathi discharge went above 3600cumecs (1,26,000Cusecs) but only 900cumecs (31,500Cusecs) was released.

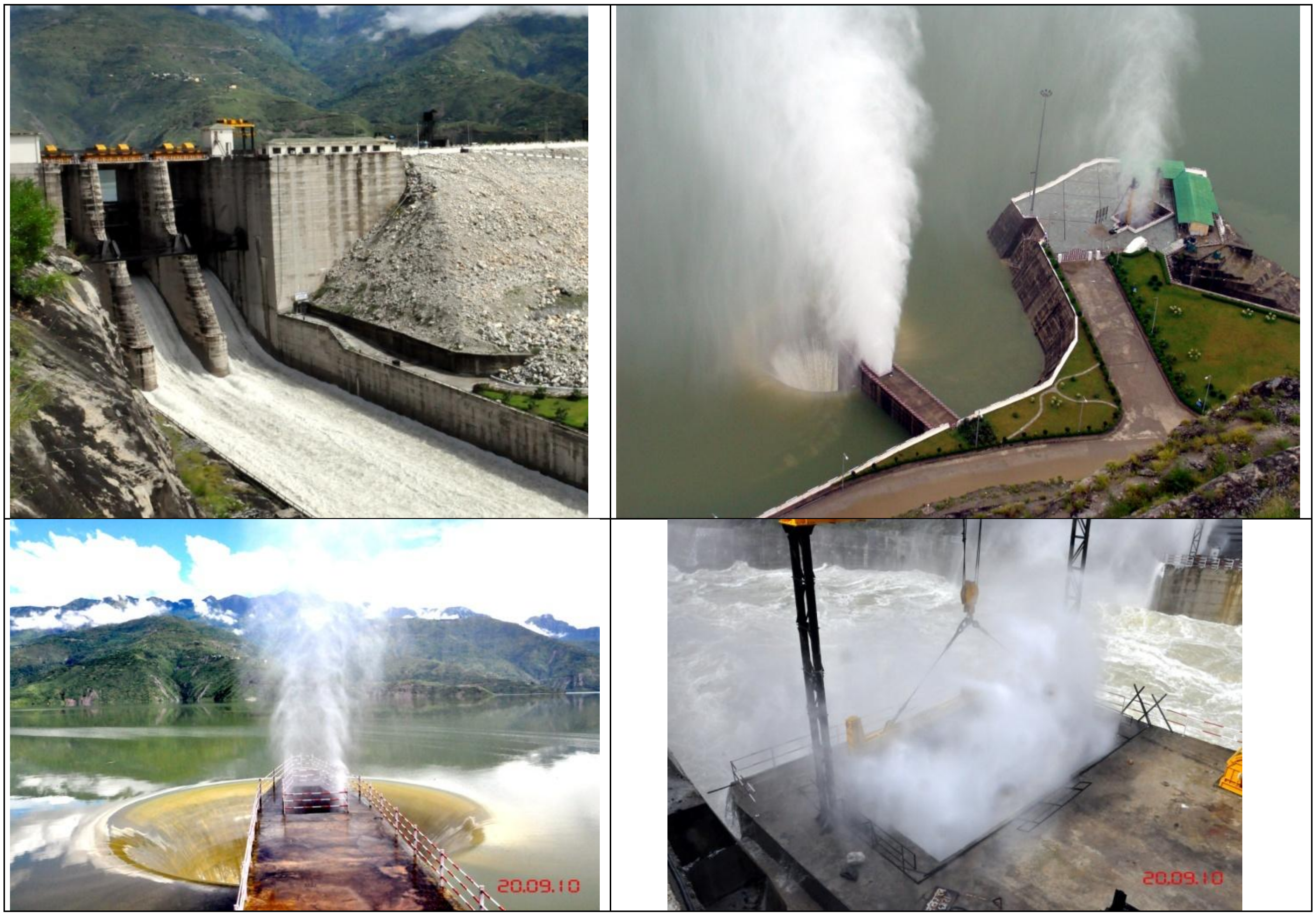


Fig. 4 : Spillways in Operation during 2010 Flood

In the flood of river Ganga during 16^{th} & 17^{th} June, 2013, discharge at Haridwar rose up to around 15,000cumecs (5,25,000 Cusecs) and water level reached 295.90m in the evening of 17^{th} (i.e. 1.90m above danger mark of 294.00m). In fact, this flood was the contribution of river Alaknanda and tributaries of river Ganga in between Devprayag and Haridwar only as the flood of the order of about 7,500Cumecs (2,62,500Cusecs) peak discharge in river Bhagirathi had been stored in the Tehri reservoir by releasing only 500Cumecs (17,500Cusecs). Had the Bhagirathi flood not been stored in Tehri dam, the peak discharge could have gone up to around 22,000Cumecs (7,70,000Cusecs) and devastation by this flood, not only at Haridwar but above and below Haridwar also, would have been beyond imagination with anticipated rise of 2.5 to 3.0m in water level above the observed highest level. It is gathered from the available records that June-2013 flood in Ganges would have been of the order or even higher which had happened in the year 1924, had Bhagirathi flood not been hold by Tehri dam.

This phenomenon can be easily imagined with the Tehri and non-Tehri scenarios. The actual observed discharge data of Bhagirathi at Tehri and Ganga at Haridwar from 16-18 June has been analyzed to understand this phenomenon. As velocity of water increases with the increase in discharge, the travel time of water from Tehri dam to Rishikesh and Haridwar via. Devprayag is about 8-14 hrs and 10-16 hrs respectively depending upon the discharge. In the case of 2013 flood, as the discharges in the rivers were high, travel time from Tehri to Rishikesh and Haridwar would have been about 10 hrs and 12 hrs respectively.

Graphs have been plotted to depict the probable impact of Bhgirathi flood on the flood of river Ganga at Rishikesh and Haridwar. In **Fig-5**, graphs showing inflow and outflow at Tehri have been plotted from 0.00hrs of 16th which depicts the discharge stored in the Tehri reservoir. In **Fig-6**, graphs showing observed discharge at Rishikesh from 10.00hrs of 16th and anticipated discharge at Rishikesh after superimposing the stored discharge of Bhagirathi at Tehri over the observed discharges of Ganga at Rishikesh with 10hrs time lag have been plotted. The same procedure is adopted for plotting anticipated discharge at Haridwar (**Fig.-7**) after superimposing the stored discharge of Bhagirathi at Tehri over the observed discharges of Ganga at Haridwar with 12hrs time lag.

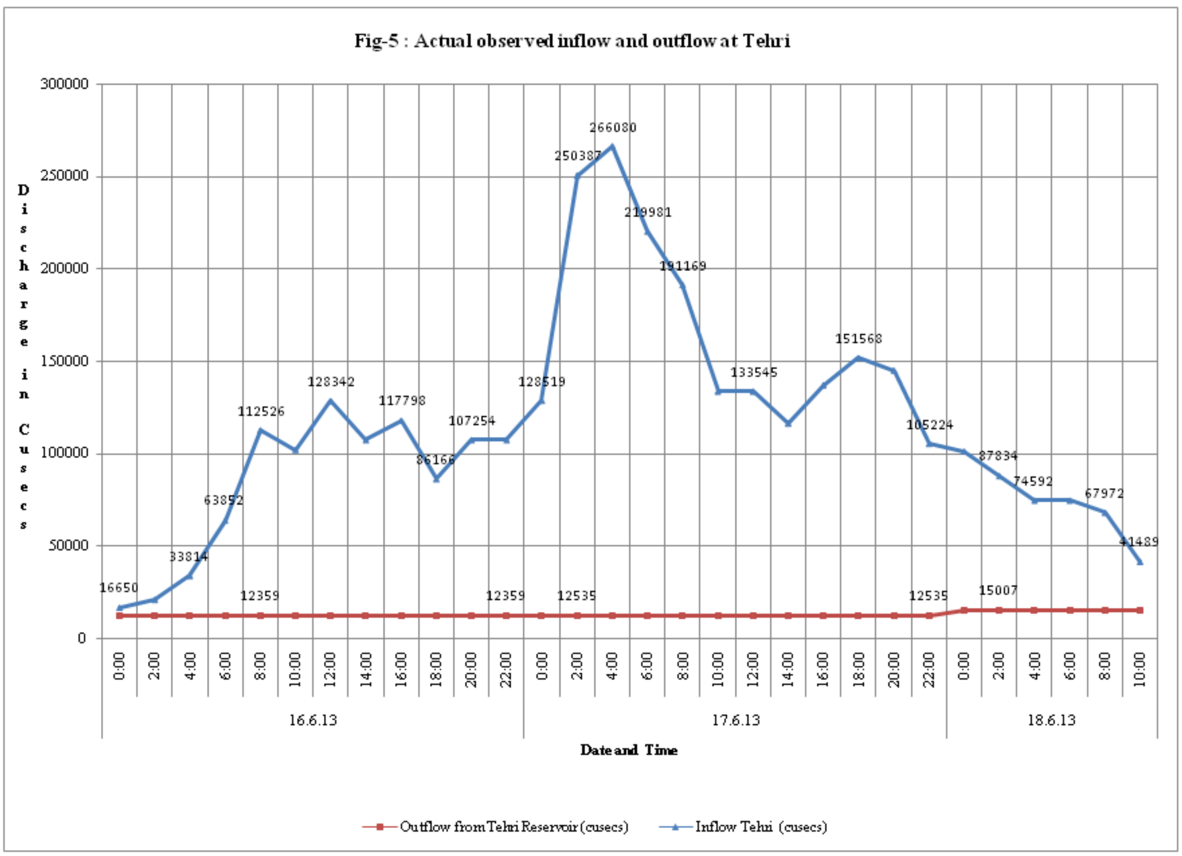


Fig -6 : Actual observed discharge of Ganga at Rishikesh and anticipated discharges after superimosing Tehri actual inflows with 10 hrs time lag

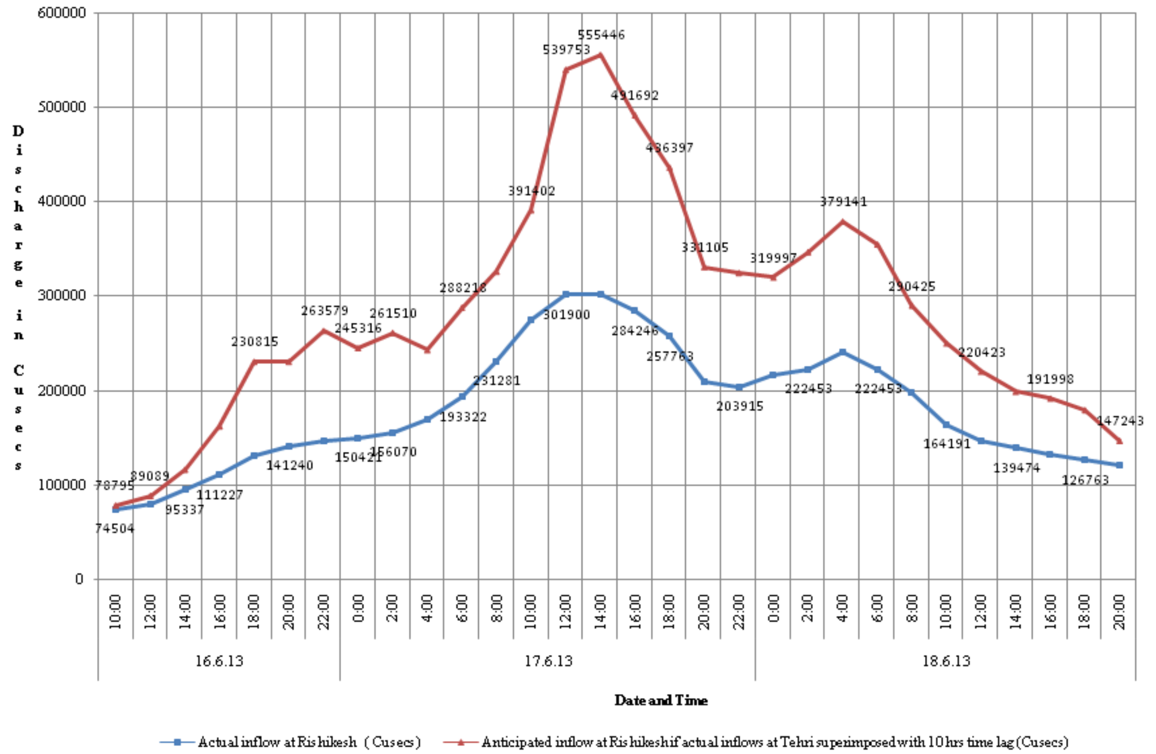
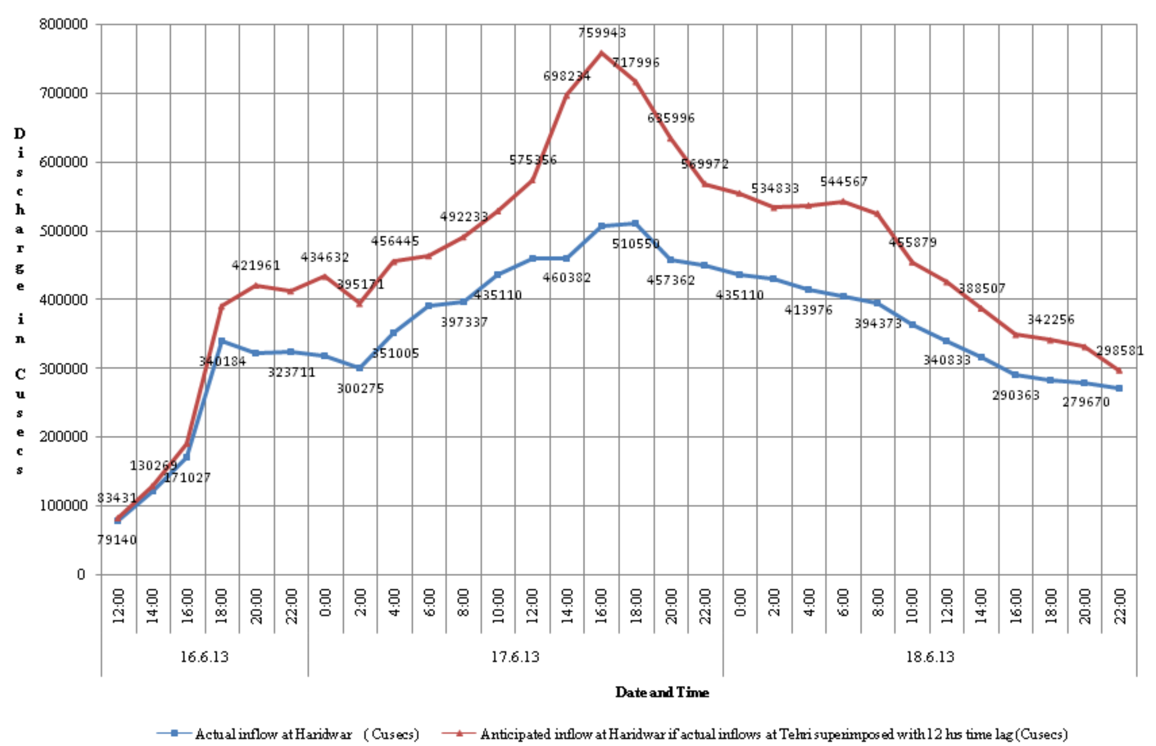


Fig -7: Actual observed discharge of Ganga at Haridwar and anticipated discharges after superimosing Tehri actual inflows with 12 hrs time lag



8.0 Leveraging Technologies for Ensuring Safety of Downstream Population

The safety of habitation and infrastructure in the downstream of dam is paramount for which dam owner need to make all out efforts for the safe operation and maintenance of dam. Unsafe operation of dam could be disastrous instead of saving the downstream habitation. Realizing this fact, THDCIL is taking all the measures suggested by CWC for safety of dam. Real Time Inflow Forecasting System for Tehri dam and Advance Early Warning System for downstream areas are among such measures taken by THDCIL.

8.1 Real Time Inflow Forecasting System

The catchment area of Tehri Dam is 7511 sq. km. out of which approximately 2323 sq. km. is snow bound. The catchment is prone to flash floods now a day. The inflow forecast helps in better management of reservoir, ensures safety of Dam by giving advance information regarding the inflow into the reservoir from the catchment and increases the flood warning time to ensure safety of downstream population. Real time inflow forecasting system has been established for Tehri dam reservoir which comprises of eleven number automatic weather stations and four number automatic G&D stations in its catchment area with control room (earth station) at Tehri dam. The system is capable to observe real time meteorological and hydrological data and transmitting the same to earth station established at Tehri for further processing of data for forecasting the inflow for Tehri reservoir. Mathematical models for forecasting the inflow has been developed by IIT, Roorkee. The system is presently operational and issuing the forecasts with 6 hrs lead time based on observed data, and day ahead forecasts based on observed data and IMD forecasts.

8.2 Advance Early Warning System

Once decision for releasing water from the dam is taken, there should be arrangements to disseminate the information quickly and reliably. In order to disseminate information to the downstream population up to Rishikesh about water releases from Tehri and Koteshwar dams, an early warning system has been established through Disaster Mitigation and Management Centre (DMMC), GOUK, Dehradun. The system with its control rooms at Koteshwar dam and DMMC, Dehradun comprises of sirens and speakers at eight stations from downstream of Koteshwar dam to Triveni Ghat, Rishikesh. The complete system including sirens, speakers and command software etc. are from M/s Federal Signal, USA. The mode of communication from control room to sirens is VSAT and GSM based. The system is having features like programmed activation, live paging, sirens, recorded voice messages and direct plug in facility for announcements at siren locations. The system is presently operational and ensures safety of downstream population by alerting them through sirens and recorded voice message about the increase of water level due to release of water from PH and Spillways.

9.0 Conclusion

In the Himalayan region, high intensity rainfall events are increasing rapidly whereas annual number of days with rainfall in India is decreasing. In Uttarkhand only, 13 incidents of cloud bursts were observed during 2018 whereas in 2019, numbers of such incidents increased to 23. It is also surprising that despite so many cloud burst incidents, Uttarkhand received 18% less monsoon rainfall in 2019. In the present scenario when naturally available water is varying over space and time drastically, none other than storage reservoir based scheme like Tehri dam project could be helpful in conserving the precious water. Small schemes like ROR or regulating dams / barrages could be a solution for power requirement or regulation but they can't withstand flash floods caused by cloud burst. In order to fulfill ever increasing demand of our population, integrated watershed management consisting of regulating structures like dams (big as well as small), barrages and canal network is also required for proper distribution and utilization of available water. The river linking project is the ultimate long term solution for water woes of India.

It will not be hypothetical to state that, Tehri dam, as conceived and designed, is playing its role of conservation of surplus water during monsoon season even in the recent trend of varied spatial and temporal distribution of rainfall within its catchment area. The releases from the dam have been nominal even in the worst cases since its commissioning which is clearly evident from the records of year 2010, 2011 and 2013. Apart from providing 1000 MW peaking power to Northern grid, it is providing additional water to the downstream population for use in drinking and irrigation purposes, and also safeguarding them from the fury of recurrent floods. The systems installed at Tehri dam ensure safety of the downstream population even more than it was prior to it came into operation. Apart from direct benefits, there are so many indirect benefits also like tourism, adventure sports and hospitality etc. which can't be undermined.

References:-

-*Report in Down to Earth on 03 July' 2018* - *Uttarakhand cloudburst: Urbanisation, Warming continue to intensify the impact*

-*Report in SANDARP on 11 Dec. 2019*- *Uttarakhand Cloud Bursts in Monsoon 2019: No Doppler Radars Six Years Since 2013 Disaster*