Operation and Maintenance Manual
For Lower Periyar Dam
State of Kerala

Kerala State Electricity Board Ltd.

KSEB

DRIP
Rehabilitation & Improvement Project

Doc No. 16_DSO_O&M_KL29HH0051

Front Cover Photograph: Upstream and downsream view of Lower Periyar dam.

Operation and Maintenance Manual for Lower Periyar Dam

Prepared by the Dam Safety Organisation
Kerala State Electricity Board Ltd.
(A Government of Kerala undertaking)
State of Kerala

Operation and Maintenance Manual

Lower Periyar Dam

Lower Periyar Hydro Electric Project

Chief Engineer (Civil-Dam Safety & DRIP)

Dam Safety Organisation

Kerala State Electricity Board Ltd.

Pallom, Kottayam.

June 2020

Kerala State Electricity Board Ltd.

Dam Safety Organisation

Disclaimer

This *Operation and Maintenance Manual for Lower Periyar Dam* in no way restricts the dam operators in digressing from her/his responsibilities. The Dam Operators must exercise appropriate discretion and good judgment based on actual site condition when implementing and using the operation and maintenance manual for managing the working of the dam and appurtenant structures.

The manual is developed for the purposes of organization and managing the operation, inspection and maintenance of the dam for reducing risk and optimizing performance of the dam as a general guide.

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Message

India has more than 5200 large dams. Their health and safety are of paramount importance for sustainable use of the valuable assets, besides providing protection to the people and property in the downstream areas. The Ministry of Water Resources, River Development & Ganga Rejuvenation through the Central Water Commission (CWC), with financial assistance from the World Bank, started the Dam Rehabilitation and Improvement Project (DRIP) to rehabilitate 198 large dam projects in seven states. Kerala State Electricity Board Ltd, through Government of Kerala participated in DRIP to rehabilitate 37 dams under 12 Hydro Electric Projects in the state.

For managing a dam in a sustainable and scientific manner, it is very crucial for each dam owner to have dam specific Operation and Maintenance Manual that lays down procedures for the daily upkeep of the dam. An Operation and Maintenance Manual for a dam is essential for ensuring its safe functioning and for deriving continued benefits. This Operation and Maintenance Manual for Dam has been prepared following the Guidelines for Preparation, Operation and Maintenance Manuals published by CWC in January 2018 under DRIP and covers requirements for project Operation, Inspection, Maintenance, Instrumentation and Monitoring the health of Dam both during monsoon and non-monsoon periods.

I recommend the dam officials to use this manual for the efficient and safe Operation and Maintenance of the Dams on regular basis.

I compliment all the experts who have contributed to the development of this manual and congratulate the Dam Safety Organisation, KSEB Ltd, Pallom and CWC for the initiation of such important policy protocol to address dam safety management in Kerala.

Bibin Joseph,
Director Generation (Civil),
KSEBLtd
Kerala

Foreword

Globally, the Operation and Maintenance (O&M) Manual of a dam is one of the most important documents which is supposed to be put in practice right from the initial filling of reservoirs. In order to address the operation and maintenance aspects, ongoing Dam Rehabilitation and Improvement Project (DRIP) has requisite scope to prepare new or update existing O&M manuals for all DRIP dams, which will become very helpful to Dam Owners in addressing the dam specific issues comprehensively in future.

This Operation and Maintenance (O & M) Manual developed is a detailed set of written descriptions with step-by-step procedures for ensuring that the dam is safely operated, frequently inspected and properly maintained. In this era of shrinking budgets, timely inspection and preventative maintenance is necessary for the safe functioning of the dam and continued productive use of the dam and reservoir.

The format of this manual is prepared following the principles published in 2018 CWC Guidelines for Operation and Maintenance of dams for the use by all Dam Owners in developing their own site-specific manuals. Each section of the document provides the necessary instructions to operate inspect and maintain their dams.

It is recommended that all dam officials in charge to use this manual for ensuring that the dam is operated and maintained in a sustainable manner and will continue to derive benefits.

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PREFACE

Operation and Maintenance (O&M) Manual is a detailed written document of procedures and protocols for ensuring that a dam is operated and maintained properly and timely to avoid further health deterioration and extend service life of these assets. An Operation and Maintenance Manual is essential for a dam for ensuring its safe functioning and for deriving desired benefits from it by describing all the elements systematically for its operation, inspection, maintenance, instrumentation and monitoring of the health.

Central Water Commission has published the Guidelines for the development of New Manual and Updating of Existing Manual vide CDSO_GUD_DS_03_v1.0 January 2018.Accordingly Kerala State Electricity Board is developing and updating the Operation and Maintenance Manual of Dams under their ownership for a healthy dam safety management system.

The dam at Pambla of Lower Periyar Hydroelectric Project under KSEBL does not have a comprehensive Operation and Maintenance Manual. Hence an attempt is made here to prepare the manual as per the new guidelines by CWC. The Lower Periyar HEP of KSEBL commissioned in 1997 includes one main concrete gravity type dam located at Pambla. The power house of LPHEP, located at Karimanal, generate 180 MW, under an average head of 203.63m.

This Operation and Maintenance Manual is prepared for Lower Periyar dam of the Lower Periyar Hydroelectric Project.

LIST OF ACRONYMS

The following acronyms are used in this publication:

AAR	Alkali-Aggregate Reaction
ACI	American Concrete Institute
ASTM	American Society for testing Materials
CDSO	Central Dam Safety Organization
CWC	Central Water Commission
CWPRS	Central Water and Power Research Station
DDMA	District Disaster Management Authority
DHARMA	Dam Health and Rehabilitation Monitoring Application
DRIP	Dam Rehabilitation and Improvement Project
EAP	Emergency Action Plan
FSCT	Federation of Societies for Coatings Technology
HCC	Hindustan Construction Corporation Ltd.
IS	Indian Standard
KERI	Kerala Engineering Research Institute
KDSA	Kerala Dam Safety Authority
KSEBL	Kerala State Electricity Board Ltd.
KWA	Kerala Water Authority
NCDS	National Committee on Dam Safety
NCSDP	National Committee on Seismic Design Parameters
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
SPF	Standard Project Flood
SPS	Standard Project Storm
RCC	Reinforced Cement Concrete
ROUV	Remotely Operated Underwater Vehicle
ROV	Remotely Operated Vehicle
SDSO	State Dam Safety Organization
SISF	State Industrial Security Force
UAV	Unmanned Aerial Vehicle
USBR	United States Bureau of Reclamation
USACE	United States Army Corps of Engineers

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CHAPTER 1
GENERAL INFORMATION

1.1 Introduction

This document represents a detailed Operation and Maintenance (O&M) Manual for Lower Periyar Dam at Pambla, of Lower Periyar Hydro Electric Project, Kerala, providing written descriptions of procedures for ensuring that the dam operates safely and is kept in a good condition by periodic inspections, repairs and maintenance in a sustainable manner. Timely maintenance is important for the continued safe functioning and productive use of the dam and reservoir.

The Manual has been prepared primarily for the dam operation staff and staff supervisors who are assigned the responsibility of physical operation and maintenance of the dam. It contains, as a minimum, all information and instructions necessary for them to perform their allotted tasks in a safe manner. In addition to instructions for dam operation staff, the Manual includes all necessary instructions for other staff directly or indirectly involved in operating and maintaining the dam.

It is essential that the Manual or a copy of the Manual along with supporting data including the atlas of all drawings and manufacturer' s technical documents is available at site for ready reference.

1.2 Purpose, Location, Description of the Project

The Lower Periyar Hydro Electric Project, the first major project in Kerala since Idukki, is a major effort at harnessing the vast water resources of Kerala from the lower reaches of the River Periyar, for cost effective power generation. With major projects like Idukki and Idamalayar and many smaller projects, the Periyar is Kerala's main source of power. The project will utilize tail water from the Neriyamangalam power station and spill from Kallarkutty dam, available yield from Perinjakutty catchment and the free catchment areas below the dams at Kallarkutty, Idukki and Cheruthoni for power production, and will feature India's longest power tunnel to channelise water over an average gross head of 203.63m for power generation. With three 60 MW generators, the Lower Periyar Project will add an installed capacity of 180 MW – the third highest in the state at that time, to contribute a firm power of 56.2 MW equivalent to 493 MU to Kerala and southern power grid annually. The average annual generation is estimated at 69MW, corresponding to 604MU.

The Lower Periyar Hydro Electric Project (LPHEP) is envisaged as a tailrace cum run-of-river scheme. The project is located on the Periyar River just below its confluence with the Mudirapuzha River (a sub basin of Periyar River). The catchment of Lower Periyar reservoir is intercepted by the dams of upstream reservoirs. The Kallarkutty Dam in Mudirapuzha river and Idukki Dam in Periyar river are the dams located in the immediate upstream of Lower Periyar. The upstream reservoirs, Kundala, Madupetty, Anayirangal, Ponmudi, Sengulam and Kallarkutty in Mudirapuzha basin and Mullaperiyar and Idukki reservoirs in Periyar River regulate the upstream catchments depending upon their storage capacity.

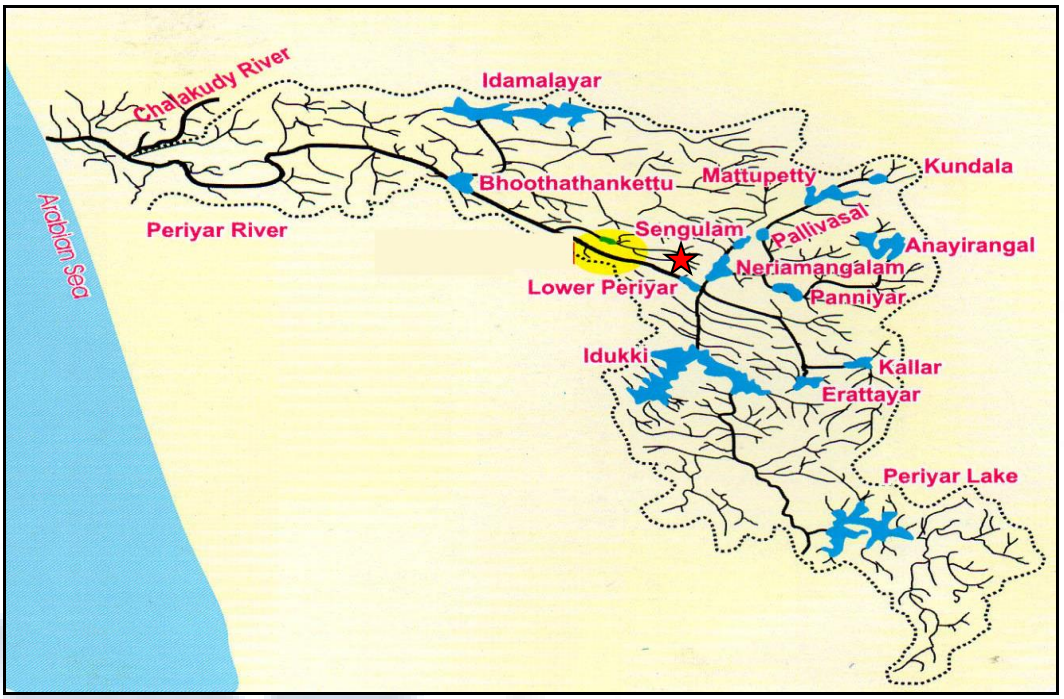

Fig 1.1 Periyar river basin map showing the Project Area

Ad diversion dam is constructed in Periyar River at Pambla and the water is diverted through a water conductor system to the Powerhouse located at Karimanal on the left bank of Periyar River. After generating power, the water is released to Periyar River itself. The Project was commissioned in 1997.

Location

The project is located in Idukki District of Kerala State. The location of the dam site is at Pambla. The location of dam is at latitude 9^0 57' 44" N and longitude 76^0 57' 24" E. The Dam and Power House are situated in Idukki District, Kanjikuzhy Panchayath, and Kanjikuzhy Village of Kerala State. The project is located along the sides of Neriyamangalam- Idukki road. The approximate distance of dam from Neriyamangalam is 28km and that of Power house is about 12km. The nearest airport is Kochi International Airport. The distance from airport to the dam site is 77 km. The nearest

rail head is Aluva. It is about 81 km from dam site. The nearest city is Kothamangalam. The index map of Lower Periyar Hydro Electric Project is given in Fig. 1.2 and Google map showing project area is shown in Fig 1.3.

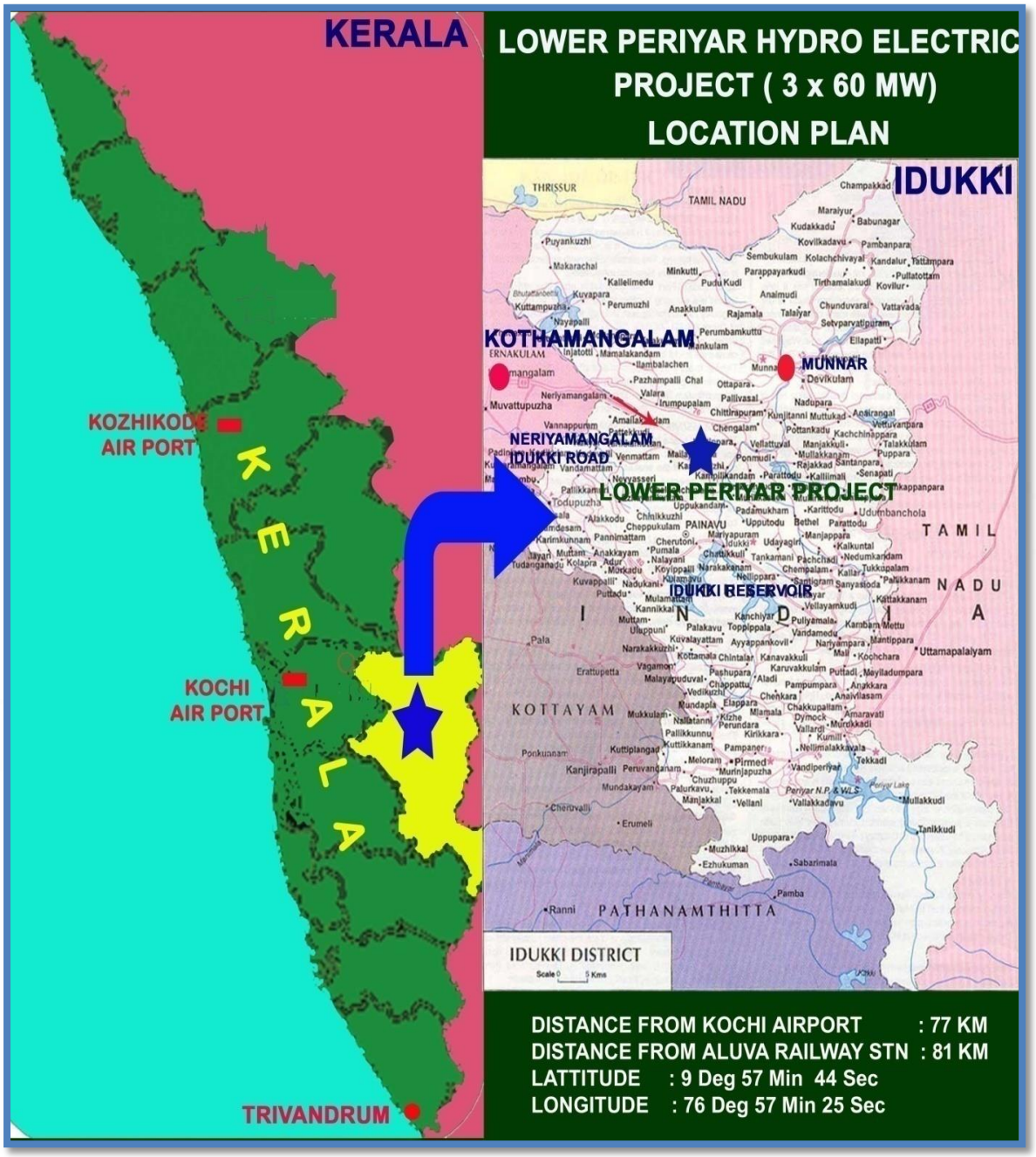

Fig 1.2 Index Map

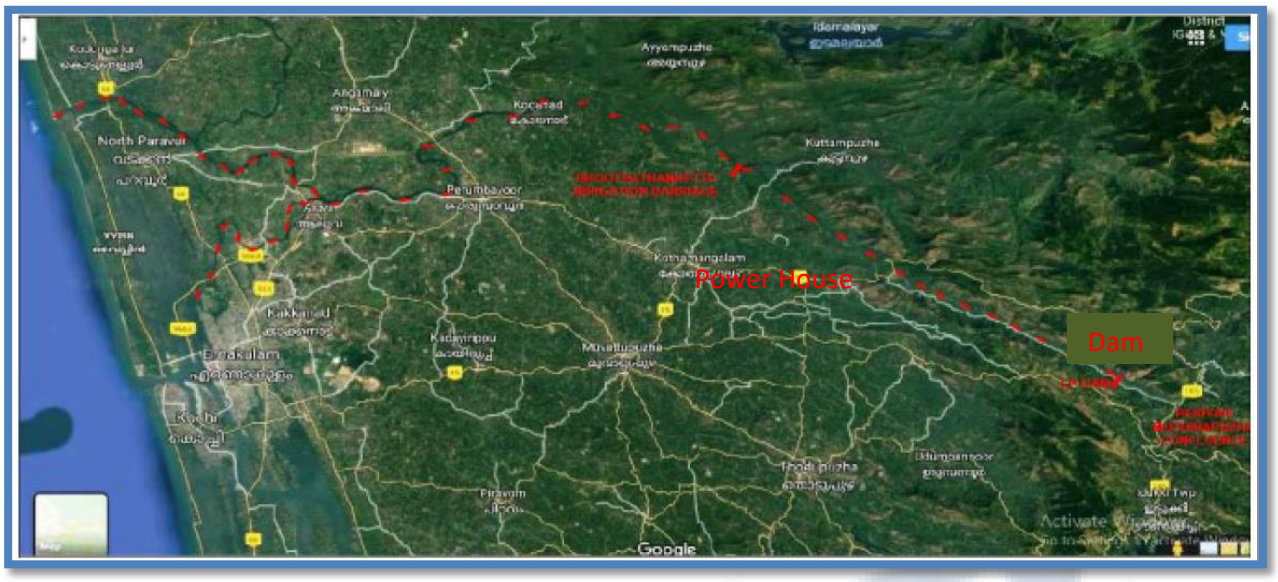

Fig 1.3 Google Map showing the Project Area

Project Components

Dam

The Lower Periyar (Pambla) Dam is a concrete gravity diversion dam of height 30.85m, above nominal bed level at the dam site, creating a small forebay of live storage capacity of 4.55Mm^3. Elevation at top of dam is + 257.00 m. MWL is +256.00 m and FRL is +253.00 m. The Google view of Lower Periyar dam is given below.

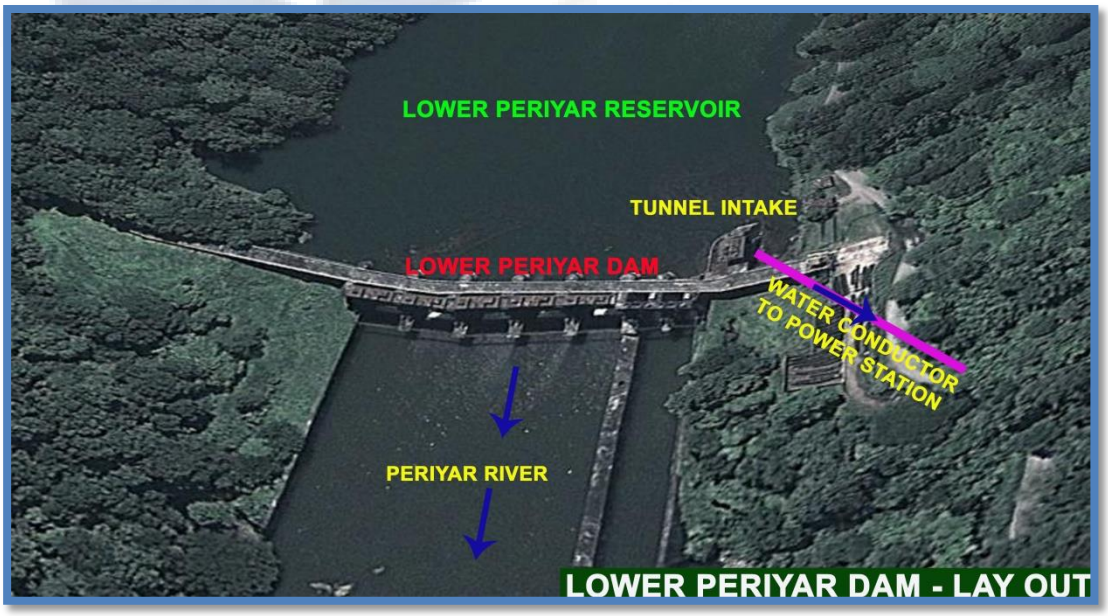

Fig 1.4 Lower Periyar Dam- Google view

Water Conductor System

The water conductor system consists of a power tunnel of length 12.791 km having finished diameter of 6.05m. The intake structure is provided near to the left abutment of the dam with tunnel intake sill level at +229.00m.

A Surge Shaft of restricted orifice type, concrete lined with 17.60m diameter up to elevation +253 and 21m diameter above 253m, is provided at the end of power tunnel. Thereafter, pressure shaft of 5.25m finished diameter and length of 387m, branching into three pressure shafts each of 2.96m dia. and of average length 207m is provided.

Power House

The Power Station consists of three Generating units with vertical shaft Francis turbine of installed capacity 60 MW each, of BHEL make. After power generation, water from the power station is released to the Periyar River.

The general layout and schematic diagram are given in fig.1.5 and 1.6.

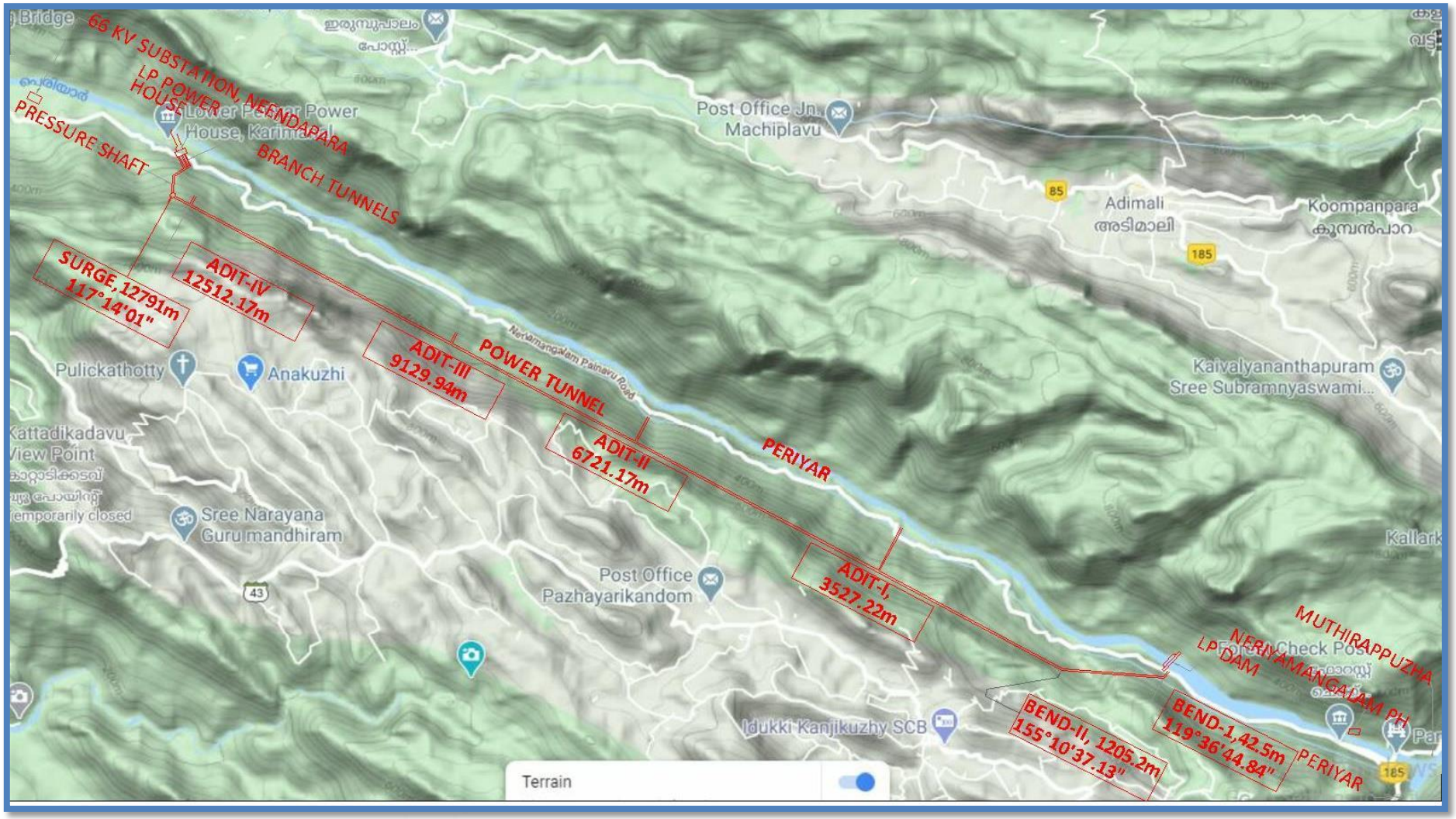

Fig 1.5 General layout

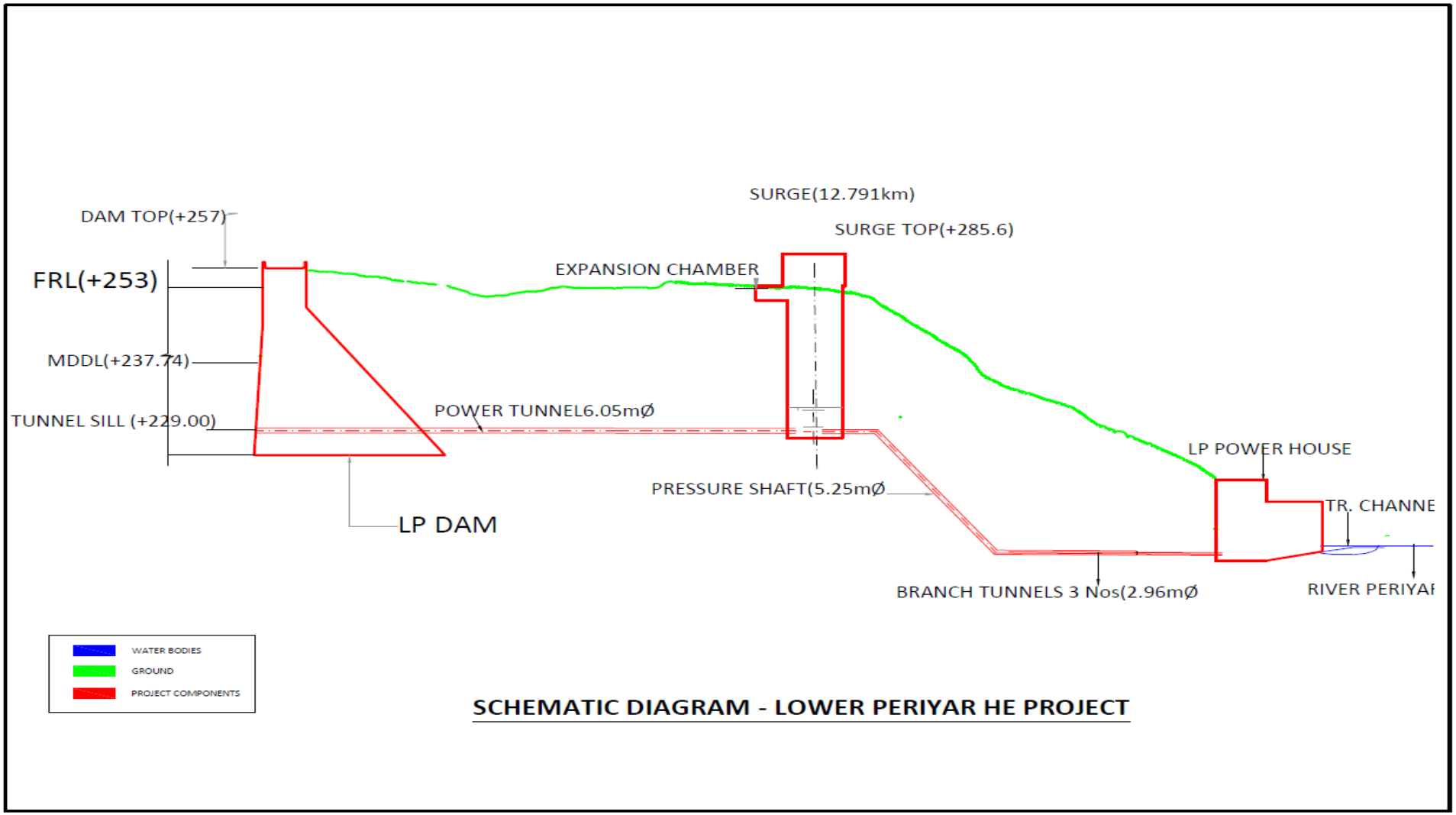

Fig 1.6 Schematic diagram

Fig 1.7 View of Lower Periyar Dam

Fig 1. 8 View of Lower Periyar Dam gates

Fig 1.9 View of Intake

Fig 1.10 View from right abutment

Fig 1.11 View of upstream

View of LPHEP power house is shown below. The layout of Power house is attached in Annexure I as Drg. 20.

Fig 1.12 Google View of LPHEP Power House

Fig.1.13 Photograph of Lower Periyar Power House

1.3 Background Details of the Project

The preliminary works like investigation, preparation of DPR etc. was carried in 1970's. The DPR estimate amounted to Rs. 41.20 Cr. The main work was split into two contracts, ie., the Tunnel and allied works were awarded to M/s Hindustan Construction Company and works related to Dam and Power Hose were awarded to M/s NPCC. Both of them started the work in 1984. The Tunnel works were almost completed by 1992. But no remarkable progress was achieved in construction of Dam and Power House. Hence the contract with M/s NPCC was terminated in 1992 and the balance work of Dam and Power house was also awarded to M/s HCC limited as new contract. The whole work was completed by October 1996 and the mechanical spinning was started. After completing all the tests the Project was commissioned in 1997.

The project has been executed under the expert management of the Kerala State Electricity Board (KSEB in technical consultancy with SNC Shawinigan of Canada.), and a panel of highly competent and experienced engineers. The various phases of the construction of the project have been undertaken by leading Indian technology and construction companies like Bharat Heavy Electricals, Hindustan Construction Company, Crompton Greaves, Switch Gear Company, PES Engineering Company and so on. The Project is part financed by the World Bank. The cost of construction on completion comes to 28,900 lakhs.

1.4 Salient Features of Lower Periyar Hydro Electric Project

A	GENERAL		
1	State	:	Kerala
2	District	:	Idukki
3	River	:	Periyar
4	Geographical Coordinates		
	Dam :Latitude	:	9^0 57' 44" N
	Longitude	:	76^0 57' 24" E
	Power house: Latitude	:	10^0 01' 00" N
	Longitude	:	76^0 51' 30" E
B	HYDROLOGY		
1	Catchment area	:	584 Sq. km
2	Average Weighted Annual rainfall	:	2794 mm
3	Average Annual runoff LP Catchment	:	292.00 Mm^3
4	Design Flood	:	13730 m^3/s

C	DAM ACROSS PERIYAR – LOWER PERIYAR DAM		
1	Type of dam	:	Concrete Gravity
2	Nominal Bed Level	:	+226.15 m
3	Deepest Foundation Level	:	+218.00 m
4	Top of dam	:	+257.00 m
5	Length of dam at top	:	284 m
6	Height of dam above bed	:	30.85m
7	Base Width	:	24.95m
8	No. of blocks	:	15 no
9	No. and size of radial gates	:	5 nos. of 13.5 m x 15.65 m
10	Length of Spillway	:	106m
11	Spillway crest Level	:	+237.74m
12	No. and size of outlet gates	:	2 Nos. lower vent, 6.75mx15.65m
13	El. of sill of outlet	:	+227 m
14	Total Discharge capacity at FRL	:	11200m^3/s
15	Total Discharge capacity at MWL	:	14200m^3/s
16	No. of Adits to foundation gallery	:	2 Nos; one in each flank
17	Volume of masonry	:	0.054 Mm^3
D	RESERVOIR		
1	Full Reservoir level(FRL)	:	+253.00 m
2	Maximum Water Level (MWL)	:	+256.00 m
3	Minimum Draw Down Level(MDDL)	:	+237.74 m
4	Gross Storage at FRL	:	5.35Mm^3
5	Dead Storage below MDDL	:	0.8 Mm^3
6	Live Storage	:	4.55Mm^3
7	Water Spread Area at FRL	:	44.5 Ha
E	POWER TUNNEL		
1	Length of Tunnel	:	12.791k m
2	Finished Diameter	:	6.05m
3	Sill level at inlet	:	+229.00 m
4	Sill level at Exit	:	+186.55m
5	Lining Thickness	:	30 cm
6	Design maximum Flow	:	124.71 m^3/s
7	Velocity	:	4.338 m/s
F	SURGE SHAFT		
1	Main Barrel		
	(a) Diameter	:	17.6m upto+253m and 21.00m above +253m
	(b) Depth	:	91.5m

G	PRESSURE SHAFT		
1	Main		
	(a) No. of Pressure Shaft	:	1 No.
	(b) Diameter	:	5.25 m
	(c) Length	:	387 m
	(d) Gradient	:	1 in 100
2	Branch Tunnels		
	(a) No. of Shafts	:	3 Nos.
	(b) Diameter of Shaft	:	2.96m
	(c) Average length	:	207m
H	POWER HOUSE		
1	Average Head	:	203.63 m
2	Power House Generator Floor level	:	+58.50 m
3	Centre line of runners	:	+48 m
4	Installed capacity	:	3 x 60 MW
5	Size of Machine Hall	:	60.5 m x 17.50 m
6	El. of Switchyard	:	+68.00 m
7	El. of Feeder Bays	:	+76.00 m
8	Normal tail water level	:	+49.37m
9	Average Gross head available	:	203.63 m
10	Average Power generation at 100% L.F	:	85 MW
11	Turbines	:	Francis turbine, vertical shaft
12	Step up transformers 11 KV/220 KV	:	Three Nos. Three Phase transformers of capacity 66.67 MVA for each generator
13	Transmission Lines 220 KV	:	a) 35km double circuit line between Idukki and Lower Periyar b) 100km double circuit line between Lower Periyar and Thrissur c) 60km double circuit line between Lower Periyar and Kochi

Table 1.1 – Salient Features of LPHE Project

1.5 Assignment of Responsibility

Kerala State Electricity Board Ltd. is the owner and has the final authority and responsibility for the operation and maintenance of the dam. Identification of all areas of responsibilities connected with the operation and maintenance of the dam are covered in this section. The officer's responsibilities for the various functions (civil, mechanical, electrical, instrumentation etc.) are identified by their designation and, in particular, the responsibilities of

operating personnel are specifically identified including the regularly scheduled duties which staff personnel are required to perform as outlined.

Project Administration Office	-	Chairman & Managing Director, KSEB Ltd. Vydyuthi Bhavanam, Pattom, Thiruvananthapuram.
Chief Controlling Officer	-	Chief Engineer (Civil -DS & DRIP), Dam Safety Organization, KSEB Ltd., Pallom, Kottayam.
Authority of Spillway operations and Flood releases	-	Chief Engineer (Civil –DS & DRIP), Dam Safety Organization, KSEB Ltd., Pallom.
Operation and safety of the dam	-	Deputy Chief Engineer, Research & Dam Safety Organization, KSEB Ltd., Pallom.
Controlling / Operation Officer at dam site	-	Executive Engineer, Research & Dam Safety Division No. IV, Pambla, Idukki.
Reservoir operations, inspection & maintenance	-	Executive Engineer, Research & Dam Safety Division No. IV, Pambla.
Dam Health Engineer	-	Executive Engineer, Research & Dam Safety Division No. IV, Pambla.
Recording reservoir data, inspection, monitoring and maintenance at site	-	Assistant Executive Engineer, Research &Dam Safety Sub Division, Pambla.
Handling Dam operations, inspection, monitoring and performing duties as Maintenance Officer at dam	-	Assistant Engineer, Research &Dam Safety Sub Division, Pambla.

1.5.1 Roles and Responsibilities of the AEE and AE during Monsoon

Flood condition assessment, warning, flood mitigation, and other responsibilities

1. Coordinate with the Asst. Exe. Engineers of other Sub Divisions and get the information on rainfall in the catchment, inflow status, reservoir level and to bring it to the notice of the EE/DyCE.

2. Assist the EE/ Dy CE /CE to issue notification to the inhabitants downstream in Newspapers, Radio, and TV News channel to be alert regarding the flood situation.

3. Assist the EE/ Dy CE /CE to coordinate with the Revenue authorities (District Administration) to alert the downstream inhabitants to evacuate the flood zone to prevent loss of life and livestock.

4. Assist the EE/ Dy CE /CE to coordinate with the CWC flood monitoring authorities on the flood condition.

5. Maintain the reservoir water level gauge register and to update on hourly basis during floods and report to EE/ Dy CE /Chief Engineer.

6. Assess the inflows in the reservoir as per the approved reservoir operation and to prepare Proforma consisting of the status of the reservoir capacity and releases from the reservoir as per the standard Performa and to submit to the EE/ Dy CE /CE.

7. Submit to the EE/ Dy CE /CE on the inflows and releases from the reservoir and status of the reservoir twice in the day.

8. Maintain the spillway crest gate operation log book.

9. Operate the Spillway crest gates for flood mitigation as per the instructions of the EE/ Dy CE /CE and to update the Gate operation Log book

10. Observe the seepages in the drainage Gallery with respect to the reservoir head and record the seepages in the infiltration gallery and to immediately bring to the notice of the EE/ Dy CE /CE in case of excessive seepage/leakage in any specific blocks and porous drains.

11. Maintain the pump operation log books for the dewatering pumps in the drainage gallery and to submit to EE/ Dy CE /Chief Engineer.

12. Observe the gates and to see that the drain holes are not clogged and floating debris is not deposited in the gate components.

13. Monitor the condition of the Welding transformers, gas cutting sets, umbrellas, tool kits, torches, chain blocks, ropes etc., on daily basis and to see that things are in place to handle any emergency situation.

14. Observe the Gates, hoists and handling equipment during operation for the smooth movements and to immediately report any untoward excessive sounds in the motors, pumps or vibrations in the gate.

15. Observe and ensure that the dam top, embankment, catwalk, approach roads are well maintained by housekeeping personnel.

16. Observe the performance of the Dam and its appurtenant structures / Gates and Hoists during flood water releases and to report to the EE/ Dy CE /CE in case of any untoward incidents or malfunctioning of the gates of excessive seepages, leakages etc.

17. Assist EE/Dy CE /CE to coordinate with the Generating staff of Lower Periyar Powerhouse downstream in the operation and power generation.

18. Assist EE/Dy CE /CE to share the flow data and the reservoir storage details to the Media on day to day basis during flood.

1.5.2 Roles and Responsibilities of the Dy CE and EE during Monsoon

1. Conduct Periodical (Pre and Post Monsoon) inspections to assess the health of the Dam and to direct the Executive Engineer for the immediate repair and maintenance for the smooth operation. Submit the inspection reports to the Chief Engineer and upload in DHARMA.

2. Observe the performance of the Dam and its appurtenant structures / Gates and Hoists before and after monsoon and to issue necessary instructions to the Executive Engineer.

3. Coordinate with the Engineers of the two sub divisions & to get the information in respect of rainfall and inflow status and to bring to the notice of the CE.

4. To issue notification to the inhabitants downstream in Newspapers, Radio, TV News channel to be alert regarding the flood situation.

5. Assist the CE to coordinate with the Revenue authorities (District Administration) to alert the downstream villagers to evacuate the flood zone to prevent loss of life and livestock.

6. Assist the CE to coordinate with the CWC flood monitoring authorities on the flood condition.

7. Submit to the CE the daily inflows and releases from the reservoir and status.

8. Operate the Spillway crest gates for flood mitigation as per the instructions of the CE and to update the Gate operation Log book.

9. Observe the seepages in the drainage Gallery with respect to the reservoir head and record the seepages in the infiltration gallery and to immediately bring to the notice of the CE in case of excessive seepage, leakage in any specific blocks and porous drains.

10. Observe the Gates, hoists and handling equipment during operation for the smooth movements and to immediately report any untoward excessive sounds in the motors, pumps or vibrations in the gate.

11. Observe the dam top, embankment, catwalk, approach roads are well maintained by housekeeping personnel.

12. Observe the performance of the Dam and its appurtenant structures / Gates and Hoists during flood water releases and to report to the CE in case of any untoward incidents or malfunctioning of the gates of excessive seepages, leakages etc.

1.5.3 Roles and Responsibilities of the Chief Engineer during Monsoon

1. To issue sanction for flood release notification after discussing with Kerala Disaster Management Authority and Revenue Authority (District Administration).

2. Coordinate with the CWC flood monitoring authorities on the flood condition.

3. Issue necessary instructions to the engineers to operate the reservoir based on the in-flows, rainfall data, releases from the upstream reservoirs and status of the reservoir.

4. Observe the performance of the Dam and its appurtenant structures / Gates and Hoists during flood water releases and to issue necessary instructions to the Dy CE/EE.

5. Coordinate with the Generation wing of KSEBL regarding the power generation requirement.

1.6 Collection & Reporting of Dam and Reservoir Data

Dam Reservoir Data and vital information as below are collected, recorded and documented for the record.

- Reservoir water surface elevation.
- Reservoir inflow.
- Spillway outflow.
- River releases.
- Irrigation, water supply and hydropower releases.
- Weather related data
- Instrumentation data
- Water quality

MWL (m)	FRL (m)	Crest Level (m)	Present Water Level (m)	Previous Year Water Level	Percentage Storage	Rainfall (mm)	Generation (Mu)	Spill	Gate operation details

Table 1.2: Daily Reservoir Data

Instruction is given to the Executive Engineer for daily collection and reporting of inflow and outflow data in a standard Proforma as in **Table 1.2** above to the Deputy Chief Engineer.

Date	Water Level	Previous Year Same day Water	Rainfall	Previous Year Rainfall	Storage	Generation	Gross Inflow	PH Discharge + Losses	Spill	Net Inflow	Remark

Table 1.3: Daily Reservoir Status

On collecting the details in the above format, a daily reservoir status is submitted to the Chief Engineer as in the **Table 1.3**.

Records/Logbooks of the operations for the following activities at Lower Periyar Dam are maintained in a chronological manner for reference. These records are helpful for identifying preventative maintenance measures that may need to be taken up, troubleshooting the cause of potential equipment failure and documenting development of any unusual conditions.

- Date and Time
- Attendance statement during normal operations – both during monsoon and non-monsoon periods.
- Operations of the spillway gates and outlet works.
- Operating hours of mechanical equipment.
- Testing / Operation of spillway gates, stop-logs and associated controls.
- Testing/operation of Outlet gates, valves and associated controls.
- Maintenance activities carried out.
- Reservoir and dam inspections.
- Unusual conditions or occurrences.
- Safety and special instructions.
- Names of officers and staff carrying out inspections and maintenance.

Periodical collection of Dam and Reservoir Data are done as follows:

Reservoir water surface elevation	This is collected daily
Reservoir inflow	This is calculated daily
Spillway outflow	This is calculated during spill
River releases	The tail water release is measured at Bhoothathankettu Irrigation Barrage and used for Periyar valley Irrigation project
Hydropower releases	The reservoir water is used for power generation
Weather related data	Collected and reported daily

Surveillance/Security arrangements	Provided at one security check posts near dam. The watch and ward of the dam structure and premises is arranged by Police Force under Govt. of Kerala. CCTV surveillance will be provided soon to cover the dam area and adjoining premises.
Water quality	Water sample analysis is conducted once in a month. The analysis consists of Physical & Chemical tests being conducted at The Regional Analytical Laboratory, Kakkanad, and Ernakulam.
Attendance statement during normal operations	Both during monsoon and non-monsoon period maintained at field office.
Operations of the spillway gates and outlet works	The spill way is designed for a safe discharge of 11200m^3/s at FRL. Take record of actual operations.
Operating hours of mechanical equipments	Maintained at field office
Testing/Operation of spillway gates and associated controls	The testing and operation are being carried out as per the manual and maintenance schedule. Other details maintained at field Office.
Testing/operation of Outlet gates, valves and associated	Maintained at field office
Maintenance activities carried out	Details maintained at field office
Reservoir and dam inspections	Periodically inspected and details maintained at field office
Unusual conditions or occurrences, including acts of vandalism	Details maintained at field office
Attendance statement at dam during emergency operations	Details maintained at field office
Changes to normal operating procedure	Details maintained at field office
Communication network checks	Network i s available at Dam site. Police wireless system regularly checked and maintained. Satellite phones are also provided at control room
Safety and special instructions	Safety equipments are available
Names and addresses of official visitors	Record of inspections maintained at office

1.7 Public Utilities and Safety

As safety of Project Staff is of prime concern, safety instructions & protection measures at the dam are to be followed by all staff / project personnel. Inspection Bungalow is provided near Dam. The Lower Periyar dam is located near to the Kothamangalam- Idukki road and frequent bus service is available day and night in this route.

The nearest medical assistance is available at Vellathooval (16km) and Adimaly (18km). District Hospital and Medical College Hospital are available at District headquarters which is about 30km from dam site. Police station is located at Karimanal which is near to the Power House site of Project. Two private hospitals with almost all medical facilities are also available at Kothamangalam which is around 45 km from dam site.

Safety equipment like safety shoe, helmet, safety belt, first aid kit and fire extinguisher are available at the dam site.

1.8 Restricted Areas

Certain areas of the dam and reservoir are restricted for entry of the general public. The purpose of restrictions is for security of the dam, public safety and uninterrupted safe operation of the dam. Warning boards showing the restricted area are placed at the dam premises. Dam premises are protected with compound wall and gates and warning and information boards are also provided at various locations.

1.8.1 Dam Safety Surveillance

Security arrangements are provided near dam at security check post at the dam top on left bank. Also CCTV surveillance will be provided soon for covering the dam and its premises.

Security Arrangement Existing - Kerala Police Force 3 Shifts per day

(3 nos of Police men)

1.9 Staff position, Communication & Warning System

The number & description of operating unit personnel posted/placed at different locations of the dam are noted in supporting documents. Means of communications both in normal and emergency situations are identified in the Communication Directory. Communication means available include landline, mobile and satellite phones, wireless sets etc. Basic facilities like communication facilities, sirens etc. are available.

A hierarchy of organizational structure for the control and safety of Lower Periyar dam is outlined below in **Fig 1.14**

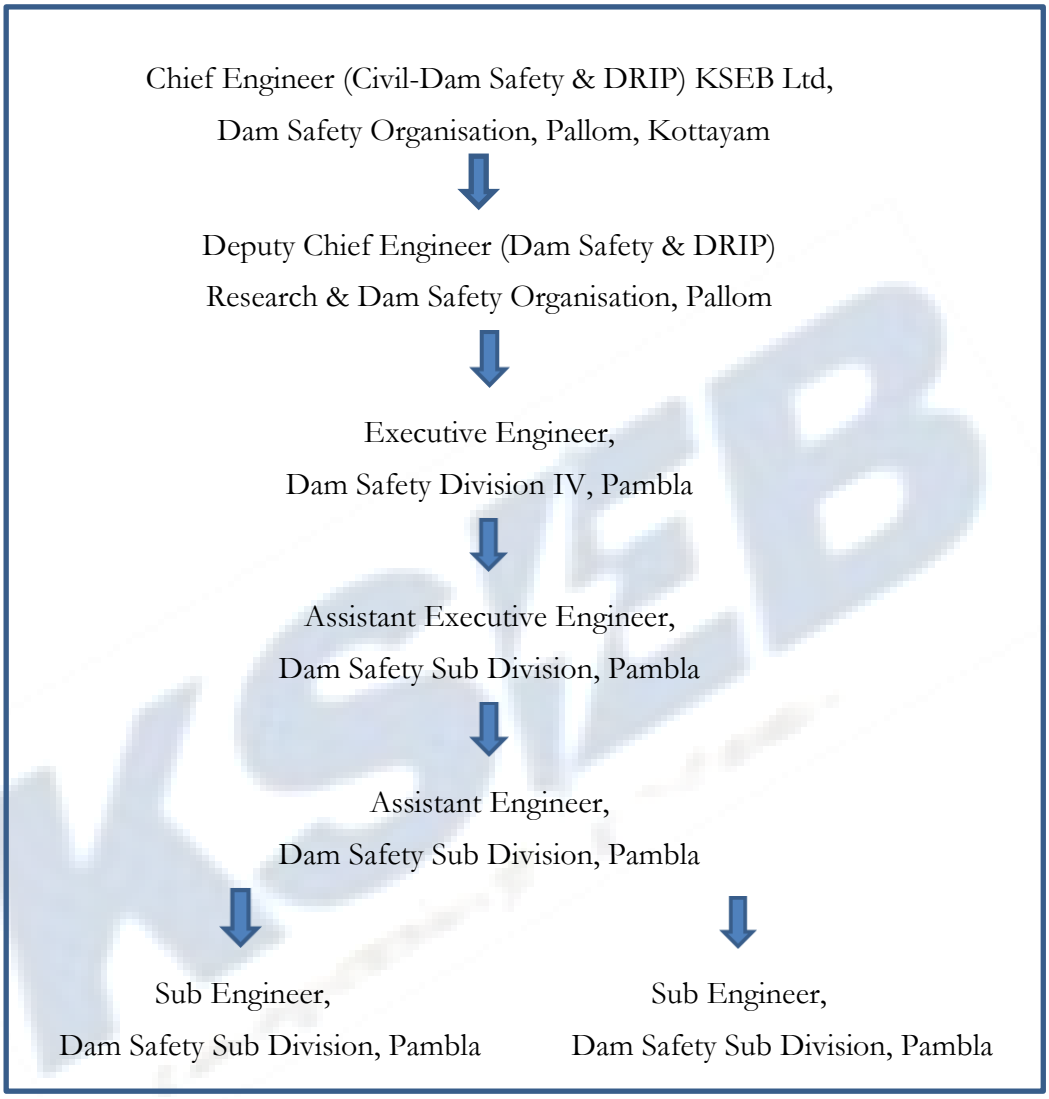

Fig. 1.14 Dam Safety Organisation Structure for Lower Periyar Dam

Present hierarchy of Controlling officers and their contacts are as below:

Designation and office address	Contact number and e-mail
Chief Engineer (Civil- Dam safety & DRIP), KSEB Ltd., Dam Safety Organization, Pallom, Kottayam	Ph: 94960018719, 9446008967 e-mail: cedamsafety@kseb.in, cedamsafety@gmail.com
Deputy Chief Engineer, Research & Dam Safety Organization, Pallom	Ph: 9446008492, 0481-2432290, 9496011540 e-mail: dirroplm2@gmail.com
Executive Engineer, Dam Safety Division No. IV, Pambla	Ph: 9446008421 e-mail: eerdspambla@gmail.com
Assistant Executive Engineer, Dam Safety Sub Division, Pambla	Ph: 9496011802 Satellite phone no :8991118833 e-mail:aeedspambla@gmail.com
Assistant Engineer, Dam Safety Sub Division, Pambla	Ph: 9847415401 e-mail:aeedspambla@gmail.com

Fig. 1.15 Phone Numbers of Controlling Officers

Warning system

Mike announcement, Newspaper, Radio and Television, Siren are used for providing warning to the downstream areas during floods.

Spillway flood releases

Lower Periyar reservoir was being operated as per 'Guidelines for Operation of Reservoirs' (IS 7323:1994). Lower Periyar reservoir is not treated as a storage reservoir as the live storage capacity is only 4.5Mm^3 and hence different warning level as in the case of storage reservoir is not fixed. During flood season, the possibility of opening of spillway gates will be informed 24 hours in advance, to the Disaster Management cell Idukki district, nearest police station, Panchayath office and village offices concerned. Warning message will be conveyed to local media, news agencies etc. regarding the possible opening of spillway gates continuously before reaching FRL. Spillway gates are normally opened at FRL ie 253.00m level based on the Gate Operation Manual.

Releases for various purposes like irrigation, water supply, and hydropower

The water from Lower Periyar reservoir is mainly used for power generation of 180 MW Karimanal power house of KSEBL around 30 Km from Kothamangalam. The tail water from power

house is fed the Bhoothathankettu Irrigation barrage and used for Periyar Valley Irrigation Project.

Routine inspection

Usually monthly inspection and quarterly inspections are carried out by the operating/controlling officers. Pre-monsoon inspection and Post monsoon inspection as per CWC guidelines are carried out by the respective officers and reports are supplied to CWC. As per the present norms, the pre-monsoon and post monsoon reports are to be updated in DHARMA web site in the prescribed revised format.

Maintenance

Routine maintenance is carried out for Spillway radial gates, Intake gate, Emergency gate and hoisting mechanism, outlet gates. Details are given under the Chapter Project Maintenance.

1.10 Supporting Documents & Reference Material

This O&M Manual is the key instruction document. Supporting documents and necessary instructions for all phases of the operation, inspection and maintenance of the dam, reservoir and appurtenant works indicated below are available at the dam control room for reference.

- Detailed drawings of the Project
- Emergency Action Plan (EAP)
- Latest Hydrology Review Report
- Latest DSRP Report
- Flood forecasting and operating criteria
- Agreements with user agencies
- Power station operation plan
- Administrative procedures
- Maintenance schedules
- Gate Manufacturer's manual and drawings
- Regional communication directory
- Instrumentation reports / results

1.11 Typical Schedule of Duties

Schedule of duties/inspections to be carried out for the operation and maintenance of the dam by the concerned official are tabulated below in **Table 1.4.**

Sl. No.	Component/ Duty	Frequency	Personnel
1	Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of foundation and abutments, Galleries, Spillway and its energy dissipation arrangements, Power Intake	Daily	Sub Engineer/Dam operators on contract
2	Record water surface elevation, reservoir inflow and spillway discharge.	Daily (Hourly basis during monsoon)	Sub Engineer/Dam operators on contract
3	Record meteorological data, Record releases from outlets /sluices	Daily	Sub Engineer/Dam operators on contract
4	Check security and safety devices, Complete logbook / site register which include the above information.	Daily	Assistant Engineer
5	Record seepage from drainage systems, Gallery drains etc. and record meteorological data.	Weekly	Sub Engineer/Dam operators on contract
6	Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of foundation and abutments, Galleries, Spillway and its energy dissipation arrangements, Power Intake	Weekly	Assistant Engineer
7	Check stand by generator (DG Sets), Drainage systems, Gallery drains etc.	Weekly	Assistant Engineer
8	Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of foundation and abutments, Galleries, Spillway and its energy dissipation arrangements, Power Intake	Fort nightly	Assistant Executive Engineer
9	Check security and safety devices, logbook and site register which include the above information.	Fort nightly	Assistant Executive Engineer
10	Check stand by generator (DG Sets), Drainage systems, Toe drains, Gallery drains etc.	Fort nightly	Assistant Executive Engineer

11	Measuring devices, communication devices, status of instruments, vegetation growth	Fort nightly	Assistant Executive Engineer
12	Check Sign/Warning display boards near vulnerable locations	Fort nightly	Assistant Executive Engineer
13	Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of foundation and abutments, Galleries, Spillway and its energy dissipation arrangements, Power Intake	Monthly	Executive Engineer
14	Check measuring devices/Instruments, Security and safety devices, Communication Devices, Status of Vegetation growth, – rectification, if needed.	Monthly	Executive Engineer
15	Check Sign/Warning display boards near vulnerable locations	Monthly	Executive Engineer
16	Replace fuse light bulbs, Inspect to maintain ventilation system, cleaning of control panel boards.	Monthly	Assistant Engineer
17	Check outlet works, updating operating instruction, check gate air vents, clean gate control switchboxes, check operation of gates, grease gate hanger/dogging	Quarterly	Executive Engineer
18	Check condition of trash rack of intake structure, Check condition of Outlet works & its Energy Dissipation Arrangement, Check operation of Valve house	Quarterly	Executive Engineer
19	Check condition of spillway, log and safety boom, Check for debris in inlet channel, Check operation of gates, Check for damages in spillway glacis, energy dissipation arrangement, d/s area etc., Check and clear spillway bridge drains, Clean inside of motor control cabinet.	Quarterly	Executive Engineer
20	Check for adherence to instrumentation schedule, Record pertinent information in Operation of Gates, Check condition of V-notch/seepage measuring devices, Check hydro mechanical components.	Quarterly	Executive Engineer

Table 1.4 Schedule of duties/inspections

1.12 Hydro-Mechanical Inspections / Checks

Frequent inspections/checks for hydro-mechanical components are to be conducted and necessary action to be taken up during maintenance. Routine maintenance is carried out for Spillway gates and hoisting machinery as part of routine maintenance before the onset of monsoon. Details are given under the Chapter Project Maintenance.

CHAPTER 2

PROJECT OPERATION

The operation of a dam will involve regulation of its reservoir as per project specific requirements, keeping records and ensuring public safety. Proper operation procedures are crucial for normal or day to day operation of a dam for maintaining a safe structure.

2.1 Basic Data

The Lower Periyar operation plan consists of step-by-step instructions for operating the dam and reservoir during routine (normal) and emergency conditions. The operating procedures for normal operations are discussed in this chapter including operating criteria for the reservoir, spillway & outlets. The operation of a dam involves regulation of its reservoir as per rule curve/ project specific requirements. This includes the use of area capacity curves and design flood; both are described below.

2.1.1 Dam

Lower Periyar (Pambla) Dam is a concrete gravity dam. Length of dam is 284 m. The spillway structure has five bays. There are two lower level outlets provided in the dam. Nominal bed level is +226.15 m. Elevation at top of dam is + 257.00 m. MWL is +256.00 m and FRL is +253.00 m. The spillway crest level is +237.74 m. The downstream slope is 0.74 H : 1 V from El. + 249.00 m and upstream slope is 1 H : 15 V from El. + 237.74 m. The effective storage above the dead storage level of +237.74 m is 4.55 Mm3. The dam has a total catchment area of 584 Sq. km and has a concrete content of 0.054 Mm3.

The dam is divided into 15 blocks with contraction joints at suitable chainages with copper sealing strips on the upstream. 62 nos of body drain holes and 62 nos of foundation drain holes are provided. All the drain holes are opened to the foundation gallery. The concrete mix used for constructing the core of dam is $M_{15}C_{150}$. Spillway portion dam is constructed with concrete of mix $M_{25}C_{20}$. General concrete mix is $M_{25}C_{40}$. Photograph showing an overall view of the dam is shown in fig.2.1.

Fig 2.1 Photograph showing an overall view of Lower Periyar Dam

2.1.2 Spillway

The spillway for Lower Periyar (Pambla) dam consists of 5 nos. of upper vents with Radial gates of size 13.5mx15.65m, for regulating the flood discharge. The crest level of upper vent spillway is +237.74 m and the thickness of intermediate piers is 4.00 m. The location plan of spillway and plan & downstream elevation of spillway of Lower Periyar dam are given in Drg. 2&3 in annexure I. The downstream and upstream sectional elevation of dam, showing the details and important levels are as shown in Drg. 4,5 &6 attached in annexure I.

2.1.3 River Outlet arrangements

The dam is installed with two nos of lower vent radial gates at an elevation of +227.00m in block No. 6 at left abutment side near the trash track of power tunnel to remove silt and accumulated debris. The size of river outlet is 6.75mx15.65m. The photograph showing radial gate and hoist arrangements is shown below.

Fig 2.2 Photograph Showing Spillway and River outlet of dam

2.1.4 Elevation Capacity Curve

The storage capacity of Lower Periyar reservoir and submergence area of reservoir for different elevations during design are given in Table 2.1 and 2.2 and the capacity curve and submergence area curve is shown in Fig 2.3 and 2.4.

STORAGE CAPACITY OF LOWER PERIYAR DAM				
	MDDL-237.74M		FRL-253.00M	
ELEVATION IN M	STORAGE IN Mm3		ELEVATION IN M	STORAGE IN Mm3
226.00	0.00		240.00	1.23
227.00	0.01		241.00	1.43
228.00	0.02		242.00	1.66
229.00	0.04		243.00	1.90
230.00	0.07		244.00	2.14
231.00	0.12		245.00	2.42
232.00	0.17		246.00	2.70
233.00	0.24		247.00	3.00
234.00	0.33		248.00	3.31
235.00	0.44		249.00	3.70
236.00	0.56		250.00	4.09
237.00	0.70		251.00	4.50
237.74	0.80		252.00	4.92
238.00	0.86		253.00	5.35
239.00	1.04			

Table 2.1 Elevation Capacity details

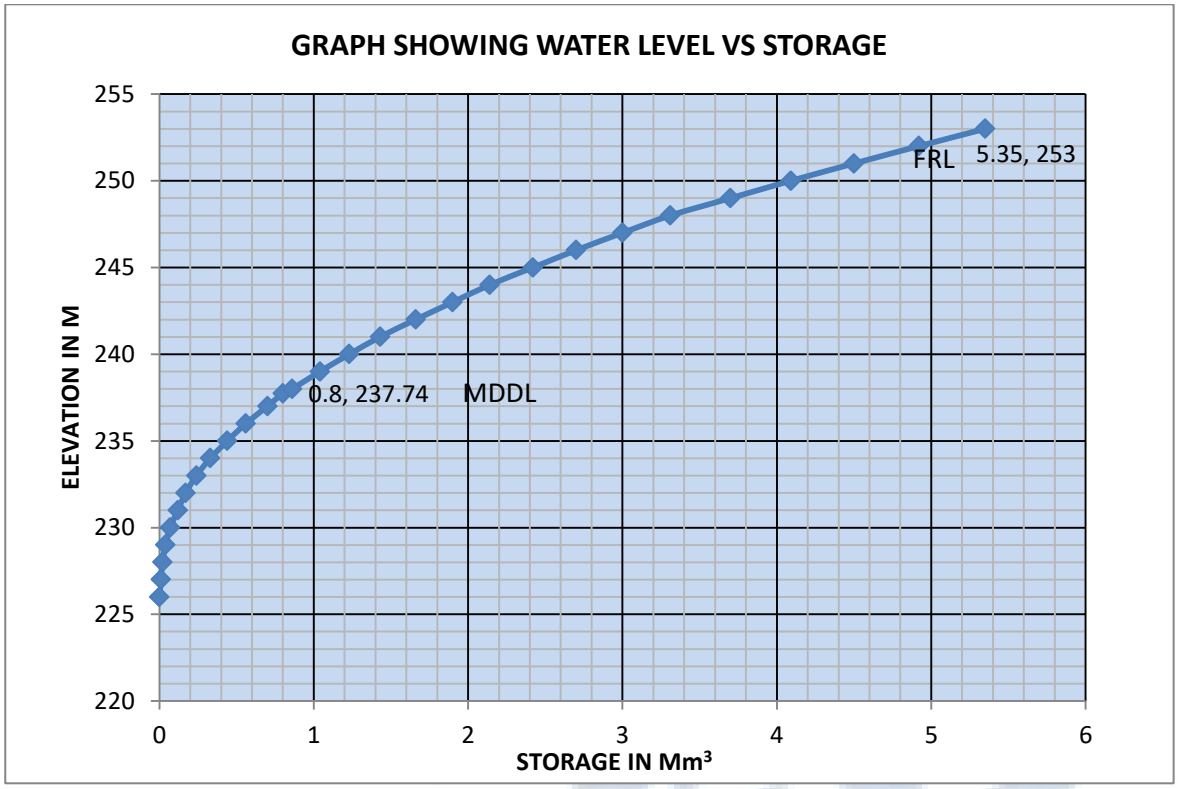

Fig 2.3 Elevation Capacity curve

SUBMERGENCE AREA OF PAMBLA RESERVOIR			
MDDL- 237.74M		FRL- 253.00M	
ELEVATION IN M	AREA IN HECTARES	ELEVATION IN M	AREA IN HECTARES
230.00	3.8750	242.00	23.0000
231.00	5.3250	243.00	24.7500
232.00	6.7750	244.00	26.5000
233.00	8.2500	245.00	28.2500
234.00	9.7500	246.00	30.1500
235.00	11.2500	247.00	32.0500
236.00	12.8500	248.00	33.9750
237.00	14.4500	249.00	35.9250
237.74	15.6340	250.00	37.8750
238.00	16.1000	251.00	39.9750
239.00	17.8000	252.00	42.0750
240.00	19.5000	253.00	44.2250
241.00	21.2500	254.00	46.4250

Table 2.2 Submergence area details of LP Reservoir

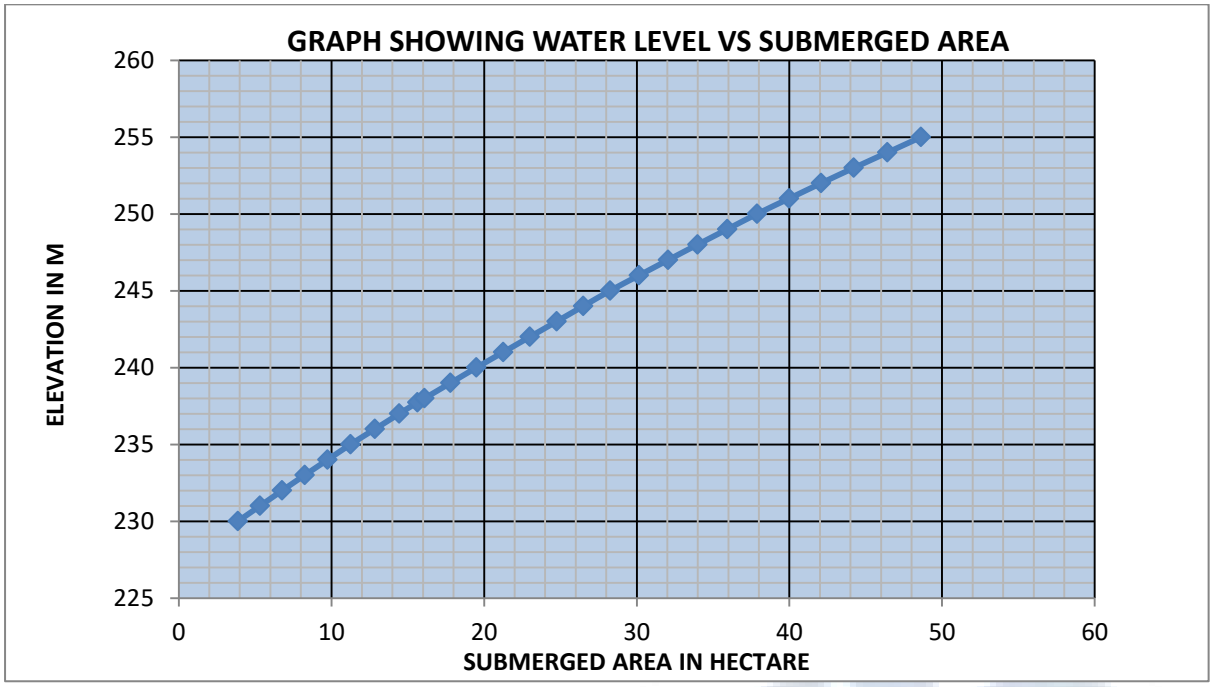

Fig 2.4 Elevation submergence area curve

2.2 Operation Plan

An effective operation plan and schedule is required for the safe project operation for which the project specific features shall be known. The salient features of the dam are given in Table 1.1.

2.2.1 Data of the historic floods

As per historical records, the maximum flood observed in Western Ghats was during 1924. The centre of the storm of the 1-day rainfall of 17th July 1924 and 2-day rainstorm of July 16- 17 was located at Devikulam in Kerala in which rainfall of 484 mm and 751 mm respectively was recorded. The second historical flood occurred during August 14 to 17 in the year 2018, which resulted in record inflow into the reservoir. The SW monsoon of the year 2018 in the State was similar to that of 1924 Devikulam storm. Kerala experienced an abnormally high rainfall from 1 June 2018 to 19 August 2018 which resulted in severe flooding in 13 out of 14 districts in the State. It is seen that the 2-day and 3-day rainfall depths of 15-17, August 2018 rainfall in Pamba, Periyar and Bharathapuzha sub-basins are almost comparable to the Devikulam storm of 16-18, July 1924. For the entire Kerala, out of 758.6 mm rainfall from 1 August 2018 to 19 August 2018, about 414 mm rainfall occurred in just three days viz. 15-17, August 2018, which created severe flooding in the State, while the same during 16-18, July 1924 was 443 mm. The 3-day rainfall of 15-17, August 2018 at Pambla dam site was 924 mm. The 4 –day rainfall of 15-18, August 2018 at Pambla dam site was 1070 mm. The spill discharge and rainfall details of LP reservoir during historic flood

on August 2018 are tabulated below in Table 2.3.

Reservoir Details from 01/06/2018 to 30/11/2019							
Date	Water Level	Rainfall	Gross Storage	Gross Inflow	PH discharge	Spill	Outflow
	M	mm	Mcm	Mcm	Mcm	Mcm	Mcm
1-Jun-18	250.60	0	4.336	2.652	2.016	0.00	2.016
2-Jun-18	249.50	0	3.895	1.835	2.276	0.00	2.276
3-Jun-18	248.10	0	3.349	0.305	0.851	0.00	0.851
4-Jun-18	249.90	11	4.051	2.474	1.772	0.00	1.772
5-Jun-18	248.60	22	3.544	1.074	1.581	0.00	1.581
6-Jun-18	248.80	0	3.622	1.572	1.494	0.00	1.494
7-Jun-18	248.90	46	3.661	1.690	1.651	0.00	1.651
8-Jun-18	250.50	81	4.295	3.553	2.919	0.00	2.919
9-Jun-18	250.80	91	4.418	9.749	6.116	3.51	9.626
10-Jun-18	253.00	168	5.350	16.846	8.254	7.66	15.914
11-Jun-18	253.00	161	5.350	20.943	8.983	11.96	20.943
12-Jun-18	253.00	217	5.350	18.539	8.949	9.59	18.539
13-Jun-18	253.00	85	5.350	13.208	7.698	5.51	13.208
14-Jun-18	253.00	107	5.350	14.949	8.949	6.00	14.949
15-Jun-18	253.00	7	5.350	8.983	8.983	0.00	8.983
16-Jun-18	250.50	4	4.295	7.303	8.358	0.00	8.358
17-Jun-18	250.80	103	4.418	8.377	8.254	0.00	8.254
18-Jun-18	248.60	0	3.544	5.399	6.273	0.00	6.273
19-Jun-18	248.80	44	3.622	6.490	6.412	0.00	6.412
20-Jun-18	248.10	41	3.349	6.486	6.759	0.00	6.759
21-Jun-18	250.30	48	4.213	9.065	8.201	0.00	8.201
22-Jun-18	250.30	33	4.213	8.080	8.080	0.00	8.080
23-Jun-18	249.20	15	3.778	6.342	6.777	0.00	6.777
24-Jun-18	248.30	9	3.427	6.095	6.446	0.00	6.446
25-Jun-18	249.40	8	3.856	6.458	6.029	0.00	6.029
26-Jun-18	250.00	30	4.090	6.524	6.290	0.00	6.290
27-Jun-18	249.00	35	3.700	5.344	5.734	0.00	5.734
28-Jun-18	247.50	62	3.155	6.509	7.055	0.00	7.055
29-Jun-18	248.80	15	3.622	6.236	5.769	0.00	5.769
30-Jun-18	248.40	0	3.466	6.290	6.446	0.00	6.446
1-Jul-18	249.90	33	4.051	0.585	0.000	0.00	0.000
2-Jul-18	248.80	19	3.622	4.923	5.352	0.00	5.352
3-Jul-18	250.00	64	4.090	6.723	6.255	0.00	6.255
4-Jul-18	251.00	0	4.500	6.127	5.717	0.00	5.717
5-Jul-18	250.90	0	4.459	5.293	5.334	0.00	5.334
6-Jul-18	248.40	0	3.466	2.673	3.666	0.00	3.666

7-Jul-18	248.40	7	3.466	5.352	5.352	0.00	5.352
8-Jul-18	249.00	36	3.700	5.951	5.717	0.00	5.717
9-Jul-18	249.70	133	3.973	10.636	8.723	1.64	10.363
10-Jul-18	253.00	145	5.350	10.360	8.983	0.00	8.983
11-Jul-18	253.00	84	5.350	15.530	8.810	6.72	15.530
12-Jul-18	253.00	66	5.350	14.830	8.740	6.09	14.830
13-Jul-18	253.00	81	5.350	21.223	8.723	12.50	21.223
14-Jul-18	253.00	92	5.350	20.943	8.393	12.55	20.943
15-Jul-18	253.00	87	5.350	24.059	8.479	15.58	24.059
16-Jul-18	253.00	176	5.350	52.123	7.263	44.86	52.123
17-Jul-18	253.00	109	5.350	35.881	8.671	27.21	35.881
18-Jul-18	253.00	119	5.350	28.835	8.445	20.39	28.835
19-Jul-18	253.00	56	5.350	29.207	8.427	20.78	29.207
20-Jul-18	253.00	112	5.350	27.376	8.306	19.07	27.376
21-Jul-18	253.00	35	5.350	16.830	8.410	8.42	16.830
22-Jul-18	253.00	30	5.350	20.045	8.375	11.67	20.045
23-Jul-18	253.00	42	5.350	22.715	8.445	14.27	22.715
24-Jul-18	253.00	175	5.350	39.709	7.819	31.89	39.709
25-Jul-18	253.00	217	5.350	35.716	4.396	31.32	35.716
26-Jul-18	253.00	105	5.350	31.304	7.454	23.85	31.304
27-Jul-18	253.00	14	5.350	15.410	9.140	6.27	15.410
28-Jul-18	253.00	80	5.350	15.958	9.088	6.87	15.958
29-Jul-18	253.00	154	5.350	26.528	9.088	17.44	26.528
30-Jul-18	253.00	35	5.350	18.532	9.122	9.41	18.532
31-Jul-18	253.00	90	5.350	17.866	9.036	8.83	17.866
1-Aug-18	253.00	48	5.350	14.103	9.053	5.05	14.103
2-Aug-18	253.00	5	5.350	15.806	9.036	6.77	15.806
3-Aug-18	253.00	5	5.350	9.893	8.983	0.91	9.893
4-Aug-18	253.00	3	5.350	8.862	8.862	0	8.862
5-Aug-18	252.00	0	4.920	8.258	8.688	0	8.688
6-Aug-18	248.40	5	3.466	5.966	7.420	0	7.420
7-Aug-18	251.20	27	4.584	11.353	8.375	1.86	10.235
8-Aug-18	253.00	126	5.350	35.599	7.993	26.84	34.833
9-Aug-18	252.50	350	5.135	88.084	3.649	84.65	88.299
10-Aug-18	252.50	157	5.135	67.900	3.910	63.99	67.900
11-Aug-18	243.00	105	1.900	66.770	2.415	67.59	70.005
12-Aug-18	249.40	21	3.856	56.482	4.796	49.73	54.526
13-Aug-18	250.40	99	4.254	57.418	5.560	51.46	57.020
14-Aug-18	250.90	96	4.459	79.915	2.850	76.86	79.710
15-Aug-18	243.50	305	2.020	192.781	0.000	195.22	195.220
16-Aug-18	2549.90	347	5.350	297.240	0.000	293.91	293.910
17-Aug-18	250.00	245	4.090	260.500	0.000	261.76	261.760
18-Aug-18	249.30	146	3.817	37.077	0.000	37.35	37.350
19-Aug-18	249.50	70	3.895	37.428	0.000	37.35	37.350

20-Aug-18	249.70	56	3.973	37.428	0.000	37.35	37.350
21-Aug-18	250.50	0	4.295	14.322	0.000	14.00	14.000
22-Aug-18	237.30	35	0.748	10.453	0.000	14.00	14.000
23-Aug-18	237.00	6	0.700	143.142	0.000	143.190	143.190
24-Aug-18	250.50	9	4.295	29.275	0.000	25.680	25.680
25-Aug-18	250.00	0	4.090	8.535	0.000	8.740	8.740
26-Aug-18	249.80	0	4.012	-0.078	0.000	0.000	0.000
27-Aug-18	249.80	0	4.012	0.000	0.000	0.000	0.000
28-Aug-18	247.40	39	3.124	-0.888	0.000	0.000	0.000
29-Aug-18	247.60	18	3.186	30.642	0.000	30.580	30.580
30-Aug-18	243.60	0	2.044	27.378	0.000	28.520	28.520
31-Aug-18	241.50	0	1.545	18.341	0.000	18.840	18.840
1-Sep-18	240.50	0	1.330	10.245	0.000	10.460	10.460
2-Sep-18	235.00	0	0.440	1.480	0.000	2.37	2.370
3-Sep-18	232.00	0	0.170	1.150	0.000	1.420	1.420
4-Sep-18	231.00	0	0.120	0.550	0.000	0.600	0.600
5-Sep-18	230.50	0	0.095	0.465	0.000	0.490	0.490
6-Sep-18	230.50	0	0.095	1.350	0.000	1.350	1.350
7-Sep-18	238.70	0	0.986	4.011	0.000	3.120	3.120
8-Sep-18	238.20	0	0.896	3.030	0.000	3.120	3.120
9-Sep-18	234.00	0	0.330	2.484	0.000	3.050	3.050
10-Sep-18	238.60	0	0.968	4.748	0.000	4.110	4.110
11-Sep-18	238.40	0	0.932	4.074	0.000	4.110	4.110
12-Sep-18	238.20	0	0.896	3.374	0.000	3.410	3.410
13-Sep-18	237.30	0	0.748	3.732	0.000	3.880	3.880
14-Sep-18	238.30	0	0.914	4.276	0.000	4.110	4.110
15-Sep-18	238.20	0	0.896	4.042	0.000	4.060	4.060
16-Sep-18	238.20	0	0.896	4.030	0.000	4.030	4.030
17-Sep-18	238.20	19	0.896	3.690	0.000	3.690	3.690
18-Sep-18	229.00	5	0.040	1.774	0.000	2.630	2.630
19-Sep-18	229.00	0	0.040	2.750	0.000	2.750	2.750
20-Sep-18	229.00	18	0.040	2.340	0.000	2.340	2.340
21-Sep-18	229.00	0	0.040	2.240	0.000	2.240	2.240
22-Sep-18	241.30	0	1.499	2.459	0.000	1.000	1.000
23-Sep-18	242.50	0	1.780	2.404	1.633	0.490	2.123
24-Sep-18	247.90	32	3.279	4.714	3.215	0.00	3.215
25-Sep-18	248.40	34	3.466	7.207	7.020	0.00	7.020
26-Sep-18	249.70	0	3.973	5.233	4.726	0.000	4.726
27-Sep-18	250.00	24	4.090	5.729	5.612	0.000	5.612
28-Sep-18	249.10	0	3.739	7.173	7.524	0.000	7.524
29-Sep-18	253.00	42	5.350	11.826	9.105	1.110	10.215
30-Sep-18	252.40	19	5.092	8.853	8.601	0.510	9.111
01-Oct-18	250.20	10	4.172	7.646	8.566	0.000	8.566
02-Oct-18	249.50	28	3.895	7.507	7.784	0.000	7.784

03-Oct-18	248.80	27	3.622	6.591	6.864	0.000	6.864
04-Oct-18	249.70	28	3.973	8.570	8.219	0.000	8.219
05-Oct-18	251.50	28	4.710	10.515	9.018	0.760	9.778
06-Oct-18	250.30	0	4.213	8.538	8.775	0.260	9.035
07-Oct-18	250.00	7	4.090	10.467	9.070	1.520	10.590
08-Oct-18	252.40	0	5.092	10.641	8.879	0.760	9.639
09-Oct-18	252.80	15	5.264	10.222	9.140	0.910	10.050
10-Oct-18	252.90	3	5.307	9.130	8.827	0.260	9.087
11-Oct-18	252.50	27	5.135	8.255	8.427	0.000	8.427
12-Oct-18	250.60	0	4.336	7.194	7.993	0.000	7.993
13-Oct-18	250.00	0	4.090	6.513	6.759	0.000	6.759
14-Oct-18	251.10	14	4.542	8.897	8.445	0.000	8.445
15-Oct-18	248.60	16	3.544	5.657	6.655	0.000	6.655
16-Oct-18	249.20	5	3.778	7.410	7.176	0.000	7.176
17-Oct-18	251.60	30	4.752	10.676	8.792	0.910	9.702
18-Oct-18	249.10	0	3.739	6.077	7.089	0.000	7.089
19-Oct-18	249.10	20	3.739	8.271	8.271	0.000	8.271
20-Oct-18	248.50	18	3.505	7.622	7.246	0.610	7.856
21-Oct-18	252.30	94	5.049	10.975	9.001	0.430	9.431
22-Oct-18	248.80	18	3.622	6.531	7.958	0.000	7.958
23-Oct-18	248.90	13	3.661	7.876	7.837	0.000	7.837
24-Oct-18	248.50	0	3.505	6.951	7.107	0.000	7.107
25-Oct-18	248.10	0	3.349	6.134	6.290	0.000	6.290
26-Oct-18	248.40	0	3.466	5.851	5.734	0.000	5.734
27-Oct-18	248.30	0	3.427	5.226	5.265	0.000	5.265
28-Oct-18	249.30	0	3.817	5.585	5.195	0.000	5.195
29-Oct-18	249.70	0	3.973	5.404	5.248	0.000	5.248
30-Oct-18	251.40	0	4.668	3.875	3.180	0.000	3.180
31-Oct-18	248.00	0	3.310	2.795	4.153	0.000	4.153
01-Nov-18	249.50	7	3.895	4.599	4.014	0.000	4.014
02-Nov-18	249.50	0	3.895	4.553	4.553	0.000	4.553
03-Nov-18	249.50	0	3.895	4.049	4.049	0.000	4.049
04-Nov-18	250.30	0	4.213	4.210	3.892	0.000	3.892
05-Nov-18	249.30	0	3.817	5.077	5.473	0.000	5.473
06-Nov-18	248.40	0	3.466	3.333	3.684	0.000	3.684
07-Nov-18	249.70	0	3.973	4.104	3.597	0.000	3.597
08-Nov-18	249.20	0	3.778	3.923	4.118	0.000	4.118
09-Nov-18	249.48	0	3.856	2.059	1.981	0.000	1.981
10-Nov-18	246.30	0	2.790	1.123	2.189	0.000	2.189
11-Nov-18	249.70	0	3.973	3.077	1.894	0.000	1.894
12-Nov-18	249.50	0	3.895	3.206	3.284	0.000	3.284
13-Nov-18	248.60	0	3.544	2.047	2.398	0.000	2.398
14-Nov-18	249.60	7.00	3.934	2.319	1.929	0.000	1.929
15-Nov-18	250.00	0	4.090	2.328	2.172	0.000	2.172

16-Nov-18	249.20	2.00	3.778	0.053	0.365	0.000	0.365
17-Nov-18	253.20	147.00	5.350	7.062	0.000	5.490	5.490
18-Nov-18	250.20	0	4.172	1.772	0.000	2.950	2.950
19-Nov-18	249.10	0	3.739	-0.433	0.000	0.000	0.000
20-Nov-18	248.50	25.00	3.505	-0.234	0.000	0.000	0.000
21-Nov-18	248.30	0	3.427	-0.078	0.000	0.000	0.000
22-Nov-18	249.70	13.00	3.973	0.546	0.000	0.000	0.000
23-Nov-18	250.30	19.00	4.213	0.240	0.000	0.000	0.000
24-Nov-18	250.20	5.00	4.172	-0.041	0.000	0.000	0.000
25-Nov-18	249.80	0	4.012	-0.160	0.000	0.000	0.000
26-Nov-18	248.70	0	3.583	-0.429	0.000	0.000	0.000
27-Nov-18	250.90	0	4.459	0.876	0.000	0.000	0.000
28-Nov-18	250.40	0	4.254	-0.205	0.000	0.000	0.000
29-Nov-18	250.10	0	4.131	-0.123	0.000	0.000	0.000
30-Nov-18	245.50	0	2.560	-1.571	0.000	0.000	0.000

Table 2.3 Discharge details of LP Reservoir during 2018

2.2.2 Design Flood and Features Related to Safety

The dam is constructed across Periyar River at Pambla, 5km downstream of Periyar –Mudirapuzha confluence. The free catchment area of dam is 584 Sq. km and the gross storage is 5.35Mm^3. The catchment of Lower Periyar reservoir is intercepted by the dams of upstream reservoirs. The Kundala, Madupetty, Anayirankal, Ponmudi, Sengulam & Kallarkutty reservoirs in Mudirapuzha (a sub basin of Periyar) and Mullaperiyar and Idukki dams in Periyar main River are the reservoirs located in the upstream of the Lower Periyar reservoir. The projects in Periyar main River involve trans-basin diversion of water to adjacent valleys for power/ irrigation benefits. The Idukki and Kallarkutty are the nearest upstream controls as far as Lower Periyar reservoir is concerned. The estimated design flood of Lower Periyar is 13730m3/s. The flood discharge capacity provided in Lower Periyar dam is 11200 m^3/s at FRL and the maximum discharge capacity at MWL is 14200m^3/s. The catchment area at the dam site is shown in fig 2.5.

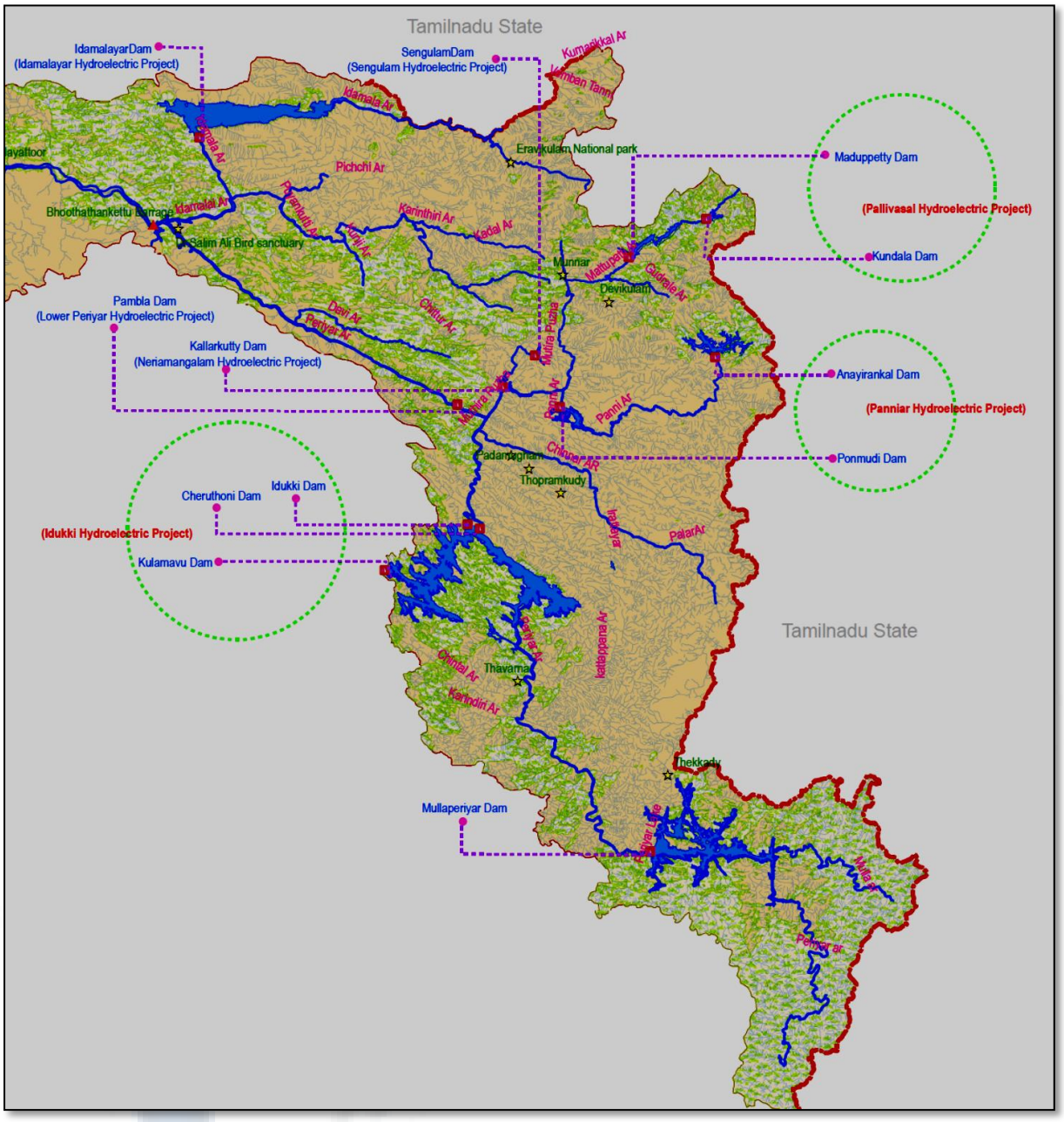

Fig 2.5 Catchment area of Lower Periyar dam

Revised Design Flood

The design flood is reviewed in accordance with IS-11223, using the most appropriate and recent available data. The hydraulic head of Lower Periyar dam is 28.85 m. The gross storage is 5.35 Mm3. Hence the inflow design flood of Lower Periyar dam as per the criteria of hydraulic head is Standard Project Flood.

The revised design flood of Kallarkutty reservoir and Idukki reservoir was approved by the Central Water Commission. The design flood of Kallarkutty and Idukki is PMF. As per the

qualification criteria the revised design flood of Lower Periyar is SPF and hence the SPF of Kallarkutty and Idukki reservoir is therefore worked out based on the procedure approved by the CWC with input as SPS. The SPF of Kallarkutty and Idukki is then routed through the river stretch downstream up to Lower Periyar. The routed hydrograph of Idukki and Kallarkutty and design flood hydrograph from own catchment of Lower Periyar is considered for arriving the combined hydrograph.

The revised design flood was estimated as 10479 m^3/s. The spill discharge capacity at FRL is 11200 m^3/s. Hence the spillway provided in the dam is adequate to dispose the flood downstream.

The revised design flood has been approved by the State Level Committee with Members Sri. M. K. Parameswaran Nair, (Member (Rtd.), KSEB), Dr. Komalavalliamma (Chief Engineer (Rtd.), State Water Resource Department), Director (Generation – Civil), KSEB Ltd., Chief Engineer (Civil-Dam Safety), KSEB Ltd. and Chief Engineer (Civil – Construction South), KSEB Ltd.

2.3 Hoisting Arrangements for Radial Crest Gates (upper vent)

The spillway for Lower Periyar dam consists of 5 nos. of upper vent Radial gates of size 13.50m x 15.65 m and 2 nos of lower vent radial gates of size 6.75mx15.65m for regulating the flood discharge of 11200m^3/s. The crest level of upper vent spillway is 237.74 m. The hoisting arrangements of shutter are installed over the top of Hoist Bridge at EL. 261.50 m. The hoisting arrangement consists of a central drive and two lateral drives coupled by a pipe shafts. The central drive has a spur type reduction gear, self-arresting worm-gear, a double shoe brake with electro hydraulic central device. The hoisting can be done either electrically or manually. The lateral drum consists of spur-type reduction gears and a rope drum. The mechanism also consists of indication needles and electrically controlled top & bottom position limit switches. For hand operation, there is a hand crank and a safety device for switching off electrical system, when the hand crank is to be used. The hoisting capacity is 150 MT. The capacity of electric motor for radial gate is 20 HP.

The gates are of structural steel frame work with a steel skin plate on the upstream side, resting on a sill beam embedded on the crest.

Stop log gates are placed in front of every radial gate for carrying out the maintenance work of gates. These stop log gates are placed in front of the radial gate using gantry crane lifting beam. The gates are operated and tested in every season when the water level is below the crest level. Periodical maintenance like painting greasing oiling etc. are also done from time to time.

2.3.1 Operation of radial gates

The operation of the radial gates can be done either electrically or manually. After observing the parameters like, quantity of inflow on account of sudden rainfall or rainfall likely to

happen, the height of gates to be raised is assessed first. This total height of opening is equally distributed to the all five gates. Gate No.3 is to be opened first to a unit height on the basis of requirement. Then Gate No.2 and 4 is operated to the same height as that of Gate No.3 and finally Gate No.1 & 5. The further increase in openings is also performed in the similar manner. The closing of the gates are being done in the reverse manner as that of opening.

Normal Operation of the Reservoir

The operating procedures developed for normal or day to day operation of a dam shall include the following:

- Instructions for operating control mechanisms.
- Instructions for operating the reservoir in accordance with operation procedures.
- General instructions for the safe operation of the dam and appurtenances. The following aspects also need to be included:
- Releases to be made for various purposes round the year including releases to be made as per Agreements with various Agencies/ Projects, riparian releases etc.
- Inflow forecasting
- Flood release procedure

Site security is a matter of concern at all major dams. This includes terrorism implications and preventing structural damage by vandals and unauthorized operation of outlet or spillway gates. In most cases restricting public access is essential, and in some instances electronic security devices should be considered.

Operation of Control Mechanisms

The Operation manual of control mechanism and installation is attached as **Annexure 2.** The Sectional elevation of spillway crest and hoist bridge of Lower Periyar dam is given in Drg.5

Radial Gate Operations for flood release

The radial gates are being opened as per the direction of higher authorized officers. The gates are being opened only after intimating higher officials, District Disaster Management Authority, Police & Revenue Department. Mike announcement regarding the spill are being intimated to habitants on downstream sides of river course. Intimation to the public is also being given through News Paper &TV/Visual Medias. Also a control room is to be opened at the dam top itself during flood season. As this reservoir is not a storage reservoir, different alert levels could not be fixed. Generally the water level is kept up to FRL. As the dam site is in forest area, the

electric power supply line to the dam is mostly through forest. During periods of heavy rain fall and storm, probability for power failure or lack of sufficient voltage is quite frequent. For obtaining uninterrupted three phase electric supply of sufficient voltage required for the operation of shutters, an 82.5 KVA Diesel Generator set is provided at Dam site. The DG set will be kept ready, after checking its fuel quantity, circuits, and change over system, etc.

Fig 2.6 Photograph Showing Upper vent (Radial Gate) of Lower Periyar Dam

Fig 2.7 Photograph Showing Hoisting arrangements of Radial gate for Upper vent

Fig 2.8 Photograph Showing Control Panel of Radial gate for Upper vent

Operating Procedure for Radial Gate for Upper vent

Switch on the main supply from DB near to the control room. Switch on the black knob at control panel. Check all warning lights and 3 phase supply. There is separate start stop switches for raising and lowering the gates. Use these switches as per requirements. The gate opening positions are readout from a scale set attached to the hoisting assembly.

2.3.2 Operation of River Outlets (Lower Vents)

The dam is installed with two nos of lower vent at an elevation of +227.00m in block no. 6 at left abutment side near to the trash rack to remove silt and accumulated debris. The size of river outlet is 6.75mx15.65m. Each outlet is provided with radial gate with hydraulic hoisting arrangements. There is a provision for stop log gate at the upstream side so as to facilitate maintenance work. The stop log gates are placed in front of the radial gate by using gantry crane lifting beam arrangement kept at dam top. The capacity of electric motor for radial gate is 20 HP.

Fig 2.9 Photograph of Lower vent gate showing top and upstream view

Fig 2.10 Photograph Showing Hoisting arrangements of Radial Gate for Lower Vent

Fig 2.11 Photograph of Main DB- LP Dam

Fig 2.12 Photograph of Control panel Lower vent

Fig 2.13 Photograph of Control panel of Lower vent(a)

Lower vent operating procedures

a) Switch on the supply from main Distribution board near to the control room.
b) Access the lower vent operating area on hoisting platform and switch on red knob on the panel board shown above.
c) Open the panel board and change position of MCB inside to on Position.
d) Select the rising or lowering mode on the panel board as per requirements
e) Check the warning lights on the main control panel
f) Select pump "1" or" 2" as per requirements
g) Push start to rise or lower and stop for stop the rising or lowering as per requirements

Note: - Check all line valves for oil pressure

Provision for manual operation is also there below the panel board.

Fig 2.14 Stop log gates

Fig 2.15 Gantry crane

2.3.3 Power Outlet

The intake structure is provided near to the left abutment of the dam as a separate structure. The sill level of the tunnel intake is +229.00m. The intake has two gates of which the emergency gate with the rubber seal at upstream side, at the reservoir side and the service gate with seal at the downstream side ie at tunnel side. Bell mouth entry is provided for smooth transition and is protected with trash rack screens. The intake opening is rectangular and has a size of 4.5x6.80m which then transforms in to circular section of dia 6.05m. The intake gate provided at the entrance is operated by an electrically driven hoist housed in a parabolically roofed platform at + 267.775m. The hoisting capacity is 55MT. The intake gates are dogged at dam top level (+257.00). The gate is designed to withstand the unbalanced head against which it can close under gravity. An air vent of dia 600mm is provided downstream of service gate to allow entry of air while depleting the tunnel and exist air at the time of filling the tunnel. The operation of intake gate is almost same as that of radial gate. Switch on from Main DB, Access intake tower, Switch on Panel board and operate raise and lower switch. The stop button is common. There is also a provision for crack opening. The hoisting capacity is 55 MT and capacity of electric motor installed is 20HP.

Fig 2.16 Photograph Showing Intake Tower and gates

Fig 2.17 Photograph of Intake Hoisting Arrangements

Fig 2.18 Photograph of Intake Hoisting Arrangements of Control Panel

2.3.4 Operation of the Reservoir

Lower Periyar reservoir is being operated as per 'Guidelines for Operation of Storage Reservoirs (IS 7323:1994). No spilling of water over the spillway will normally be permitted until FRL is reached except in monsoon. Hence no rule curve was prepared for this dam.

The reservoir water is released through spillway gates on water level reaching the Full reservoir Level i.e. +253.00 m. The spillway crest level is EL. +237.74 m. The discharge through spillway and Outlet gates for different reservoir levels is tabulated in Table 2.4 and 2.5.

Lower Periyar-Discharge through a single spillway gate for different gate openings and reservoir levels(Upper Vent)								
Reservoir Level (m)	Gate opening Height/Level							
	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4
237.74 (Crest level)	238.040	238.340	238.640	238.940	239.240	239.540	239.840	240.140
	Discharge in cumecs							
248.00	40.445	80.287	119.520	158.137	196.131	233.493	270.217	306.294
248.50	41.401	82.216	122.436	162.056	201.069	239.468	277.246	314.396
249.00	42.334	84.094	125.275	165.871	205.875	245.280	284.081	322.270
249.50	43.243	85.926	128.043	169.588	210.556	250.940	290.735	329.933
250.00	44.131	87.715	130.744	173.215	215.122	256.458	297.219	337.399
250.50	44.999	89.462	133.383	176.757	219.579	261.844	303.546	344.681
251.00	45.848	91.170	135.962	180.218	223.934	267.104	309.725	351.791
251.50	46.679	92.842	138.485	183.603	228.192	272.248	315.764	358.738
252.00	47.493	94.479	140.955	186.917	232.360	277.280	321.672	365.532
252.50	48.290	96.084	143.376	190.163	236.442	282.207	327.455	372.182
253.00	49.073	97.657	145.749	193.345	240.442	287.035	333.120	378.694
253.50	49.840	99.200	148.076	196.466	244.364	291.768	338.673	385.077
254.00	50.594	100.715	150.361	199.528	248.212	296.411	344.120	391.336
254.50	51.334	102.203	152.604	202.534	251.990	300.968	349.465	397.477
255.00	52.061	103.665	154.808	205.487	255.700	305.443	354.713	403.506
255.50	52.776	105.102	156.974	208.390	259.346	309.840	359.868	409.428
256.00	53.479	106.515	159.104	211.243	262.930	314.161	364.935	415.247

Lower Periyar-Discharge through a single spillway gate for different gate openings and reservoir levels(Upper Vent)								
Reservoir Level (m)	Gate opening Height/Level							
	2.7	3	3.5	4	4.5	5	6	7
237.74 (Crest level)	240.440	240.740	241.240	241.740	242.240	242.740	243.740	244.740
	Discharge in cumecs							
248.00	341.717	376.476	432.909	487.432	539.999	590.561	685.462	771.676
248.50	350.910	386.780	445.110	501.590	556.179	608.831	708.140	799.104
249.00	359.841	396.786	456.950	515.318	571.854	626.516	730.048	825.541
249.50	368.529	406.516	468.455	528.649	587.064	643.662	751.253	851.081
250.00	376.991	415.990	479.650	541.613	601.845	660.313	771.813	875.801
250.50	385.242	425.224	490.557	554.234	616.228	676.505	791.778	899.769
251.00	393.296	434.234	501.193	566.537	630.239	692.270	811.193	923.044
251.50	401.163	443.035	511.577	578.542	643.904	707.637	830.096	945.677
252.00	408.855	451.637	521.722	590.266	657.244	722.630	848.522	967.713
252.50	416.382	460.052	531.644	601.727	670.278	737.274	866.500	989.193
253.00	423.752	468.290	541.353	612.938	683.024	751.589	884.059	1010.151
253.50	430.974	476.361	550.862	623.914	695.498	765.592	901.223	1030.621
254.00	438.055	484.273	560.180	634.667	707.714	779.301	918.013	1050.629
254.50	445.001	492.034	569.318	645.208	719.685	792.731	934.451	1070.203
255.00	451.820	499.650	578.283	655.547	731.424	805.897	950.555	1089.365
255.50	458.516	507.128	587.083	665.693	742.941	818.810	966.341	1108.138
256.00	465.094	514.474	595.727	675.656	754.247	831.483	981.825	1126.540

	Lower Periyar HEP-Discharge through a single spillway gate for different gate openings and reservoir levels(Upper Vent)							
Reservoir Level (m)	Gate opening Height/Level							
	8	9	10	11	12	13	14	15.46
237.74	245.740	246.740	247.740	248.740	249.740	250.740	251.740	253.200
(Crest level)	Discharge in cumecs							
248.00	848.674	915.836	972.426					
248.50	881.252	954.040	1016.830	1068.864				
249.00	912.574	990.663	1059.247	1117.671				
249.50	942.765	1025.873	1099.907	1164.294	1218.359			
250.00	971.930	1059.811	1138.999	1208.986	1269.181			
250.50	1000.160	1092.597	1176.680	1251.954	1317.899	1373.909		
251.00	1027.531	1124.330	1213.080	1293.370	1364.737	1426.646		
251.50	1054.110	1155.099	1248.312	1333.380	1409.883	1477.348	1535.227	
252.00	1079.956	1184.977	1282.473	1372.105	1453.496	1526.219	1589.787	
252.50	1105.121	1214.032	1315.645	1409.652	1495.709	1573.429	1642.376	
253.00	1129.650	1242.320	1347.903	1446.114	1536.638	1619.124	1693.179	**1730.410**
253.50	1153.584	1269.893	1379.309	1481.569	1576.383	1663.429	1742.351	1822.206
254.00	1176.959	1296.798	1409.922	1516.090	1615.031	1706.453	1790.027	1915.942
254.50	1199.808	1323.074	1439.793	1549.738	1652.660	1748.289	1836.324	2011.609
255.00	1222.160	1348.758	1468.965	1582.569	1689.339	1789.022	1881.343	2109.197
255.50	1244.042	1373.885	1497.481	1614.633	1725.126	1828.726	1925.175	2208.700
256.00	1265.480	1398.483	1525.377	1645.976	1760.078	1867.465	1967.898	2310.109

Table 2.4 – Spillway discharge chart for one gate opening

Lower Periyar HEP - Discharge through a single Outlet gate for different gate openings and reservoir levels(Lower Vent)											
Reservoir level	Gate opening (m.)/ Top level of gate										
	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50
(crest) 227	227.50	228.00	228.50	229.00	229.50	230.00	230.50	231.00	231.50	232.00	232.50
	Discharge(m^3/s)										
238	31.86	62.97	93.31	122.86	151.60	179.51	206.56	232.73	257.97	282.26	305.56
239	33.31	65.90	97.76	128.87	159.21	188.76	217.50	245.41	272.46	298.63	323.87
240	34.70	68.71	102.01	134.61	166.46	197.57	227.91	257.47	286.21	314.12	341.17
241	36.03	71.40	106.10	140.11	173.42	206.01	237.87	268.97	299.32	328.87	357.61
242	37.32	74.00	110.03	145.40	180.10	214.11	247.41	280.01	311.87	342.97	373.32
243	38.56	76.51	113.83	150.51	186.54	221.91	256.61	290.62	323.92	356.52	388.37
244	39.77	78.94	117.50	155.45	192.77	229.45	265.48	300.85	335.55	369.56	402.86
245	40.94	81.30	121.06	160.24	198.80	236.74	274.06	310.74	346.78	382.15	416.84
246	42.08	83.59	124.53	164.88	204.65	243.82	282.39	320.33	357.65	394.33	430.36
247	43.18	85.82	127.89	169.40	210.34	250.70	290.47	329.64	368.20	406.15	443.47
248	44.26	87.99	131.17	173.81	215.88	257.39	298.33	338.69	378.46	417.63	456.19
249	45.32	90.11	134.37	178.10	221.28	263.92	305.99	347.50	388.44	428.80	468.57
250	46.35	92.18	137.50	182.29	226.56	270.28	313.47	356.10	398.18	439.69	480.63
251	47.36	94.21	140.56	186.39	231.71	276.50	320.77	364.49	407.68	450.31	492.38
252	48.34	96.19	143.55	190.40	236.75	282.58	327.90	372.69	416.96	460.68	503.87
253	49.31	98.14	146.48	194.33	241.68	288.54	334.89	380.72	426.04	470.83	515.09
254	50.26	100.04	149.35	198.18	246.52	294.37	341.73	388.58	434.93	480.76	526.08
255	51.19	101.91	152.17	201.95	251.26	300.09	348.43	396.28	443.64	490.49	536.84
256	52.10	103.75	154.94	205.66	255.92	305.70	355.01	403.84	452.18	500.03	547.39

Lower Periyar HEP - Discharge through a single Outlet gate for different gate openings and reservoir levels(Lower Vent)											
Reserv-oir level	Gate opening(m.)/ Top level of gate										
	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00
(crest) 227	233.00	233.50	234.00	234.50	235.00	235.50	236.00	236.50	237.00	237.50	238.00
	Discharge)m^3/s)										
238	327.82	349.00	369.03	387.84	405.35	421.46	436.03	448.87	459.72	468.10	472.68
239	348.16	371.46	393.72	414.90	434.93	453.74	471.25	487.36	501.93	514.77	525.62
240	367.33	392.58	416.87	440.17	462.43	483.60	503.63	522.45	539.96	556.07	570.64
241	385.52	412.57	438.73	463.98	488.27	511.57	533.83	555.01	575.03	593.85	611.36
242	402.87	431.61	459.52	486.57	512.73	537.98	562.27	585.57	607.83	629.00	649.03
243	419.48	449.82	479.38	508.12	536.03	563.08	589.24	614.49	638.78	662.08	684.34
244	435.45	467.31	498.42	528.76	558.32	587.06	614.97	642.02	668.18	693.42	717.72
245	450.85	484.16	516.75	548.61	579.72	610.06	639.61	668.35	696.26	723.31	749.48
246	465.73	500.43	534.44	567.75	600.34	632.20	663.31	693.65	723.20	751.94	779.85
247	480.15	516.18	551.55	586.25	620.26	653.56	686.15	718.01	749.12	779.46	809.02
248	494.14	531.46	568.14	604.17	639.54	674.24	708.25	741.55	774.14	806.00	837.11
249	507.74	546.30	584.25	621.57	658.25	694.28	729.65	764.35	798.36	831.66	864.26
250	520.98	560.75	599.92	638.49	676.43	713.75	750.43	786.46	821.83	856.53	890.54
251	533.90	574.83	615.19	654.96	694.13	732.69	770.64	807.96	844.64	880.67	916.04
252	546.50	588.58	630.09	671.03	711.39	751.15	790.32	828.89	866.83	904.15	940.83
253	558.82	602.00	644.64	686.71	728.23	769.16	809.52	849.29	888.46	927.02	964.97
254	570.87	615.14	658.86	702.05	744.68	786.76	828.27	869.21	909.56	949.33	988.50
255	582.68	627.99	672.79	717.05	760.78	803.96	846.59	888.67	930.18	971.12	1011.48
256	594.24	640.59	686.42	731.74	776.53	820.80	864.52	907.71	950.34	992.42	1033.93

Lower Periyar HEP - Discharge through a single Outlet gate for different gate openings and reservoir levels(Lower Vent)									
Reservoir level	Gate opening (m.)/ Top level of gate								
	11.50	12.00	12.50	13.00	13.50	14.00	14.50	15.00	15.26
(crest) 227	238.50	239.00	239.50	240.00	240.50	241.00	241.50	242.00	242.26
	Discharge(m^3/s)								
238									
239	534.00	538.58							
240	583.48	594.33	602.70	607.28					
241	627.47	642.04	654.88	665.73	674.10	678.68			
242	667.85	685.36	701.47	716.04	728.88	739.73	748.10	752.68	
243	705.51	725.54	744.36	761.87	777.98	792.55	805.39	816.24	820.94
244	741.02	763.28	784.45	804.48	823.30	840.81	856.92	871.49	878.39
245	774.72	799.01	822.31	844.57	865.75	885.78	904.59	922.11	930.67
246	806.90	833.06	858.31	882.60	905.90	928.16	949.34	969.37	979.31
247	837.76	865.67	892.72	918.88	944.13	968.42	991.72	1013.98	1025.13
248	867.45	897.01	925.75	953.66	980.71	1006.87	1032.11	1056.41	1068.65
249	896.11	927.22	957.56	987.12	1015.86	1043.77	1070.82	1096.98	1110.23
250	923.85	956.44	988.30	1019.41	1049.75	1079.30	1108.04	1135.95	1150.13
251	950.74	984.75	1018.06	1050.65	1082.51	1113.61	1143.96	1173.51	1188.56
252	976.86	1012.23	1046.93	1080.94	1114.25	1146.84	1178.70	1209.81	1225.68
253	1002.29	1038.97	1075.00	1110.37	1145.07	1179.08	1212.38	1244.98	1261.64
254	1027.07	1065.01	1102.33	1139.01	1175.04	1210.41	1245.11	1279.12	1296.53
255	1051.24	1090.41	1128.98	1166.92	1204.24	1240.92	1276.96	1312.33	1330.45
256	1074.87	1115.22	1154.99	1194.16	1232.73	1270.67	1307.99	1344.67	1363.49

Table 2.5 – Outlet Gate discharge chart for one gate opening (Lower Vent)

2.3.5 Rule Curve

As per the Kerala flood study report of August 2018, CWC has recommended for reviewing the rule curves of the reservoirs in Kerala. The rule curves need to be formulated for both conservation as well as operations during the flood, in case of storage reservoirs also, particularly for the reservoirs having the live storage capacity of more than 200 Mcm in order to create some dynamic flood cushion for moderating the floods of lower return periods particularly in the early period of monsoon. Accordingly, rule curve for major reservoirs under KSEB Ltd. considering the historic inflow after the filling of reservoir and the power demand during respective months were prepared.

The live storage capacity of Lower Periyar reservoir is only $4.55\,Mm^3$ and hence, the rule curve is not prepared. Water from Lower Periyar reservoir is used for generating electricity at power house located at Karimanal and the tail race water is discharged to the river Periyar in its lower reaches. The water then flows to the Bhoothathankettu Irrigation Barrage and used for Periyar valley irrigation project. The surplus water at Bhoothathankettu irrigation barrage flows down to reach Vembanattu Kayal via Perumbavoor and Aluva.

2.3.6 Safety Aspects

The spillway gates are operated step by step after assessing the reservoir water level and inflow and the sequence is defined in Cl. 2.3.1

2.3.7 Flood Release Procedure

The flood water is released through spillway gates based on the operation manual of gates and flood routing studies given in the hydrology review**.** There are five spillway gates in Lower Periyar dam. The sequence of operation of spillway gates is Gate no. **3, 2, 4, 1, and 5**. ie. Gate No.3 is to be opened first to a unit height on the basis of requirement. Then Gate No.2&4 is operated to the same height as that of Gate No.3 and finally Gate No.1 &5. Further increase in openings is also performed in this manner.

2.3.8 Reservoir Capacities

The Gross storage of the reservoir is 5.35 Mm^3 and the Live Storage is 4.55 Mm^3 at FRL of +253.00 m.

2.3.9 Climate

Lower Periyar catchment receives comparatively good rains almost throughout the year. It is

observed that the rains contributed by South-West monsoon are comparatively heavier than the rain during North- East monsoon. The average annual weighted rainfall is estimated as 2794 mm and the average annual runoff is estimated as 292 Mm^3 according to the DPR.

2.3.10 Inflow forecasting/Methodology

Following inputs/information is used for inflow forecasting.

a) Satellite images of cloud formation

b) India Meteorological Department (IMD) forecast.

c) Advance information on flood release from upstream reservoirs and power house releases from upstream stations.

d) Daily rainfall details of the nearby rain gauge stations.

The dam is located in the downstream reaches of Periyar and the capacity of the reservoir is very small compared to the upstream reservoirs. Hence the reservoir invariably spills during monsoon season. During monsoon, daily water releases from the dams located upstream at 8.00hrs &16.00 hrs in normal situation and hourly data exchange during heavy floods is necessary.

2.3.11 Inflow Computation

Inflow into reservoirs is normally estimated by the reservoir gauging method (also called the rise and fall method or inflow-outflow method). All the outflows are added together and to it the rate of rise in storage (Positive if the level rises, and negative if it falls) is added. Expressed as an equation, this will be.

Inflow (cumecs) = Total outflow (cumecs) + Rate of increase in storage (cumecs)

The rate of increase or decrease in storage can be determined from the observed rate of increase or decrease in reservoir level and the elevation capacity tables. For easy computation a table can be developed showing the rate of change of storage in the Lower Periyar reservoir for a rate of rise in reservoir level of 1 cm/hour. This table can be put to use for easy interpolation. Once the inflow is known the outflow and gate opening required to maintain the water level can be computed.

2.3.12 Emergency Operation

The Emergency Action Plan (EAP) is prepared for Lower Periyar dam. The purpose of Emergency Action Plan is to identify emergency situations that could threaten Lower Periyar Dam and to plan for an expedited, effective response to prevent failure of the dam and warn downstream residents of impending danger. This plan defines the notification procedures to be followed in the

event of a potentially hazardous situation. The procedures are intended to protect lives and prevent property damage from and excessive release of water from the dam spillways or an uncontrolled outflow of water from the breached portion of dam.

Dam owner's responsibilities before and during an Emergency event, Dam Engineers Preparedness& Responsibilities, Responsibilities for Notification, Responsibilities for Evacuation, Responsibilities for Termination and Follow-Up, Communication Networks, Emergency Detection, Evaluation and Classification, Preparedness, Remedial Actions, Emergency Operations Centre, Inundation Areas, Local Evacuation Plan, Implementation, Vicinity Map Inundation cum Evacuation Maps etc. is provided in the detailed EAP document of the Dam.

The Emergency operation will be carried out following the Emergency Action Pan (EAP). The Emergency conditions are outlined in Chapter 4 under clause **4.2.1** on Immediate Maintenance. The EAP together with this Manual will be present at site at all times

2.4 Power Generation

Lower Periyar Power House is located in Karimanal, Kanjikuzhy village, Idukki Taluk around 30 Km from Kothamangalam. The Power Station was commissioned during 1997 with three Generating units of 60 MW each coupled to vertical shaft Francis turbine of BHEL make. After power generation, water from the power station is released to the Periyar River itself. The total installed capacity of the station is 180 MW.

2.4.1 Trash rack

Trash rack arrangements are provided at the inlet face of power tunnel, in a semicircular pattern around the tunnel mouth supported by R.C.C. columns and ribs. The details are shown below as drg. 14 attached in annexure I

2.4.2 Intake structure

The intake structure is provided in the left bank side of dam in between reservoir and road perpendicular to the dam structure with the invert level at +229m. Bell mouth entry is provided for smooth transition and is protected with trash screens. The intake opening at the entry is rectangular and has a size of 4.5m x 6.8m which then transforms in to circular section of diameter 6.05m. The intake is provided with a service gate and emergency gate at the entrance which is operated by an electrically driven hoist housed in a chamber over the shaft above the FRL The general arrangement showing hoisting mechanism, panel board and motor of the intake gates is given in Fig 2.17&2.18.

The gate is designed to withstand the unbalanced head against which it can close under gravity. A duct in the tower allows air to enter the tunnel on closure of the gate. The tunnel is lined throughout with the cement concrete with an average thickness of 30 cm. The maximum discharge through the tunnel is 124.71 m^3/s with a velocity of 4.338 m/s.

Fig 2.19 Intake Structure

2.4.3 Power Tunnel

The power tunnel 12.791km long and 6.05 m finished diameter is designed for a maximum discharge of 124.71cumecs. The tunnel was constructed from nine working faces provided by four Adit tunnels. Adit-1 at Ch. 3527.22m, Adit - 2 at Ch. 6721.17m, and Adit -3 at Ch. 9129.94m. and Adit -4 at Ch. 12512.17m. The surge shaft is located at Ch. 12791m. The elevation of inlet sill is +229.00m and that of Surge exit is +186.55m. The tunnel lining thickness is 30cm. The maximum velocity of flow is 4.338m/s.

2.4.4 Surge Shaft

Lower Periyar HE Project surge shaft located near the end of 12.791km long power tunnel is of the restricted orifice type. The surge shaft has an internal diameter of 17.60m upto +253.00m and 21.00m above +253.00m. Top level of surge shaft is 285.60m and bottom level is 194.10m and has a height of 91.50m. The maximum upsurge level is +285.10m and down surge level is 196.54m. There are two nos of orifices having diameter 1.4m each. The surge shaft construction was

carried out in 1996 and a special type form work named slipped form work, very rare in that period was used for lining the shaft so as to avoid construction joint in concrete lining. There is a fixed wheel type, vertical lift, control gate of size 3.8mx6.05m in the surge shaft.

2.4.5 Pressure Shaft

The low pressure portion of the pressure shaft from surge shaft vertical bend has length of 61m, finished diameter of 5.25m and has a gradient of 1 in 100. The downward angle of pressure shaft is 52 degree. The slopping length of inclined shaft is 178.253m (Horizontal length is 109.473m). The pressure shaft has a length of 387m, in which 352m is concrete lined and balance 35m is steel lined, branching into three pressure shafts of average length 207m and finished diameter 2.96m. The pressure shafts are designed to convey a maximum of 124.71 cumecs through an average drop of 203.63 m to the power station to feed three turbo generators with an overall installed capacity of 180MW.

2.4.6 Initial Filling of the Water conductor system

Initial filling of the water conductor system was carried out in the second half of 1996 and subsequently the mechanical spinning of the first unit was started in the October 1996.

2.5 Record Keeping

The records regarding dam and appurtenant structures including detailed drawings and construction details are kept at the field office. Essential documents as per the dam safety guidelines are kept at the dam site office. Also the Rainfall data and Reservoir level are available at the site office. Following records of reservoir operations are being maintained:

1. Rainfall record on daily basis throughout the year.
2. Reservoir levels on daily basis during non-monsoon and hourly basis during monsoon.
3. Depth of outflow over the spillway on hourly basis during monsoon.
4. Estimated spillway outflows during monsoon on hourly basis.
5. Power releases.
6. Water audit register to be maintained for estimating the inflows on hourly basis during monsoon and daily basis during non-monsoon by accounting all the releases/outflows and the incremental change in storage in the reservoir.
7. All operating procedures.

CHAPTER 3

PROJECT INSPECTION

An effective inspection program is essential to identify problems and to keep a dam in a good and healthy condition. Inspection details and suggestions are kept at field office and reports send to higher offices. The current practice of Inspection at Lower Periyar dam envisages that the Deputy Chief Engineer in presence of Executive Engineer at site shall carryout pre-monsoon and post-monsoon inspections as per CWC guidelines in the format issued by CWC (**Annexure 4)**. The Deputy Chief Engineer will submit the inspection report to the Chief Engineer for onward transmission to CWC. The Executive Engineer at site will conduct quarterly inspections and will prepare health reports. The format to be followed as per CWC is now revised during January 2018 and new guidelines issued vide Doc No. CDSO_GUD_DS_07_v1.0, CWC 2018 for Safety Inspection of Dams. Now since the health reports are to be uploaded in DHARMA, the inspection reports are prepared in the new format incorporated in DHARMA. Detailed description on project inspections is available in the Guideline for Safety Inspection of dams. However an overview of the various types of inspections to be carried out at Lower Periyar dam is given below. Note that for uploading Inspection Data into DHARMA, the Inspection Instructions & Forms given in the above mentioned Guideline for Safety Inspection of Dams must be used. This Chapter provides guidance on carrying out other inspections.

3.1 Types of inspections

Four different types of dam safety inspections are to be carried out at Lower Periyar Dam. These include, but not limited, to the following:

1. Comprehensive evaluation inspections
2. Scheduled inspections (Pre & Post monsoon inspections & other scheduled inspections)
3. Special (Un scheduled) inspections
4. Informal inspections.

The frequency of each type of inspection depends on the condition of the dam and State DSO regulations. Typical inspection elements and the detail of the safety inspections are provided below. More detailed descriptions are given in the 'Guideline for Safety Inspection of Dams' (CWC 2018). A comprehensive health checklist **(Annexure 4)** for recording the status of each item being inspected and the overall condition of the equipment along with any consequential risks on the health of the dam is required to be maintained.

3.2 Comprehensive Evaluation Inspections

For comprehensive dam safety evaluation for each dam an independent panel of experts known as Dam Safety Review Panel (DSRP) needs to be constituted for determining the condition of the dam and appurtenant works. The panel will undertake evaluation of the dam once in 10 years or on occurrence of any extreme hydrological or seismic event or any unusual condition of the dam or in the reservoir rim. The terms of reference of the comprehensive dam safety evaluation shall include but not be limited to;

- General assessment of hydrologic and hydraulic conditions, review of design flood, flood routing for revised design flood and mitigation measures.
- Review and analysis of available data of dam design including seismic safety, construction, operation maintenance and performance of dam structure and appurtenant works.
- Evaluation of procedures for operation, maintenance and inspection of dam and to suggest improvements / modifications.
- Evaluation of any possible hazardous threat to the dam structure such as dam abutment slope stability failure or slope failures along the reservoir periphery.

A comprehensive evaluation inspection of Lower Periyar dam consists of five major parts:

1. Review of project records (i.e. study of all design / construction records/drawings, history of the dam's performance, past inspection notes/reports, notes on distress observed/ any rehabilitation measures undertaken earlier, instrumentation data and its interpretation.
2. Inspection of the dam and its appurtenant works.
3. To review the results and reports of additional field investigations & laboratory testing.
4. Review of design studies, review of design flood, checking of the adequacy of Spillway capacity, freeboard requirements, dam stability and any special study.
5. Preparation of a detailed report of the inspection.

3.2.1 Details to be provided to DSRP before inspection.

All relevant details / data / drawings for the dam project to be examined by the DSRP shall be provided at least 3 months in advance of the proposed visit. This will include

- General information and Scope of the Project
- Emergency preparedness,
- Details of key personnel,
- Hydrology Original and reviewed,
- Reservoir operation and regulation plan.
- Basic data and Issues related to safety of dam

- Problems if any during construction
- Drawings of dam, spillway, gates and appurtenant structures
- Seismicity aspects & details
- Status of the instrumentation
- Construction History
- Geological Report including Special problems at site and their treatment
- Field Inspection- Observation & recommendation regarding Remedial Measures
- Dam Incidents and Reservoir filling details.

Dam Incidents and Reservoir filling

On completion of the work, the tunnel was filled and the water filled up to the butterfly valve of power house through the filling valve of surge gate (3.8x6.05m). On filling the entire water conductor system the surge gate was operated but the steel rope broke and this delayed the commissioning of the project. After rectifying all defects the project was successfully commissioned in December 1997.

3.3 Scheduled Inspections

Scheduled inspections shall consist of Pre-monsoon & Post-monsoon inspection and any other inspections carried out by the State Dam Safety Organisation/any Expert panels constituted by the dam owner. These inspections are performed to gather information on the current condition of the dam and its appurtenant works. This information is then used to establish needed repairs and repair schedules, and to assess the safety and operational adequacy of the dam. Scheduled inspections are also performed to evaluate previous repairs.

The purpose of scheduled inspections is to keep the dam and its appurtenant structures in good operating condition and to maintain a safe structure. As such, these inspections and timely maintenance will minimize long-term costs and will extend the life of the dam. Scheduled inspections are performed more frequently than comprehensive evaluation inspections to detect at an early stage any developments that may be detrimental to the dam. These inspections involve assessing operational capability as well as structural stability and detection of any problems and to correct them before the conditions worsen. The field examinations should be made by the personnel assigned the responsibility for monitoring the safety of the dam. If the dam or appurtenant works have instrumentation, the individual responsible for monitoring should analyze measurements, as and when the same are received and include in the evaluation report of that data. Dam Inspection Report or an inspection brief should be prepared following the field visit.

Scheduled inspections include the following components as a minimum:

- Review of past inspection reports, monitoring data, photographs, maintenance records, or other pertinent data as may be required
- Visual inspection of the dam and its appurtenant works
- Preparation of a report or inspection brief, with relevant documentation and photographs.

The report should be filed in the dam owner's project files.

3.3.1 Pre and Post-Monsoon Checklist and Example of Report Proforma

Detailed checklists are required to ensure the health of the dam and to ensure that it continues to operate in satisfactory and safe condition. The Proforma to be used for inspection should be the one enclosed in the Doc No. CDSO_GUD_DS_07_v1.0, CWC 2018 on the Guidelines for Safety Inspection of Dams.

Schedule of undertaking Pre &Post Monsoon Inspections is given in table 3.1.

Pre monsoon Inspection to be carried out during	April -May
Post Monsoon Inspection to be carried out during	December -January
Inspecting Officers	Deputy Chief Engineer, Dam Safety &DRIP, along with Executive Engineer Dam Safety, Executive Engineer (field), Concerned field Assistant Executive Engineer and Assistant Engineer
Preparation of Inspection report	Executive Engineer, Field, (Dam Health Engineer)
Uploading Pre monsoon inspection report in DHARMA	Executive Engineer, Field ,Before June 15th
Uploading Post monsoon inspection report in DHARMA	Executive Engineer, Field ,Before February 15th
Checking and approval of report	Deputy Chief Engineer , Dam Safety& DRIP (June 30th, March 1st)

Table 3.1 Schedule of Pre &Post Monsoon Inspections

3.4 Special (Unscheduled) Inspections

Special inspections may need to be performed to resolve specific concerns or conditions at the site on an unscheduled basis. Special inspections are not regularly scheduled activities, but are usually made before or immediately after the dam or appurtenant works have been subjected to unusual

events or conditions, such as an unusually high flood or a significant earthquake. These inspections are to be carried out by teams to be constituted by state DSO after an initial assessment based on informal inspection carried out by project personnel reveal dam safety related concerns like cracking in the dam, damages, erosion/ scour, undermining/ piping/ sink holes/ liquefaction or any such undesirable feature. A special inspection may also be performed during an emergency, such as an impending dam breach, to evaluate specific areas or concerns. They are also made when the ongoing surveillance program identifies a condition or a trend that appears to warrant a special evaluation. Special inspections should focus on those dam components that are affected by the unusual event and should include at least three elements:

1. Review of available relevant files or data,
2. Visual inspection of all components of the project and surroundings, and
3. Report preparation covering status of project and recommendations.

More detailed site investigations / studies may be required (such as drilling, surveys, or seepage flow estimates) if the special inspection reveals the need for the same. Photographic documentation is to be included as part of the inspection.

3.5 Informal Inspections

An informal inspection, is a continuing effort by on-site personnel (dam owners/operators and maintenance personnel) performed during their routine duties. Informal inspections are critical specially to keep an eye on the proper operation and maintenance of the dam. These inspections consist of frequent observations of the general appearance and functioning of the dam and appurtenant structures.

Operators, maintenance crews, or other staffs who are posted at Lower Periyar dam site are supposed to conduct informal inspections on routine basis. These people are the 'first-line of defense' in assuring safe dam conditions, and it is their responsibility to be familiar with all aspects of the dam. Their vigilance while walking across the dam for inspection / surveillance, checking the operating equipment, and noting changes in conditions may prevent serious mishaps or even dam failures.

Informal inspections are important and are performed at every available opportunity. These inspections may only cover one or two dam components as the case may be, or they may cover the entire dam and its appurtenant structures in one go. The informal inspections are not as detailed as comprehensive evaluation, scheduled, and special inspections and will only require that a formal report is submitted to the dam owner's project files if a condition is detected that might endanger the dam. Report is to be submitted detailing the condition discovered along with photographs, time, reservoir water level, other features etc.

CHAPTER 4

PROJECT MAINTENANCE

A good maintenance program is required to protect a dam against deterioration, prolong its life and greatly reduce the chance of failure. Maintenance program for a dam should be developed primarily based on systematic and frequent inspections. Nearly all the components of a dam and its materials are susceptible to damage and deterioration if not well maintained. Moreover, the cost of a proper maintenance is small compared to the costs of major repairs, loss of life, property and litigation. If maintenance of a dam is neglected the consequences and costs could be enormous.

4.1 Maintenance Plan

A basic maintenance schedule for the various monitoring components prepared for Lower Periyar dam based on manual of operating parts, frequent inspections, priority, and interval is attached as **Annexure 6**. This shows the tasks to be performed and how frequently that is to be inspected/observed and repaired.

4.2 Maintenance Priorities

Maintenance activities need to be prioritized. In order of priority they need to be classified under the heads immediate maintenance & preventive maintenance.

4.2.1 Immediate Maintenance

The following conditions are critical and call for immediate attention & reservoir lowering, if warranted. These conditions may include, but are not limited to:

- The dam is about to be overtopped or being overtopped during high flood.
- The dam showing signs of piping or internal erosion along faults, weak zone etc. indicated by increasingly cloudy seepage or other symptoms.
- A dam showing signs of failure due to aging/cracking, sliding, overturning etc.
- The spillway being blocked or with some inoperable gates.
- Evidence of excessive seepage as seen in the gallery/on downstream face of the dam.

An EAP is to be activated when any of the above conditions are noted.

4.2.2 Preventive Maintenance

This can be further classified as Condition based Maintenance and Routine Maintenance.

4.2.2.1 Condition Based Maintenance

The following maintenance works are to be undertaken as soon as possible after the defective condition is noted. These include but are not limited to:

- Remove all vegetation and bushes by roots from the dam surfaces, restoring any eroded areas.
- Repair of defective gates, valves, and other hydro-mechanical equipment.
- Repair any concrete or metal components that have deteriorated.
- Cleaning of the choked drainage holes in the dam body/ foundations in concrete dams.
- Repair any damages on spillway glacis, piers, energy dissipaters, training/divide walls, downstream areas etc.
- Repairs on upstream face of dams in case of damages resulting in increased seepage.
- Controlling any heavy seepage in the foundation/ inspection galleries in Concrete dams from drainage holes.
- Repairs of any cracks/cavities/joints in concrete dams/structures.

However many of these works will require the services of experienced engineers/expert panels.

4.2.2.2 Routine Maintenance

Several tasks should be performed on a continuous basis. These include but are not limited to the following:

- Any routine repair to concrete or metal component.
- Observation of any springs or seepage areas in shear zones, faults etc., comparing quantity and quality (clarity) with prior observations.
- Monitoring of downstream development which could have an impact on the dam and its hazard category.
- Maintenance of Electrical & Hydro-Mechanical equipment and systems, eg. Servicing of spillway gates, hoisting arrangements, and gates/hoist of outlet works/sluices & stand by generator.
- Maintaining proper lighting at dam top, galleries, etc.
- Monitoring of seepage in galleries of the dam.
- Monitoring/ cleaning & removal of leached deposits in porous concrete/ formed drains in dam body and foundation drainage holes.
- Maintenance of all dam roads & access roads.
- Operation of electrical and mechanical equipment and systems including exercising gates.
- To keep the gate slots clear of silt/debris.

- Maintenance/testing of monitoring equipment (instruments) and safety alarms.
- Testing of security equipment.
- Testing of communication equipment.
- Any other maintenance considered necessary.

4.3 Procedures for Routine Maintenance

4.3.1 Controlling Damage from Vehicular Traffic

Vehicles, except for maintenance, are restricted on the dam top and kept out by fences or barricades. Any damages are repaired as soon as possible**.** Also vehicles are permitted only after security checking at check posts.

4.3.2 Controlling Vegetation

Removal of vegetation around the dam and adjoining premises is done 3 times in a year.

4.3.3 Masonry / Concrete dams & spillways

The following important issues / aspects need to addressed while undertaking the periodic maintenance, but are not be limited to:

- Cracking in concrete (potential causes are alkali – aggregate reaction, thermal stresses because of heat of hydration or temperature variations, foundation problems).
- Damages on spillway glacis, spillway piers, training/divide walls, energy dissipaters, downstream areas (probable causes are cavitation, abrasion, un-symmetrical flows, unfavorable down-stream conditions)
- Vegetation growth in spillways, spill channel, approach channel etc.
- Seepage in Galleries and on d/s face of the dam.
- Cleaning and removal of leached deposits from choked drainage holes in the dam body/foundations.
- Repair to upstream face of masonry dams in case the pointing is damaged, leading to increased seepage.
- To ensure proper access & lighting in galleries.
- To ensure that the dam is behaving as designed based on instrumentation programs.
- Periodic maintenance should be performed on all concrete surfaces to repair deteriorated areas. Repair of deteriorated concrete at the earliest following the standard specifications for repair of concrete surfaces and re-pointing of masonry joints etc.; it is most easily

repaired in its initial stages. Deterioration can accelerate and, if left unattended, can result in serious problems or dam failure.

- Status of rectification works undertaken from time to time need to be assessed during periodic maintenance.

For remedial measures of problems of special nature advice of experienced engineers/ Panel of Experts needs to be obtained.

4.3.4 Vertical lift gates

Fixed wheel vertical lift gates are provided in intake tower of the Lower Periyar dam and surge shaft for controlling the flow. The aspects to be inspected and maintained periodically for ensuring proper operation of these gates are as under;

i) The gate slot and bottom platform/sill beam should be cleaned periodically. Scales formed over the embedded parts should be removed. Second stage concrete should be checked for any development of cracks/leakages and repairs should be attended to immediately.

ii) The gate leaf should be thoroughly cleaned and repainted as and when necessary according to the procedure or guidelines- indicated in IS: 14177 or as per the recommendations of the paint manufacturer. All drain holes provided in the gate assembly should be cleaned.

iii) Rubber seals should be smoothened, if required, for proper alignment. All nuts and bolts fixing the seal to the gate should be tightened uniformly. Seals, if found damaged or found leaking excessively should be adjusted, repaired or replaced as considered necessary.

iv) The wheel shall be rotated to check their free movement. Gate roller bearings and guide roller bushes should be properly lubricated. Whenever necessary these should be opened for rectifications of defects, cleaning and lubrication and should thereafter be refitted. These may be replaced if repairs are not possible.

v) Hoisting connection of the gate leaf should be lubricated where necessary and defects if any should be rectified.

vi) All nuts, bolts, check nuts and cotter pins of the lifting devices should be checked periodically.

vii) All components should be greased and lubricated. Recommended and approved oils and grease only should be used.

viii) Roller assembly should be adjusted by the eccentricity arrangement to ensure all rollers rest uniformly on the track plates particularly in the closed position of the gate.

ix) All welds shall be checked for cracks/damages. Any weld that might have become defective should be chipped out and redone following the relevant codal provisions. Damaged nuts,

bolts, rivets, screws etc. should be replaced without delay.

x) The guide-assemblies, wheel-assemblies and sealing-assemblies shall be cleared off grit, sand or any other foreign material.

xi) The wheel pin shall be coated with corrosion resistant compound.

xii) All nuts and bolts shall be tightened.

4.3.5 Maintenance of Trash Racks

Trash racks at intakes that have become clogged with debris or trash reduce their discharging capacity. The head losses through clogged trash racks also increase. Maintenance of trash racks includes periodic inspections for rusted and broken sections and repairs are made as needed. Trash racks should be checked during and after floods to ensure that they are functioning properly and to remove accumulated debris periodically as per site requirements.

4.3.6 Maintenance of Spillway Radial Gates & Hoisting Equipment

The safe and satisfactory operation of a dam depends on proper operation of its Gates & Hoisting Equipment. Maintaining spillway gates in working condition is critical for dam safety and is to be assigned the highest priority. If routine inspection of the Hydro-Mechanical Equipment reports the need for maintenance, the work should be completed as soon as possible.

The gates are to be operated through their full range twice annually (before monsoon & after monsoon keeping a gap of at least six months). Because operating gates under full reservoir pressure can result in large discharges, exercising of gates should preferably be carried out during dry conditions or lean times of the year.

The aspects to be inspected and maintained periodically for ensuring proper operation of gates in general are given below. The O&M manuals of the gate manufacturer would however govern the overall maintenance of Gates & Hoists whenever there is any contradiction with the instructions given in the Manual.

i) The gate slot and bottom platform/sill beam should be cleaned periodically. Scales formed over the embedded parts should be removed. Second-stage concrete should be checked for any development of cracks / leakages and repairs should be attended to immediately.

ii) The gate leaf should be thoroughly cleaned and repainted as and when necessary according to the procedure or guidelines- indicated in IS: 14177 or as per the recommendations of the paint manufacturer. All drain holes provided in the gate assembly should be cleaned.

iii) Rubber seals should be smoothed, if required, for proper alignment. All nuts and

bolts fixing the seal to the gate should be tightened uniformly to required torques. Seals, if found damaged or found leaking excessively should be adjusted, repaired or replaced as considered necessary.

iv) The wheel shall be rotated to check their free movement. Gate roller bearings and guide roller bushes should be properly lubricated. Whenever necessary these should be opened for rectifications of defects, cleaning and lubrication and should thereafter be refitted. These may be replaced if repairs are not possible.

v) Hoisting connection of the gate leaf should be lubricated where necessary and defects if any should be rectified.

vi) All nuts, bolts, check nuts and cotter pins of the lifting devices should be checked periodically.

vii) All components should be greased and lubricated. Recommended and approved oils and grease only should be used.

viii) All welds shall be checked for cracks/ damages. Any weld that might have become defective should be chipped out and redone following the relevant codal provisions. Damaged nuts, bolts, rivets, screws etc. should be replaced

ix) The guide-assemblies, wheel-assemblies and sealing-assemblies shall be cleared off grit, sand or any other foreign material.

x) The wheel pin shall be coated with corrosion resistant compound.

xi) All nuts and bolts shall be tightened.

The aspects to be inspected and maintained periodically for ensuring proper operation of these gates are as under:

a) **Rubber Seals**:

Seals shall be inspected for leakages. Locations of excessive leakages shall be recorded for taking remedial measures. Weeping or slight flow in localized area will not require immediate remedial measures. However, measures like tightening of bolts are carried out. Further adjustment is carried out during annual maintenance.

b) **Trunnion block assembly and anchorages:**

i. All the nuts and bolts of Trunnion block assembly and its anchorages shall be checked for tightness.

ii. Check all the welds for soundness and rectify defects.

iii. Check whether the Yoke girder and thrust block is covered or not. If not, cover it with mild steel plates.

iv. Cover the trunnion pin with anti- corrosive jelly.

v. Remove all dirt, grit etc. from trunnion assembly and lubricate trunnion bearings of the gate with suitable water resisting grease as recommended by bearing manufacturers.

c) **Gate structures:**

i. Check all the welds for soundness and rectify defects.

ii. Check welds between arms and horizontal girders as well as between latching bracket and skin plate with the help of magnifying glass for cracks/defects and rectify the defects.

iii. Clean all drain holes including those in end arms and horizontal girders.

iv. Check all the nuts and bolts and tighten them. Replace damaged ones.

v. Check upstream face of skin plate for pitting, scaling and corrosion. Scaling may be filled with weld and grinded. Corroded surface shall be cleaned and painted.

d) **Embedded Parts:**

i) All the sill beams and wall plates shall be inspected for crack, pitting etc. and defects shall be rectified.

ii) The guide roller pins shall be lubricated.

e) **General Maintenance:**

Defective welding should be chipped out and it should be re-welded duly following the relevant codal provision (IS: 10096, Part-3).

i) Damaged nuts, bolts, rivets, screws etc. should be replaced.

ii) Any pitting should be filled up by welding and finished by grinding if necessary.

iii) The gate leaf, exposed embedded metal parts, hoists and hoist supporting structure etc., should be thoroughly cleaned and repainted when required keeping in view the original painting system adopted and as per the guidelines contained in IS: 14177.

iv) Trunnion bearing should be greased as and when required. Keeping trunnion bearings in perfect working condition is very important. All other bolted connections should also be checked up for proper tightness.

v) Bolts and trunnion bearing housing should be tightened wherever required.

vi) The seals of the gate should be checked for wear and tear and deterioration. These should be adjusted/replaced as and when necessary.

vii) The wall plates, sill beams shall be checked and repaired if necessary.

viii) Wire ropes should be properly lubricated.

ix) Oil level in the worm reduction unit should be maintained by suitable replenishment. Oil seals should also be replaced if required. Lubrication of other parts of hoists such as chains, position indicators and limit switches should also be done.

x) The stroke of the brake should be reset to compensate for lining wear. Worn out brake linings should be replaced in time.

xi) Flexible couplings should be adjusted if required.

xii) Repairs and replacements of all electrical relays and controls should be attended to.

xiii) Maintenance of alternative sources of Power such as Diesel Generating sets and alternative drives wherever provided should be carried out.

xiv) The list of essential spare parts to be kept available should be reviewed and updated periodically. The condition of spares should be checked periodically and protective coating given for use. . Ensure availability of essential spare parts at site as per the list of essential spares.

4.3.7 Maintenance of Electrically operated fixed hoists

i) General Instructions:

a) Operation of fixed hoist without lifting the gate is not possible and need not therefore be attempted. It will be possible to operate the unit and observe operation of load carrying hoist component when gate is being lifted or lowered.

b) Never open any bolt or nut on motor, gear boxes, rope drums and other load carrying hoist components when the gate is in raised position. The gate should be fully closed or rested on the gate latches before carrying out any work on hoist components including motor brake and other electrical equipment.

ii) **Inspection and Maintenance**

The aspects to be inspected and maintained periodically for ensuring proper operation of Rope drum hoists are as under

i. Entrance to all hoist platforms shall be kept locked. All keys shall remain with the shift supervisor.

ii. A cursory daily inspection shall be made of hoist and gate to ensure that there is no unusual happening.

iii. Clean all hoisting equipment and hoist platform.

iv. Check oil level in gearboxes and replenish as and when required with oil of proper grade.

v. Apply grease of suitable grade by grease gun.

vi. Lubricate all bearings, bushings, pins, linkages etc.

vii. Check all the fuses on the power lines.

viii. All bolts and nuts on gear boxes, hoist drum and shaft couplings should be checked for tightness.

ix. Check the supply voltage.

x. Drain sample gear oil from each of the gear boxes. If excessive foreign particles or sludge is found, the gear box shall be drained, flushed and filled with new oil.

xi. All the geared couplings shall be greased.

xii. Raise and lower the gate by hoist motor and check for smooth, and trouble free operation of gate without excessive vibration.

xiii. Observe current drawn by motor at the time of lifting and check if it is more than normal. If so, stop the hoist and investigate the cause and rectify.

xiv. Check the condition of painting of various components and remove rust wherever noticed and repaint the portion after proper cleaning as per painting schedule.

xv. All trash, sediments and any other foreign material shall be cleared off the lifting rope and lifting attachment.

xvi. All ropes shall be checked for wear and tear and if broken wires are noticed, the rope shall be replaced.

xvii. All the wire ropes shall be checked and all visible oxidation shall be removed.

xviii. All wire ropes shall be greased with cardium compound.

xix. Check the overload relays for proper functioning.

xx. Check all the nuts, bolts, rivets, welds and structural components for hoisting platform and its supporting structure for wear, tear and damage. All damages shall be rectified. All bolts shall be tightened. The portion with damaged painting shall be touched up.

xxi. Check the pulleys, sheaves and turn-buckles.

xxii. Raise and lower the gate for its full lift several times (at least three to four) and observe the following:

a) Check the limit switches and adjust for design limits.

b) The effectiveness and slip of the brakes shall be checked by stopping the gate in raising and lowering operations. The brakes shall be adjusted if needed.

c) When the gate is operated, there should not be any noise or chatter in the gears.

xxiii. Adjust the rope tension of wires if unequal.

xxiv. Check for all gears and pinions for uneven wear and adjust for proper contact. Grease the gears.

xxv. Repaint the hoist components, hoisting platform and its supporting structures as per requirement.

xxvi. The periodic maintenance of commercial equipment like motors, brakes, thrusts etc. shall be carried out as per manufacturers operation and maintenance manual.

4.3.8 Maintenance of Electrical components

a) The Electrical components to be inspected and maintained periodically are as under;

i) Starters should be cleaned free of moisture and dust.

ii) Each individual connector should be tried by hand to make sure that it operates freely.

iii) All wearing parts should be examined in order to take note of any wear which may have occurred during operation.

iv) If the connector hums, the contact faces should be cleaned.

(v) Examine all connections to see that no wires are broken and no connections are loose.

vi) Clean the surface of the moving armature and magnet core which comes together when the connector closes, free of dust or grease of any kind.

vii) Examine the mechanical interlocks between the reversing connector and see when the contact tips of one of the connector units are touching, it is impossible to get the contact tips of the other unit to touch.

viii) The contact tips should be kept free from burns or pits by smoothening with fine sand paper or emery paper.

ix) Replace the contact tips which have worn away half-way.

x) Do not lubricate the contacts.

xi) Examine earth connections and motor leads.

xii) Examine motor windings for overheating.

xiii) Blow out windings thoroughly by clean and dry air to clear air passage in the stator and the rotor of any accumulated dirt. The air pressure shall not be too high to damage the insulation.

xiv) Examine control equipment.

xv) Examine starting equipment for burnt contacts.

xvi) Check and tighten all nuts and bolts.

xvii) Clean and tighten all terminals and screw connections all contact surfaces shall be made clean and smooth.

xviii) Lubricate the bearings

xix) Overhaul the controllers

xx) Inspect and clean circuit breakers.

xxi) Wipe brush holders and check bedding of brushes.

xxii) Blow out windings thoroughly by clean and dry air. The pressure shall not be so high that insulation may get damaged.

xxiii) Check the insulation resistance of the motor between any terminal and the frame. If the measured resistance is less than the prescribed value, then steps shall be taken to dry out the motors either by passing a low voltage current through the winding or by placing the stator and rotor only in a warm dry place for a day or so.

xxiv) Coat the windings with an approved high temperature resisting insulation enamel or varnish.

xxv) Over haul the motor, if required.

xxvi) Check the switch fuse units and renew, if required.

xxvii) Check resistance or earth connections.

xxviii) Check air gap.

WARNING: The complete motor shall never be put in an oven for drying as that may melt the grease out of bearings.

b) Solenoid Operated Brakes

i) All fixing bolts shall be checked and tightened at least once in three months.

ii) The magnet stroke should be reset to compensate for wear.

iii) Re-adjust the brake when the magnet stroke reaches the value given on the instruction plate.

iv) Brake lining should be checked and replaced when required.

v) Examine all electrical leads and connections.

vi) Rubber bushes or couplings should be checked and replaced if defective.

vii) The pins should be tightened.

viii) Brake drum shall be cleaned to remove any dust or grease.

4.3.9 Maintenance of Metal Gate Components

All exposed, bare ferrous metal of an outlet installation, whether submerged or exposed to air, will tend to rust. To prevent corrosion, exposed ferrous metals must be either appropriately painted (following the paint manufacturer's directions) or heavily greased in respect of moving parts & on surfaces like guides & track seats on which there is movement of gates. When areas are repainted, it should be ensured that paint is not applied to gate seats, wedges, or stems (where

they pass through the stem guides), or on other friction surfaces where paint could cause binding. Heavy grease should be applied on friction surfaces to avoid binding. As rust is especially damaging to contact surfaces, existing rust is to be removed before periodic application of grease.

4.3.10 Stop Logs, Lifting Beam and Gantry Crane

The set of stop logs shall comprise of more than one unit planned to cover around 200-250 mm above the FRL or the top of spillway gate. These stop logs shall be operated under balanced head conditions (both for raising & lowering) by Gantry Crane to be located at the top of dam over the rails fixed on the roadway over the dam with the provision of an automatic engaging & disengaging lifting beam. The stop log units being in pieces, the top non-interchangeable unit with unique features as well as the other interchangeable units are stored in various spans/bays.

The following aspects are to be considered and attended during maintenance:

i) Defective/damaged/cracked welding should be chipped out and re-welded.

ii) Damaged nuts, bolts, screws etc. should be replaced.

iii) The gate leaf should be thoroughly cleaned and repainted whenever necessary

iv) Rubber seals should be grinded, if required to bring it in alignment. All nuts and bolts for fixing seals to gate should be tightened uniformly. Seals when damaged or found leaking excessively should be adjusted or replaced as and when considered necessary.

v) All components should be greased and lubricated with the recommended oil and grease only.

vi) The roller assembly should be adjusted by the eccentricity provision to ensure that all the rollers rest uniformly on track plates particularly in the closed position of the stop log gate.

vii) The drain holes in horizontal girders should be cleaned.

viii) It should be ensured that no bearing is overheated.

ix) The gate slots should be kept cleaned. The scaling over the embedded parts should be removed.

b) Lifting Beam

Lifting beam shall be used for both raising & lowering of Spillway stop log units with the use of Gantry crane.

Lifting Beam shall mainly comprise of two number structural steel channels or fabricated channels with back to back connection to make it a single fabricated structural frame. Two side guide rollers/shoes shall be provided on each side of the lifting beam. The depth of lifting beam/frame should be sufficient to accommodate to rollers on each side located at sufficient distance from one another to enable proper guided movement. The depth of lifting beam shall not be less than one tenth of the length/span of the lifting beam or 500 mm whichever is more.

Lifting beam hook mechanism shall provide for automatic engagement and release of the equipment to be handled manually by movement of the hook block. The two hooks shall be mechanically linked together for simultaneous operation.

All rotating parts of the lifting beam shall be provided with corrosion resistant steel pins and aluminium bronze bushing/roller bearings.

All nuts, bolts and washers and retaining devices for pins shall be of corrosion resistant steel.

Following issues need to be considered and attended during maintenance;

i) Bush bearing of lifting attachment and various pulleys/sheaves wheel gears etc. should be properly lubricated.

ii) Whenever it is felt that friction in the bearing has increased, these should be taken out for cleaning and lubrication and should be refitted properly.

These should be replaced, if found beyond repair.

c) Gantry Crane

Hoisting trolley of the Gantry Cranes are generally built on top of a wheeled mobile gantry structure travelling over fixed rails and is used to straddle an object or load over a workspace. The major component parts of the gantry comprise of the following:

Frame & legs, machinery housing, operator's cabin, walkways, ladders and railings, end buffers, mechanical equipment, wheels and axles, gantry drive unit, wire rope, rope drum, gears and pinions, reduction gear box, shafts for gears and pinions, sheaves and pulleys, bearings, flexible couplings, lifting hook and block, sockets for wire ropes, gear box covers, keys & key ways, counter weight, wrenches and tools, electrical equipment, electric motor, master control equipment, cables and cable reel, wiring, limit switches, miscellaneous components etc.

Following aspects need to be considered and attended to during maintenance;

- Oil level in the gear boxes. It is very important to ensure that the correct oil level is maintained. Over filling causes overheating and leakage, therefore, care should be taken that the breather holes

  are not clogged by any foreign material like dust, paint etc.
- The insulation resistance of motor winding. In case it is found to have dropped below a prescribed value, the motor should be dried prior to putting back in service. If weak insulation becomes a regular feature, the winding should be given a good coat of insulating varnish after the motor has been dried.
- Checking of all the electrical connections.
- Lubrication of each part of crane

- Removal of any loose/foreign material along the rail track
- Actuating tests of limit switches
- Actuating tests of brakes.
- All fuses in the control panel should be checked and if necessary it should be replaced.
- Necessary terminal connections of motors, brakes etc. is to be checked.
- Overload relay should be checked.
- Visual inspection of wire ropes for any snapped loose wire and its proper lubrication.
- Checking of rope clamps on the drum and tightening of bolts if required.
- Gearbox assembly should not have any leakage of oil.
- Unusual noise/vibration if any should be checked and rectified before operation

4.3.11 Surface Preparation and Painting of HM Works

i) Protection of painted surfaces is considered essential for protection & enhancement of service life.

Gates, its embedded parts, gate leaf, hoists and its supporting structures need to be protected against corrosion due to climatic condition, weathering, biochemical reaction and abrasion etc. These equipment are likely to deteriorate/ damage to any extent that the replacement of parts may become necessary and such replacement may become difficult and costly.

ii) Surface preparation & Painting requirements.

Painting for hydro-mechanical works is to be carried out as prescribed in IS: 14177 for both newly manufactured as well as old & used gates, hoists and associated works after proper surface preparation. The preparation includes thorough cleaning, smoothing irregular surfaces, rusted surfaces, weld spatters, oil, grease, dirt, earlier applied damaged layers of primers/paint by use of mechanical tools, by use of solvents, wire brush etc. The sand/grit blasting process is used for surface preparation to a level of Sa 2½ of the Swedish standard.

iii) Surfaces not requiring painting & their protection during surface preparation, painting & transportation process.

a) The following surfaces are not to be painted unless or otherwise specified:

- Machine finished or similar surface
- Surfaces which will be in contact with concrete
- Stainless steel overlay surfaces.
- Surfaces in sliding or rolling contact
- Galvanized surfaces, brass and

b) The Surfaces of stainless steel, nickel, bronze and machined surface adjacent to metal work being cleaned or painted shall be protected by using sticky protective tape or by other suitable means over the surfaces not to be painted.

c) All embedded parts which come in contact with concrete shall be cleaned as detailed above and given two coats of cement latex to prevent rusting during the shipment while awaiting installation.

iv) Application of primer & finish coats on embedded parts and gates

a) Embedded parts

• The prescribed primer shall be applied as soon as the surface preparation is complete and prior to the development of surface rusting and within the specified time prescribed by Indian Standards or the Paint Manufacturer. In case there is lapse of considerable time beyond the prescribed time limit, the surfaces shall be again cleaned prior to priming.

• Two coats of zinc rich primer with epoxy resin shall be applied to all embedded parts surfaces which are not in contact with concrete and shall remain exposed to atmosphere or submerged in water to obtain a dry film thickness of 75 microns.

• This shall be followed by three coats at an interval of 24hours of coal-tar blend epoxy resin so as

to get a dry film thickness of 80 microns in each coat. Total dry film thickness of paint shall not be less than 300 microns.

b) Gates

Primer Coat

Over the prepared surface one coat of inorganic zinc silicate primer giving a dry film thickness of 70 ± 5 microns should be applied. Alternatively two coats of zinc rich primer, which should contain not less than 85% zinc on dry film should be applied to give a total dry film thickness of 75 ± 5 microns.

Finished paint

Two coats of solvent less coal tar epoxy paints. These shall be applied at an interval of about 24 hours. Each coat shall give a dry film thickness of 150±5 microns. The total dry film thickness of all the coats including primer coating shall not be less than 350 microns.

v) Hoist and supporting structure

a) Structural component

Primer coats of zinc phosphate primer shall be applied to give a dry film thickness of 40±5 microns. Final Coats: One coat of alkalized based micaceous iron oxide paint to give a dry film thickness of 65 ± 5 microns followed by two coats of synthetic enamel paint confirming to IS: 2932 – 1974 to give a dry film thickness of 25 ± 5 microns per coat. The interval between each coat shall be

24hours. The total dry thickness of all coats of paint including the primer coat shall not be less than 175 microns.

b) Machinery: Except machined surfaces all surfaces of machinery including gearing, housing, shafting, bearing pedestals etc., shall be given:

Primer coats: One coat of zinc phosphate primer paint to give minimum film thickness of 50 microns. Motors and other bought out items shall be painted if necessary.

Finished coats: The finished paint shall consist of three coats of aluminium paint confirming to IS: 2339– 1963 or synthetic enamel paint confirming to IS: 2932 – 1977 to give a dry film thickness of 25±5 microns per coat to obtain a total minimum dry film thickness of 125 microns.

c) Machined surfaces

All machined surfaces of ferrous metal including screw threads which will be exposed during shipment or installation shall be cleaned by suitable solvent and given a heavy uniform coating of gasoline soluble removable rust preventive compound or equivalent. Machined surfaces shall be protected with the adhesive tapes or other suitable means during the cleaning and painting operation of other components.

vi) Application of paint

Mix the contents thoroughly as directed by paint manufacturer before and during use.

Painting at shop can be done by any of the three methods namely Brush/roller, Conventional spray, Airless spray etc. The paint can be made to suit the adopted method. But once the gate and equipment is in erected position the general method adopted is only brush / roller. In case of spray lot of precautions are to be taken.

For More details: Refer IS: 14177 Part (II) – 1971.

Appendix A – Brushing of paint

Appendix B – Spraying of paint

Appendix C – Spray painting defects:

Causes and remedies.

Removal of old paint / rust and carrying out fresh painting: The carrying out of fresh painting is to be considered under the following conditions:

• The rusting is noticed all over the surface or

• Rusting is severe or

• Cracking and blistering has damaged the primer coat exposing the metal and is noticed all over the surface or

• The paint film has eroded badly, the scrap of entire paint film to the base metal and carry out fresh painting.

Note: In case of maintenance and renovation:

Refer IS: 14177 (Part II) – 1971 for checking and repainting.

vii) Removal of old paint for repainting

Caution should be exercised while removing the old paint. The surfaces shall be de-rusted and descaled by either mechanically by one or more of the methods, namely:

a) Wire brushing, Scraping, and chipping.

Sand papering or cleaning with steel wool or abrasive paper

b) Power tool cleaning

c) Flame cleaning

d) Sand blasting or shot blasting and

e) Chemical rust removal.

Note: The method of application shall be decided based on conditions existing.

After cleaning painting is to be carried out as originally proposed.

Some are painted without removal of old paint and rusting this will amounts to no painting and deteriorate faster than the original one.

viii) Inspection and testing of painting of H.M works

a) The following steps are involved in inspection of painting:

- General inspection before and during painting
- Viscosity test of paints
- Paint thickness test-using Elcometer.
- Inspection of general appearance of finished work.

b) General

The aim of inspection and testing is to ascertain whether the recommended practice is being employed correctly during every stage of application and whether the final results fulfil the object of painting.

Any test carried out should be of non – destructive nature or, if it is of destructive nature, it should be

either restricted to areas which can be restored without marring the general appearances, or be such that it is possible to restore easily without necessitating a complete repetition of the work.

c) Inspection of surfaces prior to painting

Inspection methods will depend on whether it is to be painted for the first time or is to be repainted.

d) New Works (not previously painted).

The following shall be decided by inspection:

- The method of pre cleaning feasible or recommended;

- The intermediate protective treatments to be applied, if found necessary;
- The final painting schedule and the specifications for the paint for ensuring the particular performance;
- The method of application, whether by brush, roller or spray.

e) Old Work (which requires repainting)

The following shall be decided by inspection:

- Whether the entire existing paint requires removal; and/or
- Whether repainting without paint removal would be adequate.

4.3.12 Electrical System

Electricity is typically used at a dam for lighting and to operate the gates, hoists, recording equipment, and other miscellaneous equipment. It is important that the Electrical system be well maintained, including a thorough check of fuses and a test of the system to ensure that all parts are properly functioning. The system should be free from moisture and dirt, and wiring should be checked for corrosion and mineral deposits. All necessary repairs should be carried out immediately and records of the works kept. Maintain generators used for auxiliary emergency power - change the oil, check the batteries and antifreeze and make sure fuel is readily available.

Monitoring devices usually do not need routine maintenance. Open areas are particularly susceptible to vandalism. As such all electrical fittings like bulbs, lights, loose wires etc. in open areas should be checked routinely and replaced/repaired where needed. The recommendations of the manufacturer should also be referred to

4.3.13 Access Roads

Access road surfaces must be maintained to allow safe passage of automobiles and any required equipment for servicing the dam in any weather conditions. Routine observations of any cut and fill slopes along the sides of the road should be made. In case of unstable conditions/slopes developing blockage of the road, protective works including retaining walls shall be provided as remedial measures. Drains are required to be provided and maintained along roads to remove surface and subsurface drainage. This will prolong the life of the road. Road surfacing should be repaired or replaced as necessary to maintain the required traffic loadings.

4.3.14 General Cleaning

For proper operation of spillways, outlet valves, inlet and outlet structures, stilling basin / energy dissipation arrangements, dam slopes, trash racks, debris control devices etc., regular and thorough cleaning and removal of debris is necessary. Cleaning is especially important after large floods, which tend to send more debris into the reservoir. The dam has two transverse galleries meeting

to the foundation gallery. The dam top road and these galleries are to be cleaned regularly.

4.4 Materials and Establishment Requirements during Monsoon

Materials required during monsoon period for both immediate maintenance and preventive maintenance must be stocked in adequate quantities for emergency situations that may arise. At Lower Periyar Dam, round the clock patrol is to be carried out during monsoon period. At the same time the manpower requirements during monsoon period are to be enhanced. Details of manpower / organizational structure are given in Chapter -1.

Following materials are required for handling the situations during monsoon period:

- Gunny Bags
- Sand, Boulders/Wire crates
- Bamboos/ Balli's
- Baskets, ropes
- Petromax Lamps with Spares
- Torches with spare cells
- Kerosene Oil
- Match Boxes
- Rain Coats
- Gum Boots
- Warning sign indicator
- Danger zone lights

4.5 Preparation of O&M budget

The O&M budget for the dam should essentially include but not be limited to the following items:

i) **Establishment Cost of Regular Staff** - Salaries and allowances, Bonus, Medical Reimbursement, LTC, Leave Encashment, pension benefits, etc. (as applicable).

ii) **Establishment Cost of Work charged Staff** - Salaries and allowances, Bonus, Medical Reimbursement, LTC, Leave Encashment, Pension benefits, TA and DA , etc. (as applicable).

iii) **Establishment Cost of Daily wage Staff** - Salaries and allowances, TA and DA etc. (as applicable).

iv) **Office Expenses** –Telephone/Mobile/any other Telecommunication bills, Electricity bills, water bills, Office stationery, Day to day office requirements.

v) **Motor Vehicles** - Running and Maintenance cost of inspection vehicles, Cost of hiring of vehicles as required.

vi) **Maintenance of Colony** - Maintenance of staff quarters, colony roads, Electricity, Sanitary and Water supply systems etc.

vii) **T&P** –The T&P requirements for offices, colony, works etc. as applicable.

viii) **Works**-Painting, oiling, greasing, overhauling of HM equipment's, Repair/replacement of gates seals & wire ropes, POL for pumps & generator sets, Electricity charges and maintenance of Electric systems of dam site, specific requirements for all Civil, H.M & Electrical maintenance works, vegetation removal, maintenance/cleaning of drains in dam, maintenance of lift/elevators in dam (as applicable), maintenance of access roads & basic facilities, provision for flood contingency works during monsoon, unforeseen events/items (about 10% of the cost of works) etc.

4.6 Maintenance of Records

Maintenance of records are of utmost importance. A record shall be kept for all maintenance activities, both immediate and preventive maintenance works. Information that must be recorded includes, but not limited to, the following:

- Date and time of maintenance,
- Weather conditions,
- The type of maintenance,
- Name of person or contractor performing maintenance,
- Description of work performed,
- The length of time it took to complete the work with dates,
- Equipment and materials used, and
- Before and after photographs.

The data should be recorded by the person responsible for maintenance.

CHAPTER 5

INSTRUMENTATION AND MONITORING

A dam's instrumentation furnishes data for deciding if the structure is functioning as intended and provides continuous monitoring to warn of any unsafe developments or phenomena that can lead to dam failure by drawing information from a wide spectrum of instruments and procedures, ranging from simple to complex. The program must be based on prevailing geotechnical conditions at the dam, and must include consideration of the hydrologic and hydraulic factors present before and after the project is in operation. The extent and nature of the instrumentation depends not only on the complexity of the dam and the size of the reservoir, but also on the potential for threat to life and property losses downstream. The involvement of personnel with experience in the design, installation, regular monitoring, and evaluation of an instrumentation system is of prime importance to the success of the program.

Instruments installed at a dam can indicate occurrence of any anomalous or problematic behavior. They can show that whether the dam behavior is as per design or otherwise. Actual measurements of uplift pressure in a Gravity dam and comparison with the uplift pressure assumed in original designs is an example.

5.1 Instrument Types and Usage

A wide variety of instruments and procedures are used to monitor dam behavior. The parameters often monitored by instruments include:

- movements (horizontal, vertical, rotational and lateral)
- pore pressure and uplift pressures
- water level
- seepage flow
- water quality
- temperature
- Crack width
- seismic activity
- weather and precipitation data
- stress and strains

Even though gallery is provided in Lower Periyar Dam, dam is not instrumented with any of instruments like Pendulum, Pore Pressure meter, Joint meter, Resistance Thermometer etc. "V"

notch is provided in Lower Periyar dam. There are 62 Vertical body drain holes and 62 nos of foundation drain holes are provided in the dam. All drain holes are opened to foundation gallery. The drain holes are monitored regularly.

Fig 5.1 View of gallery

5.2 Parameters monitored

5.2.1 Water Level

Water level gauge is provided at the left bank of the dam. Automatic water level recorder is also installed. Daily water levels are taken two times. During monsoon, hourly readings are taken and recorded.

Fig 5.2 Automatic water level recorder

5.2.2 Seepage Flow

Seepage is measured with V notches.

Fig 5.3 V notch in gallery of Lower Periyar dam

5.2.3 Seepage assessment

In Lower Periyar dam the porous drains and foundation drain holes are connected to the common drain in foundation gallery. Drain culvert is located in Block no. 5. The collected water is pumped out using a pump installed at pump chamber at elevation +243.15m. Total seepage is measured using three nos of "V" notches established in the bottom gallery.

5.2.4 Seismic Activity

The project area falls in zone no III of the seismic zone map of India. The dam is required to be safe using the appropriate seismic coefficients in the BIS code and as approved by NCSDP. Historical significant earthquake events in the near vicinity are as under

Event 1: Date: 12/12/2000, Epicenter: Erattupetta, Magnitude: 5 and

Event 2: Date: 1/7/2011, Epicenter: Erattupetta, Magnitude: 4.8

There is no Seismic observatory or accelerograph installed at Lower Periyar Dam.

5.2.5 Weather Conditions

The rainfall data are measured with ordinary rain gauge installed in dam premises.

5.3 Frequency of Monitoring

Water levels are monitored daily, the seepage data is monitored on fortnightly basis and water quality is tested on monthly basis.

5.4 Data Processing and Evaluation

The steps required to process and evaluate data, whether collected manually or automatically, are the same. Instrument data should be processed and evaluated according to the procedures established by the monitoring program. Accumulation of instrument data by itself

does not improve dam safety or protect the public. Interpretation of data, so collected, needs to be carried out judiciously. Help of experienced personnel from the concerned field from Institutes / manufacturers / instrument suppliers could prove to be useful.

5.4.1 Data Collection

On daily, fortnightly and monthly basis, as the case may be.

5.4.2 Data Presentation

On monthly basis.

5.4.3 Data Interpretation

As per standard practice & on monthly / six monthly / yearly basis or as decided by design authorities.

5.4.4 Dam Performance Evaluation

Performance evaluation is conducted for safe normal operation involving all concerned engineers / officers before and after monsoon.

In case, the data deviates from expected behavior or design assumptions, action should be taken. The action to be taken depends on the nature of the problem, and should be determined on a case-by-case basis

5.5 Methods of Behavior Prediction

5.5.1 Visual Observations

Observations by on site personnel (dam owners/operators and maintenance personnel) may be the most important and effective means of monitoring the performance of a dam. An inspector should examine visually walking along the dam alignment for any leakages, any distress, wet spots on downstream face of dam, seepage from foundation gallery etc.

5.5.2 Monitoring Results

Analysis and observation of the instrument readings on water level, leakages, uplift and other parameters can ascertain the visually observed behavior. Any deviation from the normal behavior needs to be resolved critically by taking required remedial measures in consultation with senior / experienced engineers. Details of the seepage measurements recorded at different intervals are appended below.

Date	Water Level(m)	Seepage in Litre/minute	
		V1	V3
06.06.2018	249.9	0.774	2.777
10.07.2018	253	0.946	3.524
16.08.2018	249.9	0.774	3.137
15.09.2018	238.2	0.774	3.137
16.10.2018	249.2	0.774	3.524
13.11.2018	248.6	1.138	3.524
10.12.2018	250.1	1.353	3.938
10.01.2019	249.5	1.353	3.524
12.02.2019	248.6	0.946	3.524
12.03.2019	249.4	1.138	3.137
09.04.2019	249.1	0.774	3.137
13.05.2019	248.1	0.623	2.443
10.06.2019	246.9	0.491	1.85
16.07.2019	247.8	0.491	1.59
16.08.2019	252.4	1.138	3.938
16.09.2019	229	0.491	0.946
16.10.2019	246.6	0.623	1.59
16.11.2019	247.4	0.946	2.777
15.12.2019	250	0.774	2.443
14.01.2020	251.7	0.623	1.353
16.02.2020	246	0.491	2.13
12.03.2020	249.1	0.623	2.134

Table 5.1 – "V" notch readings

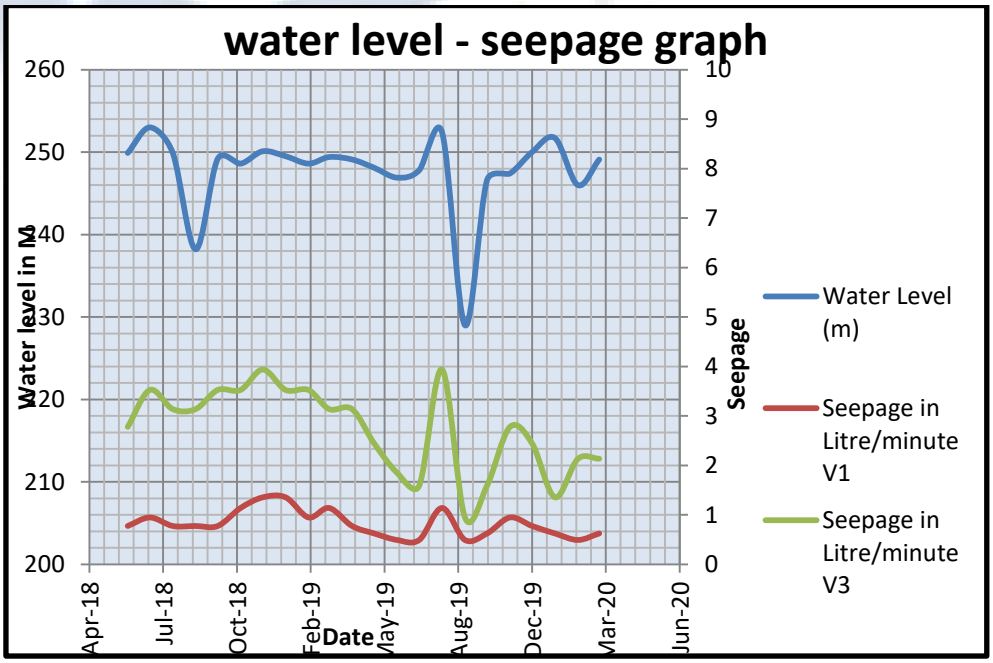

Fig 5.4 Seepage graph

CHAPTER 6

PREVIOUS REHABILITATION EFFORTS

6.1 Issues with the dam

The dam was commissioned long back and no major rehabilitation works were carried out. The Dam was inspected by experts from CWC and DSRP, recommendations given for works/remedial measures to be attempted for improving the structural safety and security and performance of the Dam. Accordingly the following works were included under DRIP I.

1. Extension of left training wall to prevent bank erosion caused by lower vent operation
2. Maintenance of approach road to gallery
3. Providing roof covering to intake hoisting structure
4. Pressure washing the downstream of dam body and painting parapet
5. Construction of catwalk bridge and ladders
6. Construction of security guard room cum control room
7. Supply and installation of high mast Light
8. Providing signage boards.
9. Dam Break Analysis and EAP
10. Repairs to 3 nos of crest gates and one low vent gate
11. Installation of CCTV cameras
12. Dam Instrumentation

Works under items 1 to 10 is completed, item 11 has commenced and work under item 12 is tendered and under evaluation.

The photographs showing the DRIP works are given below:

Fig 6.1 Photograph showing Intake Gate Roof

Fig 6.2 Photograph showing Road to Foundation Gallery

Fig 6.3 Pressure washing and Painting of parapet

Fig 6.4 Pressure washing – before and after

Fig 6.5 Photograph showing Catwalk

Fig 6.6 View of Repairs to low vents gates

Fig 6.7 Photograph showing River training works

Fig 6.8 Photograph showing Security cabin cum Control Room

Fig 6.9 View of signage boards

Tender for supply and installation of 1 no. automatic weather station and automatic water level recorder, 5 nos survey markers, 5 nos of uplift gauge, 2 nos of tiltmeter, 5 nos of thermometer, 15 nos of jointmeter, including data centre at dam site for real time data transmission to control centre for real time structural health monitoring has been invited in DRIP I.

Another major rehabilitation work undertaken is replacement of all the trash rack panels (42 nos) of intake of power tunnel of LPHE project which was damaged in floods of 2018&2019. The fabrication and erection was completed in January 2020.

Fig 6.10 Photographs of Trash rack replacement Work

CHAPTER 7

UPDATING THE MANUAL

Whenever features of the dam and appurtenant structures change, the O & M Manual must be edited and portions rewritten to reflect these changes. This task is often ignored. Updating information in the O&M Manual should be done whenever major changes like construction of an additional spillway, construction of dam on the upstream etc. take place.

Aspects to be considered when updating the Manual must include: Increase/decrease in the frequency of an inspection or the maintenance routine based on additional data/ experience acquired, Changes in the operation and/or maintenance procedures based on additional data/experience acquired, Alterations to the project data because of changes/modifications in the dam by way of additional spillway etc.

It is recommended that the O & M Manuals may be reviewed/updated after every 10 years by the respective Dam Owners.

ANNEXURE 10

GLOSSARY

Abutment - that part of a valley side against which a dam is constructed. Right and left abutments are those on respective sides of the observer looking downstream.

Air Vent Pipe - a pipe designed to provide air to the outlet conduit to reduce turbulence during release of water and safeguard against damages due to cavitation.

Appurtenant Structures - ancillary features of a dam, such as the outlet, spillway, energy dissipation arrangement powerhouse, tunnels, etc.

Arch Dam - a concrete or masonry dam that is curved to transmit the major part of the water pressure to the abutments.

Auxiliary Spillway (Emergency Spillway) - a secondary spillway designed to operate only during exceptionally large floods.

Base Width (Base Thickness) - the maximum width or thickness of a dam measured horizontally between upstream and down-stream faces and normal (perpendicular) to the axis of the dam but excluding projections for outlets, etc.

Berm - a horizontal step or bench in the sloping profile of an embankment dam.

Buttress dam - a dam consisting of a watertight upstream face supported at intervals on the downstream side by a series of but-tresses.

Cofferdam - a temporary structure enclosing all or part of a construction area so that construction can proceed in a dry area.

Concrete Lift - in concrete works the vertical distance between successive horizontal construction joints.

Conduit Outlet Works - a closed conduit for conveying discharge through or under a dam for different project purposes.

Consolidation Grouting (Blanket Grouting)- the injection of grout to consolidate a layer of the foundation, resulting in greater im permeability, strength, or both.

Construction Joint - the interface between two successive placing or pours of concrete where a bond, not permanent separation, is intended.

Core Wall - a wall built of impervious material, usually concrete or asphaltic concrete, in the body of an embankment dam to prevent leakage.

Crest gate (spillway gate) - a gate on the crest of a spillway to control overflow or reservoir water level.

Crest Length - the length of the dam at its crest (dam top) top of a dam, including the length of the spillway, powerhouse, navigation lock, fish pass, etc., where these structures form part of the length of a dam. If detached from a dam, these structures should not be included.

Crest of dam - Used to indicate the "top of dam". To avoid confusion to indicate the crest of spillway and top of dam may be used.

Culvert - a drain or waterway built under a road, railway, or embankment, usually consisting of a pipe or covered conduits.

Cut off - an impervious construction or material which reduces seepage through the foundation material.

Cut off trench - an excavation later to be filled with impervious material to form a cut off.

Cut off wall - a wall of impervious material (e.g., concrete, asphaltic concrete, steel-sheet

piling) built into the foundation to reduce seepage under the dam.

Dam - any artificial barrier including appurtenant works constructed across rivers or tributaries thereof with a view to impound or divert water; includes barrage, weir and similar water impounding structures but does not include water conveyance structures such as canal, aqueduct and navigation channel and flow regulation structures such as flood embankments, dikes, and guide bunds.

Dam failure - failures in the structures or operation of a dam which may lead to the uncontrolled release of impounded water resulting in downstream flooding affecting the life and property of the people.

Dam incident - all problems occurring to a dam that has not degraded into „dam failure" and including the following: a) Structural damage to the dam and appurtenant works; b) Unusual readings of instruments in the dam; c) Unusual seepage or leakage through the dam body; d) Change in the seepage or leakage regime; e) Boiling or artesian conditions noticed below an earth dam; f) Stoppage or reduction in seepage or leakage from the foundation or body of
the dam into any of the galleries, for dams with such galleries; g) Malfunctioning or inappropriate operation of gates;
h) Occurrence of any flood, the peak of which exceeds the available flood discharge capacity or 70% of the approved design flood; i) Occurrence of a flood, which resulted in encroachment on the available free-board, or the adopted design freeboard; j) Erosion in the near vicinity, up to five hundred meters, downstream of the spillway, waste weir, etc.; and k) Any other event that prudence suggests would have a significant unfavorable impact on dam safety.
Dam inspection - on-site visual examination of all components of dam and its appurtenances by one or more persons trained in this respect and includes investigation of the non-overflow portion, spillways, abutments, stilling basin, piers, bridge, down-stream toe, drainage galleries, operation of mechanical systems (including gates and its components, drive units, cranes), interior of outlet conduits, instrumentation records, and record-keeping arrangements.
Dam owner - the Central Government or a State Government or public sector undertaking or local authority or company and any or all of such persons or organizations, who own, control, operate or maintain a specified dam.

Dam safety - the practice of ensuring the integrity and viability of dams such that they do not present unacceptable risks to the public, property, and the environment. It requires the collective application of engineering principles and experience, and a philosophy of risk management that recognizes that a dam is a structure whose safe function is not explicitly determined by its original design and construction. It also includes all actions taken to identify or predict deficiencies and consequences related to failure, and to document, publicize, and reduce, eliminate, or remediate to the extent reasonably possible, any unacceptable risks.

Dead storage - the storage that lies below the invert of the lowest outlet and that, therefore, cannot be withdrawn from the reservoir.

Decommission - Taking a dam out of service in an environmentally sound and safe manner or converting it to another purpose.

Design flood - see spillway design flood.

Design life - the intended period that the dam will function successfully with only routine maintenance; determined during design phase.

Distress condition - the occurrence or potential development of such conditions in the dam or appurtenance or its reservoir or reservoir rim, which if left unattended to, may impede the safe operation of dam for its intended benefits or may pose unacceptable risks to the life and property of people downstream.

Diversion channel, canal, or tunnel - a waterway used to divert water from its natural course. These terms are generally applied to temporary structures such as those de-signed to bypass water around a dam site during construction. "Channel" is normally used

instead of "canal" when the waterway is short. Occasionally these terms are applied to permanent structures.

Documentation - all permanent records concerning investigation, design, construction, operation, performance, maintenance and safety of dams and includes design memorandum, construction drawings, geological reports, reports of specialized studies simulating structural and hydraulic response of the dam, changes made in design and drawings, quality control records, emergency action plan, operation and maintenance manual, instrumentation readings, inspection and testing reports, operational reports, and dam safety review reports.

Drainage area - an area that drains naturally to a point on a river.

Drainage layer or blanket - a layer of permeable material in a dam to relieve pore pressure or to facilitate drainage of fill.

Drawdown - the lowering of water surface level due to release of water from a reservoir.

Earth dam (Earth fill dam) - An embankment dam in which more than 50 percent of the total volume is formed of compacted fine-grained material obtained from a borrow area.

Earthen dam or earth filled dam - see embankment dam.

Embankment dam (Fill dam) - any dam constructed of excavated natural materials.
Emergency Action Plan (EAP) - a plan of action to be taken to reduce the potential for damage to property and loss of life in the area affected by failure of a dam or other potentially hazardous practice.

Emergency gate - a standby or reserve gate which is lowers only for repairing / servicing of the service gate.

Emergency spillway - see spillway.

Face - the external surface of a structure, e.g., the surface of a wall of a dam.

Failure - the uncontrolled release of water from a dam.

Filter (filter zone) - A band or zone of granular material that is incorporated into a dam and is graded (either naturally or by selection) to allow seepage to flow across or down the filter without causing the migration of material from zones adjacent to it.

Fixed wheel gate (fixed-roller gate, fixed axle gate) - a gate having wheels or rollers mounted on the end posts of the gate. The wheels move against rails fixed in side grooves or gate guides.
Flap gate - a gate hinged along one edge, usually either the top or bottom edge. Examples of bottom-hinged flap gates are tilting gates and belly gates, so called due to their shape in cross-section.

Flashboards - a length of timber, concrete, or steel placed on the crest of a spillway to raise the retention water level but that may be quickly removed in the event of a flood, either by a tripping device or by deliberately designed failure of the flashboard or its supports.

Flood gate - a gate to control flood release from a reservoir.

Flood routing - the determination of the attenuating effect of storage on a flood passing through a valley, channel, or reservoir.

Flood surcharge - the volume or space in a reservoir between the controlled retention water level (Full Reservoir Level) and the maximum water level. Flood surcharge cannot be retained in the reservoir but will flow over the spillway until the controlled retention water level is reached.

Flood wall - a concrete wall constructed adjacent to a stream to prevent flooding of property on the landward side of the wall, normally constructed in lieu of or to supplement a levee where the land required for levee construction is expensive or not avail-able.

Flood plain - an area adjoining a body of water or natural stream that has been, or may be, covered by flood water.

Flood plain management - a management program to reduce the consequences of flooding, either by natural runoff or by dam failure, to existing and future properties in a floodplain.

Foundation of dam - the natural material on which the dam structure is placed.

Freeboard - the vertical distance between a stated reservoir level and the top of a dam. Normal freeboard is the vertical distance between Full Reservoir Level (FRL) and the top of the dam. Minimum freeboard is the vertical distance between the Maximum Water Level (MWL) and the top of the dam.

Full Reservoir Level (FRL)/Normal water level - for a reservoir with un-gated spillway it is the spillway crest level. For a reservoir, whose outflow is controlled wholly or partly by movable gates, siphons or other means, it is the maximum level to which water can be stored under normal operating conditions, exclusive of any provision for flood surcharge.

Gallery - (a) a passageway within the body of a dam or abutment, hence the terms grouting gallery, inspection gallery and drainage gallery (b) a long and rather narrow hall, hence the following terms for a power plant viz. valve gallery, transformer gallery and bus bar gallery.

Gate - a device in which a leaf or member is moved across the waterway from an external position to control or stop the flow.

Gravity dam - a dam constructed of concrete, masonry, or both that relies on its weight for stability.

Grout cap - a pad or wall constructed to facilitate pressure grouting of the grout curtain beneath it.

Grout curtain (grout cut off) - a barrier produced by injecting grout into a vertical zone, usually narrow horizontally, in the foundation to reduce seepage under a dam.

Hazard Classification - a system that categorizes dams according to the degree of adverse incremental consequences of a failure or improper operation of the dam. CWC classifies dam hazards as "low", "significant", or "high".

Height above lowest foundation - the maximum height from the lowest point of the general foundation to the top of the dam.

Homogeneous earth fill dam - an embankment dam constructed of similar earth material throughout, except internal drains or drainage blankets; distinguished from a zoned earth fill dam.

Hydraulic fill dam - an embankment dam constructed of materials, often dredged, that are conveyed and placed by suspension in flowing water.

Hydraulic height - the height to which water rises behind a dam and the difference between the lowest point in the original streambed at the axis of the dam and the maximum controllable water surface.

Hydrograph - a graphic representation of discharge, stage, or other hydraulic property with respect to time for a point on a stream. (At times the term is applied to the phenomenon the graphic representation describes; hence a flood hydrograph is the passage of a flood discharge past the observation point.)

Inclinometer - an instrument, usually consisting of a metal or plastic tube inserted in a drill hole and a sensitized monitor either lowered into the tube or fixed within it. The monitor measures at different points the tube's inclination to the vertical. By integration, the lateral position at various levels of the tube may be found relative to a point, usually the top or bottom of the tube, assumed to be fixed. The system may be used to measure settlement.

Intake - any structure in a reservoir, dam, or river through which water can be drawn into an aqueduct.

Internal Erosion - see piping.

Inundation map - a map delineating the area that would be inundated in case of a failure.

Leakage - Uncontrolled loss of water by flow through a hole or crack.

Lining - a coating of asphaltic concrete, reinforced or unreinforced concrete, shotcrete, rubber or plastic on a canal, tunnel etc. to provide water tightness, prevent erosion, reduce friction, or support the periphery of structure. May also refer to lining, such as steel or concrete, of outlet pipe or conduit.

Low-level outlet (bottom outlet) - an opening at a low level from a reservoir generally used for emptying or for scouring sediment and sometimes for irrigation releases.

Maintenance - the recurring activities necessary to retain or restore a dam in a safe and functioning condition, including the management of vegetation, the repair or replacement of failed components, the prevention or treatment of deterioration, and the repair of damages caused by flooding or vandalism.

Masonry dam - a dam constructed mainly of stone, brick or concrete blocks that may or may not be joined with mortar. A dam having only a masonry facing should not be referred to as a masonry dam.

Maximum cross-section of dam - a cross section of a dam at the point of its maxi-mum height.
Maximum water level - the maximum water level, including flood surcharge, the dam is designed to withstand.

Membrane (Diaphragm) - a sheet or thin zone or facing made of a flexible material, sometimes referred to as a diaphragm wall or diaphragm.

Minimum operating level - the lowest level to which the reservoir is drawn down under normal operating conditions.

Morning glory spillway - see spillway.
One-Hundred Year (100-Year) Exceedance Interval - the flood magnitude expected to be equaled or exceeded on the average of once in 100 years. It may also be expressed as an exceedance frequency, i.e. a percent chance of being exceeded in any given year.

Operation - the administration, management, and performance of maintenance activities necessary to keep a dam safe and functioning as planned.

Outlet - an opening through which water can be freely discharged from a reservoir.

Outlet gate - a gate controlling the outflow of water from a reservoir.

Overflow dam - a dam designed to be overtopped.

Parapet Wall - a solid wall built along the top of a dam for ornament, for the safety of vehicles and pedestrians, or to prevent overtopping.

Peak Flow - the maximum instantaneous discharge that occurs during a flood. It coincides with the peak of a flood hydrograph.

Pervious Zone - a part of the cross-section of an embankment dam comprising material of high permeability.

Phreatic Surface - the top most flow line in an embankment dam.

Piezometer - an instrument for measuring pore water pressure within soil, rock, or concrete.

Piping - the progressive development of internal erosion by seepage, appearing downstream as a hole or seam discharging water that contains soil particles.

Pore Pressure - the interstitial pressure of water within a mass of soil, rock, or concrete.

Pressure Cell - an instrument for measuring pressure within a mass of soil, rock, or concrete or at an interface between one and the other.

Pressure Relief Pipes - Pipes used to relieve uplift or pore water pressure in a dam's foundation or structure.

Primary Spillway (Principal Spillway) - the principal or first-used spillway during flood flows.

Probable Maximum Flood (PMF) - a flood that would result from the most severe combination of critical meteorologic and hydrologic conditions possible in the region.

Probable Maximum Precipitation (PMP) - the maximum amount and duration of precipitation that can be expected to occur on a drainage basin.

Program — any authorized activity used to implement and carry out goals, actions, and objectives contained within the authorizing legislation.

Program Life - the period in a contract, conservation plan, or plan during which the conservation practice or conservation sys-tem shall be maintained and used for the intended purpose; determined by program requirements.

Pumped storage reservoir - a reservoir filled entirely or mainly with water pumped from outside its natural drainage area.

Radial gate - a gate with a curved upstream plate and radial arms hinged to piers or other supporting structures.

Regulating dam - a dam impounding a reservoir from which water is released to regulate

Rehabilitation - the completion of all work necessary to extend the service life of the practice or component and meet applicable safety and performance standards.

Relief well - vertical wells or boreholes, constructed downstream of an embankment dam to relieve the pressure from confined pervious layers in foundation overlaid by an impervious layer to arrest boiling.

Repair - actions to restore deteriorated, damaged, or failed dam or its component to an acceptable by meeting functional condition.

Replacement - the removal of a structure or component and installation of a similar, functional structure or component.

Reservoir area - the surface area of a reservoir when filled to controlled retention level.

Reservoir routing - the computation by which the interrelated effects of the inflow hydrograph, reservoir storage, and discharge from the reservoir are evaluated.

Reservoir surface - the surface of a reservoir at any level.

Riprap - a layer of large stones, broken rock, or precast blocks placed randomly on the upstream slope of an embankment dam, on a reservoir shore, or on the sides of a channel as a protection against wave action. Large riprap is sometimes referred to as armouring.

Risk assessment - as applied to dam safety, the process of identifying the likelihood and consequences of dam failure to provide the basis for informed decisions on a course of action.

Rock fill dam - an embankment dam in which more than 50 percent of the total volume comprises compacted or dumped pervious natural or crushed rock.

Rock fill Dam - see embankment dam.

Roll Crete or Roller-Compacted Concrete - A no-slump concrete that can be hauled in dump trucks, spread with a bull-dozer or grader, and compacted with a vibratory roller.

Rolled fill dam—an embankment dam of earth or rock in which the material is placed in layers and compacted using rollers or rolling equipment.

Seepage - the interstitial movement of water that may take place through a dam, its foundation, or its abutments.

Service Life - the actual period after construction of a dam, during which the practice functions adequately and safely with only routine maintenance; determined by onsite review.

Service/Regulating gate (regulating valve) - a gate or valve that operates under full pressure

and flow to throttle and vary the rate of discharge.

Shaft Spillway (Morning Glory Spill-way - water spills and then is conducted through, under, or around a dam by means of a conduit or tunnel. If the upper part of the shaft is splayed out and terminates in a circular horizontal weir, it is termed a "bell mouth" or "morning glory" spillway.

Side Channel Spillway - a spillway whose crest is roughly parallel to the channel immediately downstream of the spillway.

Sill - (a) A submerged structure across a river to control the water level upstream. (b) The crest of a spillway. (c) A horizontal gate seating, made of wood, stone, concrete or metal at the invert of any opening or gap in a structure, hence the expressions gate sill and stop log sill.

Siphon Spillway - a spillway with one or more siphons built at crest level. This type of spillway is sometimes used for providing automatic surface-level regulation within narrow limits or when considerable discharge capacity is necessary within a short period.

Slide gate (sluice gate) - a gate that can be opened or closed by sliding it in supporting guides.

Slope - (a) the side of a hill or mountain. (b) The inclined face of a cutting or canal or embankment. (c) Inclination from the horizontal. In the United States, it is measured as the ratio of the number of units of horizontal distance to the number of corresponding units of vertical distance. The term is used in English for any inclination and is expressed as a percentage when the slope is gentle, in which case the term gradient is also used.

Slope Protection - the protection of a slope against wave action or erosion.

Sluiceway - see low-level outlet.

Spillway - a structure over or through which flood flows are discharged. If the flow is controlled by gates, it is a controlled spillway; if the elevation of the spillway crest is the only control, it is an uncontrolled spillway.

Spillway Channel (Spillway Tunnel) - a channel or tunnel conveying water from the spillway to the river downstream.

Stilling Basin - a basin constructed to dissipate the energy of fast-flowing water, e.g., from a spillway or bottom outlet, and to protect the riverbed from erosion.

Stop logs - large logs or timber or steel beams placed on top of each other with their ends held in guides on each side of a channel or conduit providing a cheaper or easily handled temporary closure than a bulkhead gate.

Storage - the retention of water or delay of runoff either by planned operation, as in a reservoir, or by temporary filling of over-flow areas, as in the progression of a flood crest through a natural stream channel.

Tail water Level - the level of water in the tailrace at the nearest free surface to the turbine or in the discharge channel immediately downstream of the dam.
Tailrace - the tunnel, channel or conduit that conveys the discharge from the turbine to the river, hence the terms tailrace tunnel and tailrace canal.

Toe of Dam - the junction of the downstream face of a dam with the ground surface, referred to as the downstream toe. For an embankment dam the junction of upstream face with ground surface is called the up-stream toe.

Top of Dam - the elevation of the upper-most surface of a dam, usually a road or walkway, excluding any parapet wall, railings, etc.

Top Thickness (Top Width) - the thickness or width of a dam at the level of the top of the dam. In general, "thickness" is used for gravity and arch dams, "width" for other dams.
Transition Zone (Semi-pervious Zone) - a part of the cross section of a zoned embankment dam comprising material of intermediate size between that of an impervious zone and that of a permeable zone.

Trash rack - a screen located at an intake to prevent the ingress of debris.

Tunnel - a long underground excavation usually having a uniform cross section. Types of tunnel include: headrace tunnel, pressure tunnel, collecting tunnel, diversion tunnel, power tunnel, tailrace tunnel, navigation tunnel, access tunnel, scour tunnel, draw-off tunnel, and spillway tunnel.

Under seepage - the interstitial movement of water through a foundation.

Uplift - the upward pressure in the pores of a material (interstitial pressure) or on the base of a structure.

Upstream Blanket - an impervious layer placed on the reservoir floor upstream of a dam. In case of an embankment dam, the blanket may be connected to the impermeable element in a dam.

Upstream Blanket - see blanket.

Valve - a device fitted to a pipeline or orifice in which the closure member is either rotated or moved transversely or longitudinally in the waterway to control or stop the flow.
Water stop - a strip of metal, rubber or other material used to prevent leakage through joints between adjacent sections of concrete.

Weir - (a) a low dam or wall built across a stream to raise the upstream water level, called fixed-crest weir when uncontrolled. (b) A structure built across a stream or channel for measuring flow, sometimes called a measuring weir or gauging weir. Types of weir include broad-crested weir, sharp-crested weir, drowned weir, and submerged weir.

Zoned embankment dam - an embankment dam composed of zones of materials selected for different degrees of porosity, permeability and density.

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