August 10, 2018
Cheruthoni Dam, Idukki District

CHAPTER III
FLOOD FORECASTING AND RESERVOIR OPERATION

3 FLOOD FORECASTING AND RESERVOIR OPERATION

Flood Management includes planned engineering measures (structural and non-structural) aimed not only at controlling the flood, but also providing optimum utilisation of stored surplus water during lean seasons. Structural measures include multipurpose reservoirs and retarding structures for storage of flood waters, channel improvements to increase flood carrying capacity of the river, embankments for keeping the water away from flood prone areas, improvements in drainage system etc. which have the effect of restricting the movement of flood water into flood plains. Non-structural measures such as flood forecasting and warning, soil conservation, flood proofing, flood plain zoning etc. largely depend upon how accurately the estimation of future stage or flow of incoming flood and its time sequence at selected points along the river, could be predicted[35].

The devastating floods in Kerala during August 2018 severely affected 13 of the 14 districts in the State resulting in huge loss of life and property. Kerala received 2,346.60 mm rainfall between 01 June and 19 August 2018, which was about 42 *per cent* higher than the normal rainfall of 1,649.50 mm during the same period[36]. Further, the rainfall over Kerala during June, July and August 01 - 19, 2018 was 15 *per cent*, 18 *per cent* and 164 *per cent* respectively above normal (CWC, 2018). As the Performance audit included examining technical aspects which required expert support, Indian Institute of Science (IISc) Bangalore was engaged as Consultant to study the Kerala floods of August 2018, from a hydrological perspective. The focus of the study was the Periyar river basin which covers an area of 5,159.71 square kilometres. The following paragraphs are the findings of Audit including those based on the study undertaken through IISc, Bangalore.

3.1. Adequacy of rain gauges in Periyar basin

Rain gauges[37] are instruments used by meteorologists and hydrologists to gather and measure the amount of liquid precipitation over an area in a predefined period of time. Measurement of rainfall at several critical locations in the basin is extremely important because of the high spatial variability of rainfall. The accuracy of rainfall estimation over a region with significant spatial variability in rainfall is dependent on distribution of rain gauges in the region. Rain gauge density[38], therefore, plays an important role in quantifying the rainfall amount over a region.

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35 Manual on Flood Forecasting, CWC, 1989
36 CWC Report, 2018
37 Rain gauges are also known as udometers, pluviometers, or ombrometers.
38 Rain gauge density is defined as the ratio of the area of the catchment to the number of rain gauges there.

An examination of the existing density of IMD rain gauges[39] in the Periyar basin with respect to norms stipulated by the Bureau of Indian Standards[40] was carried out by IISc, to assess the adequacy of rain gauges in the basin. **Figure 3.1** shows the locations of the existing rain gauges and flow gauges in the basin.

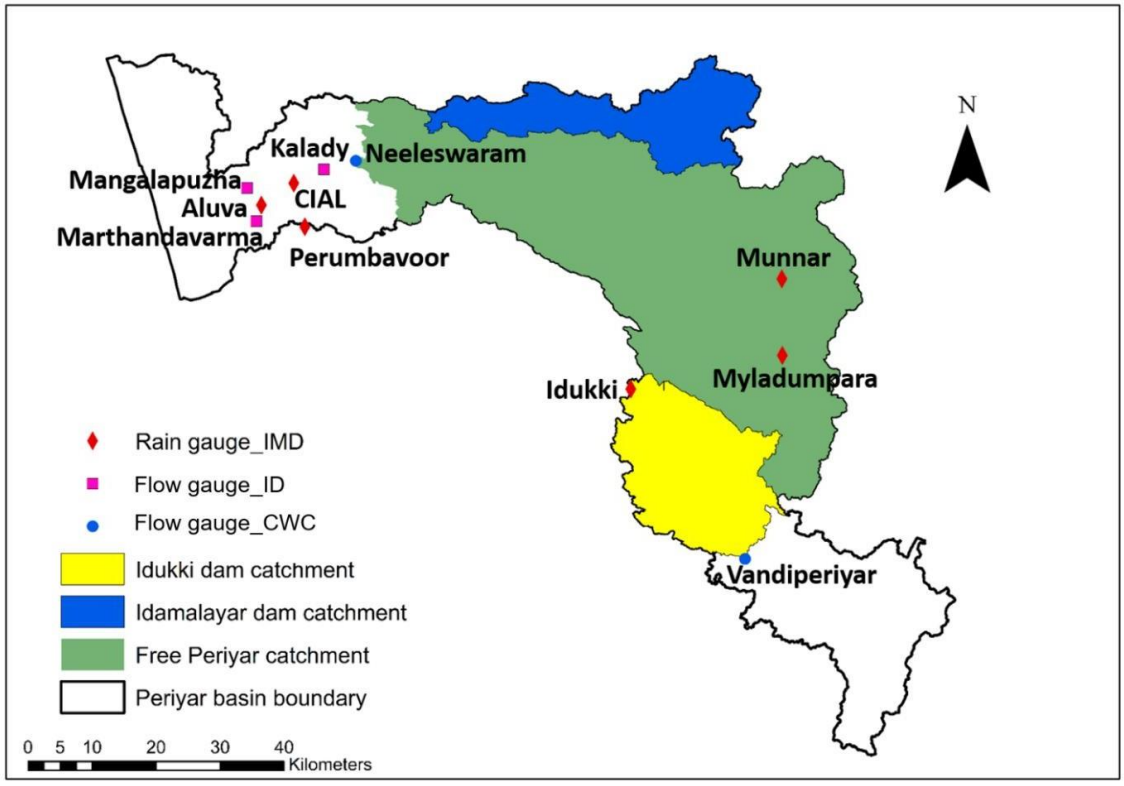

Figure 3.1: Locations of existing rain gauges and flow gauges in the Periyar basin (2019)

(Source: IMD, CWC and Irrigation Department)

The rain gauge density as recommended by BIS code (IS 4987:1994) is given in **Table 3.1**.

Table 3.1: Recommended minimum rain gauge density

Region type	Rain gauge density (sq. km per gauge)
Plains	500
Regions with average elevation of 1000 m above MSL	250-400
Hilly areas with heavy rainfall	150

(Source: BIS Code, IS 4987:1994)

Periyar basin is characterised largely as a hilly terrain upto Neeleswaram and receives heavy rainfall. Therefore, according to the IS 4987:1994 one rain gauge per 150 sq. km is required in the basin, up to Neeleswaram (Region type III), whereas, the area downstream of Neeleswaram lies in the Region type I

[39] IS 5225:1992 provides that the Director General of Meteorology, New Delhi has been designated the sole authority for ensuring the correct rainfall registration in India.

[40] IS 4987:1994 Recommendations for establishing network of rain gauge stations.

(Plains) and therefore requires one rain gauge per 500 sq. km. The Periyar basin is divided into a number of sub-catchments. The details of additional rain gauges needed in the catchments are given in **Table 3.2**.

Table 3.2: Number of IMD rain gauges in place and additional numbers required

Catchment	Area (sq.km)	Density of rain gauge required (sq.km/gauge)	Minimum number of rain gauges required	Existing number of IMD rain gauges	Additional numbers required
Start of the basin boundary till Vandiperiyar	737.61	150	5	0	5
Idukki	569.55	150	4	1	3
Idamalayar	469.49	150	4	0	4
Free Periyar (downstream of Idukki and Idamalayar till Neeleswaram)	2367.22	150	16	2	14
Downstream of Neeleswaram	1015.83	500	3	3	0
Total	**5159.71**		**32**	**6**	**26**

(Source: Kerala Floods 2018, Report of IISc, Bangalore, July 2020)

It is therefore evident that against the recommended minimum requirement of 32 rain gauges in the Periyar basin, only six rain gauges were in place. Audit observes that the shortfall of 26 rain gauges in the basin resulted in lack of real time data on spatially distributed rainfall which could have an adverse impact on flood forecasting and alleviation measures.

Additional Chief Secretary, Water Resources Department, GoK, stated (November 2020) that the Irrigation Department maintains 10 meteorological stations with rain gauges in Periyar basin. Audit was also informed that installation of 18 Tipping Bucket Rain Gauges was in progress and Government intends to develop a full-fledged inflow forecasting and flood early warning system National Hydrology Project (NHP).

Though agencies like KSEBL, Irrigation Department etc. maintain rain gauges in Periyar basin, IMD informed (February 2021) Audit that only data generated by those gauge stations conforming to IMD standards (measured at 0830 hours IST daily and reported to IMD) is utilised by IMD. Since data from Irrigation Department gauges were not utilised by IMD, they were not considered while assessing the adequacy of rain gauges in Periyar basin. However, as the already installed/ proposed to be installed rain gauges under the NHP could also be useful for increasing the accuracy of rainfall estimation by IMD, the Irrigation Department may examine the feasibility of sharing of data with the IMD for the purpose by ensuring that the gauges conform to IMD specifications. This needs to be prioritised as irregular distribution of rain gauges could create an information gap in time and space, ultimately hindering decision-making.

The Government further replied (April 2021) that the equipment for installing 18 Tipping Bucket Rain Gauges in Periyar basin under National Hydrology Project have IMD specifications and therefore, the data generated by TBRGs of Irrigation Department could be used by the IMD. Nine of these have

already been installed and the remaining nine TBRGs will be installed, commissioned and made fully operational by 31 May 2021.

Recommendation 3.1: Adequacy of the number of rain gauges capable of generating real time data in order to ensure accuracy of rainfall estimation may be ensured. System of sharing data from rain gauges with IMD must be put in place at the earliest.

3.2. Adequacy of flow gauge density in Periyar Basin

Flow gauge[41] density helps to determine the minimum network of flow gauges required to avoid serious deficiencies in developing and managing water resources[42]. Adequate flow gauge density is especially important in flood prone regions to provide useful information on flow depth/ discharge to help in operational decisions.

Audit observed that against the requirement of three flow gauges in the 5,159.71 sq.km. Periyar basin as per World Meteorological Organisation 2008 norms (one flow gauge per 1,875 sq.km. hilly terrain), five flow gauges were installed in the Periyar basin by CWC and the Irrigation Department, of which three gauges at Kalady, Mangalapuzha and Marthandavarma are maintained by the Irrigation Department and the other two gauges at Neeleswaram and Vandiperiyar are maintained by the CWC. Thus, the existing number of flow gauges in the basin as a whole, was adequate. However, there was shortfall of one flow gauge in the free Periyar catchment, comprising of 2,367.22 sq.km of hilly terrain. Thus, in addition to the Neeleswaram flow gauge, an additional flow gauge needs to be located just upstream of Bhoothathankettu barrage[43], which is a major control point in the basin, receiving flows from a large free catchment (contributed by Perinjankutty, Pooyamkutty and Muthirapuzha tributaries and overflows/ spills from Idukki, Lower Periyar and Idamalayar dams).

Additional Chief Secretary, Water Resources Department, GoK replied (November 2020 and April 2021) that in addition to the three gauges in the Periyar basin, it is proposed to install three[44] Radar Level Sensors (RLS) under NHP. Once it is fully operational, it is expected that heavy flow from upper catchment of Bhoothathankettu could be measured and observed on real time basis. Chief Engineer, Irrigation Design and Research Board (IDRB) has assured that the RLS, which will provide real time data in every 15 minutes, will be commissioned and made fully operational by 31 May 2021.

3.3. Flood Forecasting Stations not set up in the State

The activity of flood forecasting includes level forecasting and inflow forecasting. Level forecasts are issued once the water level in a river touches a

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41 Flow gauge is a device that measures flow rate of a liquid, gas or steam. It could be measuring, for instance, the velocity of fluid over a known area.

42 Source: World Meteorological Organisation (WMO), 2008.

43 IISc Report on Kerala Floods by P P Mujumdar et al.

44 at Bhoothathankettu, Malayattoor and Neriyamangalam

pre-defined warning level (usually one meter below the danger level but dependent on threat perception of the particular location). The level forecasts help user agencies in deciding mitigating measures like evacuation of people and shifting people and their movable properties to safer locations. Inflow forecasting is used by various dam authorities in optimum operation of reservoirs for safe passage of flood downstream as well as to ensure adequate storage in the reservoirs for meeting demand during non-monsoon period.

Audit noticed that CWC requested (November 2011) Government of Kerala to provide the list of reservoirs which required inflow forecasting stations and list of cities/ towns for flood forecasting purpose. CWC confirmed (August 2019) to Audit that GoK did not furnish the details and hence, no Flood Forecasting Stations (FFS) were set up by the CWC in the State. This was despite 275 flood forecasting stations having been set up by CWC across the country by the year 2017.

The Department of Water Resources (WRD) replied (November 2020) that the Irrigation Department had to address specific technical matters such as the technology of flood forecasting proposed to be used, usability of the system in steep, flashy rivers in Kerala. The viability of an effective forecasting system suitable for peculiar terrain of Kerala was discussed with CWC officials on several occasions.

Audit however noticed that subsequent to floods of 2018, three level forecasting stations and two inflow forecasting stations were installed (2019) by CWC in the State indicating the suitability of the FFS in the State.

The Department informed (April 2021) that the list of flood prone cities/ towns requiring flood forecasting stations and also the list of reservoirs, which need inflow forecasting has been forwarded on 17 April 2021. Government is on course to develop a full-fledged inflow forecasting and a flood early warning system under National Hydrology Project operational in all river basins in Kerala for real time monitoring by installing 99 Tipping bucket Rain Gauges, 56 Radar Level Sensors and 13 Automatic Weather Stations. Equipment including data loggers have been procured and 33 TBRGs, one RLS and seven AWS installed and the remaining would be installed by 31 May 2021.

The failure of GoK to provide list of reservoirs and cities/towns to CWC resulted in non-installation of FFS in the State and resultant deprival of data which State could have utilised for flood forecasting purpose.

3.4. Non-completion of a project intended for obtaining data required for flood management

The project Modernisation of Hydrology Information System implemented by Irrigation Department, GoK involved supply, installation and commissioning of Real Time Data Acquisition System (RTDAS) capable of delivering real time data on rainfall, streamflow etc. and assuring data retrieval for a specific period without interruption. The objective of RTDAS was to provide reliable

hydrological information required for flood/ drought management, water availability and quality management, streamflow forecasting, integrated operations of reservoirs etc.

Based on competitive tender, the work was awarded (April 2014) to the lowest bidder[45] for ₹1.34 crore with time of completion (TOC) as three months (July 2014). The TOC was initially extended up to 25 October 2014 based on the supplier's request. Citing delay in installation of server (to be done by Irrigation Department), it was extended upto 30 September 2016. No further extension of time was provided and ₹30.19 lakh being the cost of 14 Radar Level Sensors (RLS) was paid to the firm in June 2016.

Audit observed that though all the equipment were installed, many of them were not functional (status as of August 2020) as detailed in **Table 3.3**.

Table 3.3: Status of Real Time Data Acquisition System

Sl. No.	Item of work	Quantity	Unit rate	Total quoted amount	Status of execution (as of August 2020)
1	Supply, installation, testing and commissioning of Tipping Bucket Rain Gauges (TBRG) with data collection platform consisting of data logger	8	79,080	6,32,640	Data from one TBRG was not being received in the central server.
2	Supply, installation, testing and commissioning of Automatic Weather Stations (AWS) with data collection platform consisting of data logger	19	2,65,300	50,40,700	Data from nine AWS was not being received in the central server.
3	Supply, installation, testing and commissioning of Radar Level Sensors (RLS) in river gauging stations with data collection platform consisting of data logger	18	2,75,100	49,51,800	Data from five RLSs was not being received in the central server.
4	Installation and commissioning of ground station consisting of telemetry GSM/GPRS transmission system and software to evaluate streams of data	1	2,25,000	2,25,000	Commissioned in June 2019
Total (less discount offered two *per cent*)				1,06,33,137	
AMC for five years after two years' warranty period				27,64,200	
Grand total				**1,33,97,337**[46]	

(Source: Data furnished by the Irrigation Department)

The Department had also noticed errors in data received from certain equipment and had intimated Audit that the process of verifying the reliability of data by comparing it with manual data was underway. Audit noticed that though more than five years have elapsed, the objective of obtaining real time hydrological data useful for improving flood management capabilities remained unachieved.

Government replied (November 2020 and April 2021) that even though instruments with IMD calibration and certification were installed, the instruments failed to deliver reliable data on real time basis. Most of the data could not be retrieved through data logger and showed variations when compared with manual reading. Despite Irrigation Department's constant follow-up, the firm did not attend to the same. Notice to the firm was issued on 16 April 2021 for termination of contract and the concerned Chief Engineer

[45] M/s. Astra Microwave Products Ltd, Hyderabad

[46] The firm had quoted 11.82 and 54.16 *per cent* less than the estimated amount for equipment and AMC respectively.

has been directed to take steps to blacklist the firm for breach of agreement conditions.

3.5. Inadequacies of State Emergency Operations Centre

3.5.1. Non-availability of data required for the functioning of Decision Support System established in State Emergency Operations Centre

The State Emergency Operations Centre (SEOC) is the research and technology laboratory of KSDMA and is the State nodal office for the collection, compilation and analysis of data received from all Government departments and institutions on a no-cost basis. DM Plan 2016 envisaged SEOC to be equipped with a full-fledged state-of-the-art IT and Communication network with an intelligent Decision Support System (DSS) capable of prediction and early warning of major hydro-meteorological hazards and support for emergency operation.

The work of setting up an Information Technology and Communication System (IT & CS) in SEOC which includes DSS was awarded (April 2016) to Keltron, a State Public Sector Undertaking with the targeted date for completion of work fixed as April 2019. The estimated cost of the project was ₹5.96 crore to be met from the 13th Finance Commission grant. The work was to be completed in three phases. While the first phase involving IT set up, base configuration etc. was completed in January 2017, the second phase which involved development of Decision Support System, Standard Operating Procedure etc. was completed in October 2017. The third phase *viz.*, scaling to the new SEOC building and continued handholding remains to be completed (March 2020). KSDMA stated that 85 *per cent* of the project was completed and payment of ₹4.54 crore made to Keltron till date (October 2019). The target date for completion was extended up to 31 March 2020 at the request of Keltron.

According to the Flood Management Organisation of Central Water Commission, flood forecasting requires hydro-meteorological data on real time basis at least hourly or sub-hourly for the parameters of rainfall and water level. According to the pre-development solution design document prepared by M/s. Element Blue[47] for KSDMA, 10 sets of real time data which includes rainfall, temperature, humidity etc. were to be provided by KSDMA.

KSDMA stated (March 2020) that though the DSS was capable of ingesting multiple real time data, KSDMA was unable to enable this part since no real time data was provided by IMD, CWC or Geological Survey of India. Audit examination of records to ascertain reasons for dearth of real time data necessary to make the DSS fully operational, revealed the following.

[47] M/s. Element Blue prepared the solution design document which describes the system requirement, operating environment, system and sub system architecture, files and database design, input formats, output lay-outs detailed designs.

- None of the 69 manual rain gauges utilised by the Indian Meteorological Department (IMD) generate real time data. Real time data is obtained only from the seven functional Automatic Weather Stations and 10 Automatic Rain Gauges of IMD.
- The 22 rain gauges installed by KSEBL also do not generate real time data.
- Out of the 39 river gauges operated by Central Water Commission, only one generated real time data. However, Audit observed that KSDMA had no access to this data, though CWC was sharing data from this telemetric station with the Karnataka State Disaster Monitoring Centre.
- Audit noticed that the DSS was to function on the basis of 10 available data sources which included, *inter alia*, weather data source (rainfall, temperature, humidity etc.), satellite images and derivatives, water data (reservoir water level, river flow data etc.), seismic data etc. However, Audit observed that historical data available with KSDMA was limited to rainfall, temperature, humidity and dry bulb temperature (provided by IMD).
- The Flood Hazard Susceptibility map prepared by NCESS in 2010 has been configured in the DSS despite it not possessing the necessary characteristics of such a map, as pointed out in Paragraph 2.4 of this Report. Since the DSS looks up in this map for the nearest rainfall scenario and identifies the nearest probability scenario from the look up library and uses it for identifying critical assets[48] and areas needing external assistance[49], the inadequacies of the map would impair the capabilities of the DSS.

Audit noticed that before commencement of the IT and CS project, the State IT department had raised doubts (June 2014) about the availability of data and cost involved in collection of data. KSDMA clarified (July 2014) that weather data (near real time to daily), seismic data (near real time), reservoir data (daily digital from KSEBL) and historical data from IMD and Irrigation Department (stream flow) were available with KSDMA. Being the nodal agency for collection, compilation and analysis of data, it was incumbent upon SEOC to ensure availability of required data for prediction and early warning of major hydro-meteorological hazards and intelligent support for emergency operation. However, as per details furnished to Audit, data presently available with SEOC was limited. The absence of real time/ historical data and an adequate flood hazard map would impair the functioning of the DSS.

Department of Revenue and Disaster Management in its reply dated (December 2020) stated the following points;

[48] critical assets such as schools, hospitals, shelters etc.
[49] Source: Pre-development solution design document.

- Establishing warning systems and providing disaster alerts are the functions of notified Central agencies under the Disaster Management Act 2005/ NDM Plan and not of KSEOC.
- Decision Support System of KSDMA is not for analysing raw data and generating alerts. KSDMA's function is confined to crisis management in accordance with the magnitude of an event as projected by the notified agencies.
- KSDMA referred to GOs dated 18 October 2019 and 06 May 2020 as examples of KSEOC's efforts for ensuring real time data. Since 2017, it has been engaging with IMD (which has statutory responsibilities laid down in NDM Plan) for sourcing real time data.
- CWC has only one real time monitoring station in the State. It is the responsibility of CWC to have increased the number after assessing the hazard potential. Kerala was never identified nationally as a priority State for implementation of flood monitoring systems. Detailed demands of KSDMA for improving flood forecasting was placed before CWC (March 2017) and the Rajya Sabha Committee on Petitions (30 May to 02 June 2017).
- One of the fundamental requirements of real time operations is the availability of accurate river flow forecasts. The dilemma of prudent inflow forecasting is reflected in the counter affidavit of Government of India in WP (C) 2996 of 2018 where CWC has admitted the limited scope of riverine flood forecasting systems in Kerala. The technology and science are not developed as yet to implement a pragmatic and usable forecasting system in Kerala's flashy rivers. Until these technical bottlenecks are resolved, it is not possible to determine the feasibility and usability of inflow forecasting and flood forecasting in the rivers of Kerala. Hence, Audit observation that KSDMA/ KSEOC should have such data was contested.
- DSS of KSDMA is a management decision making tool and not meant for such analysis.
- KSDMA possesses data of satellite images, various derivatives such as slope, aspect, NDVI, Seismic Catalogue etc. as well as reservoir data, together with over 60 geospatial data. KSEOC utilised the available data for providing risk maps to districts[50] for enabling crisis management. Maps of immediate threat zones due to any opening of shutters of Cheruthoni dam of Idukki reservoir overlaid with satellite images were provided to DEOCs of Idukki, Thrissur and Ernakulam on 28 July 2018 based on the inundation history of 2013 and rapid assessment of available satellite images.

[50] by email with maps dated 28.07.2018 from KSEOC to DEOC

- The Flood Susceptibility Map of Kerala is accurate enough for all practical purposes and can be used for DM preparedness till such time as CWC is able to provide large scale flood prone area maps.
- KSDMA was in receipt of daily rainfall data from IMD. Seismic data was available real time during the period from KSEB- KSDMA joint project. Reservoir data of KSEBL reservoirs was available in digital format from KSEBL as well as historic data from IMD, Irrigation department and Ground Water department. Inadequacy of real time monitoring systems of Central agencies is a reason for KSEOC developing a system with futuristic data management possibility.

Audit observes that the DM Plan 2016 envisaged SEOC to be equipped with a full-fledged state-of-the-art IT and Communication network with an intelligent Decision Support System (DSS) capable of prediction and early warning of major hydro-meteorological hazards and support for emergency operation. Even two years after the targeted date of completion of April 2019, the system cannot be relied upon to predict and give early warning of major hydro-meteorological hazards since its effective functioning is dependent on the receipt of externally sourced real time data which is yet to be made available. The IT department of GoK had even before commencement of the project raised doubts about the availability of data for functioning of the DSS. The reply of GoK is silent about how DSS is to be optimally used by KSDMA in the absence of required data and how the State proposes to meet the pressing need of an effective early warning system. The inadequacies of Flood Prone Area Map of the State and the lack of GoK response to the request of CWC to install Flood Forecasting Station have also been discussed in Paragraphs 2.4 and 3.3 of this Report. Prudent project implementation would require the consideration of the likelihood of essential inputs being available in time, for effective functioning of the system and fulfilment of what is stated in the State's Disaster Management Plan.

Recommendation 3.2: Keeping in view the criticality of flood management projects and in order to ensure their successful and time-bound implementation, Government may ensure that projects for procurement/ installation of systems meant for flood management such as information systems, decision support system etc.,

(i) are entered into only after fulfilment of a pre-determined common list of prerequisites as well as consideration of aspects such as a) the likelihood of timely availability of input data from all sources including external sources, b) whether Government would be in a position to meet its commitments such as installations of servers without delay, previous experience of bidders etc. and

(ii) are covered by a stringent monitoring mechanism with clearly defined responsibilities and accountability.

3.5.2. Maintenance of Communication Infrastructure

The Disaster Management Act, 2005[51] envisages that the State Executive Committee would ensure that communication systems are in order. Recognising that communication systems were the first to be affected in the event of a calamity, the Handbook on Disaster Management issued by KSDMA therefore required all Emergency Operations Centres (EOC)[52] to have built-in redundancy of different layers of communication networks for ensuring effective communication system even during the most adverse circumstances. Keeping communication system in order even during the most adverse circumstances would be one of the main functions of the EOC.

Tahsildars of Idukki and Chalakudy Taluks informed Audit that there was total failure of communication infrastructure in their respective areas during the floods of 2018. Assistant Engineer (AE) in charge of Poringalkuthu dam in Thrissur informed Audit that communication infrastructure in the dam had failed on 16 August 2018 and could be restored only after one week. Similarly, AE of Lower Sholayar dam (Thrissur District) informed Audit that a landslide had occurred during the 2018 floods obstructing the road to dam office and no reliable and uninterrupted communication facility was available in the dam site. The official at the dam site had depended on the mobile network of Tamil Nadu which was available at some distance from the dam. Officials of both the dams intimated Audit that failure of communication network had created difficulty in contacting higher authorities for help and directions.

Audit, therefore examined the status of implementation of various projects/ schemes meant for ensuring failsafe communication in the State as availability of reliable communication systems would be integral to flood preparedness.

The Revenue and Disaster Management Department informed (November 2020) that uninterrupted communication systems[53] required in SEOC and DEOC to combat disaster as laid down in the Orange Book include dedicated mobile phone, optical fibre internet, hotline, landphone, Fax, VSAT module, Satellite phones, police wireless, Whatsapp groups, Facebook, Twitter, dedicated email, HAM radio and YouTube channel. The healthy mix of civilian and official communication systems through several media reduces significantly chances of communication failure. When one system fails, another would be used and none of them is an always-on system. It acknowledged that GSM, telephonic and internet communication was temporarily disrupted in parts of Idukki due to power failure and optical fibre

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51 Section 22(2)(p) of the Disaster Management Act 2005

52 Recognising the need for such a State-level dedicated facility for disaster management, the Government of Kerala (GoK) has established the State Emergency Operations Centre (SEOC). The SEOC is envisaged to cater to varying levels of disasters with a state-of-the-art Decision Support System (DSS), integrated with a multichannel communication network. It has advanced redundant satellite-based communication network (National Disaster Management Services Project) and multi-channel terrestrial communications systems including VHF, GSM, 4G, 3G and broadband internet connectivity. (Paragraph 1 and 2 of the EOCESFP 2015, renamed in 2019 as Orange Book of Disaster Management).

53 According to the reply of Government there are 16 types of communication systems, however, the reply as well as the Orange Book lists only 14 types of communication system.

disconnection and the Cell-sites on Wheels (CoWs) deployed provided the required connectivity. Deployment of communication systems at dam sites was taken care of, adequately by dam owners and management of dams was not a function of KSDMA.

Audit observes that the Disaster Management Act 2005 does not exclude communication systems at dam sites from the purview of the SEC or KSDMA.

The deficiencies in maintenance of effective communication systems, as noticed during the course of audit, are detailed below.

3.5.2.1. National Disaster Management Services

The National Disaster Management Services (NDMS), a project implemented by National Disaster Management Authority, envisaged to provide to States, failsafe communication infrastructure[54] and technical support[55]. Thus, VSAT[56] phones were installed by BSNL at the SEOC at Thiruvananthapuram and DEOCs at Idukki, Ernakulam and Wayanad during March and April 2016 respectively. Satellite phones were also provided to these districts after the floods of 2018 for providing additional redundancy in communication. Government of Kerala also nominated (March 2016) the Member Secretary, KSDMA as the nodal officer for the Project.

Audit examined the status of the VSAT communication system/ satellite phones in the test-checked districts and noted that the system was not completely dependable as seen from the following;

- Audit was informed (October 2019) by the Additional District Magistrate, Idukki that VSAT connection was not working regularly and that voice of the speaker was not audible. The connection was not working from 15 August 2018 and that only after issuing many reminders to SEOC was it repaired in December 2019.

  It is significant that VSAT was not functional in Idukki during the floods of 2018, when terrestrial and mobile communication network in the district had failed. Further, the system in Idukki district became functional after over a year.

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[54] NDMS is a grant-in-aid in kind project to establish a satellite-based communication network in all States. In Kerala, the project is implemented in creating satellite-based communication linkages between SEOC and DEOCs of Idukki, Ernakulam and Wayanad. The instrumentation includes VSAT Connectivity, Satellite Phones and HF Radio sets. The satellite-based network was to provide additional redundancy in communication. The project was implemented by SEOC vide GO (Rt) No. 2203/2016/DMD dated 30 March 2016. MoU was entered between the NDMA and Government of Kerala on 05 May 2016 for the implementation of the project with duration of 24 months (EOCESFP 2015, renamed in 2019 as Orange book of Disaster Management). Paragraph 4 of the revised scheme proposal for NDMS pilot project for satellite-based communication network refers to failsafe communication infrastructure.

[55] Source: Paragraph 4 of revised scheme proposal for NDMS pilot project for satellite-based communication network.

[56] Very small aperture terminal

- VSAT at DEOC, Ernakulam remained non-functional for about 45 days during January-November 2019. VSAT at DEOC, Wayanad was non-functional in October-November 2019 as per SEOC, Thiruvananthapuram records.
- Audit observed that even in SEOC which commenced operation in its new premises at Thiruvananthapuram from January 2019, VSAT was re-installed only in November 2019. SEOC could not utilise this communication tool for about 10 months. NDMA also informed SEOC (November 2019) that daily testing of VSAT sites at SEOC, Thiruvananthapuram and DEOC, Idukki indicated either faulty or non-responsive systems and required that these VSAT sites be made functional.
- Audit noticed that though satellite phones had been made available at DEOCs and dams, they would not function indoors and were unreliable during overcast conditions. The inability of Satellite phones to function during adverse weather conditions affects its effectiveness as a means of communication during disaster.
- Joint check conducted by Audit along with departmental officers at DDMA Idukki (25 October 2019) revealed that the satellite phone was non-functional. ADM Idukki cited expiry of validity period of satellite phone connection as a reason for non-functioning of satellite phones.

The Department responded (December 2020) that NDMS is not a fail proof communication system but an alternate communication system along with the other systems provided by KSDMA. Performance of NDMS depends on BSNL for bandwidth and hardware maintenance, ISRO for satellite health, KSEBL for power, weather systems for cloud cover and failure of any of these can result in the system becoming non-functional. Inadequacy of bandwidth was reported to NDMA in December 2016. Ensuring connectivity through ISRO bandwidth was BSNL's responsibility. KSDMA informed BSNL and NDMA in September 2016 that the system was agreed to be commissioned only after imparting necessary training to its engineers and ensuring seamless functioning. Initial handing over of systems occurred only on 05 October 2018 and final handing over on 01 and 02 February 2019 after training of DEOC and SEOC staff at BSNL. The department stated that Audit was commenting on a non-commissioned system. Since handing over, the system was augmented further and is maintained meticulously. It added that all complaints other than power related, could only be reported to the toll-free number of BSNL. The logbook of VSAT at SEOC indicated that calls were made to DEOC, Idukki on 10 August 2018, 30 August 2018, 14 September 2018 and 19 November 2018. The log also indicated that the system did work prior to and during the flood and the voice of the speaker was clear. As regards the relocation of VSAT to the new SEOC premises after a gap of one year, the department stated that KSDMA took all possible steps to operationalise the VSAT terminal through frequent requests to BSNL and intervention of

NDMA. Satellite phones were delivered on 17 August 2018. As it is with any satellite signals, reflectivity interference could affect signals temporarily in cloudy conditions and high solar insolation. Possibility of purchasing antenna to enable indoor use of the device is being explored with BSNL. The non-functioning of satellite phone during physical verification was attributed to the lack of support from the service provider who got it functional on 22 November 2019 after detailed proposal for recharge was received from him on 13 November 2019. The reply added that during the short durations when satellite phones were non-functional, there were other communication systems to supplement the failsafe communication.

Audit observes that the department's response corroborates the audit observations as the NDMS system (VSAT and satellite phone) with all its limitations did not provide assurance of being a fully dependable communication system. The observations of Audit regarding the non-functioning of VSAT and satellites phones are based on the remarks provided by end users, i.e., ADM (Disaster Management), Idukki, engineers in dam sites and officials at DEOC. Audit observed that no entries were made in the VSAT log maintained by DEOC, Idukki after 26 March 2018. Further, the reply of Government that functioning of Satellite phone is temporarily affected during cloudy conditions and high solar insolation, is supportive of the audit finding. As regards the Department's contention that commissioning of VSAT had not taken place by the time of the 2018 floods, the fact remains that the system was being relied upon by the end-users from March/ April 2016 and the department itself lists and recognises VSAT module among the effective communication systems followed in KSDMA. As part of its normal time functions, the SEOC was to ensure proper functioning of multi-channel alternate communication systems.[57]

3.5.2.2. Non-functional Very High Frequency Radio communication system

The Department of Revenue and Disaster Management established[58] a network of 379 Very High Frequency (VHF) Radios[59] in the State (2010) for enforcing effective early warning system with an outlay of ₹2.65 crore. VHF radio network of KSDMA is a wireless communication technology similar to that used by the Police Department. The advantages of VHF communication over other forms of communication includes its ability to function in severe weather conditions as the equipment is shock and dust proof, resistant to humidity and able to work with a 12-volt battery.

[57] Paragraph 4.1 of EOCESFP 2015, renamed in 2019 as Orange Book of Disaster Management
[58] with the financial assistance of UNDP and the Tsunami Rehabilitation Programme
[59] State level - 5, Revenue Divisional Office - 2, District level - 14, Taluks - 63 and vulnerable Village - 295.

A survey conducted by Audit in 2013 for inclusion in the Report of CAG[60], had revealed that 82 *per cent* of the equipment were non-functional, due to improper installation, non-execution of repair works and absence of technically skilled personnel. The letter of Director, Institute of Land and Disaster Management (ILDM) (January 2018) addressed to Additional Chief Secretary, Revenue and Disaster Management, GoK also indicates that VHF network was inactive since its installation. Audit observed that an amount of ₹35 lakh (November 2013) was provided to ILDM for engaging technical staff to revamp[61] the VHF equipment at Collectorate and Taluk level and subsequently 130 equipment were repaired. However, the revamping activities were abandoned in November 2016 due to lack of further Government sanction. A revamping proposal of ₹1.28 crore submitted to GoK by ILDM (January 2018) is yet to receive approval (December 2019). VHF equipment which was installed incurring an expenditure of ₹2.65 crore to ensure hassle free communication was not functional during the floods of 2018 in any of the test-checked District Collectorates and Taluks. Deputy Collector (DM) Idukki stated (December 2019) that they were dependent on the VHF maintained by Police for communication during the floods of 2018. Taluks and villages which are involved in ground level relief and rescue works during disaster have to depend mainly on land phones, email, CUG mobile network and a fully functional VHF would be a step towards strengthening the communication network at the ground level.

The Revenue and Disaster Management Department responded (November 2020) that as VHF systems were meant not for day-to-day communication but for use in periods of disaster (unlike in the Police department), they are liable to frequent repairs on account of prolonged idling. VHF systems were used intermittently after the warranty period depending on the periodic repairs. The asset installed in 2008-10 being more than 10 years old had outlived its normal useful life. Any further spending on the asset would result in unfruitful expenditure, hence the decision not to sanction further expenditure and to recommend handing over to the Police department. By preventing avoidable expenditure on revamp and utilising the wireless phones of the Police personnel for flood management, the 2018 flood situation was managed well by KSDMA and the DDMAs. The department avoided expenditure on a failed and redundant system, it added.

Audit noticed that though Government had provided different types of communications, most of them were vulnerable to failure during a disaster owing to their dependence on internet or terrestrial network. The VHF of Police department had withstood the disaster of 2018 as stated in the paragraph and hence can be considered as a reliable communication network.

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[60] Report of C&AG of India on General and Social Sector, Government of Kerala for the year ended March 2013. The survey was part of Paragraph 3.9 'Unfruitful expenditure on Early Warning Systems'. The paragraph was discussed in PAC and PAC had sought additional details from Revenue and Disaster Management Department.

[61] for repairing nine out of 14 VHF supplied to Collectorates, 24 out of 64 VHF supplied to Taluks and three out of five Repeaters.

The Kerala State Disaster Management Plan, 2016 elaborates the procedure for maintaining the VHF system and ensuring that the system remains functional, it includes daily checking and sorting out any technical issues using the services of Police Telecommunication wing. Hence, the contention of Government that VHF networks were not intended for day-to-day communication purposes but for use during periods of disaster, and equipment were liable for frequent repair on account of prolonged idling, is not acceptable.

Recommendation 3.3: KSDMA may ensure that fail-safe communication infrastructure is available in vital installations such as at dam sites and that a built-in redundancy of different layers of communication capable of functioning during the most adverse circumstances exists in flood-prone locations across the State.

3.5.3. Non-functional state-of-the-art Digital Seismographs

Idukki district in Kerala hosts 17 dams including the 125-year-old Mullaperiyar dam[62]. Consequent to an earthquake of 3.8 M on Richter scale (July 2011) in the Idukki region, GoK decided to establish (August 2011) a state of the art digital system of seismographs in and around Mullaperiyar dam site for obtaining real time Seismic data as the existing equipment were analogue type and incapable of immediate analysis of data. The work was awarded to M/s. Encardio Rites Electronics Pvt. Ltd. (M/s. Encardio) for ₹3.90 crore. The new equipment was capable of providing reliable, compact and portable data. As stated earlier in this Report, the data from the seismographs would also be an input to the Decision Support System being established at the SEOC.

After setting up (March 2014) six digital seismographs and five accelerographs[63] near and around Mullaperiyar dam site[64] for the effective monitoring of seismic activities, GoK further accorded sanction (August 2016) to purchase one full spare set[65] of GURALP seismograph for ₹50.93 lakh for installation at a suitable site within the ILDM premises[66].

Audit observed that though the vendor supplied (December 2016) one full set of GURALP seismograph along with its allied items and the instruments, these were not installed and were stored in the KSDMA building. Audit further observed that the warranty period of the six digital seismographs and five accelerographs, set up in March 2014, expired in March 2017. A proposal (March 2017) of the vendor offering a three-year AMC for ₹66.32 lakh was not successfully concluded. Resultant non-maintenance of the equipment

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62 Mullaperiyar dam lies in seismic zone III, where as per the seismic zoning map of India, earthquake of intensity seven in the Richter scale could be expected.

63 An electromagnetic device used to measure acceleration forces

64 Seismographs at Vallakadavu, Meencut, Chottupara, Aladi, Kulamavu and Pamba; Accelerographs at Idukki dam and Vallakadavu observatory in Idukki District

65 Since the spares of any malfunctioning instrument are to be imported, components from the spare instrument could be used as a replacement till M/s. Encardio substitutes the spare.

66 Institute of Land and Disaster Management under Department of Revenue at Thiruvananthapuram which accommodated the SEOC till it was shifted to the new building in January 2019.

possibly led to the seismographs installed in Idukki becoming non-functional since January 2019. No seismic data is being received by the Central Receiving Station (CRS) since then. Sanction accorded by GoK in July 2018 for entering into an AMC with the vendor became infructuous as the vendor M/s. Encardio intimated KSDMA (December 2018) that they had ceased functioning as the distributor for GURALP instruments in India. After inspection of equipment, a new vendor intimated (August 2019) KSDMA that majority of the original equipment had reached its end of life and offered to replace/ repair the faulty instruments for ₹49.50 lakh before entering into an AMC. The offer was not accepted (January 2020) pending receipt of clarifications from the original vendor.

Want of proper maintenance of the seismographs and related equipment resulted in expenditure of ₹3.90 crore becoming infructuous with the State being forced to depend on data from the erstwhile analogue seismograph instead of obtaining real time seismic data. Further, non-installation of the seismograph purchased in December 2016 meant idling of equipment worth ₹50.93 lakh for the last three years in Thiruvananthapuram.

The Revenue and Disaster Management Department in its reply (December 2020) stated as follows;

- The paragraph has nothing to do with the subject matter of preparedness for floods.
- The six digital seismographs and five accelerographs set up in March 2014 were proprietary items. Any repair or AMC had to be through services of the principal/ their authorised dealers in India. Extended warranty period expired in 2017. AMC could not be concluded beyond this period since the authorised dealer ceased to function after December 2018. New vendor after inspection in August 2019 reported that majority of the items had reached their end of life.
- The equipment custodian KSEBL had utilised its internal skills to revitalise and use the system as long as the original equipment continued to work.
- The offer of the new dealer to repair the instruments for ₹49.50 lakh and then enter into AMC did not appear economical, since the equipment had already outlived their normal life.
- Audit conclusion of failure to ensure adequate maintenance resulting in infructuous expenditure was pre-conceived and irrelevant.
- The purpose of collecting seismic data is served by two digital seismographs in the State, one of IMD in Thiruvananthapuram and the second of NCESS at Peechi.
- Audit observation on non-installation of the spare seismograph was not accepted as the spare intended for replacement in the event of

failure of one of the already installed seismographs could not be considered as idling equipment.

During the Exit conference (18 January 2021), it was also informed that the seismographs were not for detection of earthquakes in the State. The responsibility of earthquake detection and monitoring is that of IMD and KSDMA is in receipt of such detections that are relevant to the State. The purpose of the KSDMA funded, KSEBL established seismic monitoring system was for confined monitoring of the selected area in Idukki and at a global scale of earthquake detection and monitoring, all the systems deployed in Idukki would only count as one system. Further, under the initiative of KSDMA, the National Centre for Seismology (NCS), New Delhi has deployed one seismograph in Idukki. Therefore, earthquake detection purpose is well served. The system was funded by KSDMA to KSEBL and KSEBL had the responsibility of deploying and maintaining the system ever since the beginning. During the active period of the system, the system worked satisfactorily.

The contention of the Government that the seismographs at Thiruvananthapuram and Peechi are sufficient could not be accepted since while initiating the project proposal by KSEBL, expert opinions from National Geophysical Research Institute (NGRI) and NCESS were obtained by KSEBL and NGRI had opined that any network around a reservoir should be located in such a way that there is minimum azimuthal gap and a station should be located in the centre of the network for assessing depth resolution of earthquakes. NCESS while underscoring the necessity of the project added that the seismic observatories of IMD and NCESS could complement the proposed network. Further, following mild tremors in Idukki area in February 2020, KSEBL conducted a meeting (March 2020) to assess the situation and it was opined that the observations from the above Seismographs are highly important for the study of seismic behaviour of Idukki region as it has link with the safety of KSEBL dams and hence action is to be taken to initiate reviving the equipment/ system. Audit clarifies that it is based on the linkage to dam safety and possibility of flooding from dam break that this audit observation has been included in this Audit Report. GoK's contention that the spare equipment cannot be considered as idling is also not acceptable as the sanction order for purchase of the spare instrument specifically stated that the spare instrument shall be mounted in the campus of Institute of Land and Disaster Management, Thiruvananthapuram and data received in the present network at the Central Receiving Station at KSDMA.

In the wake of frequent mild tremors which occurred in Idukki during February 2020, KSEBL contacted CWC for expert advice and CWC recommended to constitute an expert group with representation from a few organisations including National Centre for Seismology (NCS), New Delhi. NCS as part of their study installed (March 2020) seismic equipment in Idukki utilising their own funds and the data was streamed to its Headquarters at New Delhi. KSDMA's contention that the equipment installed by NCS is more than

sufficient cannot be accepted since the objective of the subject scheme was to extract real time seismic data which would be relayed to the State's own CRS that could be monitored at close quarters as recommended by NGRI and NCESS. Audit observes that the single seismograph set up in 2020 is not intended to be a substitute for a system of six seismographs and five accelographs in place earlier.

Further, Audit noticed that the situation which warranted the establishment of these seismographs in 2014 still exists as evident from the tremors felt in Idukki as recently as February 2020.

Recommendation 3.4: Keeping in view the role of the seismograph network in Idukki in studying seismic behaviour and their linkage to the safety of dams in the region, Government of Kerala may ensure that the network of seismographs as recommended by NGRI is put in place at the earliest and the agencies concerned receive real time seismic data from these locations.

Reservoir operation

Dams ensure a large number of potential benefits, but are also structures with potential hazards. Any uncontrolled or excessive release of huge amount of water has potential for loss of life and damage to property due to flooding. Of the 59 dams in the State, 17 dams are in Idukki district. Kerala received 2,346.60 mm rainfall between 01 June and 19 August, 2018, which was about 42 *per cent* higher than the normal rainfall.

Audit engaged the services of the Indian Institute of Science Bangalore (IISc) to study, from a hydrological perspective, the operations of reservoirs in the Periyar basin, during and immediately preceding the flood period[67]. Salient features of Mullaperiyar, Idukki, Idamalayar, Lower Periyar dams and Bhoothathankettu barrage are given in **Appendix 3.1.** While the Mullaperiyar dam is controlled by Tamil Nadu, the Idukki and Idamalayar dams are under the control of KSEBL. Lower Periyar dam is situated downstream of Idukki dam and has a very small capacity compared to the three major dams. Audit findings with regard to reservoir operations are given in succeeding paragraphs.

3.6. Assessment of impact of dam spillage on flooding in downstream areas

Audit evaluated the relative contributions of the spills from the two major dams, Idukki and Idamalayar, to the flood flow observed at Neeleswaram gauge station, based on observed data. Contribution of the spills from Mullaperiyar dam to the Idukki inflows was also examined. Data on reservoir inflows, power house (PH) discharge, spills, storage and water levels at the dams, barrage and flow gauges provided by the KSEBL, CWC and Irrigation Department was used to assess the impact of the spills on the floods.

[67] June - August 2018

Since observed flow and river level data was available at Neeleswaram gauge station, the spills from the reservoirs were compared with the observed flow at Neeleswaram to assess the impact of spills on the floods. The percentage contribution of the reservoir spills, on a daily scale, to the Neeleswaram gauge station is shown in **Table 3.4**.

Table 3.4: Contribution of daily spills from Idukki and Idamalayar dams to the observed flow at Neeleswaram gauge station

Date	Total observed spills from Idukki and Idamalayar dams (MCM)*	Flow observed at Neeleswaram (MCM)	Contribution of total spills from Idukki and Idamalayar dams to flow at Neeleswaram (*per cent*)[68]
1	**2**	**3**	**[(2) / (3)] * 100**
14-08-2018	91.06	196.13	46.43
15-08-2018	192.47	532.83	36.12
16-08-2018	234.53	793.93	29.54
17-08-2018	185.85	796.44	23.34
18-08-2018	104.11	612.75	16.99

***The spills presented for Idukki and Idamalayar dams for a day correspond to the observed flow during the 24 hours from 7AM on that day to 7AM on the next day.*

(Source: Report of IISc, Bangalore)

The contribution of the spills from Idamalayar and Idukki dams together, to the flows at Neeleswaram gauge station during the period 14 to 18 August 2018 was significant at 46.43 *per cent*, 36.12 *per cent*, 29.54 *per cent*, 23.34 *per cent* and 16.99 *per cent* respectively, though as the extreme rainfall event continued for a few days, the contribution of the spills in percentage terms is seen to have declined.

Further, as the spills from the Mullaperiyar dam pass through the Vandiperiyar gauge station and subsequently contribute to the inflows to the Idukki reservoir, the role of spills from Mullaperiyar dam in the escalation of flows at Idukki reservoir during the flood period was also examined as shown in **Table 3.5**.

Table 3.5: Contribution of spills from Mullaperiyar dam to Idukki inflows

Date	Spills from Mullaperiyar dam (MCM)	Inflows observed at Idukki dam (MCM)*	Contribution of spills from Mullaperiyar to Idukki inflows (*per cent*)
1	**2**	**3**	**[(2) / (3)] * 100**
14-08-2018	2.17	84.18	2.58
15-08-2018	46.10	165.06	27.93
16-08-2018	56.74	154.96	36.62
17-08-2018	33.87	111.70	30.32
18-08-2018	33.26	92.51	35.95

***The flow data presented for Idukki and Mullaperiyar dam correspond to the observed flow during the 24 hours from 7AM on that day to 7AM on the next day.*

(Source: Report of IISc, Bangalore)

[68] The volume of total spills from the two dams (Idukki and Idamalayar) together is added and its percentage contribution is analysed to the flows at the barrage and Neeleswaram gauge station.

As evident from the table, the operation of the Mullaperiyar dam had a negligible effect on 14 August but its contribution to the inflows at Idukki was significant during 15 to 18 August (>20 *per cent*), considering the magnitude of the floods.

Government in its response stated (September 2020) that the contribution of Mullaperiyar dam to the inflows of Idukki during the period of severe floods from 15-18 August 2018 was very significant. Since sudden and unexpected releases from Mullaperiyar dam by Tamil Nadu Government was expected any moment without notice and the quantum of inflow to Idukki reservoir was not known in advance, KSEBL had to provide sufficient flood cushion to ensure safety of the dam as well as controlled release. But for the sudden release of 169.97 MCM of water from Mullaperiyar during the extreme flood days, the attenuation of downstream flood would have been more significant.

The departmental response indicates the need to prioritise and have in place an integrated reservoir management plan, particularly in multi dam basins. This is significant both because i) the control of reservoir/ dam operations in the State is distributed among KSEBL and the Irrigation department and ii) there is the likely impact of spills from dams under the control of one State in the downstream reservoirs and rivers of another State.

The National Disaster Management Plan lists among the responsibilities of the State (in the context of understanding floods), the implementing and monitoring of flood preparedness, river basin and reservoir management plans including updating rule curves and improving the system of water release from reservoirs.[69]

Audit examined the aspect of the compliance of dam operators to rule curves and the findings are as follows.

3.6.1. Compliance of dam owners to rule curves

A Rule Curve or rule level specifies the storage or empty space to be maintained in a reservoir during different times of the year with the assumption that a reservoir can best satisfy its purposes if these storage levels are maintained. The rule curve as such does not give the amount of water to be released from the reservoir as it will be dependent on the amount of inflows and other extractions. The rule curves are generally derived by operation studies using historic or generated flows[70]. Though it is always desirable to fill a reservoir up to Full Reservoir Level (FRL) (or upto Maximum Water Level (MWL) during emergency situations, if the dam is structurally stable), it is

[69] Paragraph 7.2.1, NDMP 2019

[70] Upper rule curve represents the water levels to be maintained in the reservoir such that if these are maintained throughout the year, all the demands from the reservoir can be fully met. Keeping the upper rule level below FRL (in monsoon months) can give extra room for flood absorption in the reservoir. Lower rule curve is calculated such that if the storage level goes below this level, only the highest priority demands can be met throughout the year. Generally, the water level in the reservoir is maintained between upper and lower rule curve values.

generally recommended that some spill should be made from the reservoir to keep up the downstream river channel and to avoid encroachment in the river.

During field visit, the IISc team accompanied by Audit personnel were informed by KSEBL that no rule curve was followed for reservoir operations during the flood period. However, Audit noticed that KSEBL had in its possession the Rule Curve framed in 1983 (**Appendix 3.2**). Audit observed that only after the floods of 2018, KSEBL developed new rule curves (KSEBL, 2019) which were updated in 2020 (KSEBL, 2020) though the Operation of Reservoir – Guidelines[71] envisaged (Paragraph 5.0) that the rule curves are to be reviewed constantly and if necessary, modified so as to have the best operation of reservoirs.

Audit made available to IISc, the rule curves (1983 and 2020) for the Idukki dam along with the rule curves for the operation of the Idamalayar reservoir (2020) (**Appendix 3.3**), for carrying out simulations of reservoir operation to determine the volume of spills that would have resulted if these rule curves were followed during the flood period. The simulations of the reservoir operation were carried out for the period June to September 2018. The steps followed in simulating the reservoir operation are given in **Appendix 3.4**. The results of the simulations are given below.

3.6.2. Operation of Idukki reservoir using the 1983 rule curve

The Idukki reservoir operation was simulated with the rule curves developed in the years 1983 (**Appendix 3.5)** and 2020 (**Appendix 3.6**) to determine the quantum of spills and to compare these spills with the actual spills that occurred during the 2018 flood period. **Table 3.6** shows the observed spills at Idukki dam during the flood period and the spills if the rule curves of 1983 were followed.

[71] IS 7323:1994, reaffirmed in1999

Table 3.6: Comparison between actual spills and the spills simulated using the rule curves of 1983 for Idukki dam

Date	Actual spills 2018 (MCM)**	Spills when rule levels are applied (MCM) Initial storage level for simulation (starting date - June 30)		
		Upper Rule Level#	Lower Rule Level*	Actual Storage Level##
14-08-2018	46.26	74.06	0.00	74.06
15-08-2018	111.24	154.94	0.00	154.94
16-08-2018	124.65	144.88	123.82	144.88
17-08-2018	115.20	101.59	101.59	101.59
18-08-2018	70.16	82.72	82.72	82.72
Total	**467.51**	**558.19**	**308.13**	**558.19**

#Start with upper level; Spills computed once storage crosses upper level
*Start with lower level; Spills computed once storage crosses upper level
##Start with actual level; Spills computed once storage crosses upper level
**The actual spills (2018) presented for a particular day are the observed spills during the 24 hours from 7 AM on that day to 7 AM on the next day
(Simulations were carried out from June to September 2018; results for the flood period alone are shown)
(Spills are accounted only if the simulated level exceeds the crest level)

(Source: Report of IISc, Bangalore)

The simulations revealed that the spills from Idukki reservoir during the flood period (14-18 August) would have been higher (558.19 MCM against the actual spills of 467.51 MCM) if the simulations started with the actual storage level or the upper rule level. Thus, for reservoir operations during the floods of 2018, the rule curve of 1983 for Idukki reservoir could not have been relied upon to achieve minimal or no spills. This shows the necessity for ensuring rule curves are regularly updated as required by the National Disaster Management Plan and by the Reservoir Operation Guidelines[72]. In the case of Idamalayar reservoir, there was no rule curve in place at the time of the 2018 floods for the guidance of dam operators.

However, subsequent to the floods of 2018, and based on the Central Water Commission's recommendations in their Study Report on 'Kerala Floods of 2018' to review rule curves for major reservoirs in the State, the existing rule curves were reviewed by KSEB. Subsequently, rule levels as prepared by CWC were approved by the Government of Kerala in May 2020. KSEBL also resolved to give approval to the modified rule levels prepared by CWC for operation of Idukki, Idamalayar, Kakki and Banasurasagar reservoirs. Audit also noted that in the new O&M Manual[73], reservoir operation protocols including "rule curves" were included.

3.6.3. Dam operations based on 2020 rule curves

In order to see how the application of Rule curve of 2020 for Idukki dam operations would impact spills from the reservoir in case a scenario similar to the floods of August 2018 were to happen again, simulation studies were carried out. Simulation of the reservoir operation of Idukki reservoir shows

[72] IS 7323:1994 (Paragraph 5.0) - Rule curves once prepared should be constantly reviewed and modified so as to have the best operation of the reservoirs.
[73] As per the guidelines of CWC of January 2018.

that if it was operated according to the rule curve of 2020, the spills from the reservoir during the flood period would be 531.03 MCM which is higher than the actual spills of 467.51 MCM (14-18 August, 2018) as shown in **Table 3.7**.

Table 3.7: Comparison between actual spills and the spills simulated using the rule curve of 2020 for Idukki dam

Date	**Actual spills (2018) (MCM)****	**Spills when rule level is applied (MCM)** Initial storage level for simulation (starting date -June 10)	
		Rule Level[#]	Actual Storage Level[##]
14-08-2018	46.26	68.63	68.63
15-08-2018	111.24	149.51	149.51
16-08-2018	124.65	139.45	139.45
17-08-2018	115.20	96.16	96.16
18-08-2018	70.16	77.29	77.29
Total	**467.51**	**531.03**	**531.03**

[#]Start with rule level; Spills computed once storage crosses rule level
[##]Start with actual level; Spills computed once storage crosses rule level
**The actual spills (2018) presented for a particular day are the observed spills during the 24 hours from 7 AM on that day to 7 AM on the next day
(Simulations were carried out from June to September 2018; results for the flood period alone are shown)
(Spills are accounted only if the simulated level exceeds the crest level)

(Source: Report of IISc, Bangalore)

When the exercise was carried out similarly (**Appendix 3.7**) for Idamalayar dam using the new rule curve of 2020, the study indicated that the spills when reservoir operations were carried out using the rule curve would be lesser than the actual spills in 2018. **Table 3.8** shows the observed spills at Idamalayar dam during the flood period and the spills if the rule curve of 2020 is followed.

Table 3.8: Comparison between actual spills and the spills simulated using the rule curve of 2020 for Idamalayar dam

Date	**Actual spills (2018) (MCM)****	**Spills when rule level is applied (MCM)** Initial storage level for simulation (starting date - June 10)	
		Rule Level[#]	Actual Storage Level[##]
14-08-2018	44.80	56.13	56.13
15-08-2018	81.23	97.20	97.20
16-08-2018	109.88	85.54	85.54
17-08-2018	70.65	51.24	51.24
18-08-2018	33.94	33.38	33.38
Total	**340.50**	**323.49**	**323.49**

[#]Start with rule level; Spills computed once storage crosses rule level
[##]Start with actual level; Spills computed once storage crosses rule level
**The actual spills (2018) presented for a particular day are the observed spills during the 24 hours from 7 AM on that day to 7 AM on the next day
(Simulations were carried out from June to September 2018; results for the flood period alone are shown)
(Spills are accounted only if the simulated level exceeds the crest level)

(Source: Report of IISc, Bangalore)

It is observed that if the Idamalayar reservoir was operated according to the rule curve of 2020, the spills from the reservoir during the flood period (14-18 August, 2018) would be 323.49 MCM (less than the actual spills of 340.50

MCM). Even if the rule curve of 2020 was followed considering the observed actual level on June 10 for initialisation, the spills during the flood period would still have been 323.49 MCM which is less than the actual spills of 340.50 MCM.

Hence, the simulation studies using the 2020 rule curve for Idamalayar gave a result indicating lesser spills unlike in the case of Idukki.

The Department in its reply (December 2020) said that as per the rule curve of 2020, the water level to be maintained at the Idukki reservoir during 11 to 20 August is 2,386.81 feet with 1,725.71 MCM. This would give a dynamic flood cushion of 270.63 MCM (upto FRL 2,403 ft). The dynamic flood cushion would enable the dam managers to transiently accommodate the heavy inflow into the reservoir during the flooding period and distribute the consequent spill in a regulated manner.

Audit notes that even after a considered decision by KSEBL in consultation with KSDMA in August 2018 to introduce a dynamic flood cushion of four feet below FRL (68.87 MCM) (the rule curve of 1983 for Idukki reservoir permitted KSEBL to store water during the month of August 2018 upto FRL), spills of 467 MCM could not be avoided. Audit also saw that despite such decision, the outflow did exceed inflow in respect of Idamalayar reservoir on two days (16-17 August, 2018) and in respect of Idukki on one day (17 August 2018).

Hence, KSEBL may consider the feasibility of conducting simulation or other studies to ensure that the approved rule curve of 2020 along with provision of dynamic flood cushion would suffice to handle situations similar to the extreme rain event of 2018 with minimal spills, if any.

Need for assurance about the adequacy of the new rule curves is emphasised also because IISc's studies[74] to examine the effect of reservoir spills on the flood inundation depth and extent showed that if the discharge from Bhoothathankettu barrage consisted only of the runoff generated with heavy rainfall[75], the extent of simulated flood spread would have reduced from 520.04 sq. km to 441.44 sq. km and the maximum simulated depth (with respect to ground level) at Neeleswaram would have reduced from 12.32 m to 9.68 m[76]. KSEBL acknowledged (June 2020) that the 15 *per cent* reduction of area was a realistic assessment.

The Secretary, Power Department (December 2020) in his response to the audit observation said that the methodology followed by KSEBL in controlling the flow is to operate within the dynamic flood cushion below the FRL and ensure that the levels do not exceed the FRL. Keeping in view this principle, the inflow and outflow in both Idukki and Idamalayar were coordinated. While so coordinating, the sudden inflow without notice from

[74] using HEC-RAS
[75] and no contribution from reservoir spills
[76] Simulations by IISc using HEC-HMS modelling showed that the flood peaks obtained from the 'with-dam scenario' were attenuated when compared to the virgin simulations (no dam scenario).

Mullaperiyar as well had to be reckoned. Still the crisis situation was managed well within the prescribed parameters. In Idamalayar on 15 August 2018, the FRL was breached by 0.15 m and the outflow maintained was less than inflow and on 16 August 2018 the FRL was again breached by 0.75m and still the outflow was maintained at a lower level. At that point of time, due to the extreme flood situation, the inflow increased drastically and there was no other alternative but to increase the outflow to maintain the FRL, considering the safety of dam, as well. The Secretary, Power Department further stated that the position as explained above would indicate that the reservoir operation in the crisis situation was prudently managed and spills were maintained at optimum levels.

The Government vide letter dated 16 April 2021 also informed that in the case of Idamalayar reservoir, the difference between total outflow and total inflow was only 9.86 MCM which is only 2.90 *per cent* of the total inflow of 338 MCM into this reservoir. Considering the total combined inflows of 946.40 MCM (608.40 + 338), a total combined outflow of 815.37 MCM (excluding PH discharge from Idukki reservoir) was only discharged to the Periyar basin from both reservoirs (between 14 and 18 August 2018). The integrated operation by KSEBL resulted in moderation of 131.03 MCM. KSEBL had let the outflow exceed inflow only in the recession limb of the flood hydrograph which is a standard operation procedure. The response indicated that in Idamalayar, for five hours on 15 August 2018, the outflow was marginally more than the inflow (in the rising limb of the flood hydrograph) but this was before the flood hydrograph's sharp rising and touching its peak inflow. This was unavoidable as Idamalayar reservoir levels breached its FRL and integrated reservoir operation necessitated such release. Attenuation of 1,128 cumecs when the peak inflow of 2,328 cumecs occurred at 03:00 hrs on 16 August 2018 in Idamalayar reservoir was also pointed out. Further, as Idukki PH discharges to the adjacent Muvattupuzha basin and not to Periyar basin, the same should not be added to the outflows to the Periyar basin.

The departmental reply above seeks to indicate that spills that took place, including outflow exceeding inflow (on two days in the case of Idamalayar reservoir and one in Idukki reservoir), during the August 2018 floods were optimal and acceptable given the circumstances such as inflow from Mullaperiyar without warning and the fact that the outflow exceeded the inflow on the receding limb. However, the KSEB's response that outflow exceeds inflow only in the receding limb, is silent about the downstream conditions. The Neeleswaram CWC Gauge station in the month of August 2018 recorded very high-water flow on 15 and 16 August (as well as on 17 and 18 August). On all these days (15 to 18 August 2018), the flow (refer **Table 3.4** of this Report) exceeded 363 MCM/day which was adequate for the river to breach its banks[77]. The water level as measured at Neeleswaram CWC Gauge station on 16, 17 and 18 August was similarly very high at 12.10 m,

[77] Response of KSEBL dated June 2020 relying on research article by Dr K.P Sudheer, IIT Madras, et al, 'Role of dams on the floods of August 2018 in Periyar River Basin, Kerala'.

12.12 m and 10.55 m respectively when compared to average water level of 4.55 m[78] for the month of August 2018. Thus, the release of water from the dams so close to the peak inflow (even if it was in the recession limb) could aggravate the flood situation downstream. Further, on 17 August 2018, the hourly data indicates that the outflows from Idukki dam exceeded the inflows during 16 hours of the day and on 16 and 17 August, the outflows from Idamalayar reservoir exceeded the inflows for 10 and 21 hours of the day respectively. Besides, even if PH discharge were to be excluded for Idukki, the net inflow would be negative (-3.50 MCM) for Idukki on 17 August. Further, in the case of Idamalayar, though attenuation occurred at peak inflow, the fact is that net inflow over the 14-18 August period was negative (-9.86 MCM). Besides, the Guidelines for operation of spillway gates of Cheruthoni dam (1990) specify that outflow is never to exceed inflow except under emergencies and when the reservoir is to be depleted to the desired level. Thus, Audit feels that it cannot be cited as a standard operating procedure, even during the receding limb of a flood hydrograph, particularly so close to the peak inflow.

Hence, Audit reiterates the need for assurance about the adequacy of the new rule curve along with the provision of dynamic flood cushion given the fact that the frequency of incidents of excessive rainfall and flooding in the State has increased in recent years. As the rainfalls in July 2018 had resulted in an average inflow of 25 MCM per day to Idukki and the average inflow to Idukki between 09 August 2018 and 19 August 2018 was more than three times and of the order of 79 MCM per day, which was unprecedented in the history of the dam, there is an urgent need to be prepared for such extreme rainfall events in the future including through establishment of inflow forecasting stations[79]. The possibility of unscheduled releases from upstream reservoirs also needs to be considered along with the factoring of downstream conditions. It is desirable further to develop the rule curves keeping in view the integrated operation of the major reservoirs in the basin. Rule curves developed considering various aspects including integrated operation of reservoirs would provide more assurance.

Recommendation 3.5:

a) KSEB may ensure flood release operations for reservoirs are based on approved rule curves which further need to be regularly reviewed and updated.

b) KSEB may conduct simulation or other studies to ensure that the approved rule curves of 2020 for Idukki and Idamalayar would be adequate to handle situations similar to the extreme rainfall event of 2018, without consequential flooding.

[78] Water level on 14 August was 5.91 m as per CWC data.

[79] The reservoir level can be better managed by providing a dynamic cushion to moderate flood through meticulous planning by reviewing the reservoir levels and inflow forecast at all time steps. *(Source: Rule curve for major reservoirs of KSEB – May 2019)*

c) Feasibility of putting in place rule curves based on integrated operation of reservoirs within an approved time frame must also be considered.

3.7. Siltation of reservoirs and reduction in storage capacity

Dams and Reservoirs are subject to siltation. Sedimentation causes loss of active storage volume, and thus reduced ability to compensate for outflows for hydro power, irrigation, drinking water and flood retention. Uncontrolled deforestation, forest-fires, overgrazing, improper methods of tillage, unwise agriculture practices and other activities are mainly responsible for accelerated soil erosion which causes siltation in dams. Paragraph 7.10 of Reservoir Operation Guidelines[80] issued by the Bureau of Indian Standards requires capacity surveys of reservoirs to be undertaken once in three to five years or when the loss of capacity was five *per cent*, whichever was earlier.

- Audit observed that of the 18 reservoirs[81] under the ownership of KSEBL, sedimentation studies of only 11[82] were carried out during the period from 1989 to 2011. As on the date of audit (August 2019), no capacity surveys or sedimentation studies were conducted in any of the KSEBL reservoirs after 2011. Though the sedimentation surveys (in 2007 and 1995 respectively) indicated significant capacity loss as in Kallarkutty dam (47 *per cent* of gross storage in 45 years) and Anayirankal reservoir (30.92 *per cent* in 33 years), KSEBL had not conducted any further study to assess the change in silt deposit and reduction in the capacity of the dams. Though KSEBL identified (2010) six dams[83] for conducting desiltation, none of them had been desilted till the date of audit (August 2019).

  Secretary, Power Department stated (September 2020) that the live storage in five major reservoirs *viz.* Idukki, Idamalayar, Kakki, Banasurasagar and Sholayar (out of 18 reservoirs[84]) constitutes 92.27 *per cent*. Siltation is negligible in these major reservoirs as its annual storage loss is less than 0.2 *per cent* as per the sedimentation studies conducted through various agencies. In respect of the eight small reservoirs for which studies were conducted, desilting could not be carried out due to difficulty in depositing removed silt and obtaining permission from Forest Department. The Handbook on assessing and managing reservoir sedimentation published by CWC in February 2019 indicates that the annual storage loss due to sedimentation is significantly low in Kerala reservoirs.

  Audit observes that the statement that sedimentation in the five major KSEBL reservoirs is negligible is not based on any recent study or

[80] IS 7323:1994, Paragraph 7.10
[81] Eighteen storage reservoirs which are formed under 32 dams.
[82] Kakki, Kallarkutty, Lower Periyar, Ponmudy, Poringalkuthu, Kundala, Madupetty, Anayirankal, Pamba, Kuttiadi, Idukki and Idamalayar reservoirs
[83] Lower Periyar, Kallarkutty, Ayyappancovil and Kulamavu area of Idukki Hydro Electric Project, Anayirankal, Kundala and Madupetty Reservoirs
[84] with live storage capacities ranging from 0.39 to 1460 MCM

assessment (through CWC or otherwise) as sedimentation assessment of Idukki, Idamalayar, Kakki and Sholayar were conducted during 2004, 2011, 1999 and 2003 respectively. In respect of Banasurasagar reservoir, commissioned during 2005, no sedimentation study is seen conducted. Thus, 9 to 20 years have elapsed since conduct of capacity survey or sedimentation study, even though Reservoir operation guidelines (IS 7323:1994) provide for capacity survey every three to five years.

Kerala State Electricity Board Ltd. informed vide letter dated 01 February 2021 that sedimentation study had been repeated for Poringalkuthu and Kundala reservoirs in 2020. KSEBL also completed sedimentation surveys for five more reservoirs *viz.* Kallarkutty, Madupetty, Ponmudy, Anayirankal and Sengulam in 2020 but reports of the survey are awaited. Proposals for conducting sedimentation studies for the remaining reservoirs are now included under Dam Rehabilitation and Improvement Project (DRIP) - II and submitted to CWC for their approval. Chief Engineer (Civil – Dam Safety and DRIP) further stated (February 2021) in the backdrop of the 2018 floods that it was decided to carry out the sedimentation study for Idukki, Idamalayar, Kakki, Banasurasagar and Sholayar reservoirs and the same is included in Dam Rehabilitation and Improvement Project-II.

- Audit observed that the position was slightly better in the case of 20 reservoirs under the control of the Water Resources Department. Siltation study was conducted in respect of all these reservoirs. The study revealed significant levels of siltation in Aruvikkara reservoir (43 *per cent*), Mangalam reservoir (21.98 *per cent*), Peppara reservoir (21.70 *per cent*) etc. However, desiltation activities were not undertaken in any of these reservoirs. Though sanction was accorded (September 2017) by GoK for desiltation of Mangalam and Chulliyar reservoirs, the works were yet to commence as of the date of audit (November 2019).

In its reply, the Water Resources Department (November 2020) stated that silting was generally less in Irrigation dams. However, Audit observed that sedimentation in Peppara, Mangalam and Kanjirampuzha reservoirs of 21.70, 21.98 and 21.27 *per cent* of its storage capacity was significant.

During the Exit Conference (02 February 2021) and subsequently, vide letter from ACS, Water Resources Department dated 19 April 2021, Audit was informed that the desilting of Mangalam dam commenced[85] in the first week of December 2020 and that of Meenkara, Valayar and Chulliyar reservoirs entrusted to Kerala State Mineral Development Corporation Ltd. and Kerala Irrigation Infrastructure Development Corporation. With respect to

[85] ACS, WRD reply dated 19 April 2021 indicated that work for desilting Mangalam dam is a three-year long project which started on 17 December 2020. As on 10 April 2021, 0.098 MCM sediments (3.32 *per cent*) removed out of a total estimated quantity of 2.95 MCM.

Kanjirappuzha reservoir, bathymetric survey has been completed. Administrative sanction was accorded for the desiltation of Aruvikkara reservoir in January 2021 and two bids received are under consideration of the High-Level Empowered Committee. Further, though all efforts are taken to get the dams desilted, as the participation in tendering process was very low, the works had to be retendered more than once. ACS also stated that with the constitution of River Basin Conservation and Management Authority, the coordination work could be institutionalised and turned into a regular process.

Recommendation 3.6: In view of the possible loss of active storage volume of dams through sedimentation and its consequential adverse impact on flood control, KSEB and Irrigation Department may ensure that sedimentation studies as prescribed in Reservoir Operation Guidelines issued by Bureau of Indian Standards are conducted and timely action taken to arrest the capacity loss of reservoirs.