Operation and Maintenance Manual for SHOLAYAR DAMS State of Kerala

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SHOLAYAR DAMS
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Chief Engineer
(Civil DRIP & Dam Safety)
Kerala State Electricity Board

सत्यमेव जयते

Operation and Maintenance Manual for Sholayar Dams

Prepared by the Dam Safety Organisation
Kerala State Electricity Board Ltd

(A Government of Kerala undertaking)
State of Kerala

Front Cover Photograph: Upstream view of Sholayar Flanking and Sholayar Main dams.

Government of Kerala

Operation and Maintenance Manual

Sholayar Dams

KSEB

Prepared

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Dam Safety & DRIP

Approved

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Kerala State Electricity Board Ltd
Pallom, Kottayam.

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Kerala State Electricity Board Ltd
Dam Safety Organisation

Disclaimer

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

The manual was developed for the purpose of organising and managing the operation, inspection and maintenance of the dams for reducing risk and optimizing performance of the dams 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.

Smt. Supriya S,
Chief Engineer (Civil – Dam Safety & DRIP)
Kerala State Electricity Board Ltd,
Pallom, Kottayam

PREFACE

Operation and Maintenance 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 Page xii January 2018. Accordingly Kerala State Electricity Board Ltd is developing and updating the Operation and Maintenance Manual of Dams under their ownership for a healthy Dam Safety management system.

Sholayar Dams under KSEBL has an Operation and Maintenance Manual which is not so comprehensive according to the present standards. Hence an attempt is being made here to revise the manual as per the new guidelines by CWC.

Team Involved in preparing this O & M Manual of Sholayar dams

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Name of the Project: Sholayar Hydro Electric Project

Sholayar Hydro Electric Project is the second major hydro electric project commissioned in Chalakudy River Basin in Kerala. The installed capacity of the project is 54 MW (3X18). Annual energy generation expected from this project is 233 Million Units. The Project was commissioned in 1965. The project is located in Athirappilly Panchayath of Thrissur District. The nearest Railway station is Chalakudy (69 km). Nearest Air Port is Cochin International Airport, Nedumbassery, Kochi.

There are three dams as part of this project. They are Sholayar main, Sholayar Flanking and Sholayar saddle dams. These dams create a single reservoir. The spillway arrangement is provided in the flanking dam. The storage capacity of the reservoir is 153.48 Million Cubic Meter. The FRL is 811.68m.

CHAPTER 1
GENERAL INFORMATION

1.1 Introduction

This document represents a detailed Operation and Maintenance (O&M) Manual for Flanking Dam, Main Dam and Saddle Dam of Sholayar 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 Sholayar Hydro Electric Project

The Sholayar H.E. Project is the second Hydel scheme in the Chalakudy basin; the first project being Poringalkuthu left bank scheme. The project comprises of a Main dam across the Sholayar river, a Flanking dam across the valley on the left bank of the river and a saddle dam across the Saddle at Ambalapara. The reservoir formed by these three dams has a capacity of 153.48 Million Cubic Meter. Water from the reservoir is diverted through a tunnel of 738.53 m long to a system of three penstocks of about 822.96 m each. These three penstock pipes lead the water to three turbines of 31100 HP each installed at Anakkayam valley for power generation. The average head on the turbine is 320.04 m.

The project is situated at about 10^0 19' North latitude and 76^0 44' East longitude. The project is accessible from Pollachi, a town in Coimbatore District and from Chalakudy the nearest railway station on the Shornur – Cochin line of Southern Railways. The Anamalai Road starting from Chalakudy passes very near the Dam site and Power Station. The distance from Chalakudy to take-off points of road to the Power Station and dam sites are 59.53 km and 64.36 km respectively.

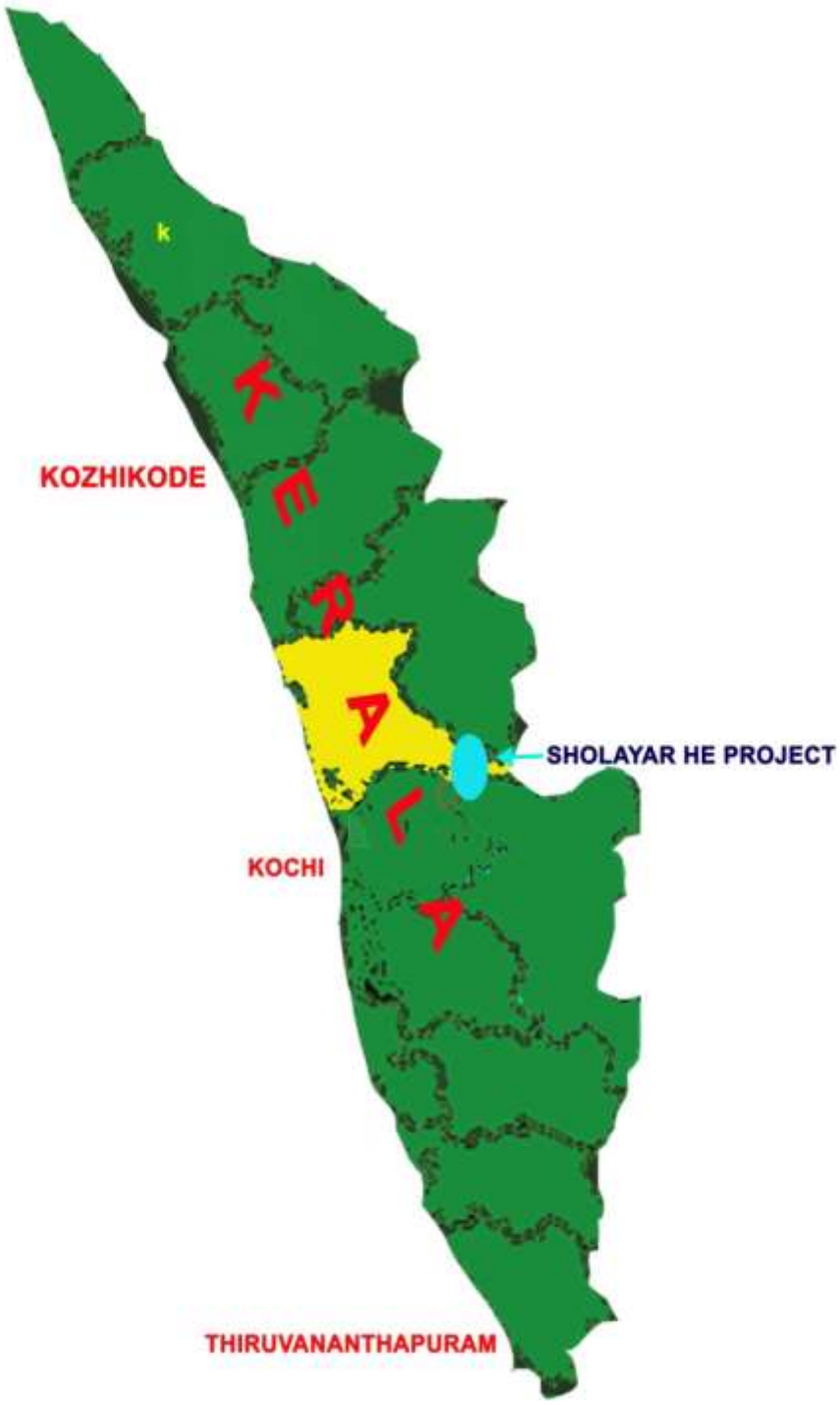

Fig 1.1 Location Map

Location Sketch

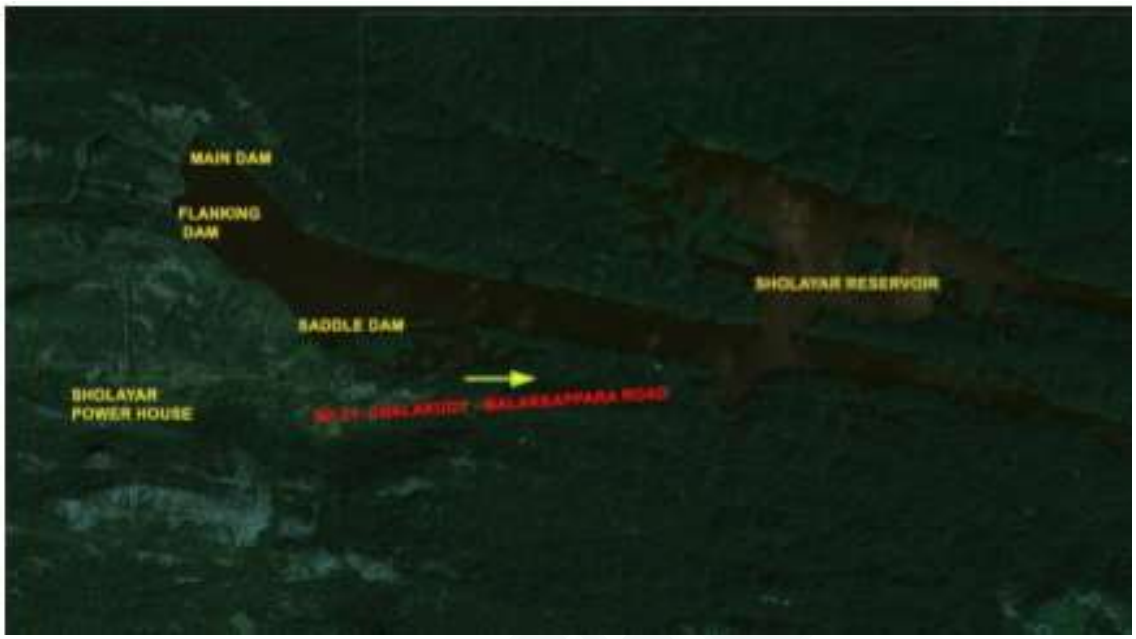

Fig 1.2 General Layout of Sholayar Hydro Electric Project

Fig 1.3 Sholayar Hydro-electric Project, view from Google earth.

1.3 Background Details of the Project

The development of Chalakudy river basin was commenced by the erstwhile Cochin State before integration with Travancore and the Poringalkuthu Left Bank Project first stage with 24000 KW installed plant capacity to generate 16000 KW at 50% load factor with one

of the three 8000 kw plants as stand bye, was taken up for construction in the year 1946 with Mr. S. J Bruford as the Chief Engineer, H. E Department and completed in 1957.

After integration of the erstwhile Travancore and Cochin States, it was in 1951, after detailed study of the topographical maps of the region, the immense possibilities of very economical power development by diversion of the Sholayar Waters into the head reach of Anakayam Valley was noticed by Sri. V. Ranganathan, then Executive Engineer, Dams Division, Mattupatti (later became Chief Engineer, Civil, KSE Board). As the outcome of the studies conducted by Sri. Ranganathan, a preliminary report on Hydro Electric Development of the Chalakudy River valley was drawn up by him in Sept. 1951 and submitted to the Government.

In his report he had recommended 6 H.E. Schemes to be taken up for detailed study in the basin. The Sholayar H.E. Scheme was suggested as the most economical and most attractive scheme.

There were several alternative ways of exploiting the Sholayar waters for Hydro Electric Generation. Quite an economic scheme was to divert the Sholayar waters south from a storage reservoir in the river down to the Edamalai river through a composite system of tunnel and penstocks. Edamalai is a low level river running west to east roughly parallel to Sholayar joining Periyar above Boothathankettu, north of Kothamangalam. The Power House was to be located at about RL +500.00 at the right bank of Edamalai river. This would have been a high head scheme with a gross head of 609.60 m and over and capable of generating 60000 KW of basic power. The execution of the Poringalkuthu Left Bank Scheme first stage at high cost, the high head scheme referred to above would have been the obvious choice on economic grounds. But as a scheme had already been launched at Poringalkuthu, the proposal of the new scheme and economy of the new scheme must have been considered with what had been done already and so a medium head scheme, a more attractive and more economical scheme utilizing the waters of Sholayar for Power generation and irrigation in the same basin itself was recommended.

The cost per KW of installed capacity of the scheme was then considered to be the lowest in the execution of H.E. Schemes in India. Besides, the scheme had the merit of

making available of a continuous firm draft of 12.74 cumecs for the generation of power in the Poringalkuthu Power Station, the reservoir of which was still lower down in the valley.

The preliminary investigations were commenced from the year 1954-55 and detailed investigations and preliminary works of the scheme began from 1956-57.

The details of the different engineering structures of the project are:

1. A main dam across Sholayar river
2. A flanking dam across the valley on the left bank of the river.
3. A saddle dam across the saddle at Ambalapara.
4. A high pressure concrete lined tunnel 710.49 m long, having horse shoe shape and a sectional area of 7.90sqm up to the surge shaft.
5. A low pressure pipe line 71.32 m long, 3.20 m dia. from surge shaft.
6. A set of 3 surface penstock pipes each about 818.39 m long.
7. A Power House at the right bank of the Anakayam stream, a tributary of Chalakudy river accommodating 3 vertical Francis type turbines each of 31000 HP coupled to 3 generators of 18000 KW capacity each.

1.4 Salient Features of the Project

General		
1	Location	River basin : Chalakudy Sub River basin : Sholayar District : Thrissur, Panchayat : Athirappally Latitude 10 ° 19' N Longitude 76°44' E
2	Means of Access	The nearest Railway station is Chalakudy (69 km). Nearest Air Port is Cochin International Airport, Nedumbassery, Kochi.
Geophysical Features		
1	Catchment area	66.18 km^2
2	Nature of catchment	The Uppermost reaches are in hilly and forest area
3	Climate	Moderate {tending to cool}
4	Mean annual precipitation	305 cm
5	Silt Charge per year	0.01 Mm^3

6	Geological features at dam site	Rock type varied from Granitic gneiss to banded gniess
Technical Details of reservoir		
1	Gross Storage Capacity	153.48 Mm^3
2	Dead Storage	3.40 Mm^3
3	River Bed Level (El.)	+762.00 m
4	Dead Storage Level at MDDL(El.)	+776.94 m
5	Full Reservoir Level (FRL) (El.)	+811.68 m
6	Maximum Water Level (MWL) (El.)	+811.68 m
7	Maximum area of water spread	8.705 Sq. km
A. Flanking Dam		
1	Deepest Foundation Level (El.)	+785.16 m
2	River Bed Level (El.)	+768.10 m
3	Crest level (El.)	+805.28 m
4	Top Level of Dam	+812.90 m
5	Length of dam	259.08 m
6	Height above deepest foundation	27.74 m
7	Width of Dam at top	4.27 m
8	Type of spillway	Ogee
9	No. of Bays	5
10	Type & size of gates	Radial, 6.40 m (W) X 10.96 m (H)
11	Spillway capacity	1739 m3/s
12	Energy Dissipation arrangement	Ski - jump
B. Main Dam		
1	Top Level of Dam	+812.60 m
2	Deepest Foundation Level (El.)	+746.45 m
3	Outlet level	+768.09 m
4	Details of outlet works	1 No. disperser valve 1.8 m dia.
5	Emergency gate at face of outlet	Size 3.10m (W) X 1.63m (H)
6	Type of gate hoist system	Rope drum Suspension beam for the gate hoist moves along with the gate, so that the gate is supported by 2 ropes till it reaches the bottom near the opening. Beyond this, the suspension beam is held in position and from there the gate is suspended by 4 ropes.
7	Length of dam at top	430.53 m

8	Width of dam at top	7.32 m
9	Width at deepest foundation	55.78 m
10	Height above deepest foundation	66.15 m
	C. Saddle Dam	
1	Top Level of Dam	+813.82 m
2	Deepest Foundation Level of masonry portion (El.)	+795.22 m
3	Length of dam at top	109.12 m
4	Width of dam at top(masonry portion)	1.83 m
5	Width of dam at top(earth embankment)	6.10 m
6	Height above deepest foundation of masonry portion	18.59 m
	Power Tunnel	
	Length	710.49 m
	Shape	horse shoe
	Sectional area	7.90sqm
	Maximum flow	23.36 cumecs
	Designed velocity of flow	2.96 m/second
	Inlet level at intake	+718.46 m
	Slope	1 in 120
	Surge Shaft	
	Type	Circular 9.14 m dia. at the bottom up to elevation +809.55 m and 15.24 m dia. up to elevation +816.86 m
	Length of surge gallery	60.96 m
	Size of surge gallery	3 m x 3 m rectangle surmounted by a semi-circle at one end and 3 m x 1.5 m rectangle surmounted by a semi-circle at the other end
	Power House	
	Size	50.29 m x 14.02 m x 16.76 m
	Generator floor (El.)	+475.48 m
	Type of turbine	3 Vertical Francis type turbine each of 31000 HP
	Generators	11 KV, 3 Nos. of 18000 KW each
	Maximum head on turbines	339.24 m
	Overhead travelling crane capacity	75 Tonnes

Table 1.1 Salient Features of Sholayar Hydro Electric Project

Fig 1.4 Upstream view of the Flanking Dam

Fig 1.5 View of Main Dam

Fig 1.6 View of Saddle Dam

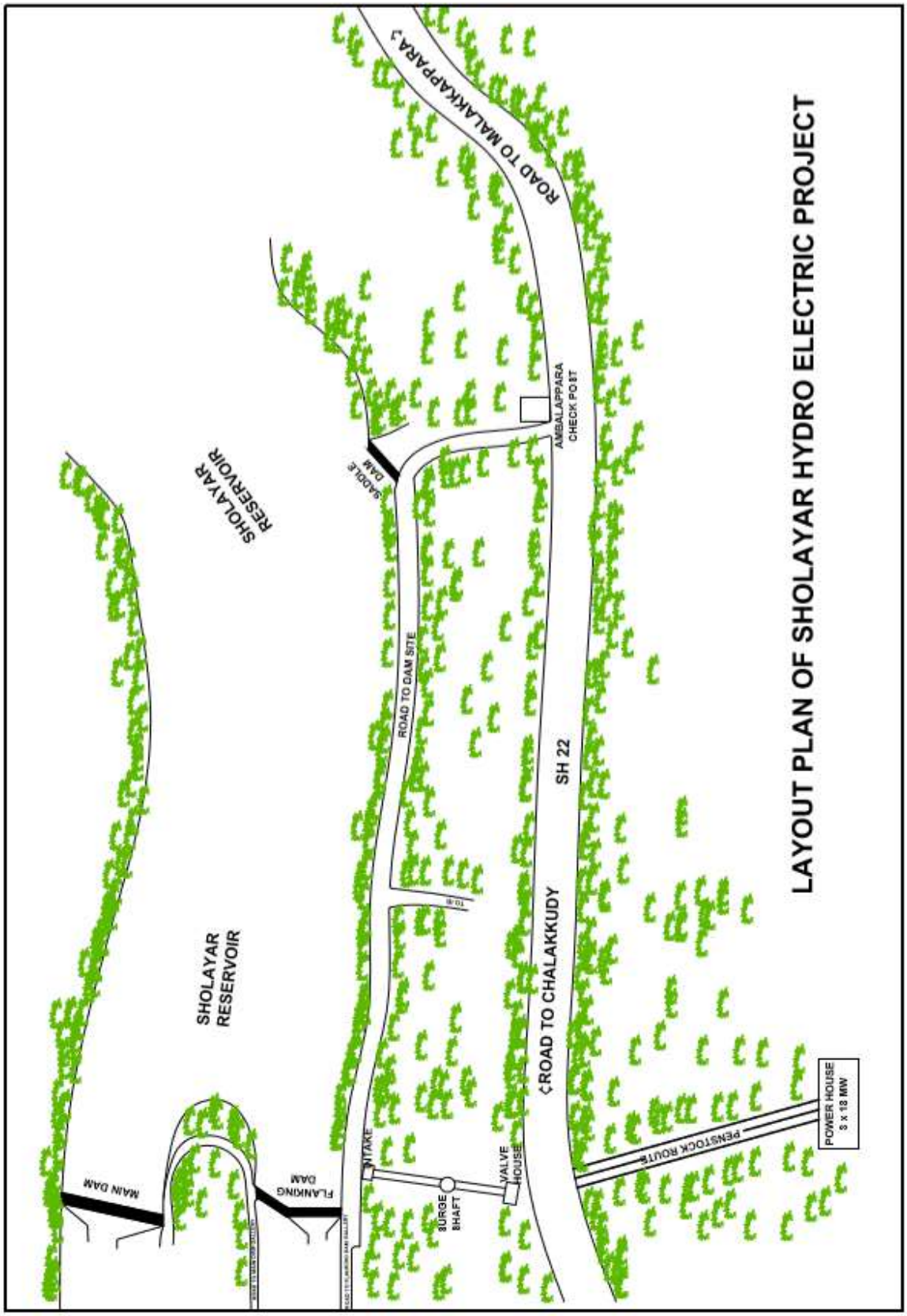

Fig 1.7 Layout Plan

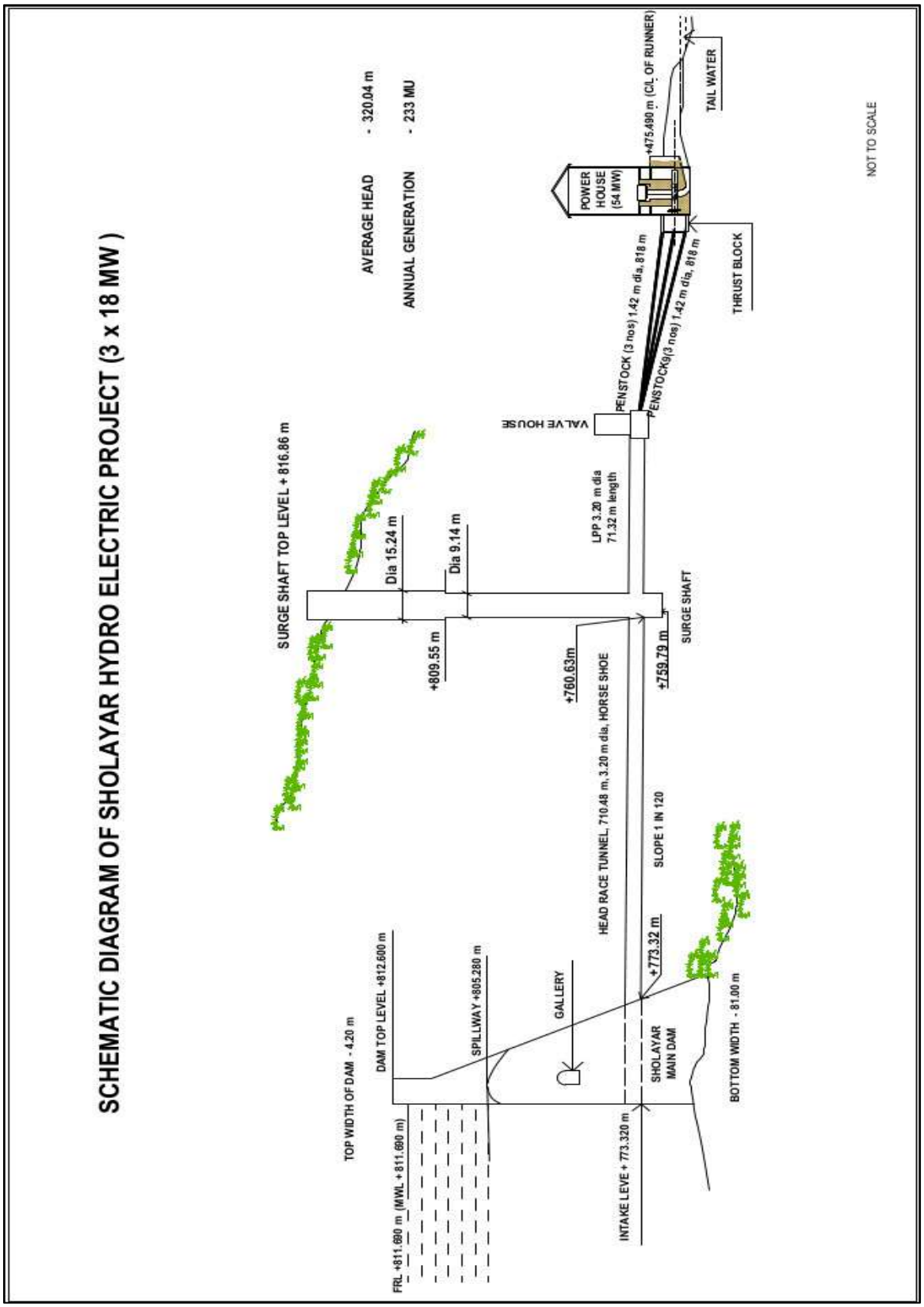

Fig 1.8 Schematic Diagram

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 dams. 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 below, including the regularly scheduled duties, which the staff personnel are required to perform. The same are outlined in the following tables.

Sl No	Particulars	Remarks
1	Project Administration Officer	Chairman & Managing Director, KSEBLtd.
2	Chief Controlling Officer	Chief Engineer (Civil – DS&DRIP).
3	Authority of operation of Spillway and Flood releases	Chief Engineer (Civil – DS&DRIP),KSEBLtd
4	Operation and safety of the dam	Deputy Chief Engineer, Research & Dam Safety Organization& DRIP, KSEBLtd., Pallom
5	Controlling / Operation Officer at dam site	Executive Engineer, Research & Dam Safety Division No. III, Idamalayar.
6	Dam Health Engineer	Executive Engineer, Research & Dam Safety Division No. III, Idamalayar.
7	Recording reservoir data, inspection, maintenance	Assistant Executive Engineer, Dam Safety Sub Division, Poringalkuthu

Table 1.2 – Overall Responsibilities for Sholayar Dams.

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 Project Engineers of Upper Sholayar Project of Tamil Nadu to get the information on the rainfall in the catchment and inflow status and to bring it to the notice of the EE/Dy CE.
2	Assist the EE/ Dy CE /CE to issue notification to the inhabitants downstream in Newspapers, Radio, 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	Observe the gates and to see that its drain holes are not clogged and floating debris is not deposited in the gate components
12	Monitor the condition of the Welding transformers, gas cutting sets, umbrellas, tool kits torches chain blocks ropes bellies etc. on daily basis and to see that things are in

	place to handle any emergency situation
13	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
14	Observe the dam top, embankment, catwalk, approach roads are well maintained by housekeeping personnel
15	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.
16	Assist EE/Dy CE /CE to coordinate with the Generating staff of Sholayar Power House downstream in the operation and power generation.
17	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.
18	Assist EE/ Dy CE /CE to coordinate with the Project state of Tamil Nadu and sharing the details of the flood condition in the river and reservoir releases

Table 1.3 – Roles & Responsibilities of AEE & AE

1.5.2 Roles and Responsibilities of the DYCE and EE during Monsoon

SL No	Flood condition assessment, warning, flood mitigation, and other responsibilities
1	Conduct Periodical inspections to assess the health of the Dam and to direct the Executive Engineer for the immediate repair and maintenance for the smooth operation.
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 Project Engineers of the State of Tamilnadu & to get the information in the rainfall in respect of Upper Sholayar catchment and inflow status at the state boundary and to bring it 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 live stock
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.

Table 1.4 – Roles & Responsibilities of Dy. CE& EE

1.5.3 Roles and Responsibilities of the Chief Engineer during Monsoon

SL No	Flood condition assessment, warning, flood mitigation, and other responsibilities
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 DyCE/EE

5	Coordinate with the Generation wing of KSEBL regarding the power generation requirement.
6	Conduct Pre and Post Monsoon inspections of the Dam and submit the report to CWC.

Table 1.5 – Roles & Responsibilities of the Chief Engineer

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.
- 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 1.6 Daily Reservoir Data

Instruction is given to the Executive Engineer for daily collection and reporting of inflow and outflow data in standard proforma as in **Table 1.6** above to the Deputy Chief Engineer.

On collecting the details in the above format, a daily reservoir status is submitted to the Chief Engineer as in the **Table 1.7.**

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

Table 1.7 Daily Reservoir Status

Records/Logbooks of the operations at Sholayar 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, 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 power house
Hydropower releases:	The reservoir water is used for power generation

Weather related data:	Collected and reported daily
Security arrangements:	Provided at three security check posts near Dam. CCTV surveillance will be provided soon covering the dam and premises.
Water quality:	The quality of water is tested at Regional analytical laboratory, Kakkanad, Ernakulam district.
Attendance statement during normal operations	Both during monsoon and non-monsoon period maintained at field office
Operations of the spillway gates and outlet works	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 controls	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:	Regularly checked and maintained
Safety and special instructions:	Safety equipment provided
Names and addresses of official visitors:	Record of inspections maintained at office.

1.7 Public and Project Staff - Health 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. Security personnel are located on the left abutment for providing public notices of events and status of security of the dam and downstream river conditions.

Access Roads

The Project is accessible from Pollachi, a town in Coimbatore District of Tamil Nadu State and from Chalakudy the nearest railway station on the Shornur – Cochin line of Southern Railways. The Anamalai Road starting from Chalakudy passes very near the Dam site and Power Station. The distance from Chalakudi to take-off points of road to the Power Station and dam sites are 59.53 km and 64.36 km respectively.

The dam site was made accessible through an approach road of about 1.80 km long branching off from Chalakudi Anamalai road. The Power House site was also made accessible through an approach road of about 1.89 km. Branch roads to the temporary staff colony, semi-permanent staff colony and permanent staff colony were also constructed from the approach road to dam site. Altogether about 13.50 km of new access roads were constructed for this scheme and are maintained by KSEBL.

Location of public utilities / conveniences

Inspection Bungalow and Canteen are located near the dam. Police station is located at Athirappally, 45 km away from the dam. A Govt. Primary Health Centre is located at Nurseryppadi near Athirappally, 55 km away from dam.

Safety equipment available at the dam: First aid kit and fire extinguishers are available.

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. Restricted areas will include the following:

- Confined spaces such as adits, galleries etc.
- Spillway approach areas, chutes and energy dissipation arrangements.
- Intake structure of the tunnel.

Sign boards are displayed at the prohibited areas of the dam.

1.8.1 Details of the Security arrangements at Sholayar Dam Site

Security arrangements are already provided through private agency at three security check posts near dam. Also CCTV surveillance will be provided soon covering the dam and premises.

Security Arrangement Existing	-	Private agency (Ex – Servicemen)
No of security persons engaged	-	3 persons at a shift.

1.9 Staff Position, Communication & Warning System

The number & description of operating unit personnel posted/placed at different locations of the dam are indicated in supporting documents. An engineering organizational chart for the control and safety of Sholayar dam is shown in **Figure 1.9** below. Means of communications both in normal and emergency situations are identified in the Communication Directory. Communication means available include land line, mobile phone and satellite phones. An organizational structure for the purpose is shown below:

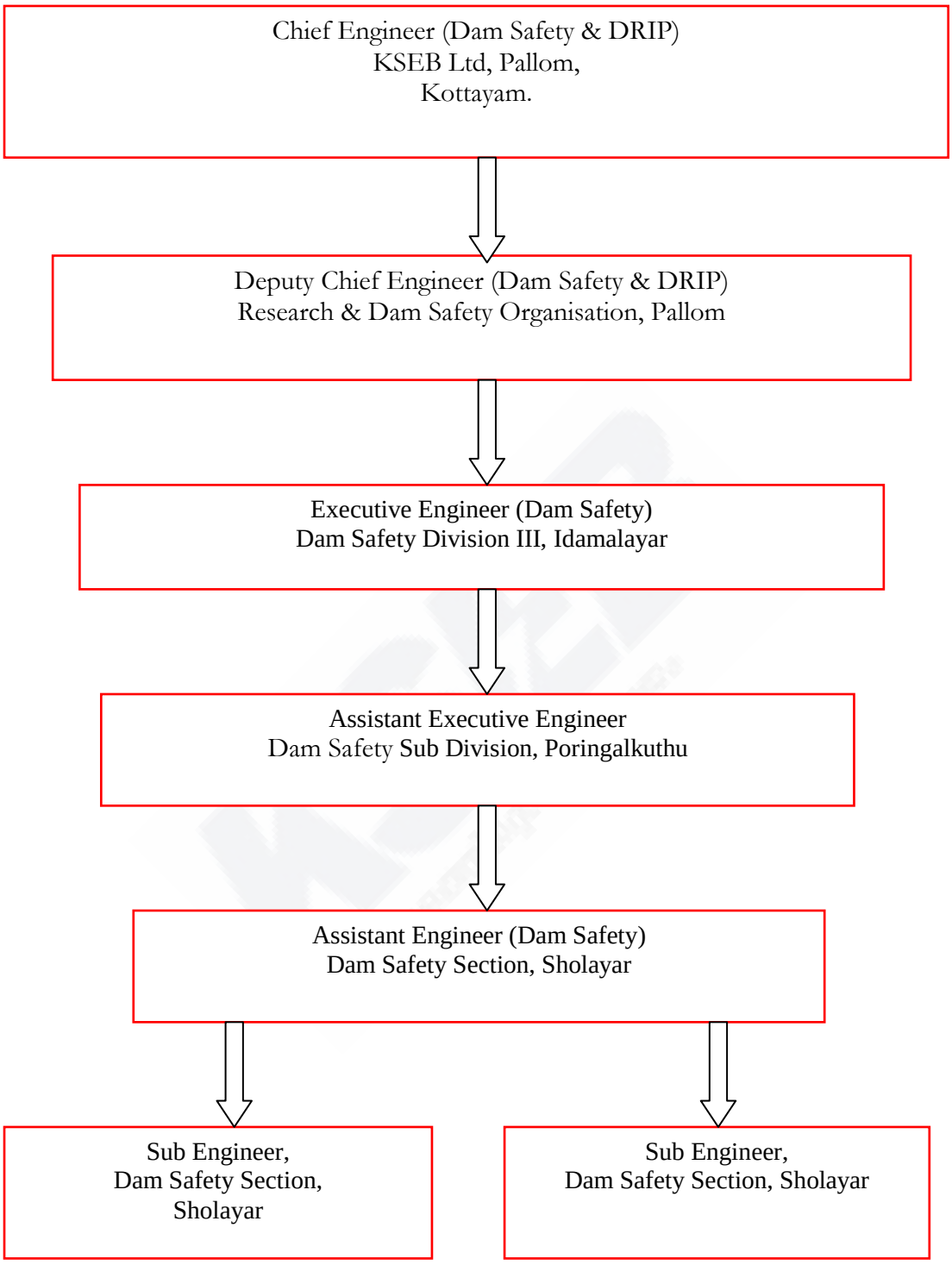

Fig 1.9 – Dam Safety Organisation Structure for Sholayar Dam

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

Chief Engineer Civil (Dam safety & DRIP), KSEBL, DSO Building, Pallom, Kottayam
Phone: 9496018719, e-mail: cedamsafety@gmail.com

Deputy Chief Engineer, Research & Dam Safety Organization, Pallom
Phone: 9446008492, 0481-2432290, 9496011540 e-mail: dirroplm2@gmail.com.

Executive Engineer, Dam Safety Division No. III, Idamalayar
Phone: 9446008426, e-mail: ddidamalayar@gmail.com.

Assistant Executive Engineer, Dam Safety Sub Division, Poringalkuth
Phone: 9496018372, e-mail: aeedrippgl@gail.com

Assistant Engineer, Dam Safety Section, Sholayar.
Phone: 94960119979

Spillway flood releases

As per the guidelines issued by the Central Water Commission for developing Emergency Action Plan for Dams issued in February, 2016 (Doc. No. CDSO_GUD_DS_01_v2.0), a three colour alert system (Blue, Orange and Red) shall be issued by the dam owner on detecting a distress in the dam according to the nature of the emergency level, to the various statutory authorities in charge of District Administration, Disaster Management etc. in order to take appropriate action to reduce the risk to lives and property from the consequences of potential dam failures. The above guidelines also envisage using the alerts in the case of a large controlled release from the dam due to severe weather and emergency conditions. A three stage/colour alert system is issued for the major reservoirs of KSEBL based on the above for a controlled release through the spillway for enabling the District Administration to take disaster mitigation measures.

In Sholayar reservoir, the first warning (Blue Alert) as water level reaches 1.50m below the rule level, second warning (Orange Alert) as water level reaches 1m below the rule level and third warning (Red Alert) as water level reaches 0.50m below the rule level are given for opening of spillway gates. Warnings are given in local media including TV etc. regarding the possible opening of spillway gates continuously up to rule level. Also intimations are given to Disaster Management, District Administration, and Police

Department etc. Spillway gates are opened at rule level based on 'Guidelines for Operation of Reservoirs' (IS 7323:1994) and Gate Operation Manual. As per the PAP Agreement the water level has to be maintained at FRL of 811.68 m on September 1st and February 1st of every water year. During the period from September 2nd and January 31st the water level has to be kept between 810.16 m and FRL.

The different stage/colour alert levels are fixed considering the normal rainfall intensity and for general guidance. In the case of extreme rainfall event or identifying any distress in the dam, appropriate protective action shall be initiated by the Dam managers. Sanction has to be obtained from the District Collector for spilling the water. Evacuation is required at plains in the case of large release/extreme rainfall event.

Release for hydropower

Water from the reservoir is mainly used for power generation at **3 x18 MW** power house of KSEBL. The tail water from Sholayar power house is collected in Poringalkuthu reservoir and is used for power generation at Poringalkuthu Power house. There is no water supply arrangement directly from the reservoir. The entire water after generation at an average 349.50MCM per annum is released to downstream from the reservoir.

Routine inspection

Usually monthly inspection and quarterly inspections as per KDSA are carried out by the operating/controlling officers. Pre-monsoon inspection and Post-monsoon inspection as per CWC are carried out and reports are supplied to CWC. The pre-monsoon and post-monsoon reports are to be updated in DHARMA web site.

Maintenance

Routine maintenance is carried out for Spillway gates, Intake gates as part of routine maintenance before the onset of monsoon. Details are given under the Chapter, Project Maintenance.

1.10 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:

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,	Quarterly	Executive Engineer

	d/s area etc., Check and clear spillway bridge drains, Clean inside of motor control cabinet.		
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
21	Inspection of Spillway & outlet works, hydro mechanical components, Check paint on gates, Check lubrication of wire ropes and application of cardium compound, Check mechanical hoist bearings and flexible coupling bearings, Check gear systems, Exercise gates and valves, Check oil reservoir level in hydraulic system, Check pressure release valve, Check lubrication of gate rollers, Check rubber seals and seal clamp bar.	Half yearly (Pre and Post Monsoon)	Deputy Chief Engineer along with Executive Engineer in charge of dam
22	Submission of Inspection report to State DSO, CWC and uploading into DHARMA.	Half yearly	Chief Engineer/Deputy Chief Engineer
23	Comprehensive inspections	Annually	Dam Safety Authority along with Dam Owners
24	Inspect dam and gate structures, trash racks and stilling basin / energy dissipation arrangement, which normally are underwater (by dewatering or by divers/ROV as necessary). Review Dam operation procedures and EAP and update as necessary.	Five Yearly	Chief Engineer/Deputy Chief Engineer
25	Comprehensive inspection of performance of the dam and gate structures and reservoirs, trash racks and stilling basin/ energy dissipation arrangement.	Ten Yearly	DSRP

Table 1.8 Schedule of duties/inspections

1.11 Hydro-Mechanical Inspections / Checks

Special duties required to be performed by H-M operating personnel are given in this section. Frequency of inspections / checks for hydro-mechanical components and necessary actions to be taken up during maintenance are as under:

1. Gates

a. Embedded Parts

Sl. No	Embedded Part	Frequency
1	Checking of seal beams. Seal Seats, Guide track & all other exposed embedded parts with respect to their alignment, distortion :if any due to continuous use, pitting and un-necessary cracks due to wear & carrying out requisite repairs, rectification by welding, grinding etc.	Half Yearly
2	Removing debris & other foreign material deposited on embedded parts& cleaning the same.	Monthly
3	All cracks & defective weld joints to be ascertained & rectified.	Half Yearly
4	All dirt, debris, grit, foreign material etc. to be removed from trunnion assemblies as well as trunnion chair and lubricate trunnion bearing & the sliding surface on trunnion chair with specified lubricant/ grade to ensure smooth sliding movement of trunnion.	Monthly
5	All nut& bolts connecting Trunnion Assembly & Trunnion Chair and Trunnion & Yoke, girder, Trunnion pin lock plate to be checked & Tightened and replacement of the same, if found defective.	Monthly

Gate structure

Sl. No	Gate Parts	Frequency
1	Regular inspection of the gate along with the hoist to be carried out daily to ensure that there is no unusual development/ observation	Daily
2	Check all welding for soundness & rectify defects	Quarterly

3	Check welding between arms & horizontal girders as well as arms & Trunnion with the help of magnifying glass for cracks/ defects and rectify the defects	Quarterly
4	Clean all drain boles including those in end arms, horizontal girders & defective nuts & bolts	Quarterly
5	Check all nuts & bolts provided and tighten them, and replace the defective nuts & bolts	Quarterly
6	Check upstream face of Skin plate for pitting, scaling and corrosion. Scaling formation are to be removed. Pitting shall be filled with weld &Corroded surface shall be cleaned & painted	Yearly
7	Joints of side & bottom rubber seals to be checked for their proper alignment and fixing & to be rectified/ adjusted if there is leakage through joints	Monthly
8	Nuts & bolts for rubber seal connection to be tightened and damaged nuts and bolts to be replaced	Quarterly
9	The excessive or widespread leakages if any shall be reported to the Engineer in charge. If the seals are required to be replaced the same shall be carried out	Quarterly
10	The guide roller pin is to be lubricated	Quarterly

Table 1.9 Frequency of inspection of Hydro Mechanical components

1.12 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 shown below are available at the dam control room:

- Emergency Action Plan (EAP)
- Flood forecasting and operating criteria
- Basin or river operating plan
- Interstate agreements
- Agreements with other user agencies
- Power station operation plan
- Administrative procedures

- Reservoir / River pollution contingency plan
- Maintenance schedules
- Gate Manufacturer's instructions and drawings
- Regional communication directory
- Instrumentation reports / results

CHAPTER 2

PROJECT OPERATION

2.1 Basic Data

The Sholayar 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 and outlets. The operation of a dam involves regulation of its reservoir as per rule curve/ project specific requirements. This includes the use of elevation storage curve and design flood; both these aspects are described below.

2.1.1 Elevation Storage curve

The Elevation - Storage Curve for Sholayar Reservoir in tabular and graphical form are shown in **Fig. 2.1** and **Table 2.1**.

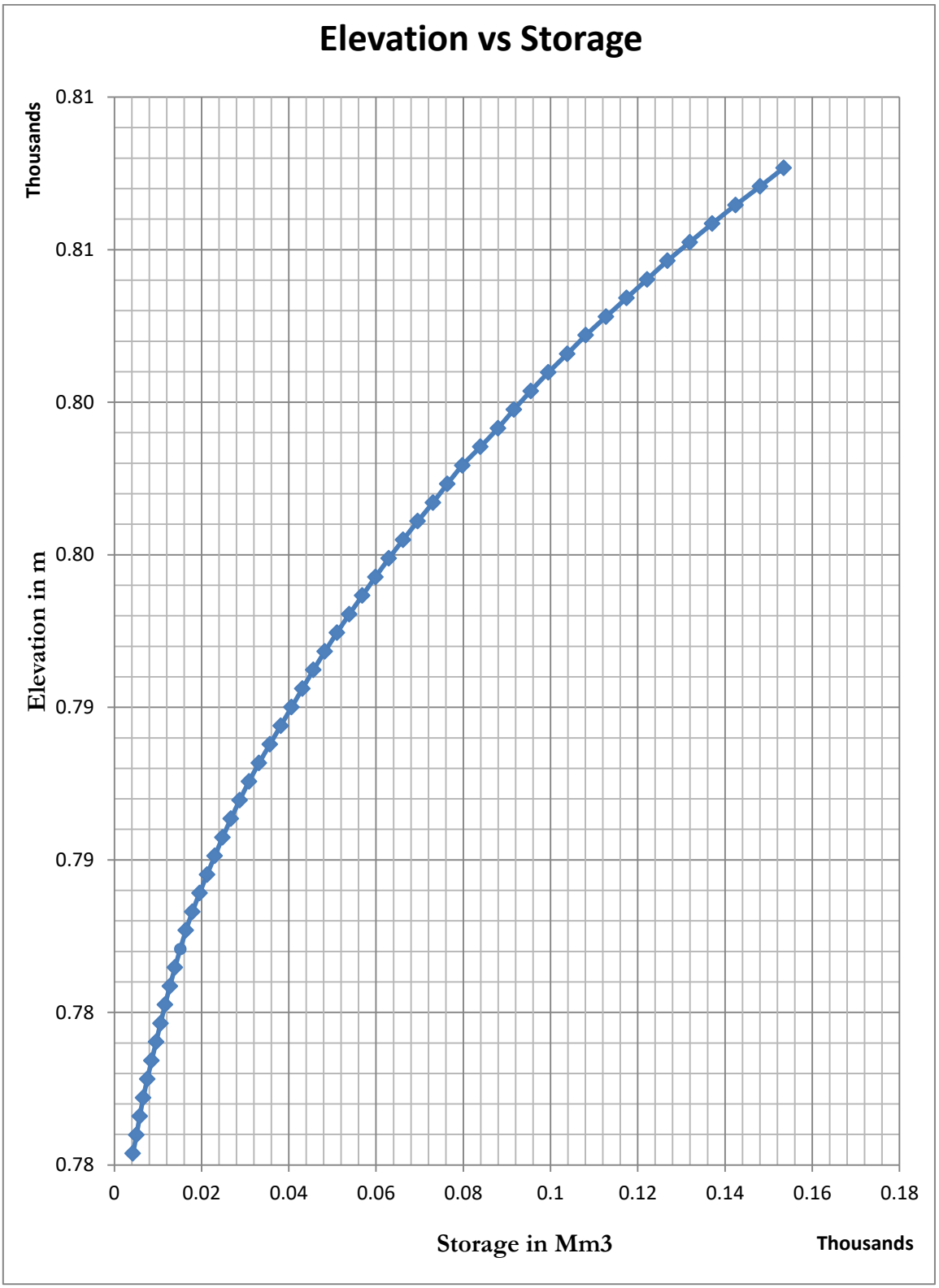

Figure 2.1 - Elevation storage curve for Sholayar Reservoir

ELEVATION - CAPACITY OF SHOLAYAR RESERVOIR				
MDDL (m)	**FRL (m)**	**MWL (m)**		**Dead Storage in Mm^3**
776.94	811.68	811.68		3.4
Reservoir level		**Gross storage**		**Remarks**
in ft	in m	in Mcft	in Mm^3	
2557.00	779.37	150.32	4.26	
2559.00	779.98	179.40	5.08	
2561.00	780.59	206.00	5.83	
2563.00	781.20	234.00	6.63	
2565.00	781.81	267.00	7.56	
2567.00	782.42	302.00	8.55	
2569.00	783.03	338.00	9.57	
2571.00	783.64	374.00	10.59	
2573.00	784.25	411.00	11.64	
2575.00	784.86	450.00	12.74	
2577.00	785.47	491.00	13.90	
2579.00	786.08	534.00	15.12	
2581.00	786.69	580.00	16.42	
2583.00	787.30	632.00	17.90	
2585.00	787.91	690.00	19.54	
2587.00	788.52	751.00	21.27	
2589.00	789.13	813.00	23.02	
2591.00	789.74	877.00	24.83	
2593.00	790.35	944.00	26.73	
2595.00	790.96	1015.00	28.74	
2597.00	791.57	1090.00	30.87	
2599.00	792.18	1172.00	33.19	
2601.00	792.78	1259.00	35.65	
2603.00	793.39	1347.00	38.14	
2605.00	794.00	1435.00	40.63	
2607.00	794.61	1523.00	43.13	
2609.00	795.22	1612.00	45.65	
2611.00	795.83	1705.00	48.28	

2613.00	796.44	1802.00	51.03	
2615.00	797.05	1903.00	53.89	
2617.00	797.66	2008.00	56.86	
2619.00	798.27	2114.00	59.86	
2621.00	798.88	2223.00	62.95	
2623.00	799.49	2338.00	66.20	
2625.00	800.10	2457.00	69.57	
2627.00	800.71	2580.00	73.06	
2629.00	801.32	2695.50	76.33	
2631.00	801.93	2817.50	79.78	
2633.00	802.54	2964.00	83.93	
2635.00	803.15	3106.00	87.95	
2637.00	803.76	3235.00	91.60	
2639.00	804.37	3372.00	95.48	
2641.00	804.98	3514.00	99.50	
2643.00	805.59	3668.00	103.87	
2645.00	806.20	3817.50	108.10	
2647.00	806.81	3982.00	112.76	
2649.00	807.42	4147.00	117.43	
2651.00	808.02	4313.00	122.13	
2653.00	808.63	4478.00	126.80	
2655.00	809.24	4659.00	131.93	
2657.00	809.85	4841.00	137.08	
2659.00	810.46	5030.00	142.43	
2661.00	811.07	5228.50	148.05	
2663.00	811.68	5420.00	153.48	Full Reservoir Level

Table 2.1 Elevation – Capacity of Sholayar Reservoir

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. Salient features of the Reservoir are given below.

Salient features

Maximum Water Level (MWL)	-	+811.68 m
Full Reservoir Level (FRL)	-	+811.68 m
Minimum Draw Down Level (MDDL)	-	+776.94 m
Gross storage at FRL	-	153.48 Mm^3
Gross storage at MWL	-	153.48 Mm^3
Live storage at FRL	-	150.08 Mm^3
Dead storage	-	3.40 Mm^3
Water spread area at FRL	-	870.50 Ha

Fig 2.2 Downstream view of spillway

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 rain fall of 484 mm and 751 mm respectively was recorded. Hydrological studies were carried out for the Sholayar dam considering the rainfall data from 1948 -1953.

The SW monsoon of the year 2018 in the State was similar to that of 1924 Devikulam storm and 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. 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 three day rainfall of 15-17August 2018 at Sholayar Dam site was 620 mm.

The spillway shutters were open during 2000, 2005, 2007, 2009, 2011, 2013, 2014, 2017 and 2018 for excess flood moderation. Spill details of the above years are tabulated below in **Table 2.2**. `

Date	Water Level	Rainfall Sholayar Dam	Gross Storage	Gross inflow	Spill	Net Inflow
	Feet	mm	Mcm	Mcm/day	Mcm/day	Mcm/day
29-Aug-00	811.56	34.0	152.2766	2.0713	0.0995	1.2178
3-Sep-00	811.69	3.0	153.4944	1.8083	0.7411	-0.3115
4-Sep-00	811.65	5.0	153.1829	1.2120	0.3097	-0.5947
6-Sep-00	811.53	16.0	151.9934	0.8898	0.1991	-0.8071
Total Spill 2000					**1.35**	

2-Aug-05	810.92	69.0	146.7967	9.0659	1.2087	6.6977
3-Aug-05	811.69	45.0	153.4944	10.1625	8.8896	0.0000
4-Aug-05	811.69	17.0	153.4944	3.5520	2.2439	0.0000
5-Aug-05	811.69	29.0	153.4944	1.9307	0.6194	0.0000
6-Aug-05	811.69	3.0	153.4944	1.7506	0.4424	0.0000
7-Aug-05	811.69	0.0	153.4944	1.5262	0.2212	0.0000
1-Sep-05	811.69	13.0	153.4944	1.0380	0.2610	-0.3115
7-Sep-05	811.69	70.0	153.4944	1.5415	0.2430	0.0000
8-Sep-05	811.69	90.0	153.4944	5.6306	4.3256	0.0000
9-Sep-05	811.69	77.0	153.4944	6.1548	4.8617	0.0000
10-Sep-05	811.69	51.0	153.4944	4.2276	2.9336	0.0000
11-Sep-05	811.69	95.0	153.4944	5.3392	4.0351	0.0000
12-Sep-05	811.69	53.0	153.4944	5.1381	3.8338	0.0000
13-Sep-05	811.69	37.0	153.4944	3.7149	2.4126	0.0000
14-Sep-05	811.69	57.0	153.4944	3.1062	1.8086	0.0000
15-Sep-05	811.69	9.0	153.4944	2.6916	1.4118	0.0000
16-Sep-05	811.69	8.0	153.4944	2.4020	1.1050	0.0000
17-Sep-05	811.69	0.0	153.4944	2.1880	0.8848	0.0000
18-Sep-05	811.69	0.0	153.4944	2.6215	1.3697	0.0000
19-Sep-05	811.69	21.0	153.4944	2.5415	1.2377	0.0000
20-Sep-05	811.69	15.0	153.4944	3.0323	1.7573	0.0000
21-Sep-05	811.69	60.0	153.4944	2.7557	1.4549	0.0000
22-Sep-05	811.69	15.0	153.4944	2.3574	1.0611	0.0000

23-Sep-05	811.69	0.0	153.4944	2.2039	0.9064	0.0000
24-Sep-05	811.69	0.0	153.4944	2.1432	0.8406	0.0000
Total Spill 2005					**50.37**	
9-Aug-07	811.69	42.5	153.4944	4.1552	2.453	0.0000
10-Aug-07	811.69	180.0	153.4944	7.4349	5.704	0.0000
11-Aug-07	811.69	32.5	153.4944	4.3347	2.387	0.0`000
27-Aug-07	811.69	20.0	153.4944	2.4092	0.4641	0.0000
28-Aug-07	811.69	27.5	153.4944	2.4714	0.5304	0.0000
30-Aug-07	811.69	25.0	153.4944	2.5601	0.6	0.0000
31-Aug-07	811.69	70.0	153.4944	3.0674	1.1267	0.0000
1-Sep-07	811.69	17.5	153.4944	2.5153	0.5746	0.0000
2-Sep-07	811.69	1.0	153.4944	3.2353	1.3694	0.0000
3-Sep-07	811.69	35.0	153.4944	2.5007	0.6188	0.0000
4-Sep-07	811.69	2.0	153.4944	2.5241	0.6851	0.0000
5-Sep-07	811.69	6.0	153.4944	2.7608	0.9503	0.0000
6-Sep-07	811.69	42.0	153.4944	2.6064	0.6630	0.0000
7-Sep-07	811.69	7.5	153.4944	2.1579	0.2652	0.0000
8-Sep-07	811.69	0.0	153.4944	2.7399	0.7956	0.0000
9-Sep-07	811.69	27.0	153.4944	2.8223	0.8840	0.0000
10-Sep-07	811.69	70.0	153.4944	2.3950	0.6851	0.0000
11-Sep-07	811.69	3.0	153.4944	2.5892	0.6404	0.0000
12-Sep-07	811.69	57.5	153.4944	3.2564	1.3031	0.0000
13-Sep-07	811.69	0.0	153.4944	2.3257	0.3757	0.0000

14-Sep-07	811.69	17.5	153.4944	2.5183	0.6409	0.0000
15-Sep-07	811.69	7.0	153.4944	2.6139	0.6630	0.0000
16-Sep-07	811.69	28.0	153.4944	2.3677	0.4199	0.0000
17-Sep-07	811.69	15.0	153.4944	3.0098	1.0605	0.0000
18-Sep-07	811.69	48.0	153.4944	3.4835	1.5456	0.0000
19-Sep-07	811.69	80.0	153.4944	4.6661	2.7380	0.0000
20-Sep-07	811.69	23.0	153.4944	3.1668	1.6354	0.0000
21-Sep-07	811.69	38.0	153.4944	2.7913	1.5028	0.0000
22-Sep-07	811.69	32.5	153.4944	3.0325	1.7456	0.0000
23-Sep-07	811.69	70.0	153.4944	3.8804	2.3300	0.0000
24-Sep-07	811.69	22.5	153.4944	2.7538	0.8177	0.0000
25-Sep-07	811.69	47.0	153.4944	3.5244	1.5912	0.0000
26-Sep-07	811.69	42.5	153.4944	2.6449	0.7072	0.0000
27-Sep-07	811.69	0.0	153.4944	2.4517	0.6188	0.0000
28-Sep-07	811.69	2.5	153.4944	2.8350	0.9724	0.0000
29-Sep-07	811.69	0.0	153.4944	2.4253	0.5525	0.0000
30-Sep-07	811.69	0.0	153.4944	2.8530	0.9060	0.0000
1-Oct-07	811.69	15.0	153.4944	2.5203	0.5746	0.0000
2-Oct-07	811.69	0.0	153.4944	2.2533	0.3094	0.0000
29-Oct-07	811.62	55.0	152.8572	3.4125	0.8440	0.6372
30-Oct-07	811.69	48.0	153.4944	2.7883	0.8398	0.0000
31-Oct-07	811.69	0.0	153.4944	2.5498	0.7072	0.0000
1-Nov-07	811.69	0.0	153.4944	2.3169	0.3978	0.0000

Total Spill 2007					**47.21**	
2-Sep-09	811.69	15.0	153.4944	1.1367	0.685	0.0000
3-Sep-09	811.69	55.0	153.4944	1.3031	0.398	0.0000
4-Sep-09	811.69	113.0	153.4944	1.2510	0.818	0.0000
5-Sep-09	811.69	60.0	153.4944	1.2756	1.277	0.0000
6-Sep-09	811.69	45.0	153.4944	1.2765	2.329	0.0000
7-Sep-09	811.69	10.0	153.4944	1.2805	0.972	0.0000
8-Sep-09	811.69	2.5	153.4944	1.5504	0.331	0.0000
3-Oct-09	811.69	60.0	153.4944	2.5716	1.326	0.0000
4-Oct-09	811.69	15.0	153.4944	2.8633	1.567	0.0000
5-Oct-09	811.69	0.0	153.4944	2.1858	0.894	0.0000
6-Oct-09	811.69	0.0	153.4944	1.7526	0.464	-0.3115
Total Spill 2009					**11.06**	
1-Sep-11	811.69	89.0	153.4944	1.8596	2.223	0.0000
2-Sep-11	811.69	100.0	153.4944	0.6293	2.252	-1.2178
3-Sep-11	811.56	120.0	152.2766	2.8141	1.148	1.2178
4-Sep-11	811.69	32.0	153.4944	1.8314	2.077	0.0000
5-Sep-11	811.69	22.0	153.4944	1.9071	1.237	0.0000
6-Sep-11	811.69	9.0	153.4944	1.9188	1.545	0.0000
7-Sep-11	811.69	38.0	153.4944	1.8485	1.192	0.0000
8-Sep-11	811.69	3.0	153.4944	1.8846	0.861	0.0000
9-Sep-11	811.69	15.0	153.4944	1.9211	1.193	0.0000
10-Sep-11	811.69	8.0	153.4944	1.9230	0.641	0.0000

11-Sep-11	811.69	35.0	153.4944	1.5680	1.954	0.0000
12-Sep-11	811.69	35.0	153.4944	1.9202	0.398	0.0000
13-Sep-11	811.69	26.0	153.4944	1.8378	1.565	0.0000
14-Sep-11	811.69	35.0	153.4944	1.6380	0.994	0.0000
15-Sep-11	811.69	12.0	153.4944	1.2657	1.325	0.0000
16-Sep-11	811.69	34.0	153.4944	0.8840	1.740	-0.3115
17-Sep-11	811.65	10.0	153.1829	1.2557	0.574	0.0000
18-Sep-11	811.65	0.0	153.1829	1.5202	0.839	0.3115
19-Sep-11	811.69	2.0	153.4944	1.2581	1.055	0.0000
20-Sep-11	811.69	35.0	153.4944	1.2315	1.236	0.0000
21-Sep-11	811.69	12.0	153.4944	1.0122	1.214	0.0000
22-Sep-11	811.69	9.0	153.4944	0.8309	0.848	0.0000
23-Sep-11	811.69	3.0	153.4944	0.4241	0.397	-0.3115
Total Spill 2011					**28.51**	
1-Aug-13	811.23	30.0	149.3597	10.6762	5.2613	4.1347
2-Aug-13	811.69	222.0	153.4944	13.9141	12.8255	0.0000
3-Aug-13	811.69	100.0	153.4944	11.8952	10.6565	0.0000
4-Aug-13	811.69	35.0	153.4944	7.3438	6.2692	0.0000
5-Aug-13	811.69	100.0	153.4944	7.2817	6.3134	0.0000
6-Aug-13	811.69	80.0	153.4944	4.4139	3.1341	0.0000
7-Aug-13	811.69	5.0	153.4944	5.0260	3.8852	0.0000
8-Aug-13	811.69	8.0	153.4944	3.4023	2.1192	0.0000
9-Aug-13	811.69	10.0	153.4944	3.2253	1.9426	0.0000

10-Aug-13	811.69	20.0	153.4944	3.1492	1.9426	0.0000
11-Aug-13	811.69	3.0	153.4944	2.4532	1.2805	0.0000
12-Aug-13	811.69	0.0	153.4944	2.4634	1.3033	0.0000
13-Aug-13	811.69	0.0	153.4944	2.6945	1.4144	0.0000
14-Aug-13	811.69	30.0	153.4944	2.2304	1.0817	0.0000
15-Aug-13	811.69	12.0	153.4944	1.8913	0.7952	0.0000
16-Aug-13	811.69	5.0	153.4944	2.4071	1.1928	0.0000
17-Aug-13	811.69	15.0	153.4944	2.2888	1.1485	0.0000
18-Aug-13	811.69	1.0	153.4944	2.8011	1.8546	0.0000
19-Aug-13	811.69	25.0	153.4944	2.3525	1.0608	0.0000
20-Aug-13	811.69	10.0	153.4944	1.9542	0.6630	0.0000
21-Aug-13	811.69	30.0	153.4944	2.3370	1.0608	0.0000
22-Aug-13	811.69	5.0	153.4944	1.5690	0.5304	0.0000
23-Aug-13	811.69	1.0	153.4944	2.7014	1.5459	0.0000
24-Aug-13	811.69	15.0	153.4944	0.9452	0.3094	-0.6372
30-Aug-13	811.69	30.0	153.4944	1.8648	0.5746	0.0000
31-Aug-13	811.69	25.0	153.4944	2.0265	0.8398	0.0000
1-Sep-13	811.69	45.0	153.4944	0.9590	0.3094	-0.6372
6-Sep-13	811.69	3.0	153.4944	2.2630	0.9716	0.0000
18-Sep-13	811.69	90.0	153.4944	3.1728	1.7227	0.0000
19-Sep-13	811.69	40.0	153.4944	4.7361	3.0466	0.0000
20-Sep-13	811.69	65.0	153.4944	4.1895	2.3412	0.0000
21-Sep-13	811.69	40.0	153.4944	3.4523	1.5900	0.0000

22-Sep-13	811.69	0.5	153.4944	2.9548	1.1479	0.0000
23-Sep-13	811.69	0.0	153.4944	2.5180	0.7954	0.0000
24-Sep-13	811.69	0.0	153.4944	2.6898	0.7951	0.0000
25-Sep-13	811.69	0.0	153.4944	2.4137	0.7064	0.0000
26-Sep-13	811.69	0.0	153.4944	1.5473	0.2210	0.0000
27-Sep-13	811.69	0.0	153.4944	2.0485	0.8830	0.0000
28-Sep-13	811.69	0.0	153.4944	1.5300	0.5304	0.0000
29-Sep-13	811.69	0.0	153.4944	1.7659	0.6188	0.0000
30-Sep-13	811.69	20.0	153.4944	1.8457	0.6670	0.0000
1-Oct-13	811.69	20.0	153.4944	1.7564	0.5304	0.0000
2-Oct-13	811.69	0.0	153.4944	1.4121	0.4420	-0.3115
Total Spill 2013					**88.32**	
30-Aug-14	811.69	35.0	153.4944	2.2676	1.7667	0.0000
31-Aug-14	811.69	46.4	153.4944	2.1113	1.6785	0.0000
1-Sep-14	811.69	86.0	153.4944	2.3838	1.6252	0.0000
2-Sep-14	811.69	34.6	153.4944	2.5467	1.6345	0.0000
3-Sep-14	811.69	34.2	153.4944	1.8461	0.7514	0.0000
4-Sep-14	811.69	20.0	153.4944	1.3911	0.7072	0.0000
5-Sep-14	811.69	6.2	153.4944	1.3547	0.6630	0.0000
6-Sep-14	811.69	18.0	153.4944	2.4015	1.6354	0.0000
7-Sep-14	811.69	18.0	153.4944	3.2619	3.0852	0.0000
8-Sep-14	811.69	22.0	153.4944	2.5320	2.1216	0.0000
9-Sep-14	811.69	30.0	153.4944	2.4249	1.1931	0.0000

10-Sep-14	811.69	6.0	153.4944	2.2994	1.3697	0.0000
11-Sep-14	811.69	10.0	153.4944	2.1008	1.1927	0.0000
12-Sep-14	811.69	0.0	153.4944	1.6182	0.3978	0.0000
13-Sep-14	811.69	0.0	153.4944	1.5916	0.8398	0.0000
14-Sep-14	811.69	0.0	153.4944	1.3386	0.6630	0.0000
15-Sep-14	811.69	30.4	153.4944	0.6876	0.2652	0.0000
16-Sep-14	811.69	4.0	153.4944	0.6514	0.2210	0.0000
Total Spill 2014					**21.81**	
16-Sep-17	811.65	9.0	153.1829	2.6590	1.0596	0.3115
17-Sep-17	811.69	107.0	153.4944	8.0598	6.7713	0.0000
18-Sep-17	811.69	133.0	153.4944	3.4362	2.1856	0.0000
19-Sep-17	811.69	38.0	153.4944	2.2031	0.9272	0.0000
20-Sep-17	811.69	20.0	153.4944	1.3828	0.0883	0.0000
21-Sep-17	811.69	8.0	153.4944	1.7770	0.4850	0.0000
Total Spill 2017					**11.52**	
28-Jul-18	811.65	40.0	153.1829	1.7327	0.7735	0.3115
29-Jul-18	811.69	40.0	153.4944	1.8630	1.2150	0.0000
30-Jul-18	811.69	10.0	153.4944	1.6425	0.9945	0.0000
31-Jul-18	811.69	35.0	153.4944	3.5380	2.8900	0.0000
1-Aug-18	811.69	70.0	153.4944	2.1753	1.4136	0.0000
2-Aug-18	811.69	5.0	153.4944	1.7670	0.4860	0.0000
3-Aug-18	811.69	13.0	153.4944	2.0175	0.7290	0.0000
4-Aug-18	811.69	7.0	153.4944	1.5665	1.0601	0.0000

5-Aug-18	811.69	20.0	153.4944	0.7621	0.0442	0.0000
6-Aug-18	811.69	15.0	153.4944	1.9738	0.8398	0.0000
7-Aug-18	811.69	45.0	153.4944	3.1194	2.2449	0.0000
8-Aug-18	811.69	100.0	153.4944	13.9960	12.7000	0.0000
9-Aug-18	811.69	210.0	153.4944	11.4925	10.2134	0.0000
10-Aug-18	811.69	50.0	153.4944	6.5734	5.2774	0.0000
11-Aug-18	811.69	30.0	153.4944	6.2754	4.9800	0.0000
12-Aug-18	811.69	20.0	153.4944	10.0708	8.7752	0.0000
13-Aug-18	811.69	60.0	153.4944	11.8071	10.6563	0.0000
14-Aug-18	811.69	70.0	153.4944	30.7607	29.4647	0.0000
15-Aug-18	811.69	160.0	153.4944	36.3981	35.1027	0.0000
16-Aug-18	811.69	300.0	153.4944	44.4898	43.4600	0.0000
17-Aug-18	811.69	160.0	153.4944	40.2615	38.9800	0.0000
18-Aug-18	811.69	50.0	153.4944	34.6533	33.3895	0.0000
19-Aug-18	811.69	35.0	153.4944	20.5184	22.1035	-2.8603
20-Aug-18	811.38	30.0	150.6341	4.7057	8.6712	-5.2534
21-Aug-18	810.77	20.0	145.3807	6.9680	5.6729	0.0000
22-Aug-18	810.77	20.0	145.3807	2.3338	1.0387	0.0000
23-Aug-18	810.77	5.0	145.3807	4.7711	2.0600	1.4160
24-Aug-18	810.92	4.0	146.7967	3.6299	1.0608	1.2744
25-Aug-18	811.07	0.0	148.0711	3.3751	1.0608	1.0195
26-Aug-18	811.19	0.0	149.0906	1.8453	1.0608	-0.5097
27-Aug-18	811.13	1.5	148.5809	2.6052	0.5304	0.7788

23-Sep-18	811.53	0.0	151.9934	2.9380	3.0022	-1.3593
24-Sep-18	811.38	15.0	150.6341	3.2321	7.1899	-5.2534
25-Sep-18	810.77	10.0	145.3807	0.6664	1.1693	-1.7983
26-Sep-18	810.59	0.0	143.5824	1.2225	1.0608	-1.1328
27-Sep-18	810.46	15.0	142.4496	0.6232	0.1768	-0.8496
Total Spill 2018					**301.55**	

Table 2.2 – Spill details

2.2.2 Design Flood and Features Related to Safety

Hydrology
i) Catchment:

The Sholayar River is one of the main tributaries of Chalakudy river, the other important tributaries being Parambikulam, Thekkadi, Karapara and Anakayam. The river rises in the escarpment of the Western Ghats and Anamalai hills, at an elevation of about 1219.20 m and flows in a westerly direction for about 45.05 km through a plateau and then turns towards north and flows rapidly to join Parambikulam river at Orukembankutty at an elevation of about 457.20 m. About one mile downstream of the confluence of the Sholayar river and Parambikulam river, the Karapara joins the main river and from this point onwards the river is known as Chalakudy river which after a meandering course of 144.81 km joins the northern arm of Periyar and finally empties into the back waters of the Arabian Sea.

The river from its source flows within Madras state for about 24.14 km and for another 8.85 km along the boundary limits of Kerala and Madras and from the point where it enters Kerala State it flows for another 27.35 km and joins Parambikulam Ar.

The catchment area of the river above the Poringalkuthu Falls, where the Poringalkuthu Left Bank H. E. Scheme is projected is about 957.89 Sq.km and the catchment above the Sholayar dam site is 186.48 Sq.km of which 121.73 Sq. km lie within

Madras State. An agreement has been reached between the two states regarding the utilisation of waters of Sholayar. The text of the agreement is as follows.

"Madras will build a storage dam on Sholayar. Madras will start filling the Sholayar reservoir in the Kerala State from 1st July and keep it filled to near full reservoir level as soon as possible. Normally their reservoir should be filled by end of August. Also the Kerala reservoir should be at the Full Reservoir Level on 31st January every year. Kerala will withdraw total quantity of 348.29 Mm^3 every year measured every year at the Sholayar Power House site."

The entire catchment receives the benefit of both the South west and North east monsoons. The South west monsoon sets in June and lasts till August. The heaviest rainfall is during the month of June and July. The North east monsoon strikes in October and continues till November. A heavy annual rainfall, a humid atmosphere and fairly uniform temperature throughout the year are the characteristic features of the basin.

ii) Yields:

The annual rainfall varies from 330.20 cm at Poringalkuthu to 457.20 cm and over in the Anamalai and Nelliampathi hills which are at higher elevations. The lowest rainfall recorded in the catchment during the period from 1948 to 1953 is 271.78 cm in 1952 while it is 403.86 cm in 1948 (both the figures are the average of the several rain gauge stations in the entire catchment area). The weighted average rainfall of the catchment for the above 6 years works out to 321.31 cm. The average annual flow in the catchment of Poringalkuthu reservoir and Sholayar reservoir are assessed to be 1982.18 Mm^3 and 396.44 Mm^3 respectively from the rainfall data collected in the years 1948 to 1953.

River discharge measurements using weir floats or current meters were not available for the overall design of the project. Only after the start of the project discharge measurements were arranged to be taken.

iii) Storage:

The storage required has been analysed by working tables and it is found from a number of working tables prepared that the best results are obtained with a reservoir

capacity of 150.08 Mm^3 and a firm power draft of 10.76 cumecs. Due allowance for evaporation loss and for any possible silting has been made in the working tables. For this storage, the FRL of the reservoir has been fixed at +811.68 m. It has been found that any further raising of the reservoir would not make power generation any more cheaper. It is, therefore proposed to limit the FRL to +811.68 m

iv) Water Spread:

Water spread area of the reservoir formed by Sholayar main dam, Flanking dam and Saddle dam at F.R.L is 8.705 sq. km.

Design Flood

Clear flood marks to compute the maximum flood were not available at the time of preparation of the project report and so the maximum discharge was calculated from Ryve's formula ($Q = C M^{2/3}$) where Q = Flood discharge in cusecs, C = a constant and M = area of catchment. The value of C for 47 miles (75.62 km) of catchment lying within Madras state where the rainfall is comparatively high is assessed as 3000 while for the balance 25 miles (40.23 km) catchment up to the Sholayar Dam is assessed as 2500. Therefore the maximum flood discharge is calculated as $3000 \times 47^{2/3} + 2500 \times 25^{2/3} = 60400$ Cusecs (1710.32 cumecs).

From 1959 onwards correct flood discharges have been recorded from the gauging weir at dam site. During normal year the flood discharge is in the order of 368.12 to 481.38 cumecs. It is calculated that high peak flood of nearly 1698.99 cumecs can occur in an exceptionally rainy year.

Hydrology Review

As per BIS 11223-1985, the dam is classified under large dams, i.e., Reservoir Capacity above 60Mm3 and Hydraulic head above 30m. For large dams, spillways are to be designed for PMF.

Revised Design Flood

The design storm value of one day PMP of 48.51 cm has been adopted for both sub catchments. The unit hydrograph of Sholayar Dam (Tamil Nadu) as derived by CWC has been used in the study while the unit hydrograph of free catchment has been derived using

FER sub zone 5 (a) and 5 (b). The time distribution of 24 hours rainfall has been taken from the PMP Atlas. The loss rate of 0.1 cm/hr., base flow of 0.15 m3/sec/sq. km have been adopted from CWC FER sub zone 5 (a) and 5 (b) in the study. The duration of design storm has been adopted as 24 hours. The peak rate of inflow flood hydrograph at Upper Sholayar Dam (Tamil Nadu) has been assessed as 1731 m^3/sec. reservoir and channel routed 20 km to the brink of Sholayar reservoir (Kerala) using Modified Puls, Muskingum method. Reservoir routing was carried in the portion of inflow flood hydrograph in which inflow was higher than spillway capacity at FRL. The reservoir was initially assumed to be at FRL. The total design flood at Sholayar Dam (Kerala)has been assessed by adding channel routed flood from Upper Sholayar Dam (Tamil Nadu) and flood hydrograph from the free catchment at Sholayar Dam (Kerala). The peak of PMF at Sholayar Dam (Kerala) works out as **1890 m^3/sec.**

2.3A Sholayar Flanking Dam

A flanking dam was required to be constructed to close the low saddle existing at the left flank of main dam to complete the periphery of the reservoir at its maximum water level. The flanking dam is located about 0.20 km south of the main dam. The spillway of Sholayar reservoir is located in this dam. The dam is built with rubble masonry and concrete, the total volume of which comes to 0.044 Mm^3.The dam is having gravity type non overflow sections at both ends and overflow section in the spillway portion from Ch. 68.88 m to 137.16 m. The axis of the dam has a bend at Ch. 144.78 m and the alignment makes an angle of 40^0 to the axis of the dam up to this chainage. The bed level of the river near the flanking dam site is +768.10 m. The dam is 259.08M long at road level which is at an elevation of +812.90 m. The maximum height above the deepest foundation level is 27.74 m, width at the top is 4.27 m.

Fig 2.3 Sholayar Flanking Dam u/s view

2.3.1 A Components

Spillway

Spillway is of solid gravity type with the crest and downstream face curved to conform to flow of water. Clear water way provided is 5 spans of 10.97 m and including 2.44 m thick piers, the overall length of spillway is 68.27 m. The crest level is +805.28 M. The high level and low level buckets are separated by a dividing wall. The lip angle is kept at 35^0 for reducing extra height of side walls.

5 Nos. of Radial Gates of size 10.97 m x 6.40 m are installed for controlling the flood discharge. The embedded parts of the radial gates consist of sill beams of I-section of welded construction and anchorages, sliding plates of sides of angle section with anchorages. The cross beams at piers are made of box type steel. These cross beams support the trunnions of the gates. The main body of the gates consists of skin plates and stiffeners of plate angles. There are two main girders of welded I-section and two arms made out of I-section having hubs trunnions and bearing body.

The Spillway is designed for a maximum designed flood discharge of 1710.32 cumecs. Dissipation of energy of the water falling from the ogee crested spillway is effected by providing up turned buckets with inverted levels at +786.99 m and +791.56 m. The radius and lip angle provided for the upper bucket are 10.67 m and 45^0 respectively, while the corresponding values for the lower bucket are 12.19 m and 45^0. The dam is made accessible over the spill way portion by the spillway bridge and the motors of the radial gates, the winches and the control panels are located on the hoist bridge at R.L. +815.95 m

Fig 2.4 Spillway of Sholayar Flanking Dam

Foundation gallery

In Sholayar Flanking Dam, a foundation gallery is provided. The finished section of the gallery is 2.13 m x 1.52 m, a semi circle 1.52 m dia. surmounted on a rectangle 1.37 m x 1.52 m. It has a total horizontal length of 135.94 m. This include two transverse galleries for access. Beyond the galleries, on either end, drain culverts of 0.76 m x 0.76 m size for a total length of 64 m have been provided. The gallery has a longitudinal slope of 1 in 50.

There are 20 Porous Holes and 20 Foundation Drain Holes. Monthly observations of these holes are being carried out. Total seepage is measured using V-notch fitted in the gallery.

For measuring uplift pressure, Pressure gauges are used for measuring the uplift in the gallery and the readings are taken monthly.

Salient Features of Spillway

Sl. No	Feature	Description
i	Type of gate	Spillway Crest Radial gate
ii.	Size of Gate	10.97 m x 6.40 m
iii.	No. of Gates	5 Nos.
iv.	Clear width of opening	10970 mm
v.	Operation Arrangement	a) Electrical Operation b) Manual Operation
vi.	Gate position Indicator	Mechanical Dial Indicator at the control panel
vii	Crest level of spillway	+ 805.28 m
viii	Sill level of Gate	+ 805.28 m
ix	Top of Gate	+ 811.68 m
x	FRL	+ 811.68 m
xi	MWL	+ 811.68 m

Table 2.3 Salient Features of Spill way

Hoisting mechanism:

The hoisting mechanism consists of a central drive and two lateral drives coupled by pipe shafts. The central drive has spur type reduction gear, self - arresting worm gear, a double shoe brake with electro hydraulic control device. The hoist can be either electrically or manually operated. For hand operation there is a hand crank and a safety device for switching off electrical system when the hand crank is introduced. The lateral drums have got spur type reduction gears and a rope drum. There is a positive indicator in the control panel for indicating the extent of opening of the gates. It has got two concentric

needles, one for indicating the opening in metres and the other for fraction of metre ie. centimetres. There are electrically controlled limit switches for the top and bottom positions of the gate. The hoisting and lowering speed when electrically operated is 0.31 m per minute. The electrical equipment consists of 3 phase synchronise motor with short circuit rotor 2.5 kilo watts, 1400 rpm magnetic hydraulic brake unit, spindle limit switches for top and bottom position of the gates. The motors of the radial gates, the winches and the control panels are located on the hoist bridge.

Fig 2.5 Radial gate Hoists

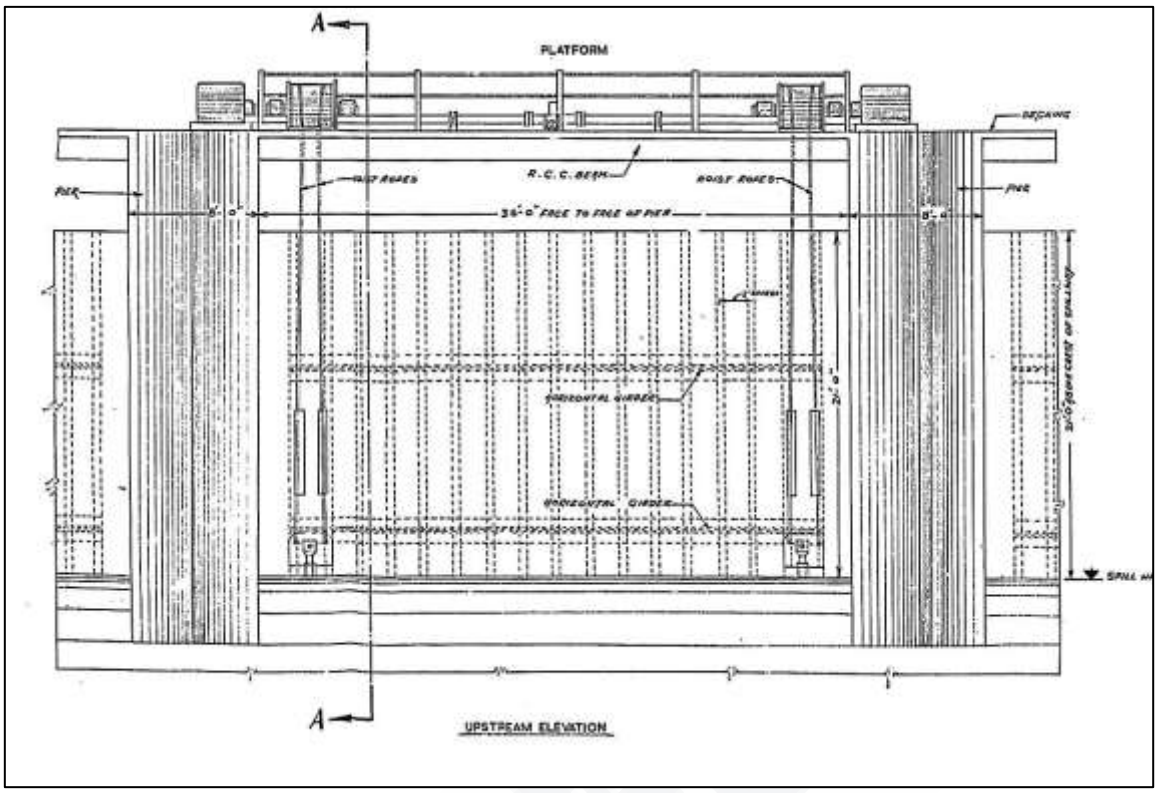

Fig 2.6 Hoisting arrangement

Fig 2.7 Control panel of Hoisting mechanism

River outlet Works

There are no river outlet works for Sholayar Flanking Dam

2.3 B Sholayar Main Dam

The Main Dam built across the Sholayar river is designed as a non-overflow straight gravity dam and is constructed in rubble masonry in cement mortar varying in proportion 1:3 to 1:5. The total quantity of concrete and masonry contained in this dam is 0.30 Mm^3. The deepest foundation level is +746.46 m and the RL at the top of Dam is +812.60 m. The height of the dam above the deepest foundation is 66.14 m, length of the dam being 430.53 m at the road level. The width at the deepest foundation is 55.78 m. The width of dam at top is 7.32 m.

There are no overflow arrangements in this dam. For the purpose of getting water down the river for emergencies, an outlet pipe of 1.83 m dia. is placed at elevation +768.10 m is at 12.19 m above the bed level. The outlet has usual emergency gate and hoists and a jet disperser.

Fig 2.8 SHOLAYAR MAIN DAM

2.3.1 B Components

i) Drainage and inspection gallery

A drainage gallery has been constructed along the full length of the dam so as to accommodate the curtain grout holes on the upstream edge of the gallery and drain holes on the downstream edge. The drainage gallery is 1.52 m x 2.74 m in size in the river bed portion between chainages 126.03 m and 220.45 m and 1.52 m x 2.13 m in size for the remaining portion. The height of the gallery is 1.4 times the width. But in between chainages 126.03 m and 251.78 m due to the steepest slope of the gallery and owing to the reason that grouting may become necessary at a later date due to the poor nature of the foundation when compared to other blocks, the height of the gallery was increased by 0.61 m. The sides are vertical with a semi-circular top for the roof.

A transverse gallery of size 1.52 m x2.74 m in size is located in Block No.3 with an ADIT house at entrance at the downstream side of the dam. This is only entrance and exit provide for the drainage gallery.

The drainage holes in the gallery are located at the downstream face of the gallery and the water coming up through these are led out to the longitudinal drain on the upstream face of the gallery through cross drains. There are 90 Porous Drain Holes and 76 Foundation Drain Holes. Monthly observations of these holes are being carried out. Total seepage is measured using V-notches fitted in the gallery.

Fig 2.9 Drainage and inspection gallery

ii) Outlet Arrangements

The outlets from the reservoir are through the spillway arrangements at flanking dam and through the outlet arrangement at main dam. The spillway will discharge water only up to +805.28 m level. When water level goes below that level and in case water is to be fed into Poringalkuthu reservoir without passing through the turbines, this is achieved through the disperser arrangement provided at main dam.

The disperser outlet arrangement is provided at chainage 161.54 m on the main dam in Block 4 at elevation +768.10 m and consists of the following.

1. A trash rack for preventing trashes getting inside the disperser arrangement.
2. Emergency gate and hoist for closing and opening of outlet arrangement.
3. A 1.83 m dia., pipe from the upstream face to the downstream face with a taper piece at the downstream end.
4. Disperser (hollow jet).

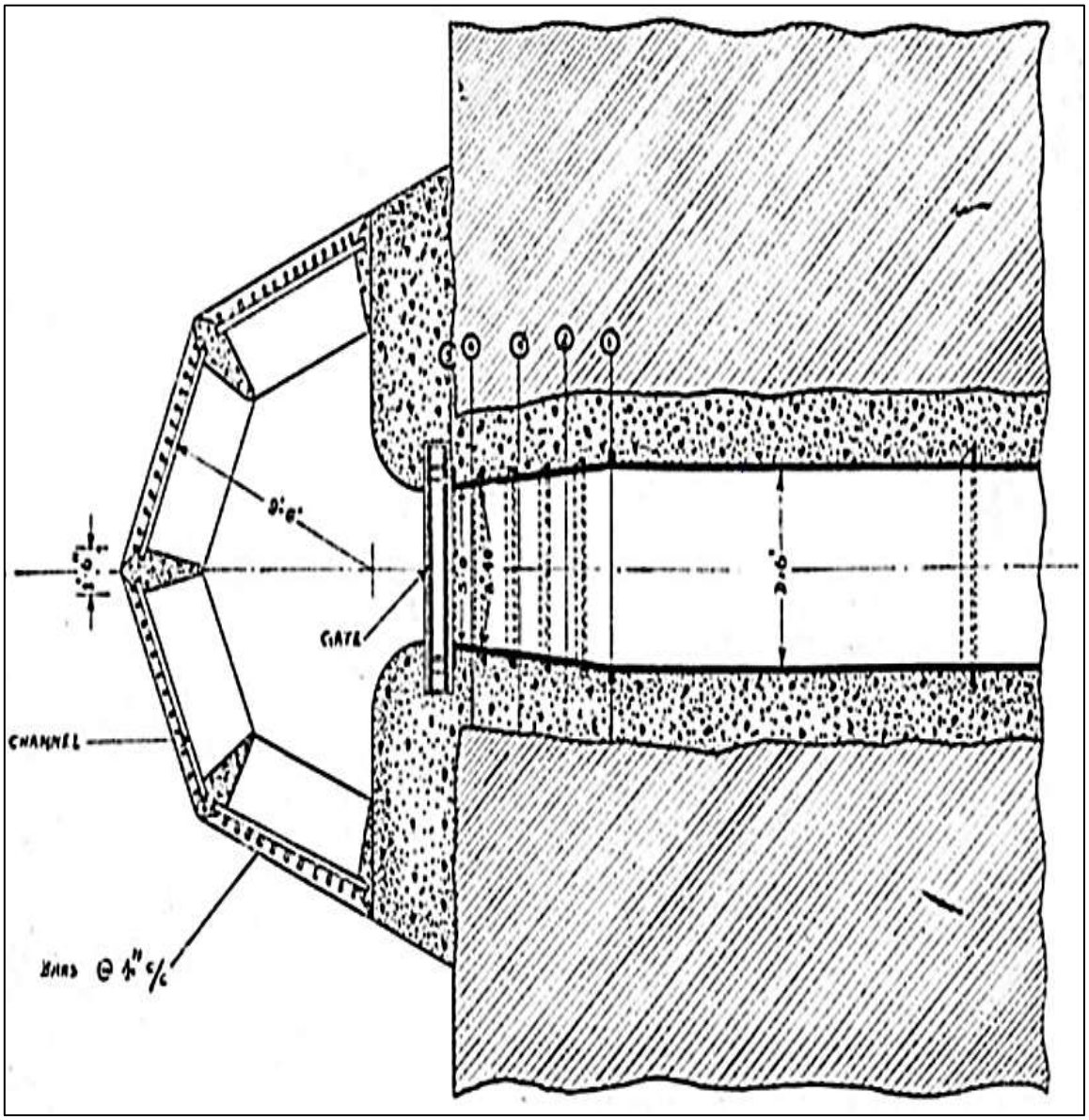

Fig 2.10 Plan of outlet arrangement

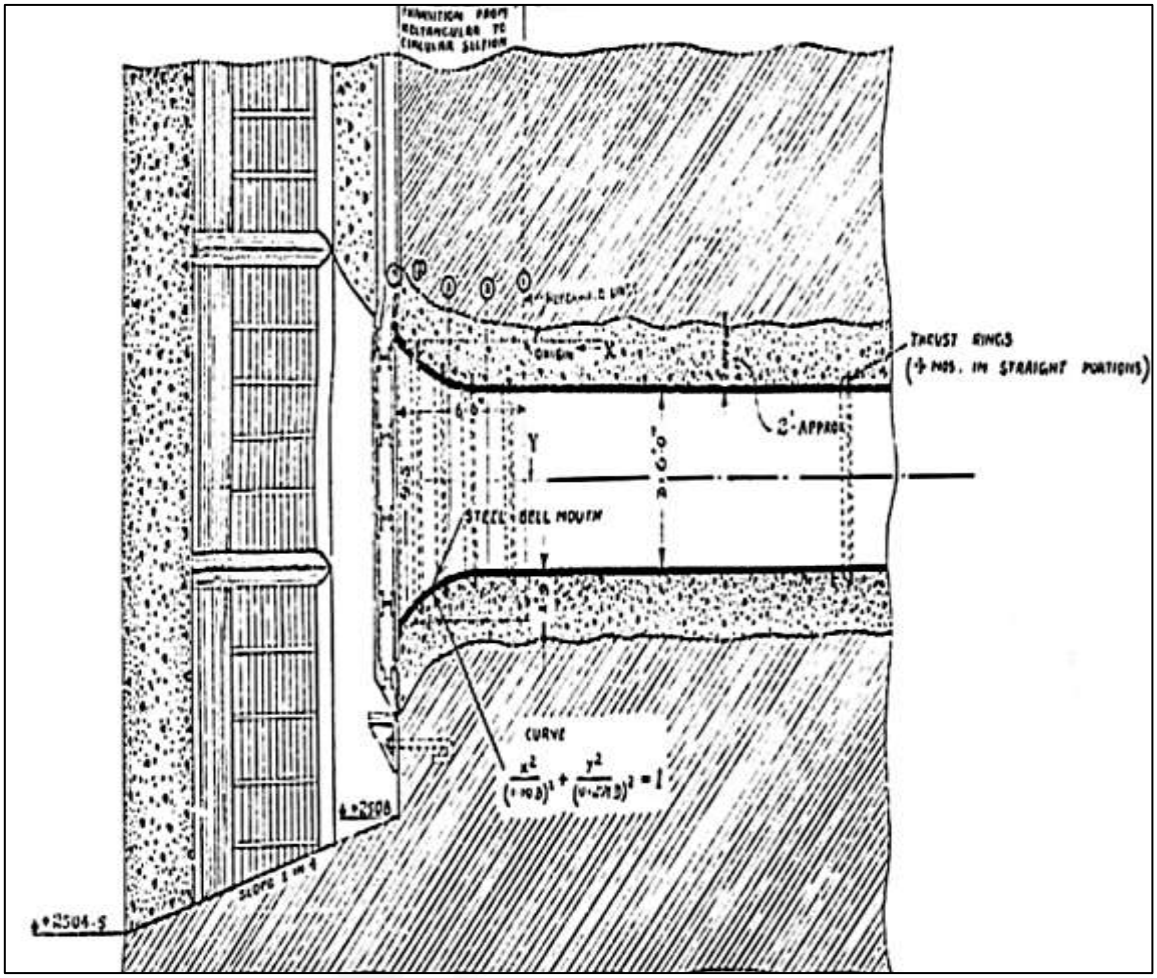

Fig 2.11 Section of outlet arrangement

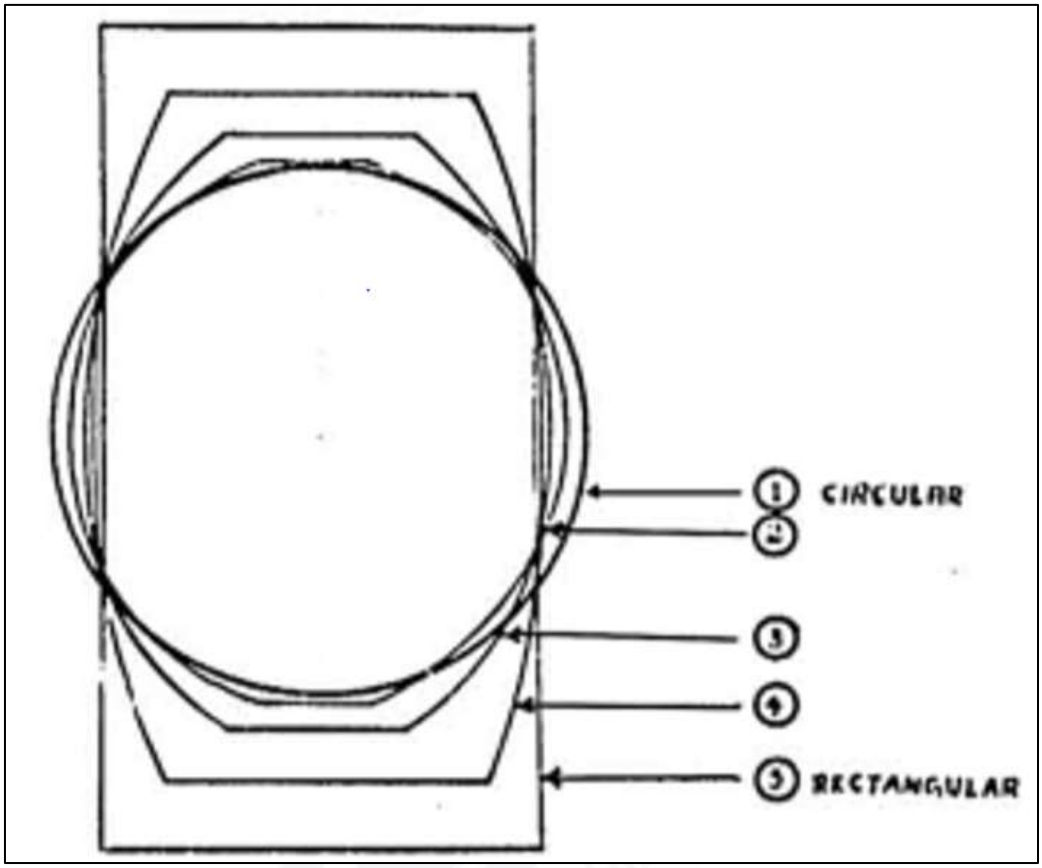

Fig 2.12 Transition Sections

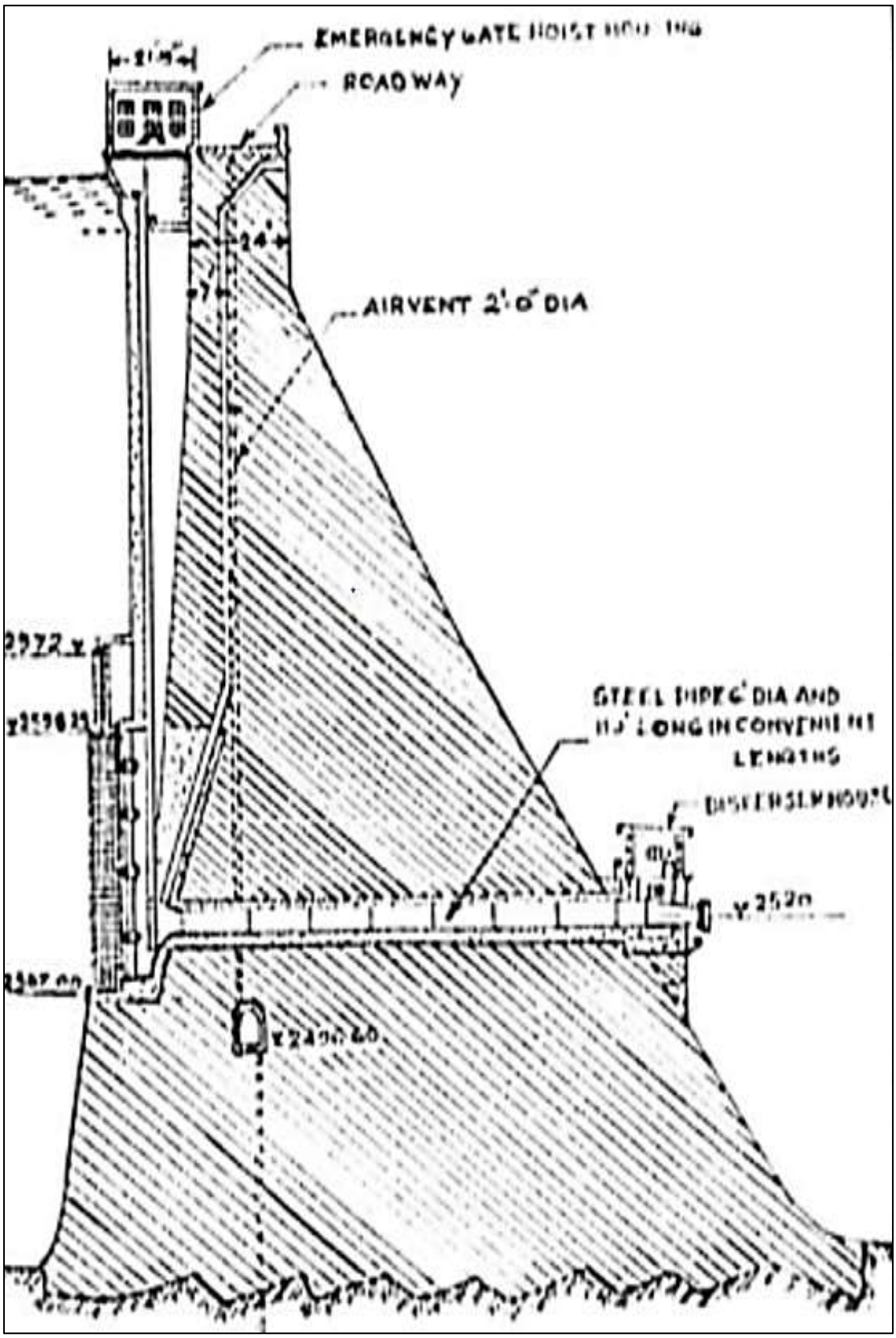

Fig 2.13 Section of Main Dam through center line of Outlet Pipe

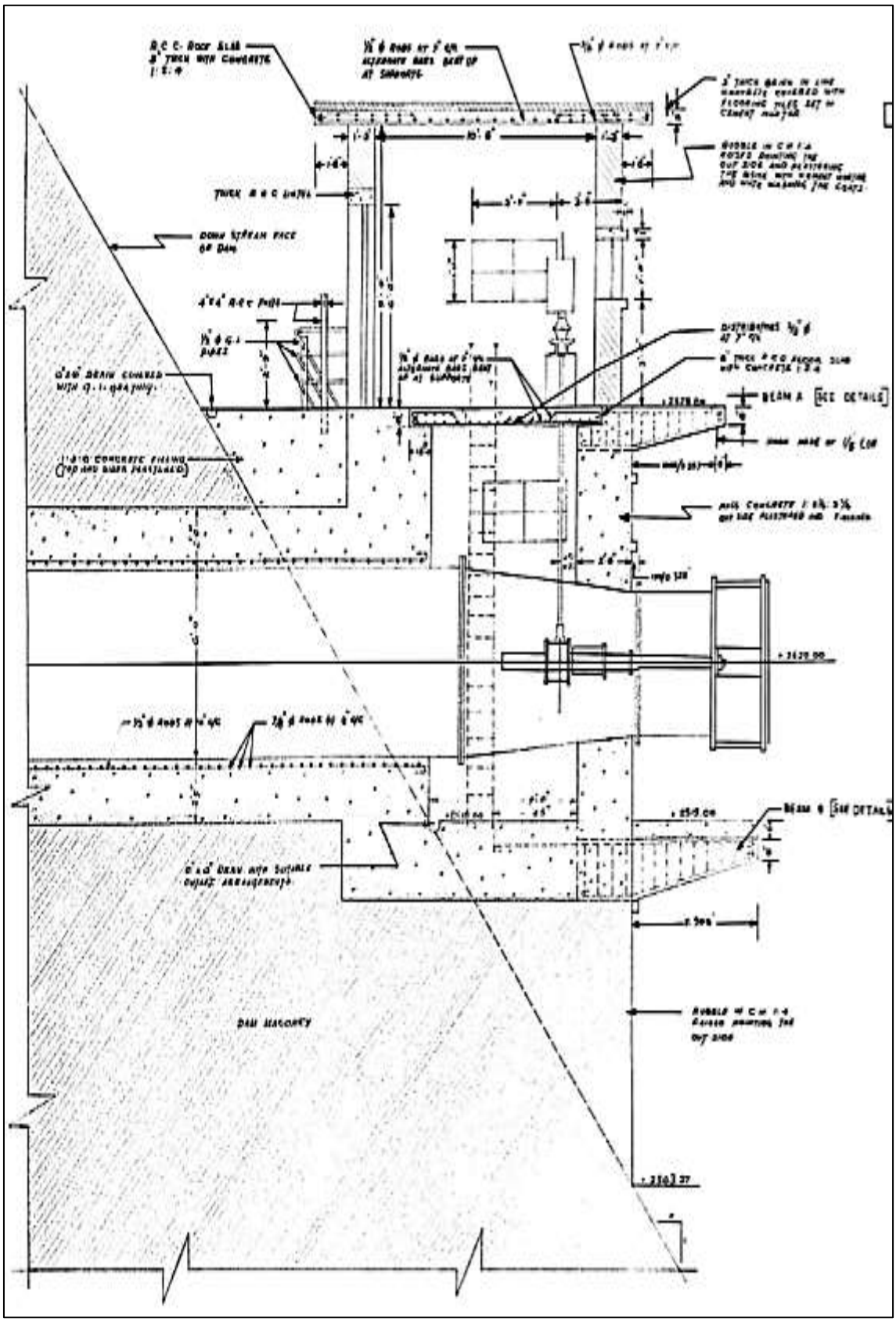

Fig 2.14 Disperser House

iii) Emergency gate and hoist

Emergency gate and hoist are supplied by M/S WaagnerBire, Austria, through their Indian Agents M/S Marshall Sons & Co. Ltd., Madras. The gate is designed for a clear opening of 2.90 m x 1.52 m. Wheels with antifriction bearing, self aligning axles etc. enable good alignment of the gate.

There is a mechanical hoist erected at elevation +812.67 m with capacity of 20 tons for operating the gate. The hoist consists of electric motor, solenoid brake and a rope drum. There is a fan brake of sturdy construction, independently acting under different brake torques. There is a suspension beam for the hoist gate, which moves along with the gate during its downward movement, so that the gate is supported by 2 ropes, till it reaches the bottom near the opening. Beyond this, the suspension beam is held in position and from there the gate is suspended by 4 ropes, so that the effort on the motor is reduced at the higher reaches and maximum effort is put when the gate contacts the frame work. Two guides of angle sections are provided for guiding the gate during its upward and downward movements. There is a position indicator attached to the hoist frame work, which indicates the position of the gate and also there are two limit switches for limiting its upward and downward movements. The hoisting speed is 1.52 m per minute and maximum lowering speed is 2.44 m per minute.

Fig 2.15 Rope drum of Emergency gate

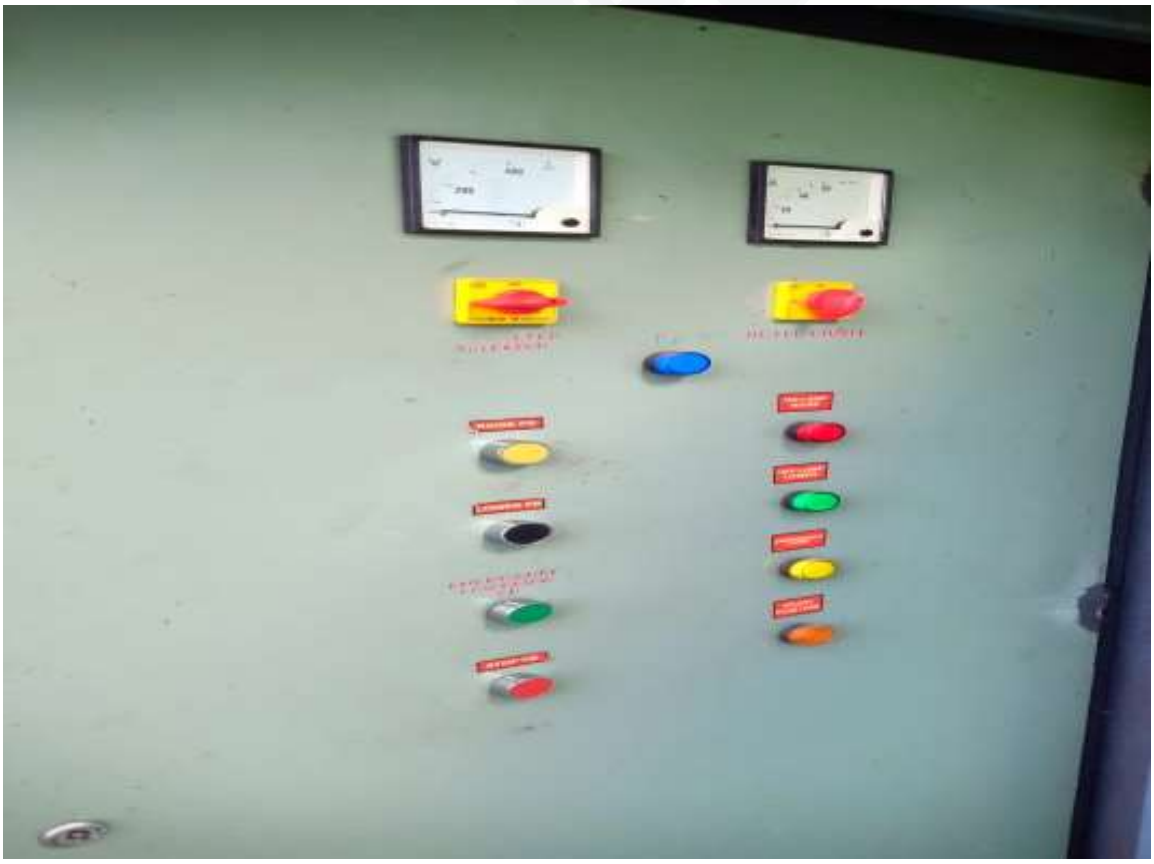

Fig 2.16 Control panel of Emergency Gate

iv) Pipe arrangements

There is a bell mouth at the entrance varying from rectangular section of 3.23 m to circular section of 1.83 m dia., and from there a steel pipe 1.83 m dia. and 1.27 cm thick and 36.27 m long is provided for carrying water. At the end there is a taper piece varying in section from 1.83 m dia. to 1.22 m dia. 2.44 m long connecting to the hollow jet. The bell mouth, pipes and taper piece are supplied by M/S Structural Engineering Works, Bombay.

v) Disperser

The disperser or discharge regulator for the outlet arrangement is supplied by M/S Neyrpic, France through their Indian Agents M/S Batliboi & Co. Pvt. Ltd., Bombay. The hollow jet valve consists of the following.

1. **Body**: This is made of welded steel plate and consists of an upstream flanged cylinder connected to the valve cone at the downstream end by means of radial ribs. The annular space is between the cylinder and the valve cone is the valve outlet. Both the radial ribs and the cylinder are carefully machined to provide guides and sliding surfaces for the bronze shoes on the valve sleeve.

2. **Valve Sleeve**: This consists of a cylinder made of stainless steel plate. The sleeve is well stiffened by means of annular and radial ribs which are also used for attaching the two operating rods. The sleeve is fitted with carefully machined bronze shoes which guide it and upon which it slides on the valve body.

3. **Seals**: Downstream end of the valve outlet is fitted with an elastic seal. Another seal attached to the body prevents upstream leakage between the body and the valve sleeve inner surface of stainless steel.

4. **Operating gear**: The valve is operated by 2 worm gears located in horizontal plane passing through the axis of the valve and consists of a chrome steel work, steel bevel gear and bronze driving nut. The operating gear gives only longitudinal motion to the worm. The worm gears are driven by the motor unit

via shafts and bevel gearing. There is a mechanical position indicator with limit contacts, which indicates the opening of the gate. The valve can also be manually operated in the case of power failure. There is a safety device for cutting off the electric supply when the crank handle is introduced. The maximum discharge through the discharge regulator under full head is 29.34 cumecs. The center of outlet pipe and disperser is fixed at + 768.10 m level.

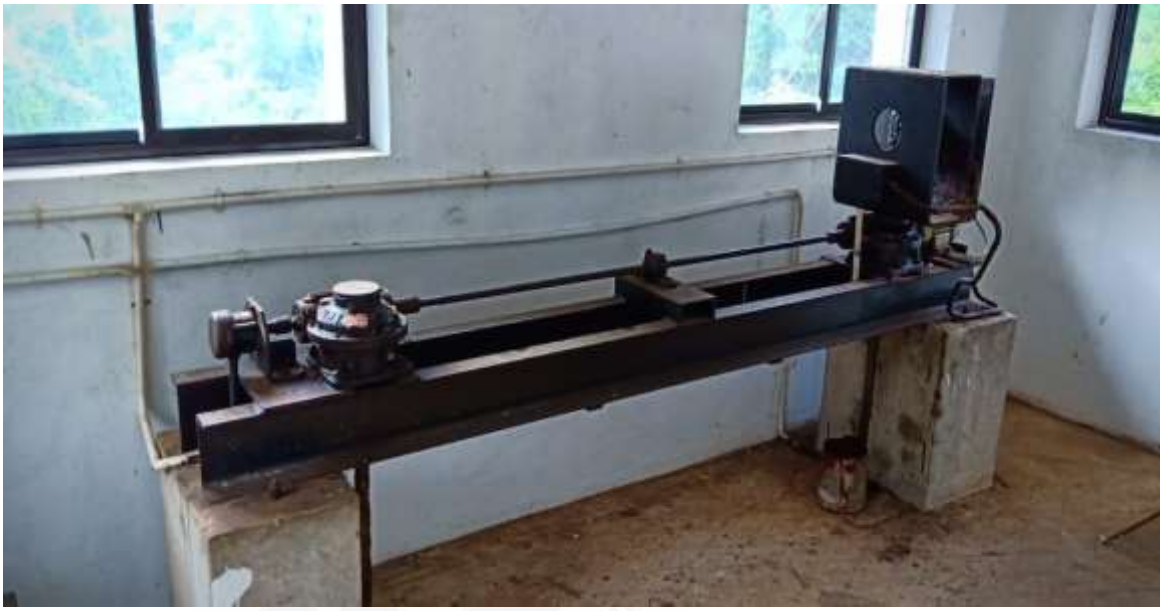

Fig 2.17 Operating gear of Disperser valve

Fig 2.18 Motor of opening arrangement of disperser valve

5. **Trash rack arrangements** : 5 rows of trash racks of size 3.12 m x 1.88 m are provided in front of the outlet arrangement for preventing trashes entering the outlet pipe. The trash bars are fixed at 10 cm centers. Necessary grooves are formed in the concrete at the time of construction of piers and a channel section made out of 1.27 cm thick plate is fixed inside the groove to form as a guide for the movement of the trash rack at the time of its removal and insertion. Dowel bars are provided in between trash racks for getting correct alignment and seating.

Fig 2.19 Disperser valve

2.3 C Sholayar Saddle Dam

The Composite Saddle Dam at Ambalapara is the third dam constructed under Sholayar Hydro Electric Project to form the Sholayar Reservoir. This dam is located in the Ambalapara Saddle between Sholayar and Anakkayam valleys. The dam is of composite type with an upstream masonry wall and earth embankment backing. The masonry portion is founded on sound rock while the earth embankment is formed over the excavation for the masonry portion and on the original surface with 0.30 to 0.60 m of the surface earth alone removed. The total quantity of concrete and masonry contained in this dam is 0.008 Mm^3. The quantity of earth fill for the embankment is 0.01 Mm^3.

The deepest foundation level for masonry portion is +795.22 m and the RL at the top of Dam is +813.82 m. Height of the dam above the deepest foundation of masonry portion is 18.59 m, length of the dam at top is 109.12 m. Top width of masonry portion is 1.83 m and earth embankment is 6.10 m.

Fig 2.20 SHOLAYAR SADDLE DAM

2.4 Operation of the Reservoir

Sholayar reservoir was being operated as per "Guidelines for Operation of Reservoirs" (IS;7323;1994), for storage reservoirs for conservation purposes like power generation. The reservoir water is released through spillway gates as per rule levels fixed. Discharge through single spillway for different reservoir levels with different gate openings is tabulated in **Table 2.4**. Discharge (Rating) curve showing discharge through one radial gate at various reservoir levels is given in **Fig. 2.21**. Total discharge in full opened position is given in **Fig. 2.22**.

DISCHARGE IN CUMECS DURING GATE OPENING OF ONE RADIAL GATE AT KERALA SHOLAYAR DAM AT VARIOUS RESERVOIR LEVELS

Reservoir level (Feet)		2663	2662	2661	2660	2659	2658	2657	2656	2655
Reservoir level (Metre)		811.68	811.38	811.07	810.77	810.46	810.16	809.85	809.55	809.24
One Gate opening in Feet	One Gate opening in Metre	Discharge in M^3/s	Discharge in M^3/s	Discharge in M^3/s	Discharge in M^3/s	Discharge in M^3/s	Discharge in M^3/s	Discharge in M^3/s	Discharge in M^3/s	Discharge in M^3/s
0.10	0.0305	2.47	2.41	2.35	2.29	2.23	2.16	2.09	2.02	1.94
0.20	0.0610	4.94	4.82	4.70	4.57	4.44	4.31	4.17	4.03	3.88
0.30	0.0914	7.40	7.22	7.04	6.85	6.66	6.46	6.25	6.03	5.81
0.40	0.1219	9.86	9.62	9.37	9.12	8.86	8.59	8.32	8.03	7.73
0.50	0.1524	12.31	12.01	11.70	11.39	11.06	10.72	10.38	10.02	9.65
0.60	0.1829	14.75	14.39	14.02	13.64	13.25	12.85	12.43	12.00	11.56
0.70	0.2134	17.19	16.77	16.34	15.89	15.44	14.97	14.48	13.98	13.46
0.80	0.2438	19.62	19.14	18.65	18.14	17.62	17.08	16.52	15.95	15.35
0.90	0.2743	22.05	21.51	20.95	20.38	19.79	19.18	18.55	17.91	17.23
1.00	0.3048	24.47	23.87	23.25	22.61	21.95	21.28	20.58	19.86	19.11
1.10	0.3353	26.89	26.22	25.54	24.84	24.11	23.37	22.60	21.80	20.98
1.20	0.3658	29.29	28.57	27.82	27.05	26.27	25.45	24.61	23.74	22.84
1.30	0.3962	31.70	30.91	30.10	29.27	28.41	27.53	26.62	25.67	24.69
1.40	0.4267	34.09	33.24	32.37	31.47	30.55	29.60	28.61	27.60	26.54
1.50	0.4572	36.48	35.57	34.63	33.67	32.68	31.66	30.60	29.51	28.38
1.60	0.4877	38.87	37.89	36.89	35.86	34.81	33.71	32.59	31.42	30.21
1.70	0.5182	41.24	40.21	39.14	38.05	36.92	35.76	34.56	33.32	32.03
1.80	0.5486	43.62	42.52	41.39	40.23	39.04	37.80	36.53	35.21	33.84
1.90	0.5791	45.98	44.82	43.63	42.40	41.14	39.84	38.49	37.10	35.65
2.00	0.6096	48.34	47.12	45.86	44.57	43.24	41.87	40.45	38.97	37.45
2.10	0.6401	50.70	49.41	48.09	46.73	45.33	43.89	42.39	40.84	39.24
2.20	0.6706	53.04	51.69	50.31	48.88	47.41	45.90	44.33	42.71	41.02
2.30	0.7010	55.38	53.97	52.52	51.03	49.49	47.90	46.26	44.56	42.79
2.40	0.7315	57.72	56.24	54.73	53.17	51.56	49.90	48.19	46.41	44.56
2.50	0.7620	60.05	58.51	56.93	55.30	53.62	51.89	50.10	48.25	46.32
2.60	0.7925	62.37	60.77	59.12	57.43	55.68	53.88	52.01	50.08	48.07

2.70	0.8230	64.69	63.02	61.31	59.55	57.73	55.86	53.92	51.90	49.81
2.80	0.8534	67.00	65.27	63.49	61.66	59.77	57.82	55.81	53.72	51.54
2.90	0.8839	69.30	67.51	65.66	63.76	61.81	59.79	57.70	55.53	53.27
3.00	0.9144	71.60	69.74	67.83	65.86	63.84	61.74	59.58	57.33	54.99
3.10	0.9449	73.89	71.97	69.99	67.96	65.86	63.69	61.45	59.12	56.69
3.20	0.9754	76.18	74.19	72.14	70.04	67.87	65.63	63.31	60.90	58.40
3.30	1.0058	78.46	76.40	74.29	72.12	69.88	67.56	65.17	62.68	60.09
3.40	1.0363	80.73	78.61	76.43	74.19	71.88	69.49	67.02	64.45	61.77
3.50	1.0668	83.00	80.81	78.57	76.26	73.87	71.41	68.86	66.21	63.45
3.60	1.0973	85.26	83.01	80.70	78.31	75.86	73.32	70.69	67.96	65.12
3.70	1.1278	87.51	85.20	82.82	80.37	77.84	75.22	72.52	69.71	66.78
3.80	1.1582	89.76	87.38	84.93	82.41	79.81	77.12	74.34	71.44	68.43
3.90	1.1887	92.00	89.55	87.04	84.45	81.77	79.01	76.15	73.17	70.07
4.00	1.2192	94.24	91.72	89.14	86.48	83.73	80.89	77.95	74.89	71.70
4.10	1.2497	96.46	93.88	91.23	88.50	85.68	82.77	79.74	76.60	73.33
4.20	1.2802	98.69	96.04	93.32	90.52	87.62	84.63	81.53	78.31	74.94
4.30	1.3106	100.90	98.19	95.40	92.53	89.56	86.49	83.31	80.00	76.55
4.40	1.3411	103.11	100.33	97.47	94.53	91.49	88.34	85.08	81.69	78.15
4.50	1.3716	105.32	102.47	99.54	96.52	93.41	90.19	86.85	83.37	79.74
4.60	1.4021	107.51	104.60	101.60	98.51	95.32	92.02	88.60	85.04	81.33
4.70	1.4326	109.70	106.72	103.65	100.49	97.23	93.85	90.35	86.70	82.90
4.80	1.4630	111.89	108.84	105.70	102.47	99.13	95.67	92.09	88.36	84.46
4.90	1.4935	114.06	110.95	107.74	104.43	101.02	97.49	93.82	90.01	86.02
5.00	1.5240	116.23	113.05	109.77	106.39	102.90	99.29	95.54	91.64	87.57
5.10	1.5545	118.40	115.15	111.80	108.35	104.78	101.09	97.26	93.27	89.11
5.20	1.5850	120.56	117.24	113.82	110.29	106.65	102.88	98.97	94.89	90.64
5.30	1.6154	122.71	119.32	115.83	112.23	108.51	104.66	100.67	96.51	92.16
5.40	1.6459	124.85	121.39	117.83	114.16	110.37	106.44	102.36	98.11	93.67
5.50	1.6764	126.99	123.46	119.83	116.09	112.21	108.21	104.04	99.71	95.17
5.60	1.7069	129.12	125.53	121.82	118.00	114.05	109.97	105.72	101.29	96.66
5.70	1.7374	131.25	127.58	123.81	119.91	115.89	111.72	107.38	102.87	98.15
5.80	1.7678	133.37	129.63	125.78	121.81	117.71	113.46	109.04	104.44	99.63
5.90	1.7983	135.48	131.67	127.75	123.71	119.53	115.20	110.69	106.00	101.09
6.00	1.8288	137.58	133.71	129.72	125.60	121.34	116.92	112.34	107.55	102.55
6.10	1.8593	139.68	135.74	131.67	127.48	123.14	118.64	113.97	109.10	104.00
6.20	1.8898	141.77	137.76	133.62	129.35	124.93	120.36	115.60	110.63	105.44
6.30	1.9202	143.86	139.77	135.56	131.22	126.72	122.06	117.21	112.16	106.87

6.40	1.9507	145.94	141.78	137.50	133.07	128.50	123.76	118.82	113.68	108.29
6.50	1.9812	148.01	143.78	139.42	134.92	130.27	125.44	120.42	115.19	109.70
6.60	2.0117	150.08	145.77	141.34	136.77	132.03	127.12	122.02	116.69	111.10
6.70	2.0422	152.13	147.76	143.26	138.60	133.79	128.80	123.60	118.18	112.49
6.80	2.0726	154.19	149.74	145.16	140.43	135.54	130.46	125.18	119.66	113.87
6.90	2.1031	156.23	151.71	147.06	142.25	137.28	132.11	126.74	121.13	115.25
7.00	2.1336	158.27	153.68	148.95	144.07	139.01	133.76	128.30	122.59	116.61
7.10	2.1641	160.30	155.64	150.84	145.87	140.73	135.40	129.85	124.05	117.97
7.20	2.1946	162.33	157.59	152.71	147.67	142.45	137.03	131.39	125.50	119.31
7.30	2.2250	164.34	159.54	154.58	149.46	144.16	138.66	132.92	126.93	120.64
7.40	2.2555	166.35	161.48	156.44	151.24	145.86	140.27	134.45	128.36	121.97
7.50	2.2860	168.36	163.41	158.30	153.02	147.55	141.88	135.96	129.78	123.29
7.60	2.3165	170.36	165.33	160.15	154.79	149.24	143.47	137.47	131.19	124.59
7.70	2.3470	172.35	167.25	161.99	156.55	150.92	145.06	138.97	132.59	125.89
7.80	2.3774	174.33	169.16	163.82	158.30	152.58	146.65	140.45	133.98	127.17
7.90	2.4079	176.31	171.06	165.64	160.05	154.25	148.22	141.93	135.36	128.45
8.00	2.4384	178.28	172.95	167.46	161.78	155.90	149.78	143.41	136.73	129.72
8.10	2.4689	180.24	174.84	169.27	163.51	157.54	151.34	144.87	138.09	130.97
8.20	2.4994	182.20	176.72	171.08	165.23	159.18	152.89	146.32	139.45	132.22
8.30	2.5298	184.14	178.60	172.87	166.95	160.81	154.42	147.77	140.79	133.45
8.40	2.5603	186.09	180.46	174.66	168.65	162.43	155.96	149.20	142.13	134.68
8.50	2.5908	188.02	182.32	176.44	170.35	164.04	157.48	150.63	143.45	135.89
8.60	2.6213	189.95	184.17	178.21	172.04	165.65	158.99	152.04	144.77	137.10
8.70	2.6518	191.87	186.02	179.98	173.73	167.24	160.50	153.45	146.07	138.30
8.80	2.6822	193.78	187.86	181.74	175.40	168.83	161.99	154.85	147.37	139.48
8.90	2.7127	195.69	189.69	183.49	177.07	170.41	163.48	156.24	148.65	140.65
9.00	2.7432	197.59	191.51	185.23	178.73	171.98	164.96	157.62	149.93	141.82
9.10	2.7737	199.48	193.32	186.96	180.38	173.54	166.43	158.99	151.19	142.97
9.20	2.8042	201.37	195.13	188.69	182.02	175.10	167.89	160.36	152.45	144.11
9.30	2.8346	203.25	196.93	190.41	183.66	176.64	169.34	161.71	153.70	145.25
9.40	2.8651	205.12	198.73	192.12	185.28	178.18	170.78	163.05	154.93	146.37
9.50	2.8956	206.98	200.51	193.83	186.90	179.71	172.22	164.39	156.16	147.48
9.60	2.9261	208.84	202.29	195.52	188.51	181.23	173.64	165.71	157.38	148.58
9.70	2.9566	210.69	204.06	197.21	190.11	182.74	175.06	167.03	158.59	149.67
9.80	2.9870	212.53	205.82	198.89	191.71	184.25	176.47	168.33	159.78	150.75
9.90	3.0175	214.36	207.58	200.56	193.29	185.74	177.87	169.63	160.97	151.81
10.00	3.0480	216.19	209.33	202.23	194.87	187.23	179.26	170.91	162.14	152.87

10.10	3.0785	218.01	211.07	203.89	196.44	188.71	180.64	172.19	163.31	153.92
10.20	3.1090	219.83	212.80	205.54	198.00	190.18	182.01	173.46	164.47	154.95
10.30	3.1394	221.63	214.53	207.18	199.56	191.64	183.37	174.72	165.61	155.97
10.40	3.1699	223.43	216.24	208.81	201.10	193.09	184.72	175.97	166.75	156.99
10.50	3.2004	225.22	217.95	210.44	202.64	194.53	186.07	177.20	167.87	157.99
10.60	3.2309	227.01	219.66	212.05	204.17	195.97	187.40	178.43	168.98	158.98
10.70	3.2614	228.78	221.35	213.66	205.69	197.39	188.73	179.65	170.09	159.95
10.80	3.2918	230.55	223.04	215.26	207.20	198.81	190.05	180.86	171.18	160.92
10.90	3.3223	232.31	224.72	216.86	208.70	200.22	191.35	182.06	172.26	161.88
11.00	3.3528	234.07	226.39	218.44	210.20	201.61	192.65	183.25	173.33	162.82
11.10	3.3833	235.81	228.05	220.02	211.68	203.00	193.94	184.42	174.39	163.75
11.20	3.4138	237.55	229.71	221.59	213.16	204.39	195.22	185.59	175.44	164.67
11.30	3.4442	239.28	231.36	223.15	214.63	205.76	196.48	186.75	176.48	165.58
11.40	3.4747	241.01	233.00	224.70	216.09	207.12	197.74	187.90	177.51	166.47
11.50	3.5052	242.72	234.63	226.25	217.54	208.48	198.99	189.04	178.53	167.36
11.60	3.5357	244.43	236.26	227.78	218.99	209.82	200.23	190.17	179.53	168.23
11.70	3.5662	246.13	237.87	229.31	220.42	211.16	201.46	191.28	180.53	169.09
11.80	3.5966	247.83	239.48	230.83	221.85	212.48	202.69	192.39	181.51	169.94
11.90	3.6271	249.51	241.08	232.34	223.26	213.80	203.90	193.49	182.48	170.77
12.00	3.6576	251.19	242.68	233.85	224.67	215.11	205.10	194.57	183.45	171.60
12.10	3.6881	252.86	244.26	235.34	226.07	216.41	206.29	195.65	184.39	172.41
12.20	3.7186	254.53	245.84	236.83	227.46	217.70	207.47	196.71	185.33	173.21
12.30	3.7490	256.18	247.41	238.31	228.85	218.98	208.64	197.77	186.26	173.99
12.40	3.7795	257.83	248.97	239.78	230.22	220.25	209.80	198.81	187.18	174.77
12.50	3.8100	259.47	250.52	241.24	231.58	221.51	210.96	199.85	188.08	175.53
12.60	3.8405	261.10	252.06	242.69	232.94	222.76	212.10	200.87	188.97	176.27
12.70	3.8710	262.73	253.60	244.13	234.29	224.01	213.23	201.88	189.85	177.01
12.80	3.9014	264.34	255.13	245.57	235.62	225.24	214.35	202.88	190.72	177.73
12.90	3.9319	265.95	256.65	247.00	236.95	226.46	215.46	203.87	191.58	178.44
13.00	3.9624	267.55	258.16	248.42	238.27	227.68	216.56	204.85	192.42	179.13

Table 2.4 Spill way Discharge

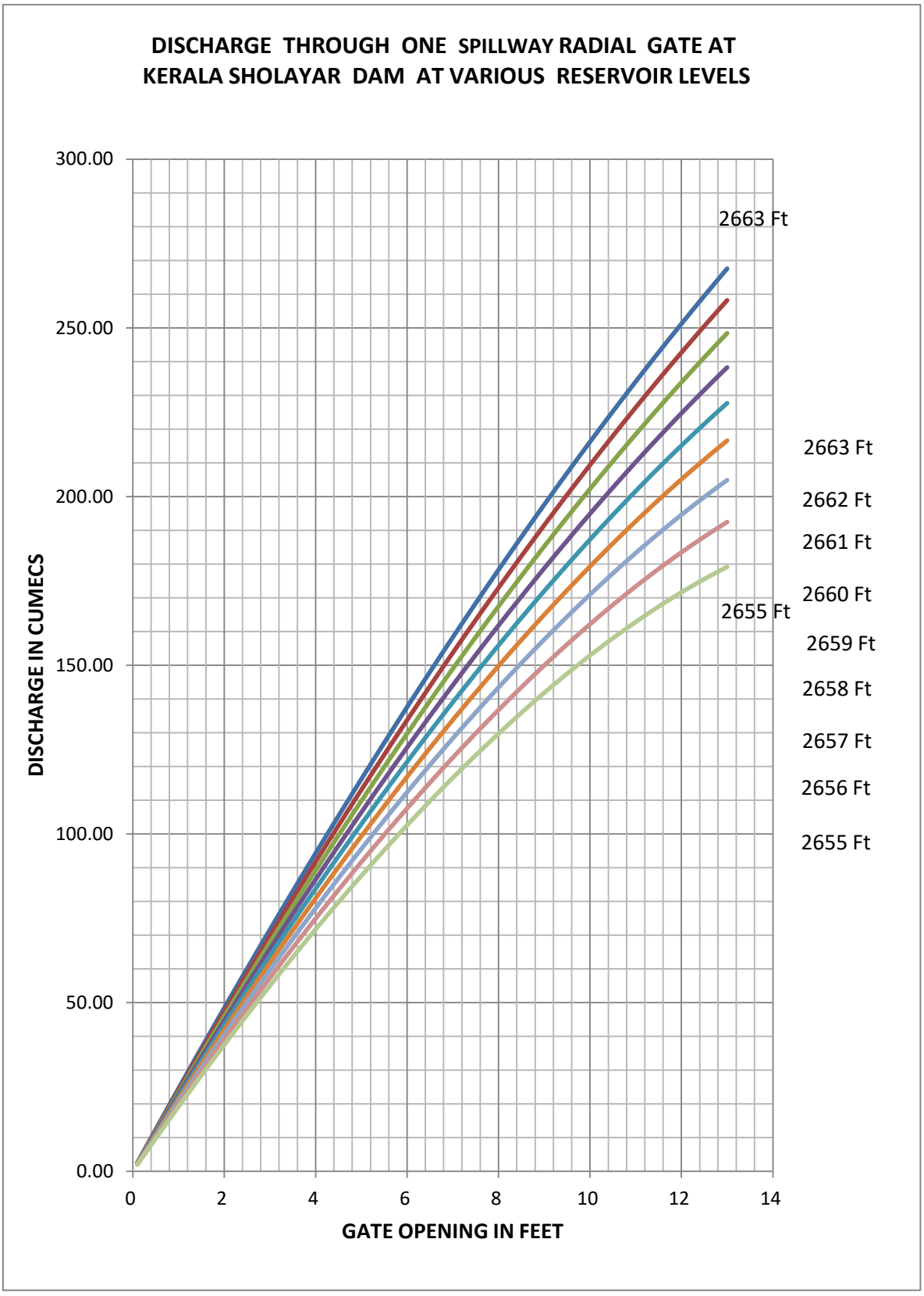

Fig 2.21 Discharge curve

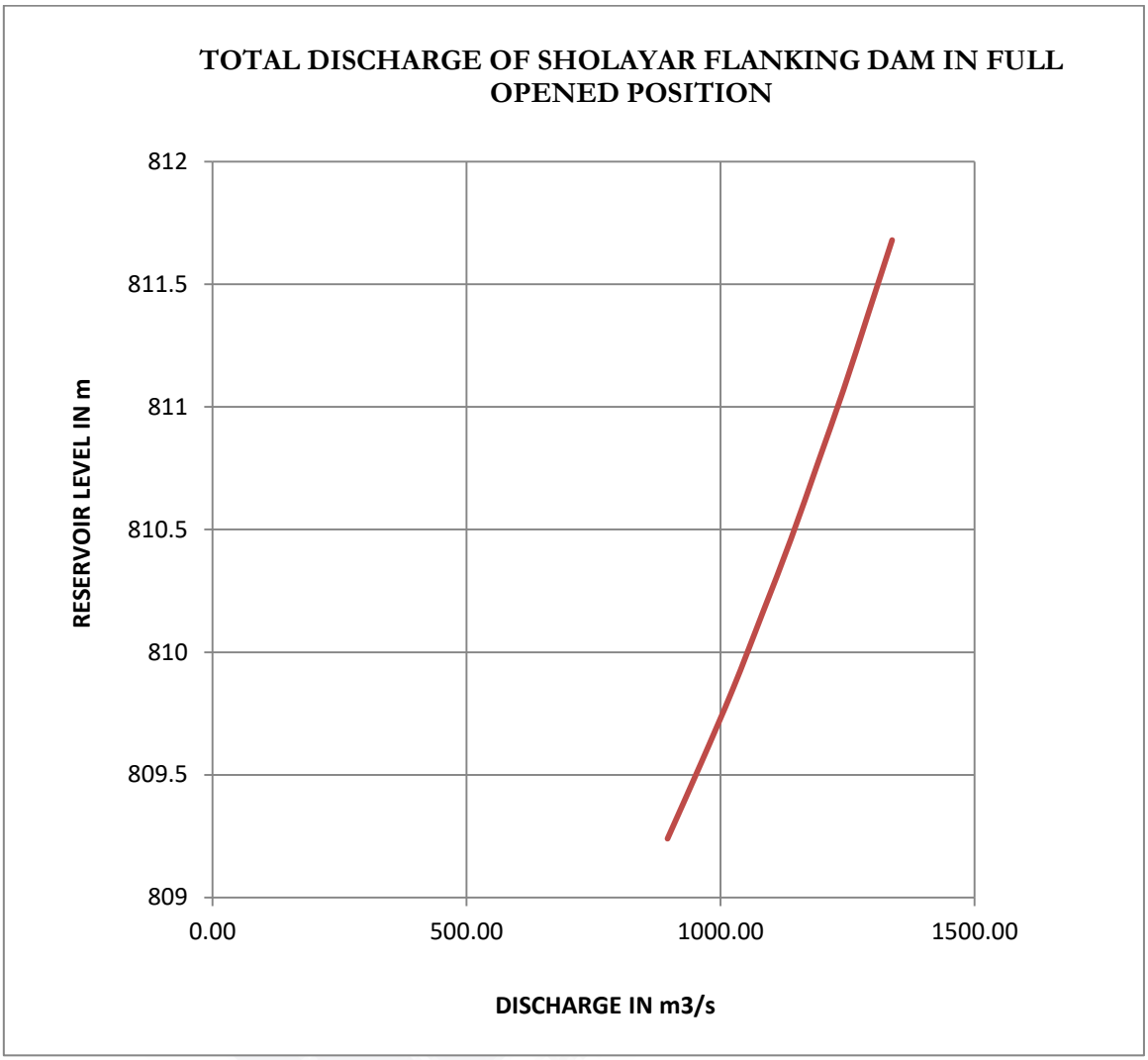

Fig. 2.22 Total Discharge in full opened position

2.4.1 Rule Curve

As per the Kerala flood study report of August 2018, CWC has recommended for reviewing the rule curves of all 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.

Sholayar reservoir comes under the system of reservoirs of Parambikulam- Aliyar Project. Maintenance of water levels in this reservoir, withdrawal/release from reservoir etc. are to be done in compliance with the Parambikulam- Aliyar Project Agreement executed between Kerala and Tamil Nadu.

- As per PAP agreement, Tamil Nadu Government shall let down water from Tamil Nadu Sholayar reservoir to Kerala Sholayar reservoir to ensure the following:
- Tamil Nadu shall commence filling Sholayar Reservoir from 1st July and fill it up to 2658feet (810.16m) as soon as possible.
- Sholayar reservoir shall be kept at the full reservoir level of 2663 feet (811.68m)on September 1st.
- From September 2nd to January 31st, the level in Sholayar Reservoir shall be maintained at about 5 feet below FRL ie. 2658 feet (810.16m).
- On February 1st, the Sholayar reservoir shall be kept at full reservoir level of 2663feet (811.68m).

During February to June 30th, no releases need to be made from Tamil Nadu reservoir provided that 12.3 TMC of water had been delivered at the Sholayar Power House by 1st February.

As such rule levels are already there for Sholayar reservoir. Review of the levels can be done only with the consensus of Joint Water Regulatory Board. Even then, based on quality prediction of rainfall, the water level in the reservoir can be lowered to 0.50 m below the FRL during August & October without conflicting with PAP agreement considering the trend of inflow in the preceding month.

Accordingly Rule curve for Sholayar Flanking Dam is given in **Fig. 2.23**.The reservoir water exceeding the rule curve level will be spilled or adjusted with power generation. This can be used till further revision.

SHOLAYAR DAM - W L FROM 2000 TO 2018

Month/ Year	June		July		August		September		October		November	
	1F	2F	1F	2F	1F	2F	1F	2F	1F	2F	1F	2F
1999-00												
2000-01	783.15	787.51	792.94	799.13	802.69	807.85	811.43	811.28	811.54	811.20	810.39	809.29
2001-02	787.17	790.89	797.55	803.86	805.55	807.63	810.27	809.38	809.76	809.68	809.42	808.85
2002-03	783.42	786.99	792.37	793.14	794.45	799.59	803.88	804.30	804.44	807.66	809.83	809.83
2003-04	779.91	782.56	789.29	794.43	799.26	803.41	807.07	807.48	807.96	810.20	809.76	810.15
2004-05	789.51	797.25	800.25	804.56	809.77	810.79	810.99	809.51	809.06	810.07	810.62	810.49
2005-06	789.44	787.90	792.02	799.67	811.40	811.45	811.66	811.61	810.94	810.70	809.73	810.47
2006-07	793.70	792.62	797.09	803.98	808.33	811.29	811.07	811.16	810.85	811.60	811.64	810.76
2007-08	788.27	788.51	798.03	808.11	811.17	811.67	811.68	811.68	811.14	811.13	811.50	811.35
2008-09	787.81	788.81	792.00	794.26	801.80	807.02	810.76	811.37	811.32	811.44	811.26	811.19
2009-10	786.68	784.40	789.16	802.14	807.26	810.18	811.61	811.47	811.59	811.31	810.85	811.44
2010-11	791.02	790.78	793.53	799.19	805.92	810.39	811.40	810.88	810.82	810.81	811.06	810.79
2011-12	792.57	794.41	796.83	803.64	809.22	811.47	811.67	811.63	810.81	810.89	811.43	811.25
2012-13	790.30	788.14	789.75	795.08	801.16	806.94	810.87	811.42	810.70	810.94	811.03	810.89
2013-14	784.18	790.09	800.46	807.14	811.65	811.64	811.48	811.64	811.55	811.38	811.10	810.63
2014-15	782.10	785.04	787.39	795.09	805.16	810.44	811.68	811.57	811.30	811.27	811.34	810.50
2015-16	787.52	787.53	892.01	796.92	802.92	807.60	810.95	811.45	811.27	810.31	809.66	807.80
2016-17	787.43	787.64	789.96	797.75	802.54	806.27	808.62	808.06	808.59	809.55	809.74	809.09
2017-18	782.30	783.89	790.24	795.94	800.82	805.35	810.20	811.66	811.16	810.59	811.10	810.65
2018-19	792.02	797.28	800.79	810.10	811.68	811.28	811.47	811.07	809.52	810.32	810.19	809.90
Average	787.29	789.07	799.03	800.22	805.41	808.54	810.46	810.45	810.23	810.58	810.61	810.28
Rule curve	**788.51**	**790.29**	**810.16**	**810.16**	**810.16**	**810.16**	**811.68**	**811.68**	**811.68**	**811.68**	**811.68**	**811.68**

SHOLAYAR DAM - W L FROM 2000 TO 2018												
Year/Month	**December**		**January**		**February**		**March**		**April**		**May**	
	1F	**2F**	**1F**	**2F**	**1F**	**2F**	**1F**	**2F**	**1F**	**2F**	**1F**	**2F**
1999-00			804.53	800.89	797.09	793.85	791.51	789.23	787.94	786.77	786.85	784.17
2000-01	808.49	808.60	809.11	808.79	806.93	805.46	803.67	801.50	798.17	796.02	792.77	789.31
2001-02	808.18	806.58	804.63	802.25	800.04	797.37	794.15	790.55	788.48	787.29	784.36	783.04
2002-03	809.44	808.04	806.28	805.89	805.77	803.96	801.96	799.70	796.66	793.01	789.32	784.60
2003-04	810.23	810.40	808.87	807.13	805.00	802.50	799.76	797.25	794.59	791.15	789.04	789.00
2004-05	810.71	810.85	810.54	810.64	810.81	808.81	806.83	804.73	802.41	800.11	797.44	793.53
2005-06	809.85	809.20	809.30	810.78	811.29	809.67	807.57	804.99	801.55	798.80	796.30	793.56
2006-07	810.24	809.95	808.24	809.30	809.64	807.99	806.00	803.13	799.36	795.87	792.69	790.36
2007-08	811.18	810.45	809.63	808.66	807.22	805.28	803.39	801.65	799.85	796.93	793.37	789.26
2008-09	810.88	811.30	811.35	811.40	810.88	808.72	806.06	803.88	801.45	798.62	795.23	791.03
2009-10	811.31	811.08	811.09	811.35	810.97	809.31	807.53	805.35	803.01	800.54	797.99	794.74
2010-11	810.61	810.62	811.06	811.55	810.53	808.29	806.30	804.12	801.68	799.22	796.31	792.54
2011-12	810.52	810.37	811.29	811.58	810.80	809.06	807.18	804.98	802.64	800.23	797.69	794.33
2012-13	810.80	810.77	809.11	807.44	805.15	803.67	801.96	799.92	797.57	794.48	791.84	788.73
2013-14	811.05	811.42	811.25	810.92	810.60	808.79	806.95	804.27	800.37	796.05	792.45	787.57
2014-15	810.31	810.70	810.94	811.24	810.94	809.20	807.04	804.24	801.01	797.80	793.84	791.76
2015-16	806.47	807.29	808.93	809.05	807.38	806.18	804.25	801.96	800.05	797.39	793.99	790.30
2016-17	809.35	808.87	807.90	806.68	805.06	803.45	801.65	799.16	795.83	792.61	789.15	784.65
2017-18	810.75	810.50	810.25	809.28	807.85	806.28	804.43	802.23	799.61	797.02	794.65	792.38
2018-19	809.68	809.13										
Average	810.00	809.80	809.17	808.67	807.58	805.68	803.59	801.20	798.54	795.78	792.91	789.73
Rule curve	**811.22**	**811.02**	**810.39**	**810.16**	**811.68**	**806.90**	**804.81**	**802.42**	**799.76**	**797.00**	**794.13**	**790.95**

Table 2.5 Reservoir Water Levels

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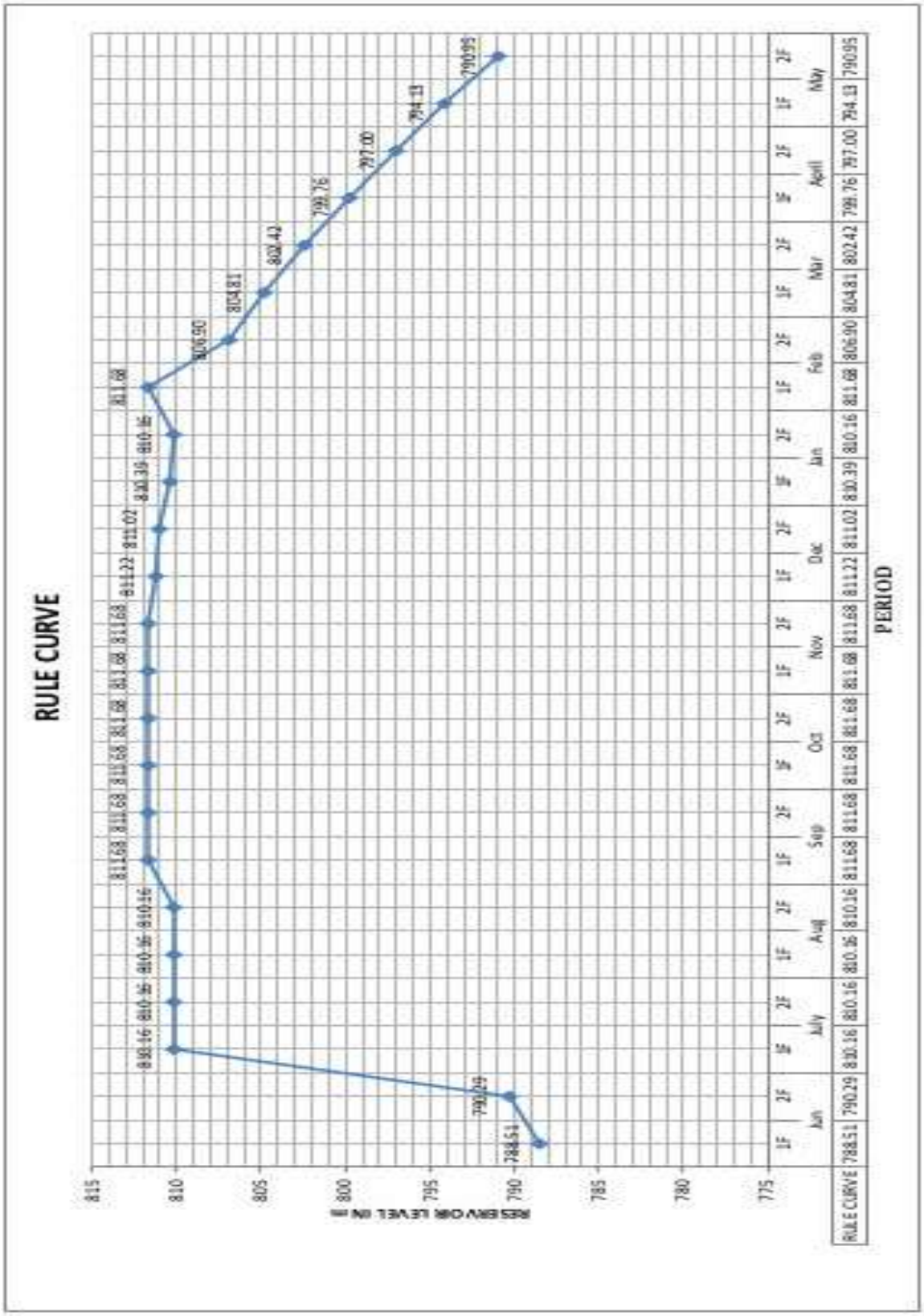


Fig 2.23 Rule curve

2.4.2 Safety Aspects

The spillway gates are operated step by step after assessing the reservoir water level and inflow and the sequencing is defined in **2.4.3.**

2.4.3 Flood Release Procedure

The flood water is released through spillway gates based on the operation manual of gates and flood routing studies attached in the hydrology review **Annexure 2**. There are five spillway gates. The sequence of operation of spillway gates is Gate no. 3, 2, 4, 1, 5 ie. The spillway gate No. 3 is operated first. Thereafter depending on requirement gates on either side of the central gate nos. 2 & 4 are opened. Spillway gates 1 & 5 are operated last. Further opening of gates, if required is done in the same way, keeping the difference in the openings of any two adjacent gates not more than 0.2m. Closing of gates is to be done in reverse order; the gate opened last being closed first.

2.4.4 Reservoir Capacities

Fig 2.24 Sholayar Reservoir

The Gross storage of the reservoir is 153.48 Million Cubic Meters and the effective Storage is 150.08 Million Cubic Meters at FRL of +811.68m.

2.4.5Inflow forecasting

The project was conceived based on the rainfall details from 1948 to 1953.The lowest rainfall recorded in the catchment during the period from 1948 to 1953 is 271.78 cm in 1952 while it is 403.86 cm in 1948 (both the figures are the average of the several rain gauge stations in the entire catchment area). The weighted average rainfall of the catchment for the above 6 years works out 321.31 cm. The average annual flow in the catchment of Poringalkuthu reservoir and Sholayar reservoir are assessed to be 1982.18 Mm^3 and 396.44 Mm^3 respectively from the rainfall data collected in the years 1948 to 1953.

Sholayar entire catchment receives the benefit of both the South west and North east monsoons. The South west monsoon sets in June and lasts till August. The heaviest rainfall is during the month of June and July. The North east monsoon strikes in October and continues till November. A heavy annual rainfall, a humid atmosphere and fairly uniform temperature throughout the year are the characteristics features of the basin.

Based on the recent flood, a flood forecasting method is proposed to be implemented. During years of heavy monsoon, incessant rains in the catchment area and releases from Upper Sholayar dam of Tamil Nadu are likely to cause flood in Sholayar River. These floods may lead to problems like people getting displaced from their homes, huge damage to crops and other assets. The floods can have disastrous impact on the environment also. Adequate measures are required to be taken up in advance to control and regulate the flow of water in the river. The regulation of flood water released from the upstream dam in Tamil Nadu is important and has an impact in Sholayar flood. The following measures are essential for effective management of floods in Sholayar River during the monsoons.

1) Nomination of liaising officers for respective reservoirs.
2) Sharing of Sub-basin wise directory of concerned officers responsible for flood management.
3) Exchange of data regarding rainfall, releases from dams, reservoir water levels.

4) Reservoir operation schedules.

5) Exchange of data regarding rainfall, releases from dams, reservoir water levels.

During monsoon, daily water releases from the Dams/Barrages at 8 hrs. & 16 hrs.in normal situation and hourly data exchange during heavy floods is necessary.

Flood warning system in catchment area: The regulation of flood from the dam on upstream of Sholayar reservoir is very crucial to quantify the inflow of floods into Sholayar dam. The dam operators of Upper Sholayar Project managed by Tamil Nadu and Kerala Sholayar dam shall work with good coordination and pass on information so as to assist in the flood forecasting. Accordingly, sequence of opening or closing of gates will be taken up in accordance with the approved gate operation schedule.

Flood communication system: The widely time tested Communication to reach every corner of the flood affected zones have been radio and television and private media for the people to move to safer places by themselves in an emergency. Communication is very important in such occasions. These days due to revolution in the telecommunication system, networks of mobile phones are widely available. Advantage of this facility will be taken. Mobile numbers of all officers and staff working in Dam operations wing, District Disaster Management, Revenue authorities will be listed and made available to all the personnel who have been assigned duty of disaster management. A satellite phone is provided at the dam site.

2.4.6 Methodology of Flood Regulation at Sholayar

2.4.6.1 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 Sholayar 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.

2.4.7 Summary of Flood Regulation Procedure

The flood regulation procedures at Sholayar can be summarized in the following 5 steps:

1. Observe the reservoir level at 1 hour intervals.
2. Determine the total outflow occurring at all outlets (including river outlet, spillway, power Intake)
3. Estimate the inflow
4. Determine the gate opening as the case maybe.
5. Open the required number of gates to the extent required to maintain constant reservoir level (i.e., release is equal to the inflow) as per the upper rule curve.

2.4.8 Emergency Operation

The purpose of Emergency Action Plan is to identify emergency situations that could threaten Sholayar Dams 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. will be provided in the detailed EAP document of Sholayar Dams.

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.

2.5 Power Generation

In the Power House, 3 vertical Francis type turbines each of 31000 HP coupled to 3 generators of 18000 KW capacity each are installed. The manufacturers are M/S Titovi Zavodi Litostroj, Yugoslavia.

2.6 Tunnel Intake arrangements

The intake arrangement comprises of:

1. Trash rack structure
2. A steel lined tunnel from the intake point to the intake shaft.
3. The intake shaft
4. Emergency gate and hoisting arrangements.

Trash rack structure is extended out into the river and from that point of the bell mouth, 28.49 m long, 3.20m dia. steel pipe starts. Beyond that there is 27.43 m long tunnel and there is a transition from tunnel section to rectangular section near the gate for a length of 6.10 m. At this point intake shaft is constructed vertically for a height of 46.63 m with the hoist chamber and control arrangements above it. The hoist is erected on the top slab of the hoist chamber constructed above intake shaft at El. +819.91 m. The hoist chamber is used for the maintenance of intake gate. There is a position indicator fixed to the hoist, which indicates the position of the gate from the sill.

Fig 2.25 Intake gate hoisting structure

Fig 2.26 Wire rope and motor in intake gate hoist chamber

As per the original design, only 10.20 m length of intake pipe was provided and orders were placed with M/S Thungabhadra Steel Product Ltd. But later on it was decided to push the intake structure 18.29 m more into the river and for that additional length, orders were placed with M/S Giovanola Binny Ltd. All the pipes were erected in position. For the steel lining, there is a bell mouth at the front which has got a size of 5.03 m x 14.81 m changing into 3.20 m circular shape at the rear. From that point the dia. of pipe is 3.20 m throughout. The steel lining has got a total length of 28.48 m.

2.6.1 Intake gate and Hoisting Arrangements

The order for the supply of intake gate and hoist was placed with M/S VOEST, Austria. The size of the gate is 2.87 m (span) x 3.96 m (height) suitable for the opening provided in the structure of size 3.66 m x 2.44 m. The sill level of the gate is +773.32 m and the hoist was erected at +825.70 m. The hoist is operated by an electric motor of 12KW at 725 rpm. Provision is given for operating the hoist manually in case of power failure and safety provisions are made to cut off power supply when manual operation is done. The lifting speed of the gate is 1.52 m per minute when electrically operated and 10.16 cm per minute when manually operated. The lowering speed under emergency which is by gravity is 2.44 m per minute. In emergency lowering the free drop of the gate is being stopped by a brake electrically operated. The gate by means of a gear operates a D.C. generator which produces available current according to speed of the fall and this actuates the brake. The details of intake gate hoist are provided in **Annexure 6**.

Fig 2.27 Intake Gate

2.7 Power Tunnel and Surge Shaft

The total length of high pressure tunnel from its mouth at the reservoir end to surge shaft is 710.49 m. It is having a horse shoe shape and a sectional area of 7.90sqm. The tunnel is designed to carry a maximum flow of 23.36 cumecs. The designed velocity of flow through the tunnel is 2.96 m/second. The level of the inlet of the tunnel at the intake is +773.32 m and there is general slope of 1 in 120 towards the surge shaft. Control of flow into the tunnel is achieved by an intake gate erected inside the intake shaft. The tunnel is lined with cement concrete to an average thickness of 20.32 cm for the sides and the bottom.

The surge shaft driven through rock has a diameter of 9.14 m at the bottom up to elevation +809.55 m and 15.24 m up to elevation +816.86 m. There is horizontal surge gallery of length 60.96 m and section area 13 sq.m. From the surge shaft the low pressure pipe line starts with its diameter 3.20 m and runs for a length of 71.32 m.

2.8 Penstocks

The water from the reservoir is diverted to the Power House at Anakayam Valley through the tunnel and through 3 penstocks, each leading the water to one of the turbines in the Power House. The penstocks are running in exposed conditions and are made of steel plates of thickness varying from 10 mm to 32 mm. The internal diameter of the penstocks is 1438 mm at the top, ie. at the point where the penstocks branches from the Trifurcation piece and is 1312 mm dia. at the Power House end. Penstocks supply water under pressure at an average head of 320.04 m and form the link between the fore bay and the Power Station.

Fig 2.28 Penstock and valve house

2.9 Initial Filling of Reservoir

The initial filling of the reservoir was carried out during 1965.

2.10 Power House

The Power House is located at the right bank of the Anakayam stream, a tributary of Chalakudy river. It is located at the bottom of the ridge through which the penstock is taken. 3 Vertical Francis type turbine each of 31000 HP coupled to 3 generators of 18000 KW

capacity each are installed in the Power House. Size of the Power House is 50.29 m x 14.02 m x 16.76 m. The maximum head on turbines is 339.24 m.

The first unit was commissioned in May 1966, though the benefits of the scheme have actually been started to be enjoyed with partial storages of the reservoir during the previous two seasons for generation of additional power in the Poringalkuthu Power Station.

Fig 2.29 Power House

Fig 2.30 Power House Turbine

Fig 2.31 Power House Control panels

2.10.1 E.O.T. Crane at Power House

The E.O.T. crane has got a main hook of 75 ton capacity and an auxiliary hook of 10 ton capacity. The crane booms are fixed on end carriages which are resting over the crane rails fixed on wooden sleepers. The centre to centre distance between the crane rails is 12.882m. The booms are of box type with rails on the top on which the carriage can move.

A hand operated 20 ton crane is provided outside the Power House for handling of the spherical valves. This crane is running on the runway rails fixed over the gantry girders erected on the top of the columns on the hill side of the Power House. The crane is capable of moving for a length of 31.70 m to command the three spherical valves.

2.11 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 dam 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.

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 are sent to higher offices. The current practice of Inspection at Sholayar dam envisages that the Deputy Chief Engineer along with Executive Engineer of the project shall carryout pre-monsoon and post-monsoon inspections as per CWC guidelines in the format issued by CWC. The Chief Engineer will review the inspection report and submit to CWC. The Executive Engineer of the Project will also conduct quarterly inspections and will prepare health reports as per KDSA. The format to be followed as per CWC has been revised during January 2018 and new guidelines have been issued vide Doc No. CDSO_GUD_DS_07_ v1.0, CWC 2018 for Safety Inspection of Dams. The health reports of the dam are to be prepared in the new format meant for incorporating the data 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 required to be carried out at Sholayar 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.

Guidance for carrying out other inspections is elaborated in the following paras:

3.1 Types of inspections

Four types of dam safety inspections could be carried out at Sholayar 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 (Unscheduled) 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 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 also 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 Sholayar 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 including.

2. Inspection of the dam and its appurtenant works.
3. To review the results and reports of additional field investigations & laboratory testing as required.
4. Review of design studies, review of design flood, checking of the adequacy of Spillway capacity, freeboard requirements, dam stability and any special study as required.
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 and recommendation regarding remedial measures
- Dam incidents and reservoir filling details

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 Organization/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 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 Reporting Proforma

Detailed checklists are to be followed to ensure evaluation of 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.DS07 v 1.0, CWC 2018 on the Guide lines for Safety Inspection of Dams **(Annexure 3)**.

Performance of Dam instruments

Sl No	Name of Dam with location	Name of instrument	No of instruments	Performance	Status of data analysis	Remarks
1	2	3	4	5	6	7

Table 3.1 Proforma for performance of Dam instruments

The officers responsible for undertaking the Pre & Post Monsoon Inspections are as under:

i) Assistant Exe Engineer in-charge of dam ii) Executive Engineer in-charge of dam iii) Dy. Chief Engineer in-charge of dam.

The information in regard to above inspection would be supplied to the Chief Engineer of the Project for further co-ordination with the concerned departments and district Authorities.

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 relevant files or data, 2) visual inspection, and 3) report preparation.

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 especially 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 Sholayar 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 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 based on manual of operating parts, frequent inspections, priority, and interval is attached as **Annexure 8**. 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 clarified 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 is about to be breached by erosion, slope failure etc.
- A dam showing signs of failure due to aging/cracking, sliding, overturning etc.
- The dam showing signs of piping or internal erosion along shear zones, faults etc. indicated by increasingly cloudy seepage or other symptoms.

- 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 surface and restoring any eroded areas.
- 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 the upstream face of masonry dams, in case the pointing is damaged, due to which there is increased seepage.
- Controlling any heavy seepage in the foundation/ inspection galleries in Concrete/Masonry dams from drainage holes.
- Repairs of any cracks/cavities/joints in concrete/masonry 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, comparing the quantity and quality (clarity) with earlier 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 e. g. Servicing of spillway gates, hoisting arrangements and gates/hoist of Intake and outlet works & stand by generator.
- Maintaining proper lighting at dam top, galleries of the dam etc.
- Monitoring of seepage in foundation galleries of masonry/ concrete dams.
- Monitoring/ cleaning & removal of leached deposits in porous concrete / formed drains in dam body and foundation drainage holes of masonry/ concrete dams.
- Maintenance of all dam roads & access roads.
- Operation of electrical and mechanical equipment and systems including exercising gates & valves.
- 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 fencing or barricades. Any damages are repaired as soon as possible. Also vehicles are to be permitted only after security checking at check posts.

4.3.2 Controlling Vegetation

Removal of vegetation around the dam and its premises is done atleast2 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, unsymmetrical 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.
- Status of rectification works undertaken from time to time need to be assessed during periodic maintenance.
- 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.

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

4.3.4 Outlet Works

Proper care and maintenance of the equipment is the most important factor in increasing the reliability of operation and life of the equipment. Following are a few important points which need attention.

1. Lubrication of moving parts

All moving parts of the equipment are to be periodically lubricated.Lubrication schedule/chart is attached below for reference. During lubrication of all open gears, it must be noted that they are not in operation and there is no foreign materials/dirts on the surfaces to be lubricated.

2. Lubrication chart

Sl. No.	Item	Recommended grade	Periodicity	Remarks
1.	Worm reducers of hoist	Servo Gear SM-90 of IOC or equivalent	Once in every year	Regular check or oil level is to be made and replenish with oil if necessary
2.	Hoists and other grease nipples	Servo Gear 2/3 of IOC or equivalent	Once in every three months	
4.	All pinion and gear wheels, guide shoes in the gate elements and lifting rollers	Servo Grease 'C' of IOC or equivalent	Once in every three months	
5.	Wire rope	Cardium compound	Once in every year, preferably before the onset of monsoon	

3. Preventive maintenance

While designing and manufacturing the equipment, sufficient care has been taken to use the correct materials and manufacturing process to avoid break down during operation.

a) Electro Magnetic Brakes

Worn out brake linings are to be replaced immediately.

b) Lifting Beam

For proper functioning of the lifting beam, lubrication of pins on the hook is a must. By properly greasing the pins, the hooks shall be free to oscillate without much effort. All wheels of the lifting beam are also to be lubricated. The operator is to ensure that both the hooks, are free to rotate for every successive operation.

c) Guide Shoe

Check the bolts and nuts periodically.

d)	Painting		
i)	Gates	-	All gates are to be properly repainted with two coats of Blend Epoxy Resin Paint once in every year. If any rusting is noticed, the rusted area is to be thoroughly cleaned and one coat of zinc rich primer is to be applied before applying epoxy paint.
ii)	Hoists	-	All parts of hoists are to be properly repainted with two coats of Aluminum paint once in every two years and this shall be done .preferably before the on set of monsoon.

Under water inspection of the trash rack provided in the outlet arrangement has to be done periodically and cleaning has to be carried out as and when required to remove the trashes trapped in the trash rack.

4.3.5 Power Tunnel &Trash Racks

The Power Tunnel is having an Intake gate with hoisting arrangement. The hoist is operated by an electric motor of 12KW at 725 rpm. Provision is given for operating the hoist manually in case of power failure. The lifting speed of the gate is 1.52 m per minute when electrically operated and 10.16 cm per minute when manually operated. The lowering speed under emergency which is by gravity is 2.44 m per minute. In emergency lowering the free drop of the gate is being stopped by a brake electrically operated. The gate by means of a gear operates a D.C. generator which produces available current according to speed of the fall. This actuates the brake.

Under water inspection of the trash rack provided in front of the Intake of Power tunnel has to be done periodically and cleaning has to be carried out as and when required to remove the trashes trapped in the trash rack.

4.3.6 Emergency Gate

An outlet arrangement is provided in Sholayar Main dam at elevation +768.10 m. The outlet has usual emergency gate and hoists and a jet disperser. The hoist is erected at elevation +812.67 m with capacity of 20 tons for operating the gate. The hoist consists of electric motor, solenoid brake and a rope drum. The Operation and Maintenance Manual of Emergency gate is given in **Annexure 6.**

4.3.7 Spillway Radial Gates & Hoisting Equipment

Sholayar Flanking Dam has 5 Radial gates for the spillway. Hoisting arrangements consist of a central drive and two lateral drives coupled by pipe shafts. The central drive has spur type reduction gear, self-arresting worm gear, a double shoe brake with electro hydraulic control device. The hoist can be either electrically or manually operated.

The safe and satisfactory operation of Sholayar Flanking 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 shows 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 gates manufacturer's would however govern the overall maintenance of Gate and Hoists whenever there is any contradiction with the inspections 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 smoothened, 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 without delay.

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 other 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. Appropriate action to replace the damaged seal needs to be taken immediately after monsoon. 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.

a) 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.

b) 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.

4.3.8 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.

4.3.9 Maintenance of Electrical components of Fixed Rope Drum Hoists

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 contactor 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 contactor 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 contactor closes, free of dust or grease of any kind.

vii) Examine the mechanical interlocks between the reversing contactor and see when the contact tips of one of the contactor 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) 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.

xii) Examine earth connections and motor leads.

xiii) Examine motor windings for overheating

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 windings or by placing the stator and rotor only in a warm dry place for a day or so.

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

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.

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.

4.3.10 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.

4.3.11 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.

4.3.12 Access Roads

For a dam to be operated and maintained, there must be a safe means of access to it at all times. 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. If unstable conditions / slope failure etc. develop, assistance of experienced Engineers/Expert Panels should be arranged and remedial measures initiated. Drains are

required to be provided and maintained along roads to remove surface and subsurface drainage. This will prolong the life of the road and help reduce deterioration from rutting. Road surfacing should be repaired or replaced as necessary to maintain the required traffic loadings. In most cases, specialized contractors will be required to perform this maintenance.

4.3.13 General Cleaning

As already suggested, for proper operation of spillways, sluiceways, approach channels, energy dissipation arrangements, discharge conduit, 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 a horizontal gallery. The dam top road and this gallery are to be cleaned regularly.

4.4 Materials and Establishment Requirements during Monsoon

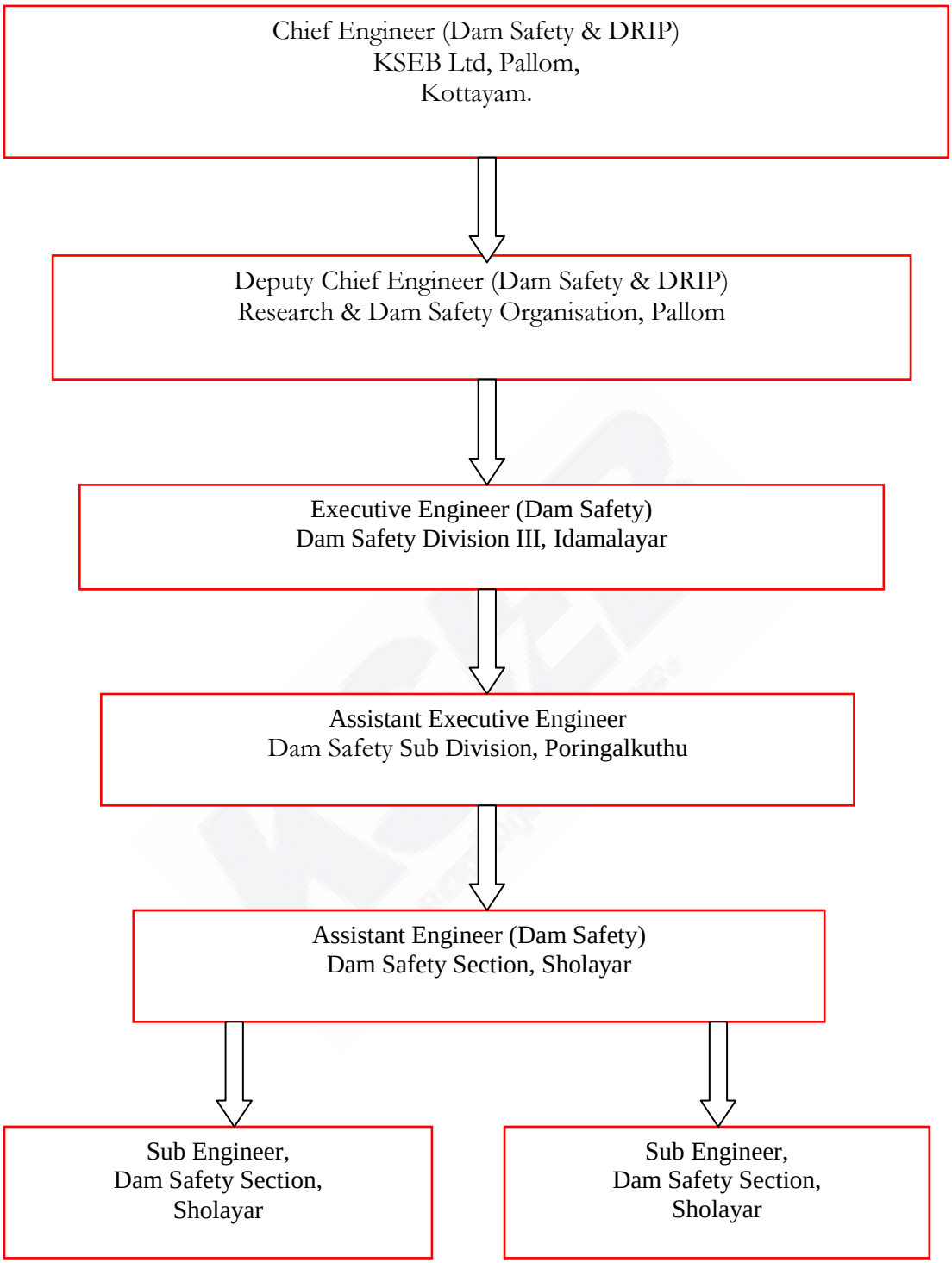
Materials required during monsoon period for both immediate maintenance and preventive maintenance must be stocked in adequate quantities for emergency situations that may arise.

Materials normally required to be stocked in sufficient quantity are:-

- Gunny Bags
- Sand
- Boulders/Wire crates
- Bamboos/Balli's
- Baskets
- Ropes
- Petro max Lamps with Spares
- Torches with spare cells
- Kerosene Oil
- Match Boxes
- Rain Coats

- Gum Boots
- Warning sign indicator
- Danger zone lights

At Sholayar Dam, round the clock patrol is to be carried out during monsoon period. At the same time the man-power requirements during monsoon period are to be enhanced. An Organisation Structure of the Control Unit for normal as well as for monsoon period is given as under:


Chief Engineer (Dam Safety & DRIP)
KSEB Ltd, Pallom,
Kottayam.
Deputy Chief Engineer (Dam Safety & DRIP)
Research & Dam Safety Organisation, Pallom
Executive Engineer (Dam Safety)
Dam Safety Division III, Idamalayar
Assistant Executive Engineer
Dam Safety Sub Division, Poringalkuthu
Assistant Engineer (Dam Safety)
Dam Safety Section, Sholayar
Sub Engineer,
Dam Safety Section,
Sholayar
Sub Engineer,
Dam Safety Section,
Sholayar

4.5 Preparation of O&M budget

The O&M budget for Sholayar Dams 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 – 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 – Rent for Office, Telephone/Mobile/ any other Telecommunication bills, Electricity bills, Water bills, Office stationaries 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.

SL. NO.	BUDGET ITEM	PREVIOUS YEAR COST (Rs)	CURRENT YEAR BUDGET (YR _____) (Rs)	REMARKS
A. ESTABLISHMENT				
1	SALARY OF REGULAR STAFF INCLUDING ALL OTHER BENEFITS			
2	TRAVEL EXPENSES			
3	OFFICE EXPENSES			
4	MOTOR VEHICLE EXPENSES			
5	MAINTENANCE OF OFFICE & COLONY COMPLEX			
	SUB-TOTAL - A			
B. WORKS				
1	**CIVIL**			
1.1	CONCRETE / MASONRY DAM			
1.2	EARTHEN DAM			
1.3	INTAKE / OUTLETS IN EARTHEN DAMS			
1.4	SLUICES IN CONCRETE / MASONRY DAMS			
1.5	APPROACH / INSPECTION ROADS WITHIN DAM AREA			
2	**HYDRO-MECHANICAL**			
2.1	SPILLWAY GATES & HOISTS			
2.2	SPILLWAY STOP-LOG & GANTRY CRANE			
2.3	OUTLETS IN EARTHEN DAMS - SERVICE / EMERGENCY GATES & HOISTS			
2.4	SLUICES IN CONCRETE / MASONRY DAMS – SERVICE / EMERGENCY GATES & HOISTS			
3	**ELECTRICAL**			
3.1	ELECTRICAL FITTINGS, MOTORS, CONTROLS FOR ALL GATE HOISTS			
3.2	POWER SUPPLY LINES			
3.3	ELECTRICAL FITTINGS ON DAM TOP, DAM GALLERIES, ETC			
3.4	STANDBY POWER / DIESEL GENERATOR			
3.5	REMOTE CONTROL/CCTV			

4	**INSTRUMENTATION**			
5	**MISCELLANEOUS WORKS**			
6	**SALARY OF WORK- CHARGED STAFF INCLUDING ALL BENEFITS**			
7	**MATERIALS TO BE STORED BEFORE MONSOON**			
	SUB-TOTAL - B			
8	**CONTINGENCY (10%) ON SUB-TOTAL OF A & B**			
9	**TOOLS & PLANTS**			
	SUB-TOTAL- C			
10	**TOTAL ANNUAL COST**			

Table 4.1 O&M Budget Costs (Annual)

4.6 Maintenance Records

Maintenance 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
- 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

The instruments installed and present status of functioning are appended below.

5.1.1 A Sholayar Flanking Dam

LIST OF INSTRUMENTATIONS INSTALLED IN SHOLAYAR FLANKING DAM		
Sl. No.	**Name of Instruments**	**Total No installed**
1	V – notch	1
2	Pressure gauge	1

Table 5.1 Instrumentation present status in Flanking Dam

5.1.2 A Parameters monitored

Uplift Pressure

Pressure gauge is installed in the gallery for measuring uplift pressure**.**

Water Level

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

Seepage Flow

Seepage is measured with V notches

Frequency of Monitoring

Water level is monitored daily and the instruments readings are taken monthly. Spillway details are included in **Chapter 2**.

Seepage assessment

In Sholayar Flanking Dam, there are 20 Periphery Holes and 20 Foundation Drain Holes. Monthly observations of these holes are being carried out. Total seepage is measured using V-notch fitted in the foundation gallery. Seepage details for the years 2016, 2017 and 2018 are tabulated below.

Date	Reservoir Water Level (m)	V notch reading (cm)	Discharge (Litres/min)
25-01-2016	809.06	3.10	8.282
25-02-2016	805.89	2.60	5.336
23-03-2016	801.90	0	0
29-04-2016	796.08	0	0
23-09-2016	807.72	8.50	103.11
26-10-2016	809.52	6.00	43.165
24-11-2016	809.09	4.40	19.879
23-12-2016	808.85	3.80	13.779

28-01-2017	806.32	2.80	6.422
28-02-2017	802.54	2.00	2.769
31-03-2017	797.36	0	0
29-04-2017	790.96	0	0
24-05-2017	784.56	0	0
09-06-2017	784.71	0	0
25-07-2017	796.59	0	0
22-08-2017	805.01	3.00	7.631
19-09-2017	811.68	6.40	50.723
24-10-2017	810.37	5.00	27.364
28-11-2017	810.80	5.30	31.655
28-12-2017	810.59	4.00	15.664
28-01-2018	808.88	2.80	6.422
23-02-2018	806.17	2.10	3.128
26-03-2018	801.93	0.50	0.087
26-04-2018	796.50	0	0
28-07-2018	811.69	6.00	43.165
28-09-2018	809.00	4.00	15.664
28-10-2018	810.68	4.20	17.696
30-11-2018	809.82	4.10	16.661
07-12-2018	809.73	4.10	16.661

Table 5.2 Seepage Details in Flanking Dam

5.1.1 B Sholayar Main Dam

LIST OF INSTRUMENTATIONS INSTALLED IN SHOLAYAR MAIN DAM		
Sl. No.	**Name of Instruments**	**Total No installed**
1	V – notch	2
2	Pressure gauge	1

Table 5.3 Instrumentation present status in Main Dam

5.1.2 B Parameters monitored

Uplift Pressure

Pressure gauge is installed in the gallery for measuring uplift pressure.

Seepage Flow

Seepage is measured with V notches

Frequency of Monitoring

Instrument readings are taken monthly.

Seepage assessment

In Sholayar Main Dam, there are 90 Periphery Holes and 76 Foundation Drain Holes. Monthly observations of these holes are being carried out. Total seepage is measured using V-notches fitted in the foundation gallery. Seepage details for the years 2016, 2017 and 2018 are tabulated below.

Date	Water Level (m)	V - notch readings (cm)		Discharge Litres/min		
		in Block no V	in Block no VII	in Block no V	in Block no VII	Total
25.01.2016	809.06	8.10	7.10	91.404	65.751	157.155
25.02.2016	805.89	6.60	4.90	54.779	26.016	80.795
23.03.2016	801.90	3.20	5.00	8.967	27.364	36.331
29.04.2016	796.08	2.50	3.60	4.837	12.037	16.874
23.09.2016	807.72	15.80	9.00	485.731	118.949	604.680
26.10.2016	809.52	3.20	9.30	8.967	129.110	138.077
24.11.2016	809.09	9.10	8.80	122.280	112.450	234.731
23.12.2016	808.85	8.10	12.10	91.404	249.297	340.701
28.01.2017	806.32	6.60	10.20	54.779	162.650	217.429
28.02.2017	802.54	5.90	9.60	41.389	139.776	181.165
31.03.2017	797.36	4.30	8.40	18.768	100.104	118.872
29.04.2017	790.96	2.30	1.70	3.927	1.844	5.772
24.05.2017	784.56	2.20	1.00	3.514	0.490	4.004

09.06.2017	784.71	2.20	1.40	3.514	1.135	4.649
25.07.2017	796.59	3.10	2.00	8.282	2.769	11.051
22.08.2017	805.01	6.40	7.00	50.723	63.460	114.183
19.09.2017	811.68	11.40	13.30	214.791	315.779	530.569
24.10.2017	810.37	8.50	9.50	103.110	136.164	239.274
28.11.2017	810.80	8.80	9.30	112.450	129.110	241.560
28.12.2017	810.59	8.50	8.00	103.110	88.609	191.719
28.01.2018	808.88	6.10	6.80	44.986	59.024	104.010
23.02.2018	806.17	5.00	5.20	27.364	30.183	57.547
26.03.2018	801.93	3.70	3.90	12.890	14.703	27.593
26.04.2018	796.50	3.00	1.80	7.631	2.128	9.758
28.07.2018	811.68	9.80	11.50	147.170	219.532	366.702
28.09.2018	809.00	7.20	7.50	68.090	75.406	143.496
28.10.2018	810.68	7.00	8.30	63.460	97.151	160.611
30.11.2018	809.82	8.80	8.50	112.450	103.110	215.560
07.12.2018	809.73	8.00	8.20	88.609	94.251	182.861

Table 5.4 Seepage Details in Main Dam

Water Quality

The quality of water including pH value is tested monthly at Regional Analytical laboratory, Ernakulam.

Seismic Activity

There is no Seismic observatory installed at Sholayar Dam.

Weather Conditions

Now the rainfall data are measured with rain gauges. But a full equipped weather station can sense all weather conditions. Automated weather station is needed.

5.2 Data Processing and Evaluation

The monthly reports are prepared for evaluation done.

5.2.1 Data Collection

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

5.2.2 Data Presentation

On monthly basis.

5.2.3 Data Interpretation

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

5.2.4 Data Processing & 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.

5.2.5 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

5.3 Methods of Behavior Prediction

5.3.1 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 d/s face of dam, seepage from foundation gallery etc.

5.3.2 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 behaviour needs to be resolved critically by taking required remedial measures in consultation with senior / experienced engineers.

Comparison of seepage measurements for different years in Flanking dam

WL (m)	Seepage (lit/min)	WL (m)	Seepage (lit/min)	WL (m)	Seepage (lit/min)	WL (m)	Seepage (lit/min)	WL (m)	Seepage (lit/min)
Jan-2014		Jan-2015		Jan-2016		Jan-2017		Jan-2018	
810.55	13.779	811.07	19.879	809.06	8.282	806.32	6.422	808.88	6.422
Apr-2014		Apr-2015		Apr-2016		Apr-2017		Apr-2018	
794.16	0	796.93	0	796.08	0	790.96	0	796.50	0
Jul-2014		Jul-2015		Jul-2016		Jul-2017		Jul-2018	
799.86	0	792.48	0			796.59	0	811.69	43.165
Oct-2014		Oct-2015		Oct-2016		Oct-2017		Oct-2018	
811.29	21.027	810.10	13.779	809.52	43.165	810.37	27.364	810.68	17.696

Comparison of seepage measurements for different years in Main dam

WL (m)	Seepage (lit/min)	WL (m)	Seepage (lit/min)	WL (m)	Seepage (lit/min)	WL (m)	Seepage (lit/min)	WL (m)	Seepage (lit/min)
Jan-2014		Jan-2015		Jan-2016		Jan-2017		Jan-2018	
810.55	121.11	811.07	123.207	809.06	157.155	806.32	217.429	808.88	104.01
Apr-2014		Apr-2015		Apr-2016		Apr-2017		Apr-2018	
794.16	0.455	796.93	34.393	796.08	16.874	790.96	5.772	796.50	9.758

Jul-2014		Jul-2015		Jul-2016		Jul-2017		Jul-2018	
799.86	11.145	792.48	13.804			796.59	11.051	811.68	366.702
Oct-2014		Oct-2015		Oct-2016		Oct-2017		Oct-2018	
811.29	262.754	810.10	185.76	809.52	138.08	810.37	239.274	810.68	160.611

Table 5.5 Comparison of seepage measurements

Chapter 6

REHABILITATION WORKS UNDER DRIP

The rehabilitation works carried out under DRIP include

1. Pressure washing, chipping and removing calcinated materials on the downstream face of Sholayar main dam
2. Constructing new security cabin at main dam.
3. Construction of office building and new security cabin near Sholayar Flanking dam.
4. Providing chipping carpet for road to dam and gallery.
5. Providing wearing coat on the top roadway of main dam and Flanking dam at Sholayar
6. Providing fencing at Sholayar dam premises.
7. Providing stone pitching on the downstream face of Sholayar Saddle dam.
8. Replacing damaged rubber seals of radial gate of Flanking Dam and Painting the gate.
9. Pressure washing, chipping and removing of calcinated materials to the downstream face of Flanking dam.
10. Laying power cable from Generator to control gates at Sholayar dam.
11. Construction of seepage collecting drain at Sholayar Main dam & Providing steel mesh for gallery outlets to prevent bats at Sholayar dam.
12. Painting the parapet, Disperser valve and other connected structures of Main dam.
13. Construction of access steps to downstream side of Sholayar Main dam.
14. Construction of catwalk way across the spillway gate pillars.
15. Replacement of guides of emergency gate at Sholayar main dam.
16. Consultancy Services for Geophysical Investigation Studies for the Analysis of Seepage in Sholayar Dam (Main dam and Flanking dam) to Identify the Root Cause of Seepage and to Recommend Remedial Measures to Control Seepage.
17. Providing UG cabling systems including fixing of generator, switchboard, distribution board etc. at Sholayar dam and premises.
18. Supply and commissioning of high mast light with cost effective lightening system with accessories at Sholayar main dam.

19. Supply and commissioning of high mast light with cost effective lightening system with accessories at Sholayar flanking dam.
20. Reaming the existing drain holes at Sholayar Main dam & Flanking dam.
21. Supply of speed boat at Sholayar dam.
22. Providing and fixing retro reflective sign boards.

Fig 6.1 Flanking Dam before construction of catwalk

Fig 6.2 Flanking Dam after construction of catwalk

Fig 6.3 Emergency gate guides before replacement

Fig 6.4 Emergency gate guide after replacement

Fig 6.5 UG cabling systems

Fig 6.6 Retro reflective sign boards

Fig 6.7 D/s face of main dam before pressure washing

Fig 6.8 D/s face of main dam after pressure washing

Fig 6.9 Access steps constructed

Fig 6.10 Office building constructed

Fig 6.11 Security guard room constructed

Fig 6.12 Flanking dam – road work

Fig 6.13 Fencing 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 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 1

BASIC DRAWINGS

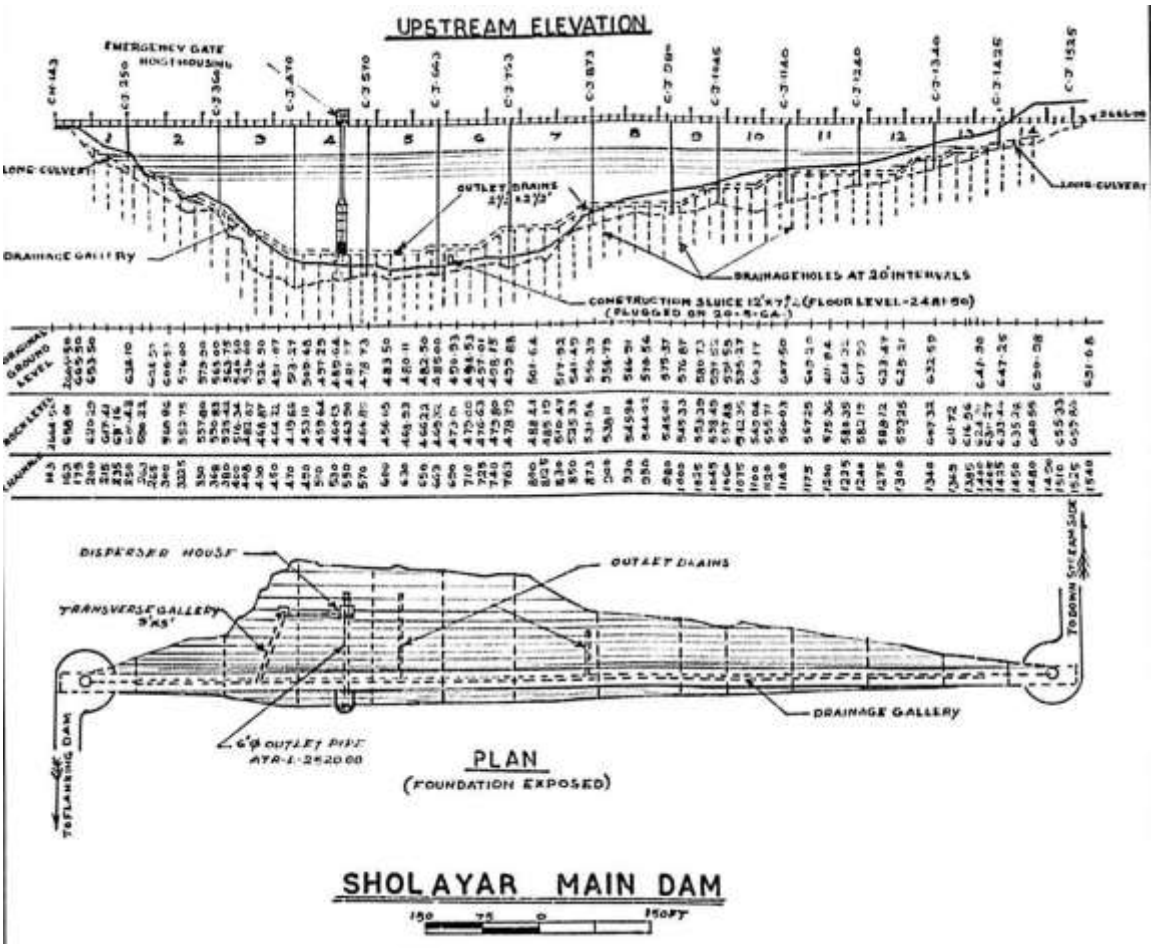


Fig 1 Plan and Up Stream Elevation of Main Dam

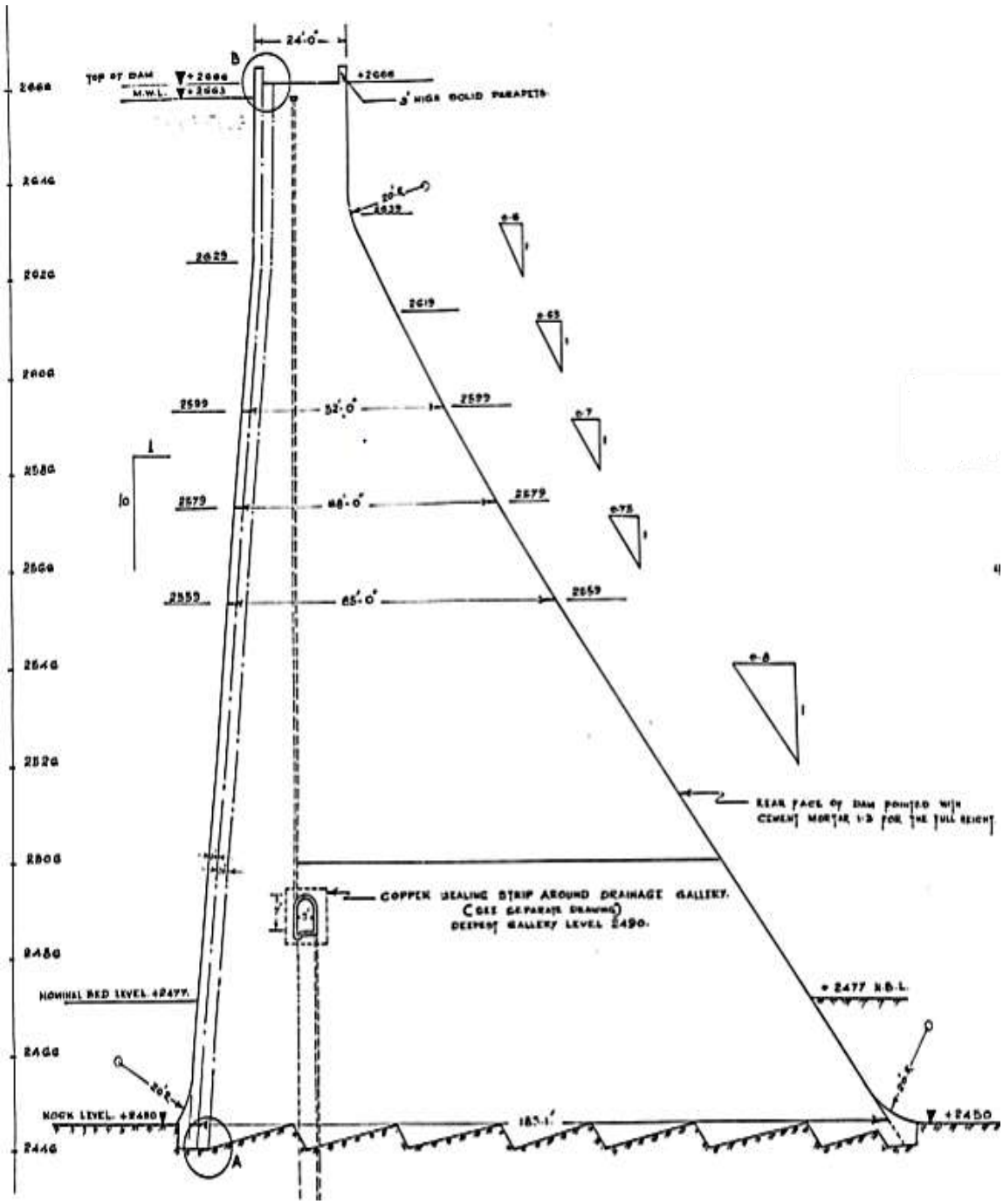


Fig 2 Section of Main Dam

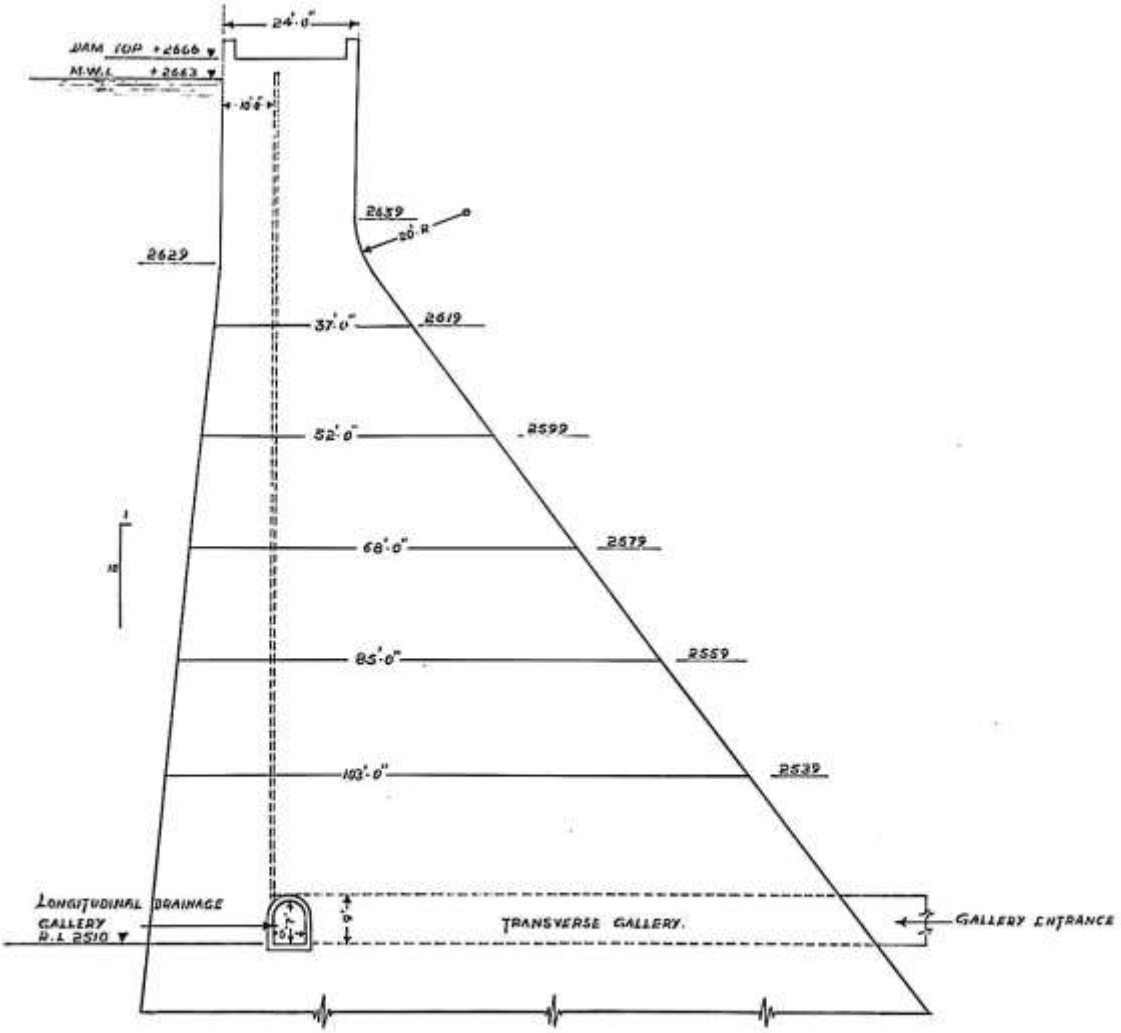
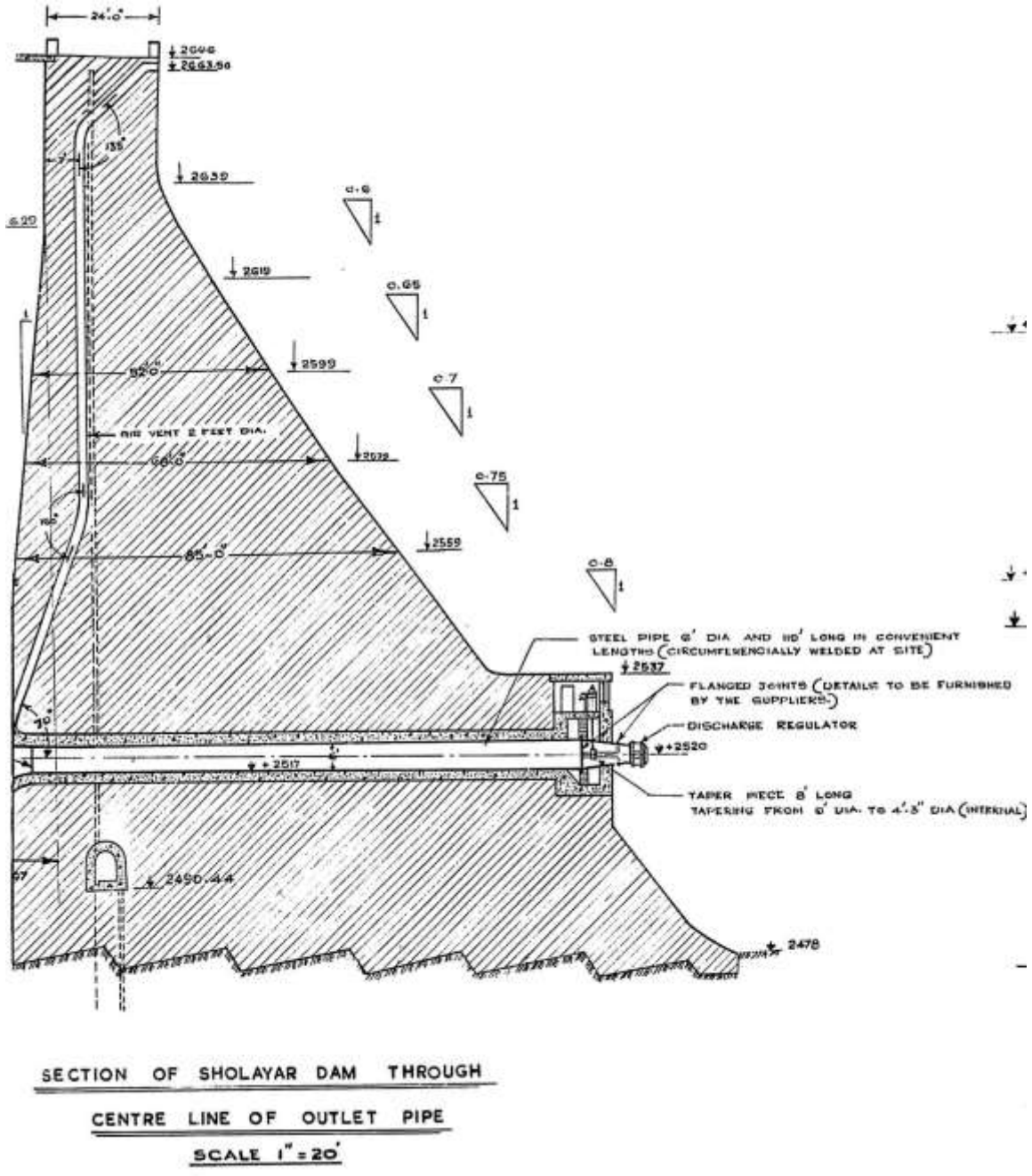


Fig 3 Section of Main Dam showing position of gallery entrance



SECTION OF SHOLAYAR DAM THROUGH CENTRE LINE OF OUTLET PIPE
SCALE 1" = 20'

Fig 4 Section of Main Dam through centre line of outlet pipe

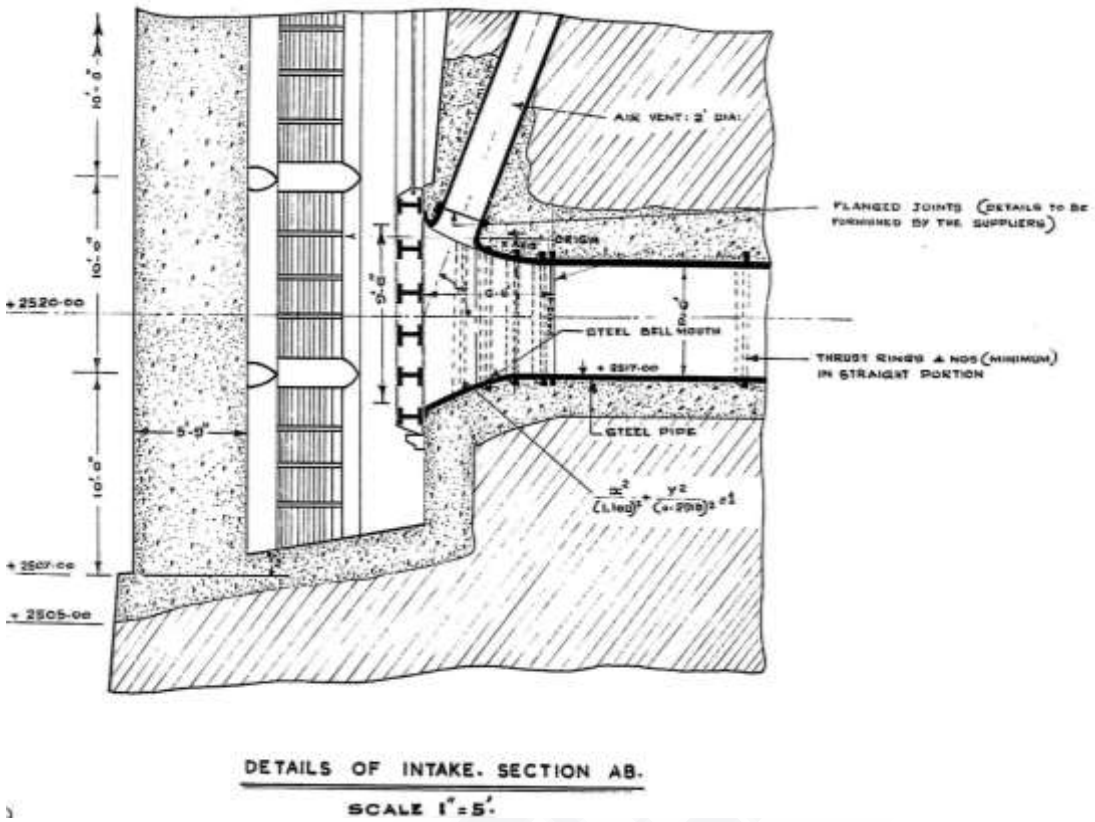


Fig 5 Details of intake at Main Dam

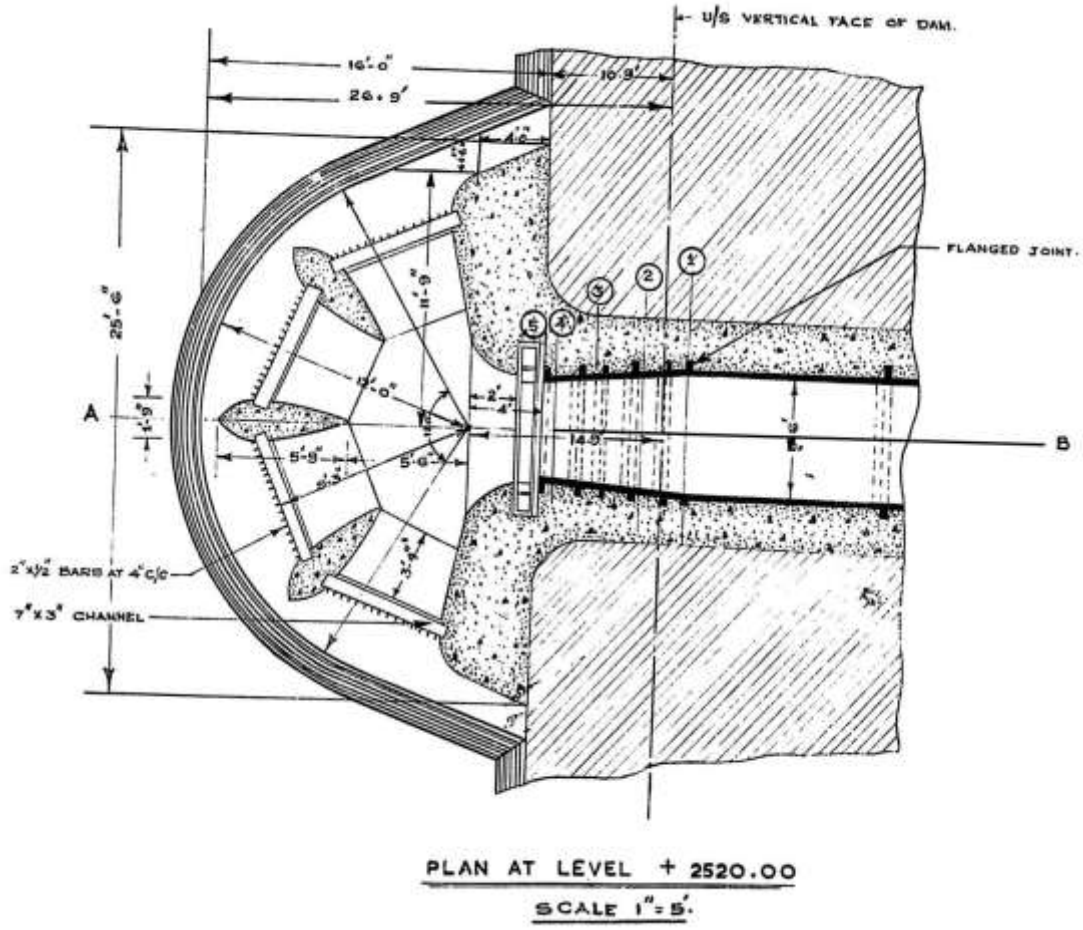


Fig 6 Plan of Trash rack of intake at Main Dam

SHOLAYAR FLANKING DAM

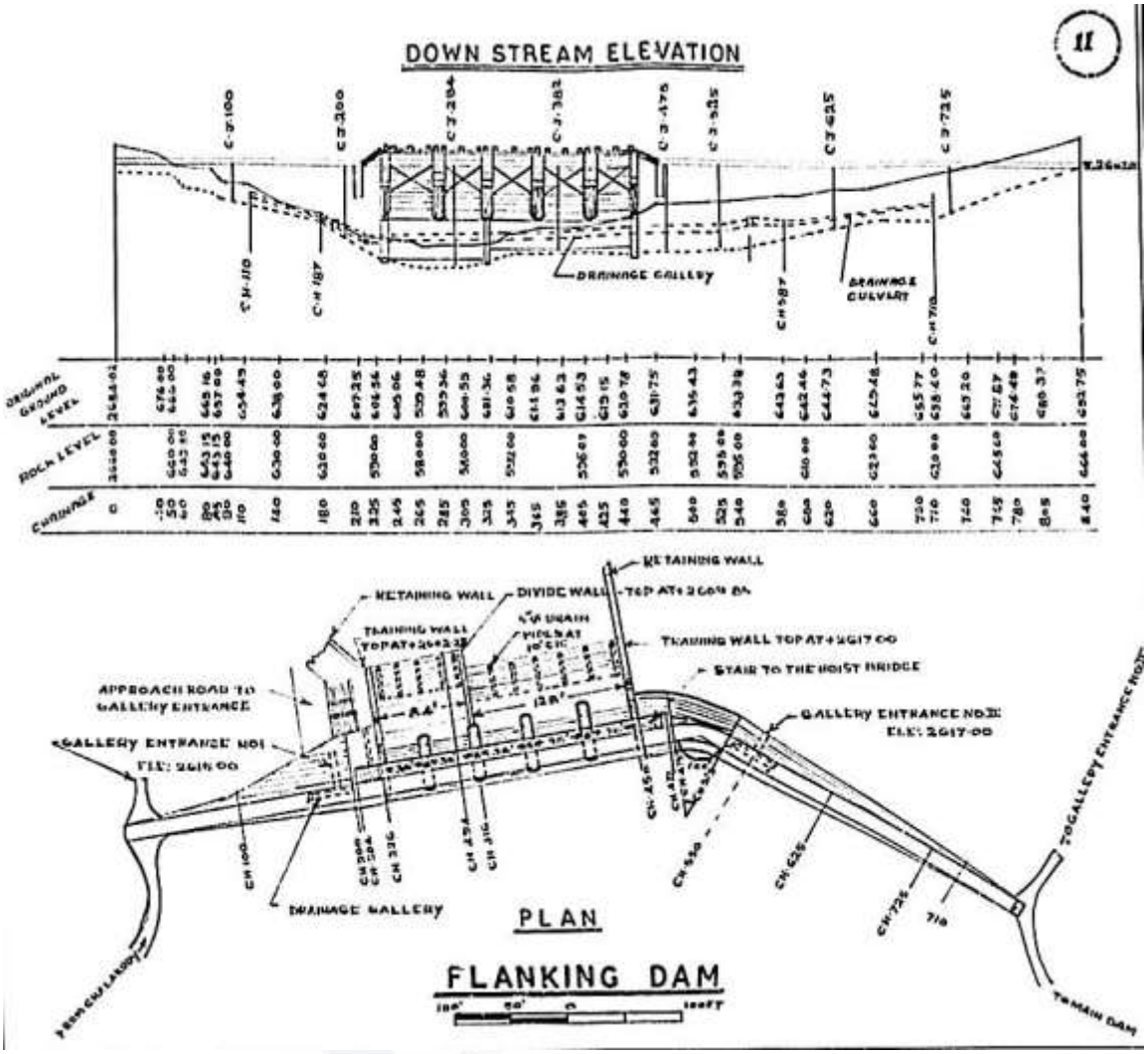


Fig 7 Plan and Down Stream Elevation of Flanking Dam

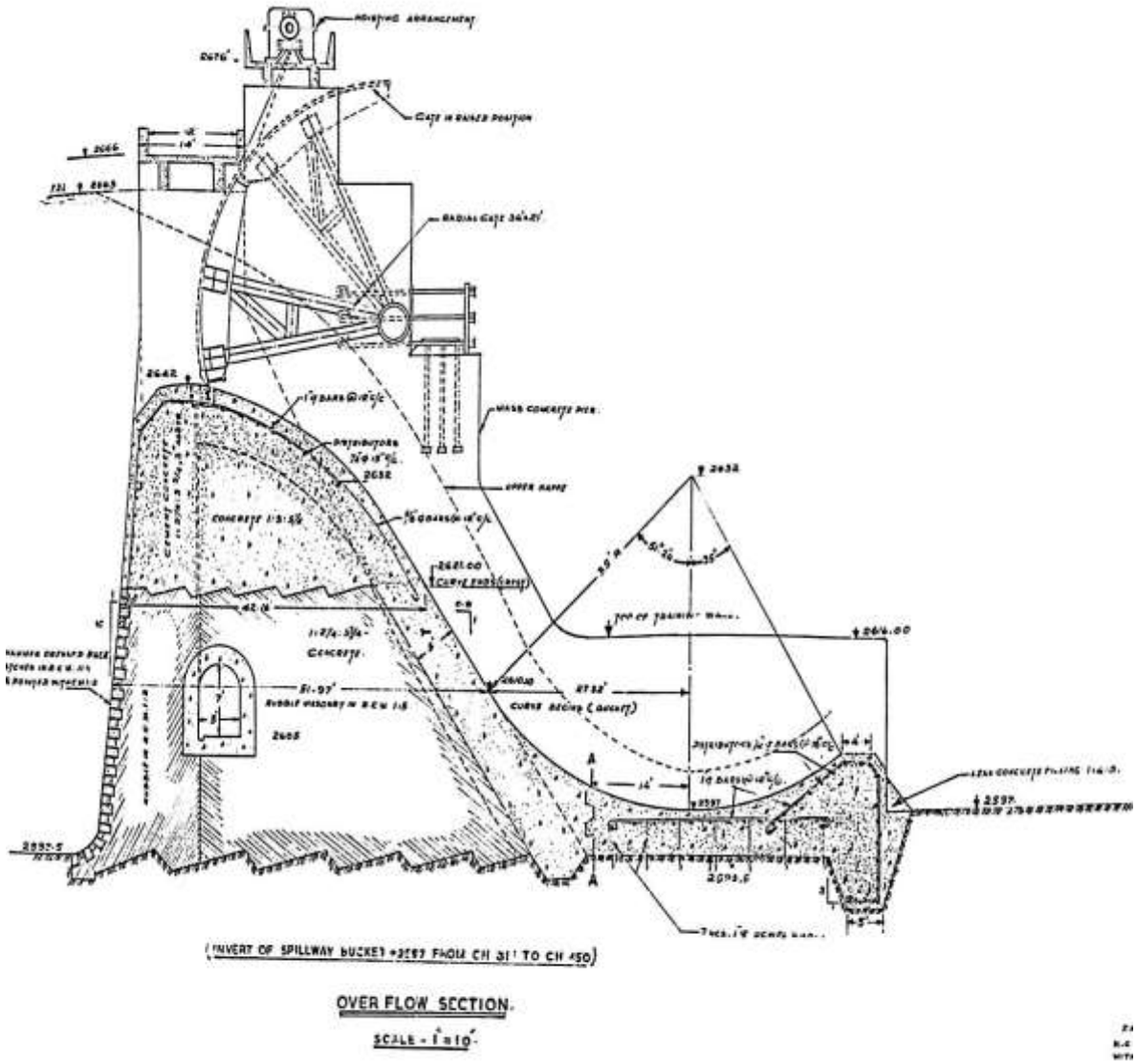


Fig 8 Overflow section of Flanking Dam

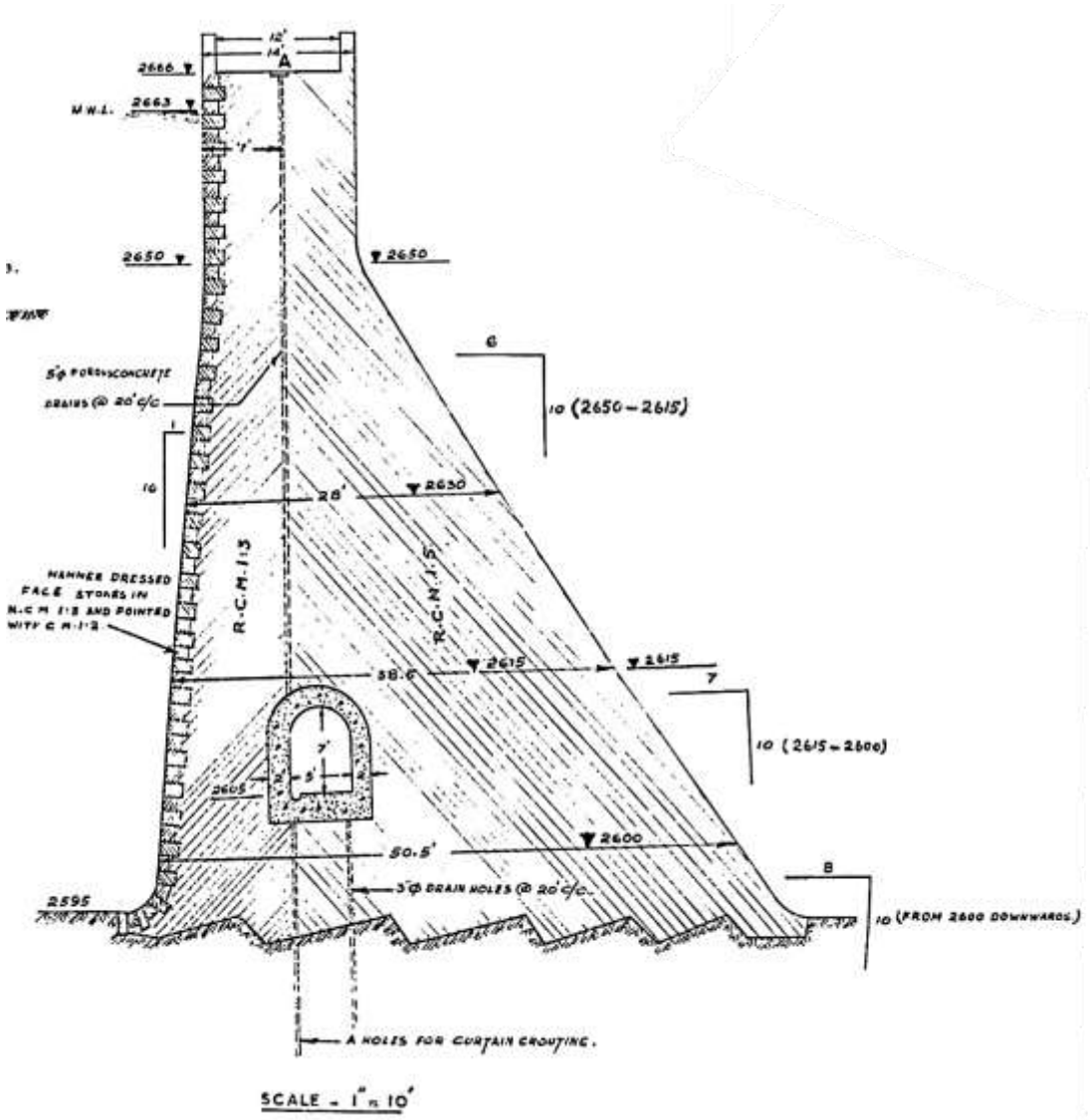


Fig 9 Section of Flanking Dam

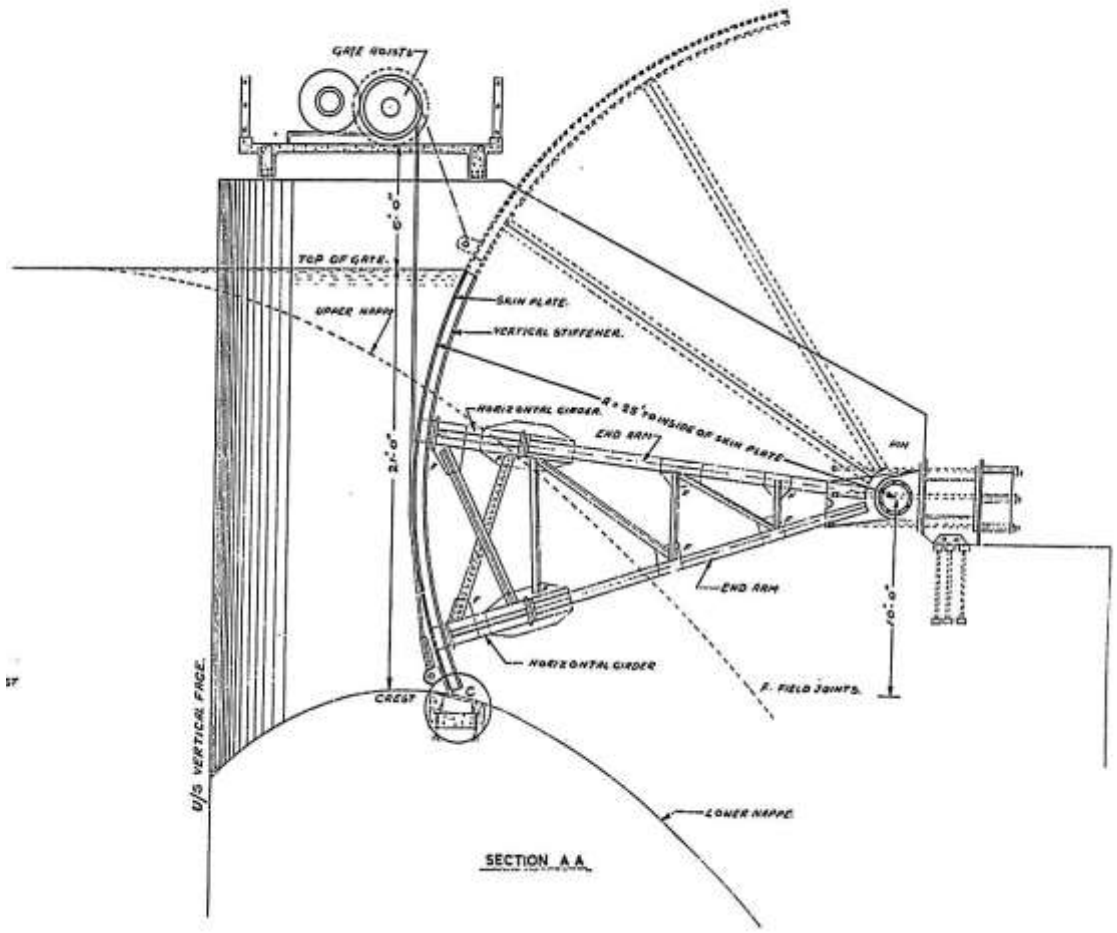


Fig 10 Details of Radial Gate

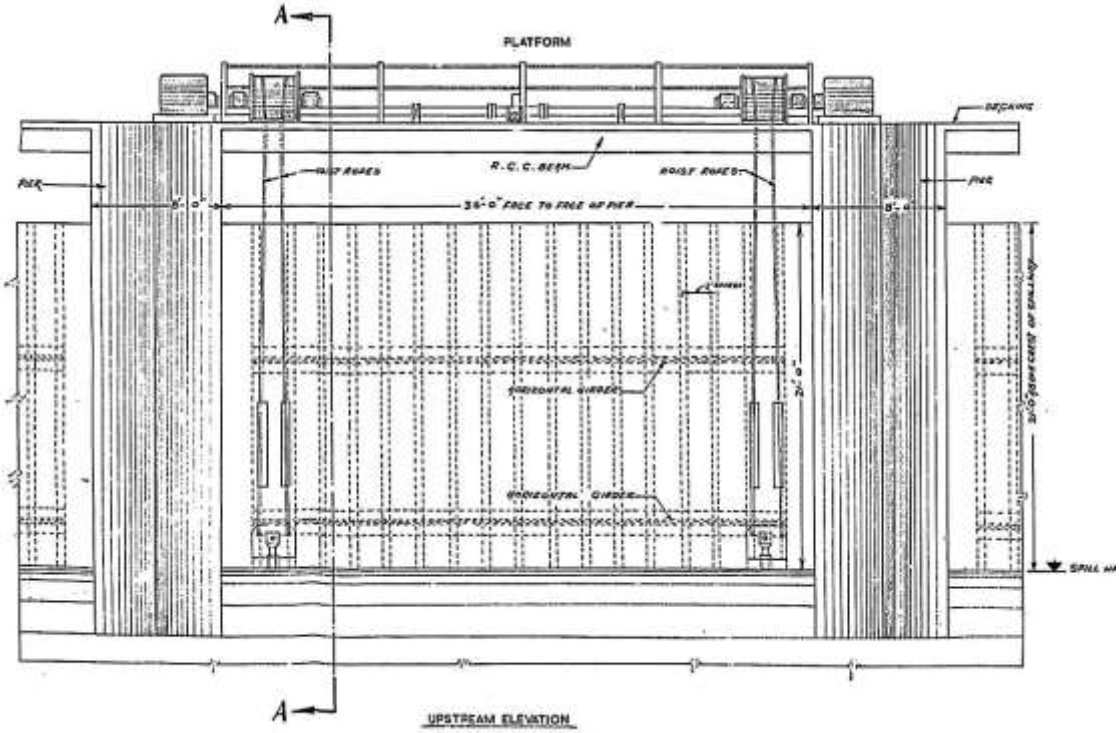


Fig 11 Elevation of Radial Gate

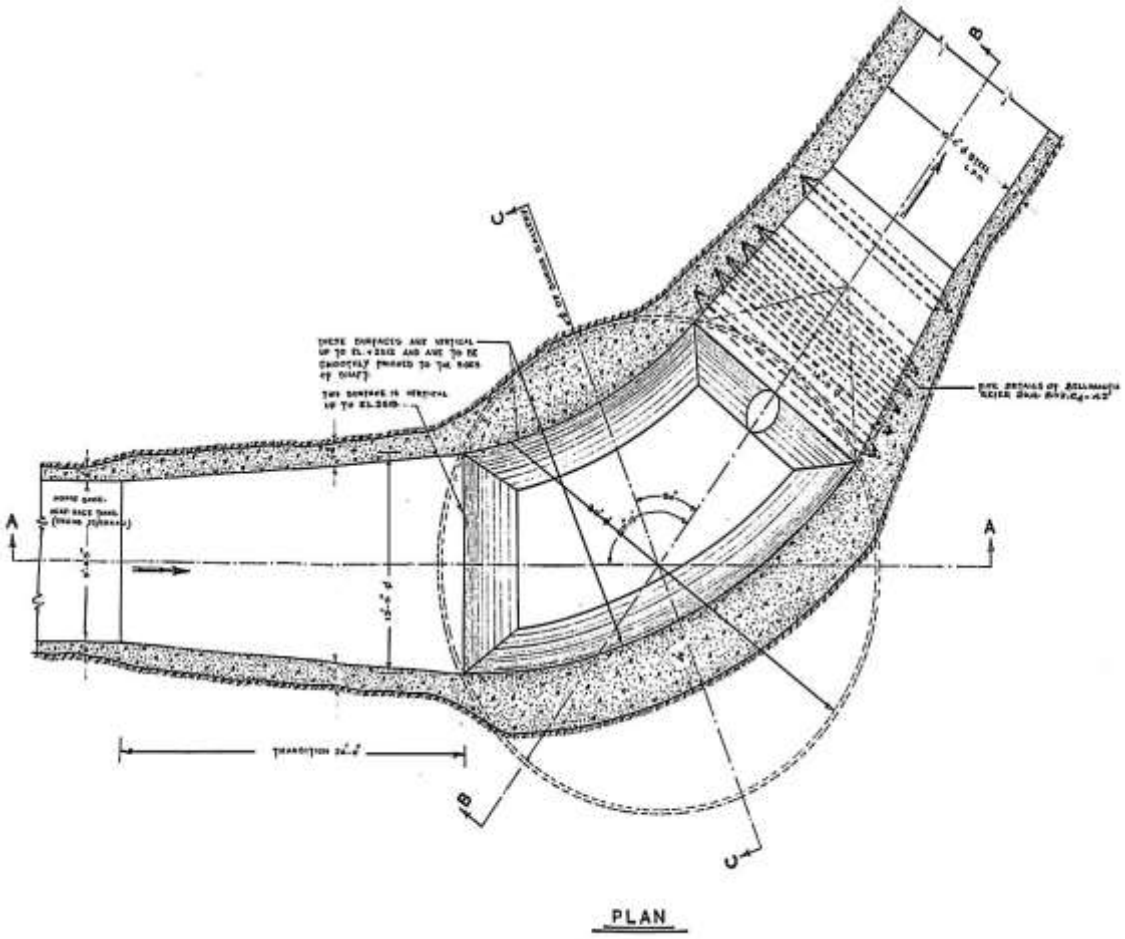


Fig 12 Plan of Surge Shaft

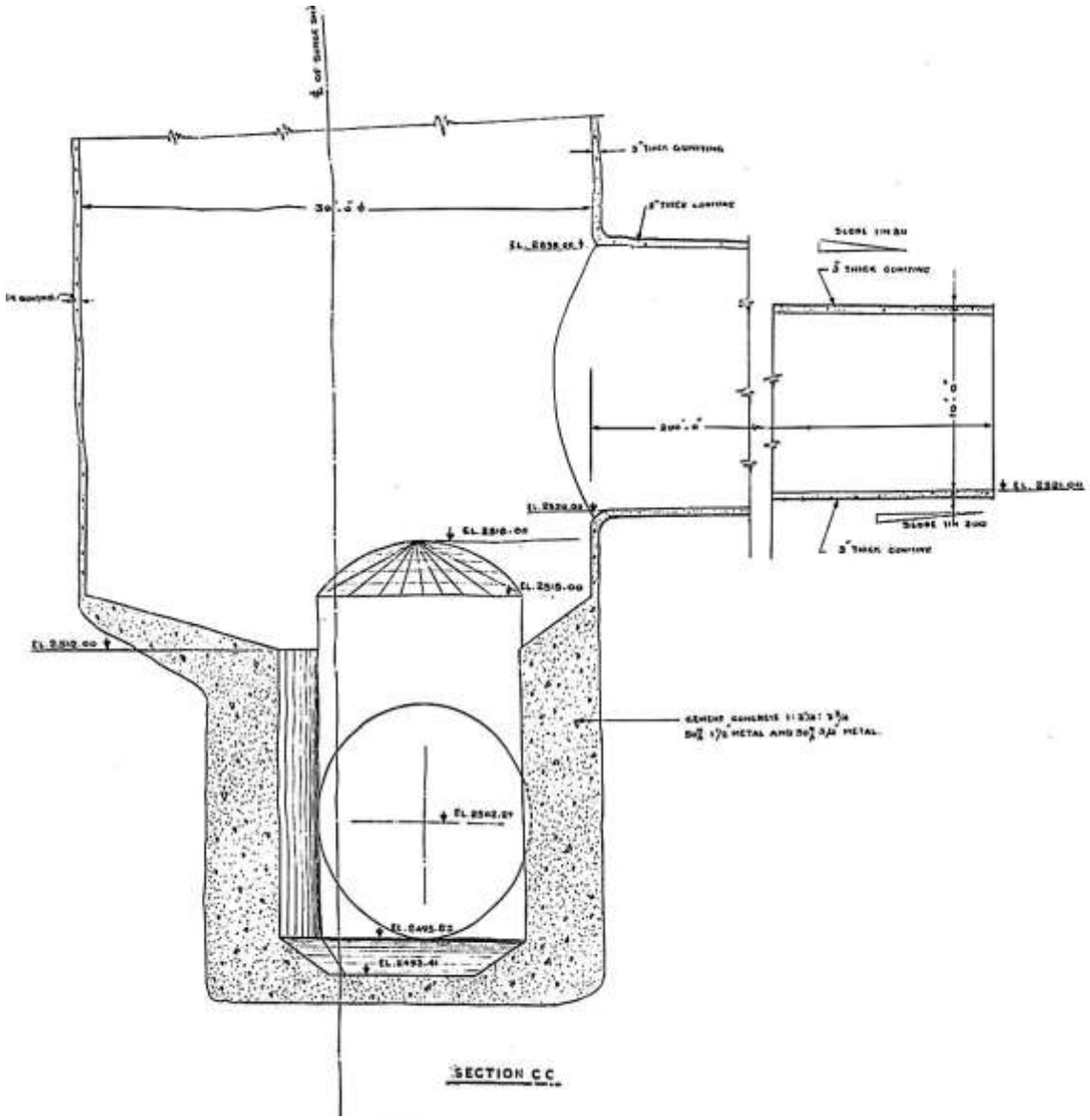


Fig 13 Cross Section of Submerged Gallery at Surge Shaft

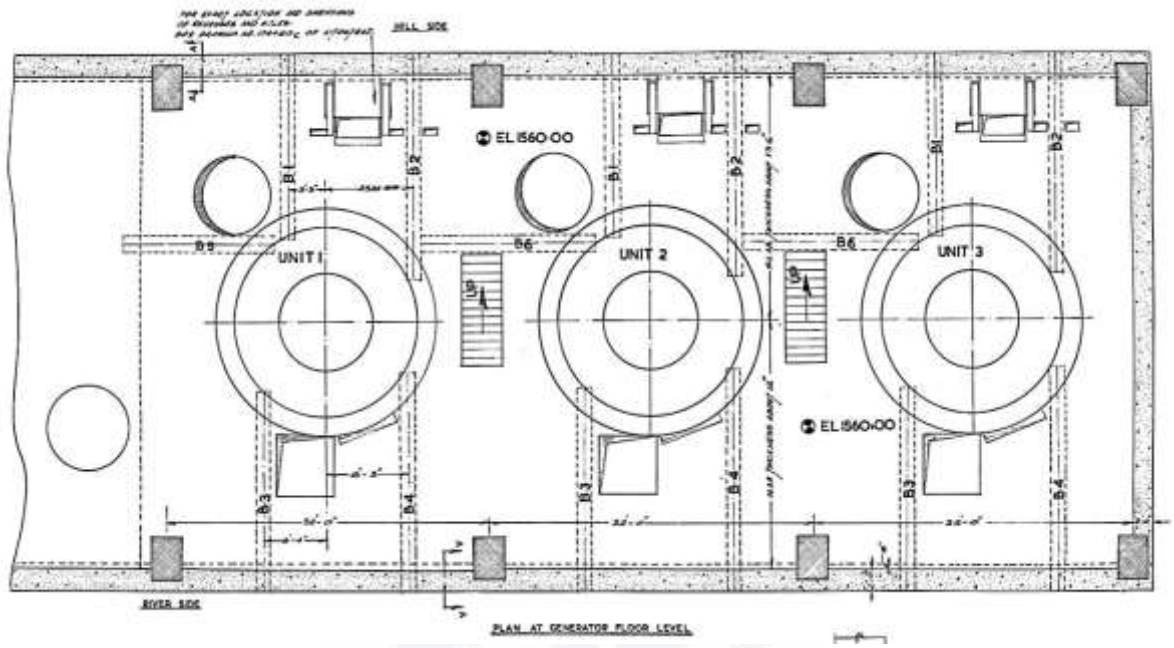


Fig 14 Plan of Machine arrangement at Power House

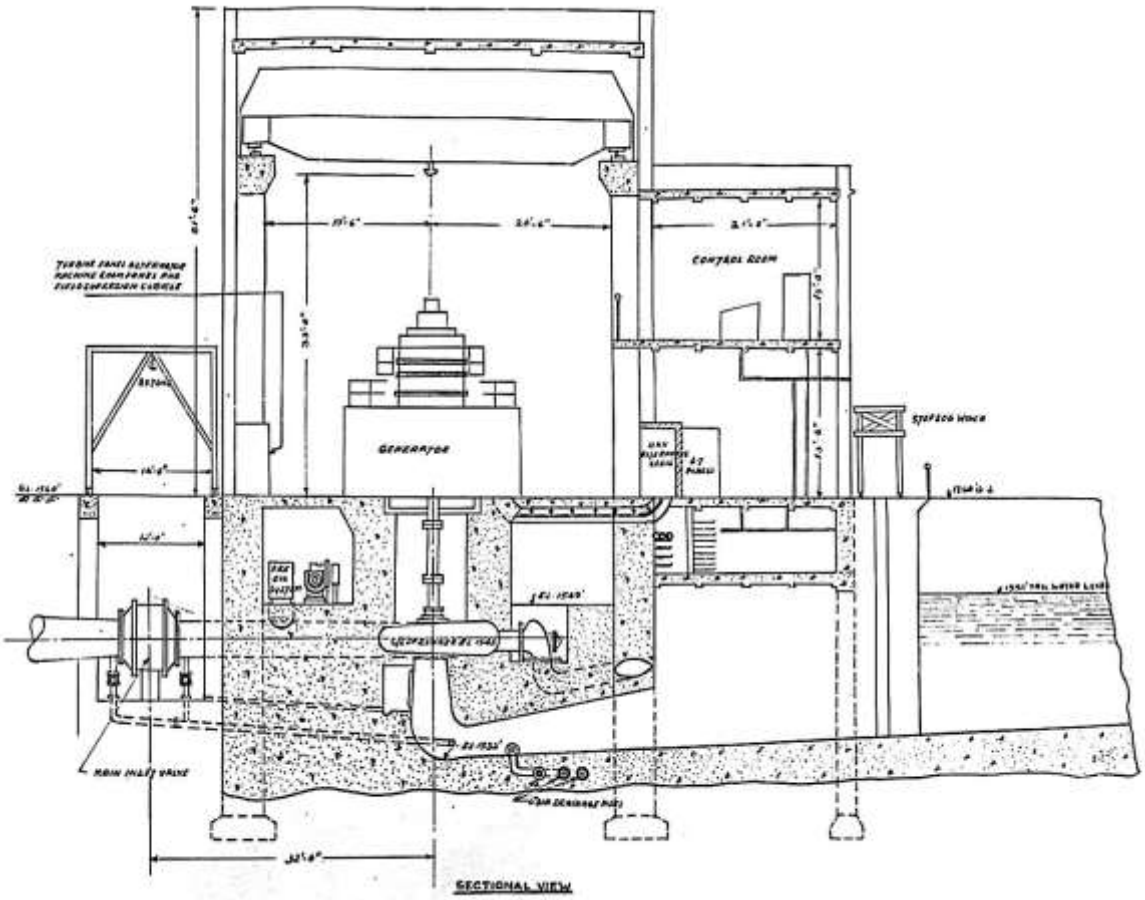


Fig 15 Cross Section of Turbine arrangement

ANNEXURE 2

HYDROLOGY REVIEW REPORTSHOLAYAR HYDRO ELECRIC PROJECT THRISSUR DISTRICT, KERALA STATE

Fig 1 Sholayar Flanking Dam and Reservoir

Fig 2 Sholayar Main Dam and Reservoir

भारत सरकार
Government of India
केन्द्रीय जल आयोग
Central Water Commission
बांध सुरक्षा (पुर्नवास) निदेशालय
Dam Safety (Rehabilitation) Directorate

No. 16/3/KSEB- Design Flood Review /DSRD(DRIP)/ 2013/674 **Dated 3.6.2014**

To
The Chief Engineer (Civil-Dam Safety)
Kerala State Electicity Board
Vidyuthi Bhavan, Pattom,
Thiruvanathapuram,
Kerala-695004

Subject: - Review of Design Flood Studies of Sholayar Project under DRIP, Kerala - Reg.

Sir,

This is with reference to your letter no. CE(C- DSO)/Sir--DRIP/ Hydrology/2013/998 dated 20.11.2013 submitting the Modified Design Flood reviews of Sholayar HE Project under DRIP. Accordingly, the same have been scrutinized by Hydrology (South) Directorate, CWC and their observations vide letter No. 7/ Kerala - 57/2011-Hyd (S)/334-335 dated 02.06.2014 are enclosed.

The Design Flood of the project has been worked out as 1890 Cumec.

It is requested to compile/prepare finalized flood study reports considering the observations of Hydrology directorate and submit the same for record and reference.

Yours faithfully,

Encl: As Above

(Jitendra Panwer)
DEPUTY DIRECTOR, DSR

Copy for information to:

Director, Hydrology (South) Dte., Sewa Bhawan, CWC

3rd Floor, Library Building, CWC, R.K.Puram, New Delhi-110 066
Tel : 011 26192633 Fax: 011 26189068

भारत सरकार
Government of India
केन्द्रीय जल आयोग
Central Water Commission
जल विज्ञान (दक्षिण) निदेशालय
Hydrology (South) Directorate

Subject: - **Review of Design Flood Studies of Sholayar Reservoir Project, Kerala proposed under DRIP- reg.**
Ref: CWC U.O No. 1/44/4/2011- Hyd(DSR)/34 dated 06.02.2014

With reference to mentioned subject matter vide which compliance report in respect to observations of this unit on design flood studies of Sholayar Reservoir Project; Kerala had been forwarded for examination/vetting. The report was submitted in December, 2011. The observations of this office were sent vide this office letter dated 11.01.2012. The compliance was submitted by the project authorities in February, 2014. The compliance to the observations and revised design flood study have been scrutinized & observations of this office on design flood are as follows:

(1) Introduction

The Sholayar Reservoir Project is located on river Sholayar, a tributary of Chalakudy River in Thrissur District of Kerala. The reservoir is formed by three dams' viz., main non-overflow gravity dam, flanking dam with spillway section and saddle dam. The construction of dam was completed in year 1965. The catchment area of Sholayar River up-to the dam site is 187.90 sq.km. The catchment area is intercepted by Upper Sholayar dam lying in state of Tamil Nadu. The catchment area up-to Upper Sholayar dam is 121.72 sq km, while catchment area below Upper Sholayar dam to Sholayar dam is 66.18 sq. km. The gross storage capacity of the reservoir is about 153.48 Mm^3 and the height of the main dam is 57.61 m. It is stated by project authorities that the capacity of spillway is 1739.65 m^3/sec. As per BIS: 11223-1985 criteria, the dam is classified as a large dam and therefore, qualifies for PMF as design flood.

(2) Design Flood Studies

The catchment area up-to Sholayar dam has been divided into two sub-catchments, i.e. catchment up-to Upper Sholayar dam and free catchment below Upper Sholayar dam. The unit hydrograph of one hour duration for each sub-catchment were derived synthetically by project authorities using Flood Estimation Report for West Coast Region Konkan and Malabar coasts- Sub Zone 5 (a) and 5 (b) in Sholayar Dam in Kerala and Tamil Nadu. One day PMP of 60 cm as given in CWC PMP Atlas for West flowing rivers of Western Ghats (Plate- 11, statistical method) has been considered as a design storm. It is stated by project authorities that the maximum rain fall in the catchment area as per their available records for the period 1985 to 2012 is 316 mm on dated 26.06.1985. Areal reduction factor of 0.9623 and 0.9393 corresponding to catchment areas of two sub-catchments, loss rate of 0.1 cm/hr, base flow of 0.15 m^3/sec/Sq km have been adopted from CWC FER sub zone 5 (a) and 5 (b) in the study. The flood hydrograph of Upper Sholayar Dam (Tamil Nadu) was both reservoir and channel routed 20 km to the brink of Sholayar reservoir (Kerala) using Muskingum method. The channel routed hydrograph added to flood hydrograph generated from free catchment. The peak design flood at Sholayar dam in Kerala has been worked out as **1233 m^3/sec.**

(3) Observations

(i) A good catchment area scaled color map preferably in 1:50000 scale showing catchment boundary, stream network, contours, location of projects, G&D sites, rain gauge station etc. should be given in the report.

(ii) The project authorities has adopted one day PMP (design storm) value of 60 cm from PMP Atlas for West Flowing Rivers of Western Ghats for Sholayar Dam (Kerala and Tamil Nadu) based on statistical method. The catchment area of project is large and is intercepted by an existing reservoir, it would be appropriate to assess design storm based on physical method using up-to date storm data. This aspect was reviewed by this office. This office assessed criticality of various storms occurred in the vicinity of the catchment. The whole catchment area up-to Sholayar Dam (Kerala) has been divided into two sub-catchments i.e. sub-catchment up-to Sholayar Dam (Tamil Nadu) with catchment area of 121.72 sq km and sub-catchment d/s of Sholayar Dam (Tamil Nadu) up-to Sholayar Dam in Kerala (free catchment) with catchment

area of 66.18 sq km. The 1 day storm of 17 July, 1924 centered at Devikulum (Maximum observed one day rainfall 48.4cm) is found to be critical and transposable to the catchment of Sholayar Dam. The design storm value for catchment has been critically placed on the Sholayar catchment for assessing the one day SPS. The one day maximum storm value transposed at catchment works out as 38.5 cm . The MAF for the event works out as 1.26 and same has been adopted to assess one day PMP for the project. Thus, the one day PMP works out as 48.51 cm for the both sub-catchment of Sholayar Dam and same may be adopted as design storm for the project.

(iii) The catchment response function derived synthetically using FER appears to be generally in order. However, efforts may also be made for collecting short interval concurrent observed discharge and rainfall date of few storm events for estimating the catchment response function.

(4) Recommended Design Flood

This office has modified the design flood study for the project addressing above observations and using hydro-meteorological approach. The design storm value of one day PMP of 48.51 cm has been adopted for the both sub-catchments. The unit hydrograph of Sholayar Dam (Tamil Nadu) as derived by CWC has been used in the study while the unit hydrograph of free catchment has been derived using FER subzone 5 (a) and 5 (b). The time distribution of 24 hrs rainfall has been taken from the PMP Atlas (Source: Report for West Flowing rivers of Western Ghats).The loss rate of 0.1 cm/hour and base flow 0.15 m^3/sec/sq km have been adopted as per FER subzone 5 (a) and 5 (b). Looking at base period of unit hydrograph, the duration of design storm has been adopted as 24 hrs and same has been convoluted with UH taking two bells of 12 hrs each. The peak rate of inflow flood hydrograph at Upper Sholayar Dam (Tamil Nadu) has been assessed as **1731 m^3/sec**. The same has been suitably reservoir and channel routed from Upper Sholayar to the brink of Sholayar reservoir (Kerala) using Modified Puls and Muskingum method. Reservoir routing was carried in the portion of inflow flood hydrograph in which inflow was higher than spillway capacity at FRL. The reservoir was initially assumed to be at FRL. The total design flood at Sholayar Dam (Kerala) has been assessed by adding channel routed flood from Upper Sholayar Dam (Tamil Nadu) and flood hydrograph from the free catchment at Sholayar Dam (Kerala). The peak of PMF at Sholayar Dam (Kerala) works out as **1890 m^3/sec** and the same may adopted as design flood in dam safety review of the project. The computations of design flood hydrograph in brief is enclosed at Annex-I.

The project authorities are requested to compile and prepare finalized design flood study reports and submit the same for record and reference. The report may include the following information.

(a) Brief of project
Particular of project may be given in brief along with index map and catchment area map of the project.
(b) Previous studies
(c) Data used
(d) Derivation of Unit Hydrograph
(e) Design Strom
(f) Base Flow
(g) Convolution and Design Flood Hydrograph
(h) Conclusion

This issues with approval of Chief Engineer, HSO, CWC.

Encl: As above

(Bhopal Singh)
Director

The Director,DSR Dte./ Dir Hydrology(DSR) Dte.,CWC, Sewa Bhawan, New Delhi
No. 7/Kerala – 57/ 2011- Hyd (S)/ 334-335 **Dated :** 02/06/2014

503 सेवा भवन (दक्षिण) रामकृष्ण पुरम, नई दिल्ली – 110 066
503, Sewa Bhawan (S), R.K.Puram, New Delhi-110 066

Fig 3 Sholayar Reservoir

SHOLAYAR DAM PROJECT (TAMIL NADU)

Finalized unit hydrograph as assessed by CWC in their design flood studies report

Time in hr	UG Ordinates in m^3/sec
0	0
1	41
2	116
3	63
4	37
5	27
6	21
7	16
8	11
9	6
10	0
Total	**338**

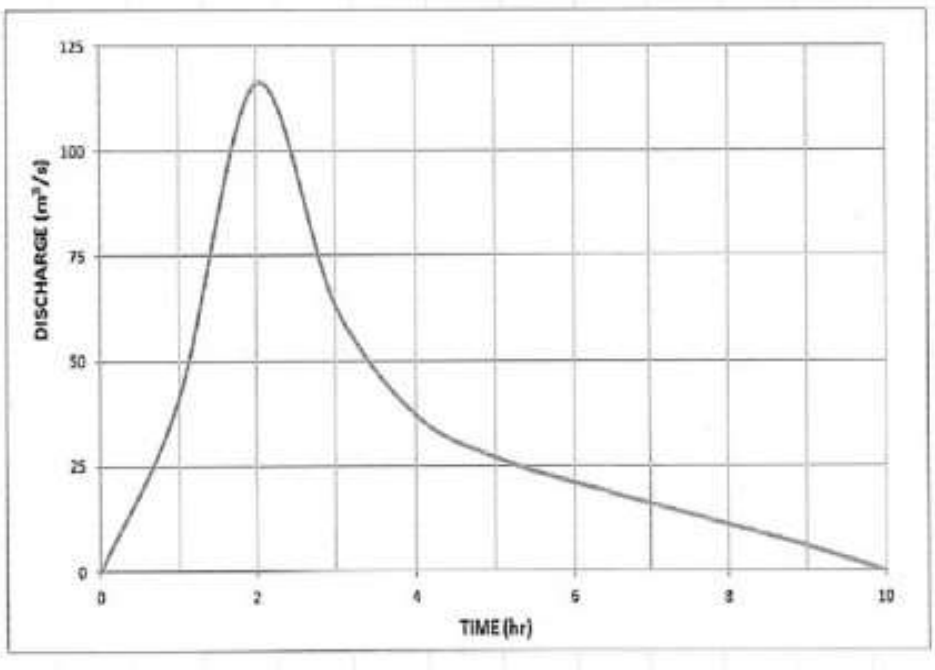


Fig 4 Unit Hydrograph

DISTRIBUTION OF ONE DAY PMP

1 day PMP	48.51 cm (As assessed from transposed strom of 17th July, 1924 centered at Devikulum)
24 hr PMP	53.51 cm (Clock hour correction of 1.15 subject to limit of 5 cm)
PMP depth for 1st 12 hr bell	38.79 cm (72.5 percent of 24 hr rainfall)
PMP depth for 2nd 12 hr bell	14.72 cm

			Cumulative rainfall depth		Incremental rainfall depth			Effective rainfall depth	
Time (hr)	Disn coeff as per PMP atlas	Normalised dist coeff	1st 12 hr bell distribution	2nd 12 hr bell distribution	Incremental rainfall 1st bell	Incremental rainfall 2nd bell	Loss rate 0.10 cm/hr	Eff incremental rainfall 1st bell	Eff incremental rainfall 2nd bell
			cm	cm	cm	cm		cm	cm
1	14	19	7.49	2.84	7.49	2.84	0.10	7.39	2.74
2	24.5	34	13.11	4.97	5.62	2.13	0.10	5.52	2.03
3	33	46	17.66	6.70	4.55	1.73	0.10	4.45	1.63
4	39	54	20.87	7.92	3.21	1.22	0.10	3.11	1.12
5	44	61	23.54	8.93	2.68	1.01	0.10	2.58	0.91
6	48	66	25.68	9.74	2.14	0.81	0.10	2.04	0.71
7	53	73	28.36	10.76	2.68	1.01	0.10	2.58	0.91
8	57	79	30.50	11.57	2.14	0.81	0.10	2.04	0.71
9	62.5	86	33.44	12.69	2.94	1.12	0.10	2.84	1.02
10	65	90	34.78	13.19	1.34	0.51	0.10	1.24	0.41
11	68	94	36.39	13.80	1.61	0.61	0.10	1.51	0.51
12	72.5	100	38.79	14.72	2.41	0.91	0.10	2.31	0.81

Table 1 Distribution of one day PMP

CRITICAL SEQUENCING OF RAINFALL

Time (hr)	Unit Hydrograph Ordinates (m^3/sec)	Critical arrangement of rainfall increments in 1st & 2nd bell		Reversed sequence	Reversed sequence	Critically sequenced eff rainfall (cm)	Critically sequenced eff rainfall (cm)
0	0	0	0			B1-B2	B2-B1
1	41	4.45	1.63	2.04	0.71	2.04	0.71
2	116	7.39	2.74	2.31	0.81	2.31	0.81
3	63	5.52	2.03	2.58	0.91	2.58	0.91
4	37	3.11	1.12	2.58	0.91	2.58	0.91
5	27	2.84	1.02	2.84	1.02	2.84	1.02
6	21	2.58	0.91	3.11	1.12	3.11	1.12
7	16	2.58	0.91	5.52	2.03	5.52	2.03
8	11	2.31	0.81	7.39	2.74	7.39	2.74
9	6	2.04	0.71	4.45	1.63	4.45	1.63
10	0					0.71	2.04
						0.81	2.31
						0.91	2.58
						0.91	2.58
						1.02	2.84
						1.12	3.11
						2.03	5.52
						2.74	7.39
						1.63	4.45

Table 2 Critical sequencing of Rain fall

Convolution B2 - B1

Time (hr)	UH Ord (m^3/sec)	Rainfall (cm)																	DRH (m^3/sec)	Baseflow (m^3/sec)	PMF (m^3/sec)
		0.71	0.81	0.91	0.91	1.02	1.12	2.09	2.74	1.63	2.04	2.31	2.58	2.58	2.84	5.11	5.52	7.39	4.45			
0	0	0.00																		0.00	18.26	18.26
1	41	29.19	0.00																	29.19	18.26	47.44
2	116	82.63	93.35	0.00																115.98	18.26	134.23
3	63	44.85	84.41	37.51	0.00															176.76	18.26	195.02
4	37	26.34	51.24	106.19	37.51	0.00														221.28	18.26	239.53
5	27	19.22	30.09	57.64	106.19	41.67	0.00													254.81	18.26	273.06
6	21	14.95	21.96	33.83	57.64	117.97	46.83	0.00												292.19	18.26	310.45
7	16	11.39	17.08	24.70	33.85	64.03	129.75	85.23	0.00											364.07	18.26	382.33
8	11	7.83	13.01	19.21	24.70	37.68	70.42	236.79	112.40	0.00										520.95	18.26	539.21
9	6	4.27	8.95	14.64	19.21	27.44	41.36	127.96	308.22	69.63	0.00									628.68	18.26	646.94
10	0	0.00	4.88	10.06	14.64	21.34	30.18	75.15	172.72	188.64	83.66	0.00								601.28	18.26	619.53
			0.00	5.49	10.06	16.28	23.47	54.84	101.44	102.59	136.82	94.63	0.00							645.41	18.26	663.67
				0.00	5.49	11.18	17.86	42.63	74.02	60.13	128.53	267.89	105.60	0.00						713.39	18.26	731.65
					0.00	6.10	12.36	32.57	57.57	43.88	75.69	145.60	298.94	105.60	0.00					777.78	18.26	796.04
						0.00	6.71	22.34	43.87	34.13	59.09	85.39	162.26	298.94	126.67	0.00				815.29	18.26	833.55
							0.00	12.19	30.16	26.00	42.85	62.31	95.29	162.26	332.00	127.53	0.00			888.59	18.26	906.85
								0.00	16.46	17.88	32.63	48.47	69.54	96.29	179.11	361.09	226.24	0.00		1046.70	18.26	1064.96
									0.00	9.75	22.44	36.91	54.09	69.54	105.19	195.97	640.54	303.05	0.00	1417.50	18.26	1435.76
										0.00	12.24	25.36	41.21	54.09	75.76	115.09	347.67	857.93	182.88	1712.76	18.26	1731.01
											0.00	13.85	28.53	41.21	59.70	85.99	204.19	469.66	516.32	1419.25	18.26	1437.50
												0.00	15.45	28.53	45.49	65.31	149.00	273.48	280.25	857.22	18.26	875.48
													0.00	15.45	31.27	49.77	115.89	199.57	164.58	576.54	18.26	594.80
														0.00	17.08	34.22	88.50	159.22	120.11	414.50	18.26	433.15
															0.00	18.69	80.70	118.26	93.42	291.05	18.26	309.30
																0.00	93.11	81.31	71.17	185.59	18.26	203.85
																	0.00	44.35	48.93	93.28	18.26	111.54
																		0.00	26.09	26.69	18.26	44.95
																			0.00	0.00	18.26	18.26

Table 3 Convolution B2-B1

SHOLAYAR DAM PROJECT - KERALA

COMPUTATION OF EQUIVALENT SLOPE

Chainage (km)	Reduced Level (m)	Height above Datum D_i (m)	Length of each segment L_i (km)	$(D_i+D_{i-1})L_i$
0	755	0	0	0
1	760	5	1	5
2	780	25	1	30
3	785	30	1	55
4.4	800	45	1.4	105
6	800	45	1.6	144
8	840	85	2	260
10	840	85	2	340
11.1	850	95	1.1	198
12.5	860	105	1.4	280
14	880	125	1.5	345
16	880	125	2	500
18	880	125	2	500
19.65	900	145	1.65	445.5

Longest River Length from outlet (L) 19.65

$\Sigma\{(Di+Di-1)Li\}$ 3207.50

Equivalent stream slope = $\{\Sigma[(D_i+D_{i-1})Li]/L^2$ S_{eq} 8.31 m /km

Table 4 Computation of equivalent slope

COMPUTATION OF UNIT HYDROGRAPH PARAMETERS

Total Catchment Area (A)	66.18	sq.km	(From hydrological review study report)
Rainfed Catchment	66.18	sq.km	(From hydrological review study report)
Longest River Length from outlet (L)	19.650	km	(From hydrological review study report)
	19.65		
Equivalent stream slope S_{eq}	8.31	m/km	
Peak discharge of unit hydrograph per unit area $q_p = 0.9178 (L/S)^{0.4318}$	0.633	m^3/sec/sq km	
Time from the centre of effective rainfall duration to the UH peak $t_p = 1.5607(q_p)^{-1.0824}$	2.559 hr	Say	2.50 hr
Width of the UH measured at 50% of peak discharge ordinate $W50 = 1.925(q_p)^{-1.0898}$	3.168 hr		
Width of the UH measured at 75% of peak discharge ordinate $W75 = 1.0189(q_p)^{-1.0643}$	1.642 hr		
Width of the rising limb of UH measured at 50% of peak discharge ordinate $WR50 = 0.5788(q_p)^{-1.1073}$	0.960 hr		
Width of the rising limb of UH measured at 75% of peak discharge ordinate $WR75 = 0.3469(q_p)^{-1.0538}$	0.5616 hr		
Base width of UH $T_b = 7.38(tp)^{0.1243}$	14.463 hr	Say	15 hr
Peak Discharge of UH $Qp = q_p \times A$	42	m^3/sec	
Unit duration of unit hydrograph t_r	1.00 hr		
Time from the start of rise to the peak of the UH $T_m = t_p + t_r/2$	3.00 hr		
Q theoretical = A*d/0.36*tr here d= 1 cm depth and tr = 1 hr	183.83	m^3/sec	
Say	184	m^3/sec	

SMOOTHENED/ ADJUSTED SYNTHETIC UNIT HYDROGRAPH

Time (hr)	Discharge (m^3/sec)
0	0
1	10
2	21
3	42
4	33
5	22
6	15
7	11
8	8
9	6
10	5
11	4
12	3
13	2
14	1
15	0
	184

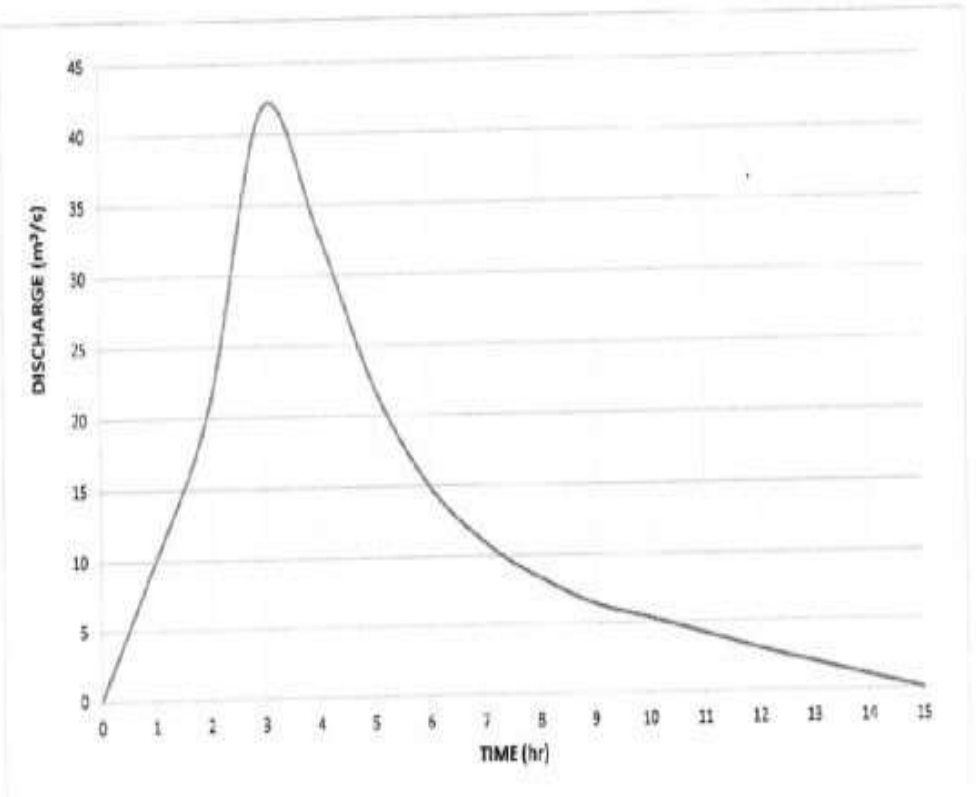


Fig 5 Smoothened synthetic hydrograph

CRITICAL SEQUENCING OF RAINFALL

Time (hr)	Unit Hydrograph Ordinates (m^3/sec)	Critical arrangement of rainfall increments in 1st & 2nd bell		Reversed sequence	Reversed sequence	Critically sequenced eff rainfall (cm)	Critically sequenced eff rainfall (cm)
0	0	0	0			B1-B2	B2-B1
1	10	2.58	0.91	1.24	0.41	1.24	0.41
2	21	3.11	1.12	1.51	0.51	1.51	0.51
3	42	7.39	2.74	2.04	0.71	2.04	0.71
4	33	5.52	2.03	2.04	0.71	2.04	0.71
5	22	4.45	1.63	2.31	0.81	2.31	0.81
6	15	2.84	1.02	2.58	0.91	2.58	0.91
7	11	2.58	0.91	2.84	1.02	2.84	1.02
8	8	2.31	0.81	4.45	1.63	4.45	1.63
9	6	2.04	0.71	5.52	2.03	5.52	2.03
10	5	2.04	0.71	7.39	2.74	7.39	2.74
11	4	1.51	0.51	3.11	1.12	3.11	1.12
12	3	1.24	0.41	2.58	0.91	2.58	0.91
13	2					0.41	1.24
14	1					0.51	1.51
15	0					0.71	2.04
						0.71	2.04
						0.81	2.31
						0.91	2.58
						1.02	2.84
						1.63	4.45
						2.03	5.52
						2.74	7.39
						1.12	3.11
						0.91	2.58

Table 5 Critical sequencing of Rain fall

COMMENTS OF SMPU ON REPORT OF DESIGN FLOOD

The design flood of the project as approved by CWC is 1890 m^3/s. The discharge capacity provided for the dam is 1739.65 cumecs. There is a diversion of 22.5 m^3/s from this reservoir to the Kerala Sholayar Power Station. In addition to this, there is also diversion from the upstream reservoir to power houses as well as reservoirs of adjacent sub basins. Hence on account of these diversions, there will be certain reduction in the peak flow of 1890 m^3/s. The ordinates of revised flood hydrograph exceed 1739.65 m^3/s only for a short period of three hour duration. The variation in the revised design flood from original is less than 10%. The flood accumulation in the reservoir works out 1.15 Million Cubic Meter. The storage available between FRL and dam top in the reservoir is more than 8 Million Cubic Meter. The rise in water level in the reservoir above FRL for 1.15 Million Cubic Meter is less than 25 cm. It may also be noted that, for the past 49 years, there is no record of flood peak exceeded the spill way capacity.

ANNEXURE 3

Composite Dam Checklist						
SN	**Inspection Item**	**Response**			**Observations and Recommendations, if any, of the authorized inspecting officer**	**Condition (Unsatisfactory/Poor/Fair/Satisfactory)**
		Y	**N**	**NA**		
A-Reservoir						
A-1.1	**General Condition**					
1.1.1	Is the reservoir water level unusually high or low?					
1.1.2	Are there signs of decline in water quality?					
1.1.3	Are there signs of recent sediment deposition?					
1.1.4	Is floating debris present?					
1.1.5	Any indications of major active or inactive landslide area in the reservoir rim? If so, indicate their locations and extent.					
1.1.6	Are there people or livestock in and around reservoir?					
1.1.7	Any other issues?					
B-Dam and Dam Reach (Embankment)						
B-1.1	**General Condition**					
1.1.1	Any major alterations or changes to the dam since the last inspection?					
1.1.2	Is there any new nearby development in the downstream floodplain?					
1.1.3	Any misalignment of poles, fencing or walls due to dam movement?					

B-1.2	**<u>Upstream Slope</u>**					
1.2.1	Any signs of bulging or concavity (depressions)? If so, indicate their locations and extent. (Check up the cross-sections with tape and level at random locations, at least two)					
1.2.2	Does the section of the dam and upstream slope appear structurally sound and stable?					
1.2.3	Presence of longitudinal or transverse cracks?					
1.2.4	Any signs of distress to stability of slopes noticed at any time in any part of the dam? If so, give brief details of the incidents and location, the method of treatment adopted and its effectiveness. Indicate the general condition of upstream pitching.					
1.2.5	Any degradation to slope protection (rip-rap)?					
1.2.6	Is there any profuse growth of bushes or weeds over any portion of the dam? If so, indicate the locations.					
1.2.7	Does the upstream slope shows existence of crab holes or holes made by rodents or burrowing animals or ant hills? If so, indicate the locations.					
1.2.8	Any other issues?					
B-1.3	**<u>Crest of Dam</u>**					

1.3.1	Is the crest profile at proper elevation? (To be test checked at random locations by taking level)					
1.3.2	Does it show any signs of excessive and/or uneven settlement? If so, indicate such locations and extent of settlement. (Surface settlement points must be installed for observing this aspect)					
1.3.3	Is the surface of the crest free from undulations and local depressions or heaving?					
1.3.4	Does it provide an all-weather road surface?					
1.3.5	Any degradation to access road (sealed/unsealed)?					
1.3.6	Does it develop any visible cracks in transverse or longitudinal directions? If so, attach a map showing their locations and extent. Depth of cracks must be ascertained by taking open trenches extending below the bottom of cracks.					
1.3.7	Have the edges of the crest gotten eroded and cut up resulting in reduced effective width?					
1.3.8	Is the crest free from local slips throughout its length on either sides?					
1.3.9	Do the headers, guard stones and parapet					

	wall provided at the edges of the crest appear in proper profile and plumb?					
1.3.10	Any degradation to upstream parapet or downstream curb wall?					
1.3.11	Evidence of livestock on dam crest?					
1.3.12	Trees or profuse growth of weeds/bushes at any location?					
1.3.13	Proper lighting arrangement at dam top?					
1.3.14	Any other issues?					
B-1.4	**Downstream Slope**					
1.4.1	Any signs of bulging or concavity (depressions)?					
1.4.2	Are there any wet or slushy patches or any concentrated leaks, springs or trickles observed on the downstream slopes or the toe? If so, indicate their locations and extent. Please look out for patches of extensive vegetation growth and examine them carefully and record the findings.					
1.4.3	Presence of longitudinal or transverse cracks?					
1.4.4	Any signs of distress to the stability of slopes?					
1.4.5	Are rain cuts/erosion channels present at any location?					

1.4.6	Are all the rain cuts and erosion channels properly treated and made good? Please indicate location of recurring damages, if any.					
1.4.7	Is there any profuse growth of bushes or weeds over any portion of the dam? If so, indicate the locations.					
1.4.8	Does the downstream slope show existence of crab holes or holes made by rodents or burrowing animals or ant hills? If so, indicate the locations.					
1.4.9	Any other degradation to slope protection (turfing)? Indicate the general condition of downstream pitching/ turfing and rock toe.					
1.4.10	Is the downstream area clear of debris and freely draining?					
1.4.11	Any other issues?					
B-1.5	**<u>Downstream Drainage</u>**					
1.5.1	Are there any signs of water logging, slushy conditions or growth of aquatic weeds on the downstream of the dam? To be checked upto 300 m downstream of toe					
1.5.2	Are there any standing pools of water in the downstream of dam? If so, give their locations and extent. To be checked upto 300 m downstream of toe					

1.5.3	Are there any boils observed in the vicinity of the downstream toe of the dam? If so, give locations.					
1.5.4	Is the downstream area sufficiently clear and freely draining?					
1.5.5	What is the depth of ground water table on the downstream as evident from the existing wells in the vicinity of the dam? To be checked upto 300 m downstream of toe.					
1.5.6	Does the water table show any marked variation in accordance with the variations in reservoir water level?					
1.5.7	Are all the exposed drains working satisfactorily?					
1.5.8	**Toe drains and cross drains:**					
	i. Are the portions of longitudinal toe drain and exposed cross drains beyond the downstream toe of the dam in regular section and freely draining?					
	ii. Is the pitching to these drains intact?					
	iii. Is there any weed growth in these drains?					
	iv. Any other defects noticed in the drains?.					
1.5.9	**Outfall Drain:**					

1.5.12	(a) Is the outfall drain in proper shape and grade and freely draining?					
1.5.13	(b) Is the outfall drain properly cleaned and maintained?					
1.5.14	Does the outfall drain show any stagnant pools of water or weed growth?					
B-1.6	**Surface Drainage of Downstream Slope**					
1.6.1	Is the condition of the downstream slope drainage arrangements, if provided, satisfactory?					
1.6.2	Is the paving to these drains intact?					
1.6.3	Are all the drains properly maintained and free of vegetation growth and debris?					
1.6.4	Does the slope have a tendency to develop severe rain cuts at any location?					
1.6.5	Any other defects noticed in the surface drainage of downstream slope?					
B-1.7	**Seepage Measurement**					
1.7.1	Is the quantity of seepage being daily or periodically measured and recorded? Please check the registers and record observations.					
1.7.2	Does it show any abnormal rise or fall? If so, explain if it has any relation to a certain reservoir level elevation.					

1.7.3	Does the seepage show a turbid colour at any stage? Indicate if such a phenomenon has been observed at any stage, at any location in the past.					
1.7.4	What is the measured rate of seepage flow with date and reservoir level:					
	i. On the day of present inspection					
	ii. Maximum since last June					
	iii. Minimum since last June					
1.7.5	Is the portion upstream and downstream of measuring points of seepage easily accessible with proper steps and paths and free of vegetation growth?					
1.7.6	Are the measuring points properly located, constructed and maintained so as to give accurate and reliable measurements of seepage in accordance with the relevant IS Codes?					
1.7.7	Is the method of taking seepage measurements satisfactory?					
B-1.8	**<u>Breaching Section (if provided)</u>**					
1.8.1	Is the breaching section easily accessible?					
1.8.2	Is the condition of the breaching section satisfactory?					
1.8.3	Is the note of instructions as to when and how to					

	operate the breaching section available on record?					
1.8.4	For reconstruction after the breach, are the following items decided in advance?					
	a) Quarry for embankment material					
	b) Suitable routes of access					
1.8.5	Is the maintenance staff fully aware of the instructions related to operation of the beaching section and for reconstruction after the breach ?					
1.8.6	Ascertain and indicate the latest event of operation of breaching section and its performance.					
1.8.7	Evidence of recent degradation?					
1.8.8	Any other issues?					
B-1.9	**Junction of Earth work with Masonry/Concrete dam sections and outlets**					
1.9.1	Is there any existence of leaks, springs or wet spots in the earth work in the vicinity of the junctions between earth work and masonry works? If so, please indicate the approximate rate and colour of the leakage and if it turns turbid at any time. Please ascertain from enquiries and record the findings.					
1.9.2	Is there any tendency for separations, cracking, settlement or upheaval of the earth work in the vicinity of masonry or					

	concrete? If so, indicate the locations and the exact nature of deficiency.					
1.9.3	Is there any tendency for surface erosion or slope instability at the junction?					
1.9.4	If the outlet conduit is located in the earth dam section, is the entire length of the conduit in perfect order and profile and free from offsets, open joints, cracks and leakage? Examine the conduit carefully from the downstream or from inside, if possible, and indicate the deficiencies observed, if any.					
1.9.5	Any other issues?					
B-1.10	**Relief Wells**					
1.10.1	Are the relief wells in good working condition and functioning well?					
1.10.2	Are the relief wells properly surged and cleaned periodically?					
1.10.3	Please indicate the dates of last surging and cleaning and the next surging due.					
1.10.4	Are the necessary plant and equipment for cleaning the relief wells, available with the office?					
1.10.5	Is the record of periodical measurements of discharge from each relief well maintained? If so, indicate total					

	discharge and maximum discharge observed from a single well on the date of inspection.					
B-1.11	**Abutment Contacts**					
1.11.1	Any presence of leaks, springs or wet spots near the abutment?					
1.11.2	Any presence of cracking, settlement or upheaval of earthwork?					
1.11.3	Any evidence of erosion or slope instability?					
1.11.4	Trees or profuse growth of weeds/bushes?					
1.11.5	Any degradation to up/downstream slope protection (rip-rap, turfing)?					
1.11.6	Any other issues?					
B2	**Dam and Dam Block/Reach (Concrete/Masonry)**					
B2.1	**General Condition**					
2.1.1	Any major alterations or changes to the dam since the last inspection?					
2.1.2	Is there any new nearby development in the downstream floodplain?					
2.1.3	Any misalignment of poles, fencing or walls due to dam movement?					
B2.2	**Upstream Face**					
2.2.1	Evidence of surface defects (honeycombing, staining, stratification)?					
2.2.2	Concrete/masonry deterioration (spalling, leaching,					

	disintegration)?					
2.2.3	Is cracking present (structural, thermal, along joints)?					
2.2.4	Evidence of differential settlement (displaced/offset/open joints)?					
2.2.5	Presence of vegetation (growth in joints between blocks)?					
2.2.6	Evidence of any other damage to joints and/or water stops?					
2.2.7	Any other issues?					
B2.3	**Crest of Dam**					
2.3.1	Evidence of differential settlement (displaced/offset/open joints)?					
2.3.2	Presence of cracking (structural, thermal, along joints)?					
2.3.3	Profuse growth of weeds/grass/plants at any location?					
2.3.4	Any degradation to access road?					
2.3.5	Any degradation to upstream parapet or downstream curb wall?					
2.3.6	Any other issues?					
B2.4	**Downstream Face**					
2.4.1	Evidence of surface defects (honey-combing, staining, stratification)?					
2.4.2	Concrete/masonry deterioration (spalling, leaching, disintegration)?					

2.4.3	Presence of cracking (structural, thermal, along joints)?					
2.4.4	Evidence of differential settlement (displaced/offset/open joints)?					
2.4.5	Presence of vegetation (growth in joints between blocks)?					
2.4.6	Evidence of any other damage to joints and/or water stops?					
2.4.7	Excessive seepage/sweating at any location on downstream face?					
2.4.8	Significant leakage at any location on downstream face?					
2.4.9	Any other issues?					
B2.5	**Abutment Contacts**					
2.5.1	Any presence of leaks, springs or wet spots in vicinity of abutment?					
2.5.2	Any presence of cracking or settlement?					
2.5.3	Profuse growth of weeds/grass/plants at any location?					
2.5.4	Any other issues?					
D	**Gallery/Shaft and Drainage**					
D-1.1	**General Condition**					
1.1.1	Slushy condition or water logging immediately downstream of dam?					
1.1.2	Any evidence of boiling in vicinity of dam toe?					
D-1.2	**Gallery/Shaft Condition**					
1.2.1	Any problems accessing or					

	inspecting gallery/shaft (obstruction)?					
1.2.2	Any safety issues (inadequate handrails, lighting or ventilation)?					
1.2.3	Problems of inadequate drainage (slippery stairs, water logging of gallery, clogged porous or foundation drains)?					
1.2.4	Evidence of differential settlement (displaced/offset/open joints)?					
1.2.5	Excessive seepage/sweating at any location along gallery/shaft?					
1.2.6	Significant or excessive leakage at any location along gallery/shaft / porous drain? If yes, provide location(s).					
1.2.7	Are proper arrangements made for the measurement of seepage into the gallery?					
1.2.8	Is the seepage measured separately from Porous pipes, Foundation drains and Monolith Joints?					
1.2.9.	Are the above arrangements satisfactory?					
1.2.10.	Has there been substantial progressive reduction in the seepage through the foundations? Indicate if it is due to choking of the drain holes and if so, indicate the number of choked					

	holes.					
1.2.11.	Are all the foundation and porous holes periodically cleaned with reaming tool and air water jetting? Indicate the last date of such cleaning and extent of variation observed in the seepage discharge before and after the cleaning.					
1.2.12	Is the seepage water and the deposit, if any, from the seepage being regularly examined for chemical composition? If so, indicate the result and the probable source of dissolved salts, if any.					
1.2.13.	Are any seepage water springs observed in the downstream area any where? If so, indicate the locations and state the physical nature of this seepage. Look out for such seepage spots particularly near the dykes, fault zone etc. Ascertain if chemical testings are made of water samples from such springs for dissolved salts.					
1.2.14	Is there any leachate deposition? If yes provide location					
1.2.15	Any other issues?					
D-1.3	**<u>Drain Condition</u>**					

1.3.1	Is the flow in the drain unusually high or low?					
1.3.2	Presence of calcium or other deposits in drain?					
1.3.3	Is the dewatering pumping station fully operational?					
1.3.4	Any problem inspecting the pump?					
1.3.5	Any obstruction preventing or impairing smooth operation?					
1.3.6	Any deterioration of pump and associated equipment?					
1.3.7	Is the sump well clean and maintained?					
1.3.8	Is the V-notch before sump well cleaned and maintained?					
1.3.9	Any other evidence of the drain being blocked/having reduced section?					
1.3.10	Is the flow in the drain noticeably sporadic/irregular?					
1.3.11	Does the drainage water have unusual colour (leachate)?					
1.3.12	Any other issues?					
D-1.4	**Body Wall (Masonry/Concrete) of 'NOF' Dam**					
1.4.1	What is the total seepage into gallery from the porous pipes in the dam at lake full condition? Compare it with the seepage when the reservoir was first filled. (For the corresponding water level)					
1.4.2	Has there been substantial reduction in this seepage?					

	Ascertain and indicate the probable reasons therefore.					
1.4.3	Has there been a tendency for gradual reduction of drainage through pipes and progressive appearance of sweating on the downstream face of the dam?					
1.4.4	Has there been considerable leaching from the seepage water and deposition of lime near the seepage exit spots?					
1.4.5	Are the samples of the seepage water and reservoir water being regularly tested for reactive and corrosive properties?					
1.4.6	Is there excessive seepage, sweating at any locations on the downstream face of the dam? (Examine the monolith or construction joints for such seepage and leaching and indicate the findings)					
1.4.7	Is there any swelling or cracking observed on the downstream face especially near the points of concentration of stresses like the toe or locations of abrupt change in geometry of the face of the opening? If so, indicate the details of observations.					
1.4.8	Is the pointing on upstream face of the					

	dam in good condition? If not, indicate the nature and extent of deficiency.					
1.4.9	Are the registers and graphs showing the periodical measurements of seepage discharge from the porous drains in the gallery and from the downstream face at various lake levels maintained at site?					
E	**Spillway and Energy Dissipation Structure**					
E 1.1	**<u>Spillway</u>**					
1.1.1	Any problems inspecting spillway (obstructed access, damaged catwalk)?					
1.1.2	Any obstructions in or immediately downstream of the spillway?					
1.1.3	Evidence of abrasion, cavitation or scour on glacis (e.g. exposed reinforcement)?					
1.1.4	Presence of displaced, offset or open joints?					
1.1.5	Presence of cracking (structural, thermal, along joints)?					
1.1.6	Evidence of surface defects (honeycombing, staining, stratification)?					
1.1.7	Concrete/masonry deterioration (spalling, leaching, disintegration)?					
1.1.8	Presence of vegetation (growth in joints between blocks)?					

1.1.9	Evidence of any other damage to joints and/or waterstops?					
1.1.10	Excessive seepage/sweating at any location on spillway glacis?					
1.1.11	Significant leakage at any location on spillway glacis?					
1.1.12	Any other issues?					
E 1.2	**<u>Waste Weir Bar and Tail Channel</u>**					
1.2.1	Is the Concrete/masonry spillway bar in good condition? Indicate if there is any leakage through the masonry or from the foundation. If so, what remedial measures are proposed/taken for minimizing the leakage? Is the record of leakage measurement maintained? What is the quantity of Seepage/Leakage on the date of inspection?					
1.2.2	Is the coping over the spillway bar in good condition?					
1.2.3	Does the upstream and downstream face of waste weir bar need pointing?					
1.2.4	Is there any scouring on downstream side of the bar and/or EDA? If so what remedial measures are proposed/taken?					

1.2.5	Are there any damages or undermining to guide walls, divide wall and other appurtenants? If so, indicate what remedial measures are proposed/taken.					
E 1.3	**<u>Structural performance of the 'NOF' and 'OF' Portions of Dam Foundations</u>**					
1.3.1	Are there any signs of structural distress noticed in the dam spillway and foundations in the form of-					
	i. Excessive deflection with respect to permissible deflection at the time of design					
	ii. Tendency of gradual sliding					
	iii. Cracking and upheaval or settlement in any part of the body wall or foundations,					
	iv. Excessive uplift,					
	v. Excessive seepage and leaching through the body of the dam and the foundation.					
1.3.2	Conspicuous weathering of materials or components in any portion of the body wall or the foundations.					
E-1.4	**<u>Energy Dissipation Structure</u>**					
1.4.1	Any problems inspecting energy dissipation structure?					
1.4.2	Any obstructions in or immediately downstream of					

	dissipation structure?					
1.4.3	Evidence of abrasion, cavitation or scour on dissipation structure?					
1.4.4	Presence of displaced, offset or open joints?					
1.4.5	Presence of cracking (structural, thermal, along joints)?					
1.4.6	Evidence of surface defects (honeycombing, staining, stratification)?					
1.4.7	Concrete/masonry deterioration (spalling, leaching, disintegration)?					
1.4.8	Presence of vegetation (growth in joints between blocks)?					
1.4.9	Evidence of any other damage to joints?					
1.4.10	Any problems with under-drainage (blockage of open drain holes)?					
1.4.11	Can the tail pond be drained easily for inspection of the stilling basin or bucket? If not, indicate the alternatives available for dewatering. Please ascertain and indicate the last event of inspection of stilling basin (or bucket).					
1.4.12	From the examination of the levels and contour plans and reference marks in tail channel; is there progressive erosion and retrogression in					

	the tail channel? If so, indicate the extent and location of such erosion with reference to the various components of dam, spillway, outlet, power house etc.					
1.4.13	Is the concrete surface of the stilling basin and apron (or bucket) in good condition?					
1.4.14	Are there any indications of pitting, cracking, spalling or wearing of the surface of bedding concrete? If so, please give details of the nature and extent of the damage.					
1.4.15	Is there any indication of abrasion and cavitation damage (pitting of concrete) especially at friction blocks , chute blocks and slotted roller teeth, the surface near the lower tangent point and the end sill? If so, please give the details of nature and extent of damage.					
1.4.16	Is the under drainage of the stilling basin (or bucket) satisfactory? Are all the open drain holes clear and functioning well?					
1.4.17	Any other issues?					
G-1.5	**Walls: Guide walls/Divide walls/Junction walls/Return walls/Spray walls etc.**					
1.5.1	Are all the locations of such wall accessible for inspection, maintenance and					

	repairs?					
1.5.2	Is the drainage of back sides of the walls (wherever applicable) from the weep holes satisfactory? If not, indicate the nature of deficiencies.					
1.5.3	Is there any tendency for the water to undercut the ends of the walls?					
1.5.4	Is there any foundation erosion or scour noticed in the vicinity of such walls? If so, give the details of nature and extent of such damage.					
1.5.5	Is there any surface erosion/damage caused, to face or body of such walls?					
1.5.6	Do any of the walls show symptoms of unusual settlement, developments of cracks and tilting? If so, give details of the defects noticed.					
1.5.7	Is there any damage to guide bunds? If so, give details of the damage.					
G-1.6	**<u>End Weir</u>**					
1.6.1	Is it accessible?					
1.6.2	Is there any erosion, pitting or spalling of the concrete or masonry surface? If so, give details					
1.6.3	Is there any scour noticed on the immediate downstream of such weir? If so, give					

	details of location and extent of such damage.					
G-1.7	**Hydraulic Performance of Energy Dissipation Arrangements**					
1.7.1	Do the flow conditions in the stilling basin (or bucket) have a tendency to draw material into the bucket and cause its churning and abrasion damage to the surface of buckets baffle blocks, apron and end sill?					
1.7.2	Is the hydraulic performance in agreement with the results of model studies? (wherever applicable)					
1.7.3	Ascertain the performance from observed tail water rating curves and deficient observation, if any, such as sweep outs and excessive erosion under plunge pools and locations of secondary rollers and retrogression.					
F	**Intake/Outlet and Water Conveyance Structure**					
F-1.1	**Intake/Outlet Structure**					
1.1.1	Any problems inspecting intake/outlet structure (obstructed/unsafe access)?					
1.1.2	Any obstructions in, upstream or downstream of intake/outlet structure?					
1.1.3	Evidence of abrasion, cavitation or scour on intake/outlet					

	structure?					
1.1.4	Any evidence of structural distress (displaced/offset/open joints, cracking)?					
1.1.5	Any evidence of surface defects and/or concrete/masonry deterioration?					
1.1.6	Any other issues?					
F-1.2	**<u>Water Conveyance Structure</u>**					
1.2.1	Any problems inspecting intake/outlet structure (obstructed/unsafe access)?					
1.2.2	Any obstructions in, upstream or downstream of water conveyance structure?					
1.2.3	Evidence of abrasion, cavitation or scour on structure?					
1.2.4	Any evidence of structural distress (displaced/offset/open joints, cracking)?					
1.2.5	Any evidence of surface defects and/or material deterioration?					
1.2.6	Any evidence of seepage or leakage from water conveyance structure?					
1.2.7	Any other issues?					
G-1	**Hydro-Mechanical Component and Pump**					
G-1.1	**<u>Spillway Gates (Radial gates, Vertical lift gates, Automatic gates)</u>**					
1.1.1	Any problems inspecting gate/Stop-logs (obstructed/unsafe access)?					
1.1.2	Is the condition of the steel surface and the surface paint					

	deteriorated?					
1.1.3	Are any connection bolts of rubber seals loosened or damaged? If so, indicate the details of defects.					
1.1.4	Do any of the rubber seals show signs of weathering, hardening, cracking or tearing and damage?					
1.1.5	Are the rubber seals of side and bottom touching uniformly all along the sealing surface?					
1.1.6	Do the rollers (wherever applicable) touch the track plates uniformly? Are the rollers well lubricated?					
1.1.7	Are the embedded parts of spillway gates, emergency gates and stop-logs in sound condition and free from corrosion, uneven wear, cracking, chipping and dents? If not, state the nature of defects or deficiencies and observation, if any, regarding such defects.					
1.1.8	Are the following members and welded, bolted and riveted connections structurally sound? If not, please give details of any uneven wear, uneven bearing, cracking, chipping and dents and indicate the findings:					

	(1) Gate leaf and stiffeners					
	(2) End arms					
	(3) Trunnion girders / Yoke girder					
	(4) Stop logs					
	(5) Lifting beams					
	(6) Gantry cranes					
	(7) Tracks					
	(8) Trunnion bracket					
	(9) Chains/ wire ropes					
	(10) Bridge structure					
1.1.9	Are the trunnion bearings of radial gates properly lubricated?					
1.1.10	Is there any damage or wear caused to the seal plates? If so, indicate the nature of damage noticed.					
1.1.11	Are any of the mechanical or structural components and fastners or seals subjected to excessive wear? If so, please give details.					
1.1.12	Is there any tendency for recurring damage to any particular component? If so, please give details.					
1.1.13	Is sufficient stock of spares which need frequent replacement maintained at the site?					
1.1.14	Any issues with storage of equipment (emergency stop logs, lifting beam and gate leaves)?					

1.1.15	Any deterioration, corrosion? scaling? pitting? or cracking? of equipment (connecting bolts, welds?)					
1.1.16	Any obstructions preventing or impairing smooth operation?					
1.1.17	Any problems with the rollers (not touching tracks, inadequate lubrication)?					
1.1.18	Any debris, etc., in the gate grooves?					
1.1.19	Any damages to Radial Gate trunnion pins? gate arms? lubrication? etc.?					
1.1.20	Any damage to embedded parts above waterline? access structure?					
1.1.21	Any damage to concrete grooves?					
1.1.22	Is the staff posted at the site for maintenance and operation of gates, hoists, equipments and electrical installations, well experienced, fully trained and conversant with the job requirements and responsibilities?					
1.1.23	Are the following documents maintained at the respective location of all the units?					
	(1) Maintenance schedules specifying each operation, its frequency and 'due' and' done' dates.					

	(2) Operating instructions with 'dos' and 'don't' for all operational units.					
1.1.24	Are the trunnion hub and the brackets well maintained?					
1.1.25	Are the trunnions likely to get submerged during actual working of the spillway? if so, ascertain the causes for the same and specify. Please enquire for occurrence of such events, if any.					
1.1.26	Are all the nuts of connecting bolts and anchorages properly tightened?					
1.1.27	Any other issues?					
G-1.2	**Hoists, Cranes and Operating Mechanisms**					
1.2.1	Are the hoists working satisfactorily?					
1.2.2	Any problems inspecting hoist/crane/operating mechanism?					
1.2.3	Is sufficient stock of spares which need frequent replacement maintained at the site?					
1.2.4	Is the full length of the chains or wire rope of the hoist in sound condition and free from broken strands?					
1.2.5	Is the electrical wiring in sound condition?					
1.2.6	Is the alternative power system for gate operation working properly?					
1.2.7	Is the alternate hand operation system of					

	hoist working properly?					
1.2.8	Any deterioration of equipment (connecting bolts, welds, surface, paint work?)					
1.2.9	Any wear or damage to wire cables and other moving parts?					
1.2.10	Any obstructions preventing or impairing smooth operation?					
1.2.11	Any health and safety concerns (e.g. lack of "danger" sign during maintenance)?					
1.2.12	Any other issues?					
G 1.3.	**Spillway Bridge, Hoist Bridge, Trunnion Level Bridge Catwalks**					
1.3.1	Are the decking, girders and structural supports of spillway bridge, hoist bridge, trunnion level bridge and catwalks structurally sound?					
1.3.2	Is the chequered platform of the bridge structurally sound and safe?					
1.3.3	Is there satisfactory arrangement to prevent unauthorized entry into the control structures and bridges?					
1.3.4	Are the structural members and joints sound and free from corrosion?					
1.3.5	When were the steel components painted last?					
1.3.6	Is the surface of steel work and paints satisfactory?					

1.3.7	Is the parapet or railing over the bridges sound, safe and painted?					
1.3.8	Is the walkway properly anchored to the piers?					
1.3.9	Are the track rails for gantry cranes structurally sound and intact?					
G-1.4	**Valves**					
1.4.1	Any problems inspecting valve?					
1.4.2	Any obstructions preventing or impairing smooth operation?					
1.4.3	Any deterioration of valve and associated equipment?					
1.4.4	Any other issues?					
G-1.8	**Trash Racks**					
1.5.1	Is the trash rack fixed or movable?					
1.5.2	What is the mode of cleaning? Is it manual or by TRCM?					
1.5.3	Is the welding work on Trash Rack in sound health?					
1.5.4	Any problems inspecting trash rack?					
1.5.5	Problems of excessive debris and/or inadequate cleaning?					
1.5.6	Any deterioration of trash rack (rust, corrosion, and damaged blades)?					
1.5.7	Any other issues?					
G-1.9	**Trash Rack Cleaning Machines**					
1.6.1	Any problems inspecting trash rack cleaning machine?					

1.6.2	Missing or inadequate spare parts (particularly requiring regular replacement)?					
1.6.3	Any deterioration of equipment (wheel trolleys, gantry structures, operating mechanism, connecting bolts, welds, surface, paint work?)					
1.6.4	Any wear or damage to wire cables and other moving parts?					
1.6.5	Any obstructions preventing or impairing smooth operation?					
1.6.6	Missing or inadequate provision of back-up/standby power supply?					
1.6.7	Any health and safety concerns (e.g. lack of "danger" sign during maintenance)?					
1.6.8	Any other issues?					
G-1.10	**<u>Pumps</u>**					
1.7.1	Any problems inspecting pump?					
1.7.2	Any obstructions preventing or impairing smooth operation?					
1.7.3	Any deterioration of pump and associated equipment?					
1.7.4	Any other issues?					
G-1.11	**<u>Approach bridge, operation platform and cabin (for outlets)</u>:**					
1.8.1	Are the decking, girders and structural supports of approach bridge structurally sound?					

1.8.2	Is the floor of the operating platform structurally sound and safe?					
1.8.3	Is there satisfactory arrangement to prevent unauthorized entry into the control structures of the outlet?					
1.8.4	Are the structural members and joints sound and free from corrosion?					
1.8.5	When were the steel components painted last?					
1.8.6	Is the surface of steel work and paint satisfactory?					
1.8.7	Is the parapet or railing over the control tower, operating platform and approach bridge sound and safe?					
G-1.12	**<u>Outlet</u>**					
1.9.1	Is the air vent periodically cleaned?					
1.9.2	Are there any structural damages to the intake well?					
1.9.3	Is there any leakage observed through the well proper and the conduit concrete or masonry? If so, give details of its location and extent.					
1.9.4	Is there any damage noticed to the conduit concrete, breast wall and gate slots?					
1.9.5	Is the bye-pass valve/filling-in-valve (wherever provided) operating satisfactory?					

	Take operation trials of the following as provided and record the observations and defects noticed, if any.					
	(1) Service gate(s).					
	(2) Emergency gate(s).					
	(3) Stop-log gate(s).					
	(4) Sluice valves.					
	Note-					
	(i) The operating trial for the emergency gate shall be taken with service gate in partially open position to test the capability of emergency gate for self-closing under these conditions. The trial for the operation of the emergency gate under balanced condition of water pressure also needs to be taken					
	(ii) To guard against the possibility of outlet gate hoist being operated forcibly after closed position of gate a "Distinctive Mark" should be insisted or check the functioning of the limit switches.					
1.9.6	Are there vibrations and noise noticed in operation of out- let gates at any time? If so, please indicate if periodical observations have been taken to ascertain their severity.					
1.9.7	Is the energy dissipation arrangement working					

	satisfactorily for all the discharges?					
1.9.8	Is there any structural damage to the energy dissipation structure? If so, give details of nature and extent of damage.					
1.9.9	Is the conduit structurally sound and reasonably leak proof? If not, give details of nature and extent of the defects.					
1.9.10	Is there any seepage noticed around the conduit as ascertained from the observations of the downstream conditions? If so, please indicate if it is likely to cause erosion and piping (In case of earth dams).					
G-1.13	**<u>Outlet Gates</u>**					
1.10.1	Is the surface of gates and the paint deteriorated?					
1.10.2	Are the connecting bolts of rubber seals properly tightened or damaged?					
1.10.3	Do the rubber seals show signs of weathering and damage and need replacements?					
1.10.4	Are the rubber seals of sides and bottom touching the bearing surface uniformly?					
1.10.5	Do all the rollers touch the track plates?					
1.10.6	Are the rollers well lubricated?					

1.10.7	Are the stem rods for lifting the gates perfectly straight?					
1.10.8	Is the operation of outlet gates smooth?					
1.10.9	Are the actual operations of lifting and lowering of the gates and hoist mechanisms adequate and smooth?					
1.10.10	Are all the gears and hoist mechanisms well lubricated?					
1.10.11	Is the storing arrangement for emergency gate leaves and the stop logs in satisfactory condition?					
1.10.12	Are the seal plates/seats in sound condition?					
1.10.13	Is the full length of wire rope (wherever applicable) of the hoist in serviceable condition and free from any broken strands?					
1.10.14	Are all the nuts of connecting bolt and anchors properly tightened?					
1.10.15	Are all the lifting beams in proper working order and in levelled condition? If not, ascertain the nature and extent of problems.					
1.10.16	Do any of the mechanical or structural parts of the gate, fasteners of hoist show signs of excessive wear? If so, please give details.					

1.10.17	Is there any tendency for recurring damage to any particular component or components? If so, please give details.					
1.10.18	Is sufficient stock of spares, which need frequent replacement, maintained at the site?					
G-1.14	**River Outlet/River Sluice**					
1.11.1	Is the overall condition of river outlet works/river sluices satisfactory?					
1.11.2	Is the operation of the gate (Service/Emergency/ Stop-log) satisfactory as ascertained by taking operating trial? If not, indicate the defects noticed.					
1.11.3	Are the trash racks (wherever provided) cleaned before monsoon?					
1.11.4	Is there excessive silting on the upstream of the sluice?					
1.11.5	When were the gates last opened for desilting, etc.?					
1.11.6	Please indicate the approximate quantity of the leakage through the gates, if any.					
1.11.7	Is there any seepage or leakage through the conduit surface?					
1.11.8	Is there any damage to the upstream and downstream convergence of the conduit?					

1.11.9	Is the condition of energy dissipation arrangement satisfactory? If not, indicate nature and extent of damage.					
1.11.10	Is there any retrogression noticed in the downstream channel? If so, give details of nature and extent of damage.					
H-1	**Access Road**					
H-1.1	**General Condition**					
1.1.1	Any problems ensuring security of dam site (including gates and fencing)?					
1.1.2	Is there a properly constructed and well maintained all weather access road to the dam site?					
1.1.3	What is the type of the pavement of the access road and its condition?					
1.1.4	Are there properly constructed and well maintained access road arrangements to the following components for inspection, maintenance and repairs? Top of Dam Spillway Gates and hoisting arrangement Drainage gallery, adits and exits Bridge structure Downstream stilling basin Junction and abutments Outlet control tower Outlet gates Toe of earth dam, downstream drainage arrangements and berms. All saddle dams.					

1.1.5	Are all the masonry structures on various access roads in good condition?					
1.1.6	Are all the structures on the access roads adequately safe for allowing passage of plant machinery for emergent repairs?					
1.1.7	Any obstructions along or at entrance to access road (temporary or long-term)?					
1.1.8	Any slope stability issues (road embankment or adjacent slopes)?					
1.1.9	Profuse growth of weeds/grass on or in vicinity of access road?					
1.1.10	Any drainage problems (standing water on or adjacent to road)?					
1.1.11	Any other degradation to road surface (ruts, potholes, cavities, cracking)?					
1.1.12	Any other issues?					
I-1	**Instrumentation**					
I-1.1	**<u>General Condition</u>**					
1.1.1	Are all the instruments installed accessible? (Attach separate list).					
1.1.2	Are all the locations properly lighted, ventilated and adequately protected from possibilities of damage?					
1.1.3	Any problems inspecting instrument (obstructed/unsafe					

	access)?					
1.1.4	Is the instrument vulnerable to damage or theft (inadequate protection)?					
1.1.5	Any problems ensuring correct functioning of instrument (lighting, ventilation)?					
1.1.6	Any evidence of degradation to condition of instrument (rusting, vandalism)?					
1.1.7	Are all the instruments in working order? Ascertain the cases of instruments going out of order and indicate.					
1.1.8	Are all the registers of observations posted up-to-date? Please take test observations and initial the register.					
1.1.9	Are all the plotting of the instrumentation data completed up-to-date?					
1.1.10	Are sufficient stocks of spares, gauges, master gauges, stationary items etc., maintained at the site for uninterrupted data collection?					
1.1.11	Operator or public safety issues?					
1.1.12	Any other issues?					
I-1.2	**<u>Communication Facilities</u>**					
1.2.1	Are following facilities available at dam site? (1) Wireless Telephone / mobile/Fax/Internet					

1.2.2	Any other issue (please indicate part, location, etc., as necessary)					
K-1	**Emergency Preparedness**					
K-1.1.	**<u>Emergency Action Plan</u>**					
1.1.1	Is the Emergency Action Plan (EAP) prepared for the dam as per the national guidelines? If not, the expected date of preparation of guidelines					
1.1.2	When EAP was last updated?					
1.1.3	If not, are any dam staff unaware or insufficiently conversant with the EAP?					
1.1.4	Any concerned authorities unaware or insufficiently conversant with the EAP?					
1.1.5	Are communication directories/contact details and other dynamic information are being updated annually?					
1.1.6	Any problems accessing or operating the communication/ warning system?					
1.1.7	Are inundation maps updated and available to concerned authorities?					
1.1.8	Are the concerned authorities informed about the system of emergency reporting procedures and warning?					

1.1.9	Are available safety spots on the downstream of the dam identified and made known to the concerned authorities?					
1.1.10	Are adequate warning devices and facilities provided at the dam?					
1.1.11	Are proper arrangements made for security of the dam and preventing cases of unauthorized trespass, vandalism and sabotage to the dam works?					
1.1.12	Date of last annual stakeholder consultation meeting along with mock drill exercise conducted					
1.1.13	Has the EAP been disseminated to all the concerned stakeholders?					
1.1.14	Any other issues?					
K-1.2	**<u>Inspection of Records</u>**					
1.2.1	Have the following Dam Safety Documents been prepared and approved by the competent authority?					
	I. As Built Drawings					
	II. EAP					
	III. Completion Report					
	IV. Data Book					
	V. O and M manual					
1.2.2	Are the relevant documents reviewed and updated from time to time?					

1.2.3	Are all the members of the maintenance staff adequately trained and fully conversant with their responsibilities concerning.					
	(a) Designer's Operation Criteria.					
	(b) Standing Operating Procedures.					
	(c) Maintenance and Vigilance Procedures of the dam.					
	(d) Maintenance and operation of all control equipments.					
	(e) Reservoir Operation Schedules, Gate Operation Schedule					
	(f) Maintenance and Operation of all instruments.					
	(g) Identification of signs of deficient behaviour.					
	(h) Reporting Procedures of emergency situations.					
	(i) Emergency repairs					
L-1.1	**Inspection Photographs**					
1.1.1	Information to be furnished as per Annexure - II					

ANNEXURE 4

REPORT OF DAM SAFETY REVIEW PANEL

Minutes of meeting conducted at K.S.E.B – I.B at Poringalkuthu in connection with the inspection of Sholayar Dams on 19.12.2012 by Dam Safety Review Panel constituted by the Government of Kerala.

Present:-

1. Sri. S.K. Das – Former Chairman CWC and Chairman DSRP
2. Dr. Komalavalli Amma – Member DSRP
3. Sri. Rajagopalan – Member DSRP, Director GSI Retired
4. Sri. K.K. Karuppankutty – Chief Engineer(C-DS), KSEB
5. Sri. P.K. Moni – Project Director (DRIP) & Director, Research &Dam Safety Organisation, KSEB
6. Sri. G. Radhakrishnan – Deputy Director, Research &Dam Safety Division, Idamalayar
7. Sri. C.S. Sajeev - Assistant Executive Engineer, Dam Safety Sub Division, Chalakudy

The DSRP panel team headed by its Chairman inspected the Sholayar Dam on 19.12.2012. The DSRP team was accompanied by the KSEB Engineers and also Engineers from the Irrigation Department. The team conducted a detailed inspection of Sholayar Main Dam, Flanking Dam and Saddle Dam and its connected structures. After conducting the inspection detailed discussions were held at KSEB – IB at Poringalkuthu and recommended the following.

1. Under water investigation of the upstream side of the Sholayar Main Dam is essential to determine the extent of cracking leading to seepage in the Dam and also carry out pulse velocity test through the Dam body to determine the quality of masonry. The Chief Engineer (C-DS) KSEB is required to contact CSMRS to conduct investigations.
2. There is significant calcination on the D/S face of Sholayar Main Dam, spillway concrete blocks and Flanking Dam as well as vegetation. These need to be removed from the surface followed by cement washing.
3. To review periodically the inflow design flood in consultation with CWC.
4. Majority of foundation drain holes which are choked have to be rehabilitated by reaming. Pressure gauges to be installed to for measuring uplift pressure.
5. Project authority to take up catchment area treatment. They are also to prepare emergency action plan

Date: 19.09.2014 Signature of Deputy Chief Engineer, SPMU, KSEB

ANNEXURE 5

GEOLOGY

A. SHOLAYAR FLANKING DAM

The excavation for the Sholayar Flanking Dam was first started in spillway blocks. During excavation good rock suitable for the foundation was not met with at anticipated levels for a considerable area of Dam foundation and quite an amount of unsuitable rock for the foundation had to be blasted and removed. Though rock was seen during drilling, the rock was not good enough to receive the foundation of the overflow section and hence this stuff was removed till good granite was met with.

As per finalised design the spillway bucket in between chainage 68.88 m and 96.32 m had to be formed from RL +786.69 m which was on the assumption that sound rock would be available at this level. But on exposing the foundation a local faulty zone was noticed between chainage 71.63 m and 89.92 m and in this portion excavation had to be done up to RL +781.35 m to meet good rock. The exposed foundation was inspected by the Chief Engineer and Geologist of Government of India. As suggested by them 1:3:5 ½ concrete filling in the bucket portion up to elevation +786.69 m that is up to the bottom level of the bucket, was done with necessary keys and fixing anchor rods. In the masonry portion of dam a 3.05 to 3.66 m thick layer of concrete was laid for the full width of dam and the dam masonry was built over it.

The spillway bucket in between chainage 96.32 m and 137.16 m was designed on the assumption that good rock would be met with at level +790.50 m and the bucket was to be formed from that level between the above chainages. Bore hole results had indicated good rock at +790.50 m. But on actual execution the excavation between chainages 96.32 m and 116.43 m had to be done below +790.50 m so as to get sound rock for forming the buckets. The additional depth of excavation below +790.50 m was filled with 1:3:5 ½ concrete and the required trenches for the toe of buckets etc. as per design drawings were formed in the concrete itself. The additional quantity of concrete required for filling the additional depth in between chainage 96.32 m and 116.43 m was 495.54m^3.

There were similar foundation problems in tackling the foundation for dam in between chainage 121.92 m and 152.40 m. The rock met with in this region was laminated and highly jointed. Expert opinion of the Geologist was also sought for before attempting building of dam in this portion. As suggested by him a small cut off trench of size 1.83 m x 0.91 m for a length of 30.48 m at the upstream side of the dam between chainage 121.92 m and 152.40 m has been excavated and filled with cement concrete 1:3:5 ½ to cut off the seepage line in this region.

Similarly the rock on the downstream edge of dam between chainage 134.11 m and 152.40 m was highly laminated and sloping towards the downstream toe. Concrete has been laid in this area also for 0.91 m height to bring the same to the level of the foundation rock on the upstream side. Also the transverse soft seams found in the foundation rock, had to be scooped out and filled with concrete for a height of 0.61 m as suggested by the Geologist. Preparation of the foundation surface of the entire area of dam for receiving masonry and concrete was done as per technical specifications for the construction of dams. The crevices and trenches were filled with concrete and additional layers of concrete wherever found necessary were also laid before starting masonry.

Although benching of rock was not provided for this dam, benching was found necessary for a small area in view of the layout of rock.

In block No. 8 a transverse faulty seam was noticed between chainage 205.74 m and 210.31 m. This was scooped out till good rock was met with and concrete was laid in that portion in two steps. A cut off trench 1.22 m x 1.22 m size at the upstream face in this portion for 4.57 m length has also been formed and concreted before starting masonry so as to cut off seepage water from the upstream side.

As per original proposals, on the left bank, the dam had to be stopped at chainage 0. But during excavation for foundation as sound rock was not met with at FRL at chainage zero for abutting the end into the hard rock, the dam had to be extended for another 6.10 m more. The rock met with at chainage zero at FRL was fractured and fissured and so it was not possible to stop the dam at chainage zero as originally designed. As further excavation would cause greater expenditure it was decided to seal this bad rock at the end with a small

quantity of about 70.79 m^3 of cement concrete, providing an additional contraction joint at chainage 1.52 m and the work was carried out accordingly.

Opinion of the Geologists on the foundation

After excavating the foundation between chainages 60.96 m to 201.17 m, the Resident Geologist Sri. V. Rama Rao inspected the foundation on 24th and 25th January 1963. The opinion of the Geologist after his inspection is reproduced below.

"Two major joints 1.52 m apart and trending N 70^0 E – S 70^0 W and dipping vertical have been noticed in the spillway section of the foundation extending from upstream side to downstream side. In the right flank the gneiss is highly weathered and jointed and excavation is still progressing. The biotite gneiss in the entire foundation of the flanking dam is highly jointed. Three major joints are noticed in the right flank in block Nos. 4 and 5. The trend of these joints are as follows:

Chainage	Trend	Amount of dip and direction
450	E-W	Vertical
489	N-70^0W	75^0 in S.W.
500	N.65^0	45^0 S.W.

The head of the water above the foundation levels in blocks 4 and 5 will be about 20.73 m. It is suggested that after reaching the foundation grade levels the joint openings may be scooped out to twice its width and should be washed with a jet of air and water before back filling with concrete and grouted. In view of the jointed nature of the rock it is recommended that 3 cut off trenches may be provided towards the upstream, middle and toe line the spillway section as well as in blocks 4 and 5 where the major joint openings are present. Additional grout holes along the joints at 3.05 m intervals may be provided for grouting the joints at deeper levels in addition to consolidation grout holes. It is also suggested that curtain grouting may also be provided for the entire length of the flanking dam."

B. SHOLAYAR MAIN DAM

For the Main Dam, three sites there investigated. Trial borings were taken at the site which was selected finally, in two lines spaced 45.72 m apart. The results show that fairly good rock was available at reasonable depth from the ground level. The construction of the Main Dam including foundation excavation was done in four stages. The first stage of construction including the excavation works was done during the period 1.06.1960 to 10.07.1962 for a total number of 515 working days. During excavation, it was noticed that in block 3 the foundation rock was all stratified, weathered and fractured. Even though excavation had been carried out to depths more than those indicated by the trial borings during investigation, the nature of rock did not improve. The Geologist were consulted and as per their advice a curt-off trench was provided at the heel of the Dam in the river bed portion. The area containing stratified and weathered rock was covered with concrete after scooping out all the loose materials.

The rock type varied from granitic gneiss to banded gneiss, at the Dam site. Two types of rock were predominant namely blocky and jointed granite and dark foliated gneiss. The existence of profused joints (straight joints, dip joints and horizontal inclined joints) fractures and foliations were likely paths for seepage of water. In the case of blocky and jointed rock bed, the joint planes were sometimes filled with silt and sand. Disintegrated and fractured rock noticed during the excavation were completely removed.

Though there were no major foundation problems in the construction of this dam, the Geologists of the Government of India were consulted at different stages of foundation excavation. The foundation problems mainly appeared in blocks 3, 9 and 10. In block 3 a major fissure right across the dam was met with. This fissure was back filled with concrete after scooping out all loose material. The transverse gallery has been located right above this fissure so as to enable any further drilling and grouting if found necessary at a later date.

In block 9 during excavation, earth band was met with. This earth band was extending underneath block 8 which was already constructed and so removal of earth band had to be done very carefully. All the earth in block 9 was entirely removed from the band and the earth to the extent that could be removed underneath block 8 also was removed. The scooped out area was completely back filled with concrete with grills of old rail pieces.

Other minor fissures noticed during excavation were completely back filled with concrete after scooping out the bad stuff.

In general first class foundation was met with in almost all blocks but for the minor localised faulty zones and fissures mainly in blocks 3, 4, 5, 6 and 9. In these blocks a thick layer of concrete to a maximum depth of about 7.62 m has been laid so as to strengthen the foundation. These areas were grouted for consolidation after the concrete was laid.

The construction of the masonry portion of the dam was carried out in three different stages. The first stage envisaged the construction of masonry up to + 780.29 m in five blocks while the second stage of construction was for the completion of the dam up to the top level in full. The diversion of the river, preparation of foundation and concreting between chainages 190.50 m and 232.56 m in blocks 5 and 6 was carried out under a separate contract.

ANNEXURE 6

MANUAL FOR OPERATION AND MAINTENANCE OF VARIOUS INSTALLATIONS

OPERATION MANUAL

FOR

EMERGENCY GATE

AT

SHOLAYAR DAM

KSEB LTD.

PREFACE

This operation manual is specially intended to cover relevant points needed for operation and maintenance of Emergency gate at sholayar dam. for KSEB Ltd. Special section is also included for periodic maintenance, lubrication, and trouble shooting etc. which will enable the user to achieve best results.

It is recommended that the personnel handling the equipment will have gone through this Manual before operating the equipment. Care should be taken to follow the operation procedures for good performance.

CONTENTS

EMERGENCY GATE

I(a). SPECIFICATION – GENERAL

a)	Designation	: Emergency Gate.
b)	Code/standards	: IS 4622 – 1992.
c)	Type	: Vertical lift
d)	Quantity	: 1 No
e)	Gate size (width x height)	: 3100 mm X 1630 mm
f)	Mode of operation	: Rope drum hoist Mechanism.
g)	Vertical travel	: 46 mtr.

2. ***PERIODICAL & PREVENTIVE MAINTENANCE***

Proper care and maintenance of the equipment is the most important factor in increasing the reliability of operation and life of the equipment. Following are a few important points which need attention.

1. Lubrication of moving parts

All moving parts of the equipment are to be periodically lubricated.Lubrication schedule/chart is attached below for reference. During lubrication of all open gears, it must be noted that they are not in operation and there is no foreign materials/dirts on the surfaces to be lubricated.

2. Lubrication chart

Sl. No.	Item	Recommended grade	Periodicity	Remarks
1.	Worm reducers of hoist	Servo Gear SM-90 of IOC or equivalent	Once in every year	Regular check or oil level is to be made and replenish with oil if necessary
2.	Hoists and other grease nipples	Servo Gear 2/3 of IOC or equivalent	Once in every three months	
4.	All pinion and gear wheels, guide shoes in the gate elements and lifting rollers	Servo Grease 'C' of IOC or equivalent	Once in every three months	
5.	Wire rope	Cardium compound	Once in every year, preferably before the onset of monsoon	

3. Preventive maintenance

While designing and manufacturing the equipment, sufficient care has been taken to use the correct materials and manufacturing process to avoid break down during operation.

a) Electro Magnetic Brakes

Worn out brake linings are to be replaced immediately.

b) Lifting Beam

For proper functioning of the lifting beam, lubrication of pins on the hook is a must. By properly greasing the pins, the hooks shall be free to oscillate without much effort. All wheels of the lifting beam are also to be lubricated. The operator is to ensure that both the hooks, are free to rotate for every successive operation.

c) Guide Shoe

Check the bolts and nuts periodically.

Fig 1 Emergency gate hoisting mechanism

d) Painting

i)	Gates	-	All gates are to be properly repainted with two coats of Blend Epoxy Resin Paint once in every year. If any rusting is noticed, the rusted area is to be thoroughly cleaned and one coat of zinc rich primer is to be applied before applying epoxy paint.
ii)	Hoists	-	All parts of hoists are to be properly repainted with two coats of Aluminum paint once in every two years and this shall be done .preferably before the on set of monsoon.

3. PRE-OPERATIVE CHECKS

Before operation of the equipment, please ensure the following:

a) All the moving parts are properly lubricated.
(Ref. Lubrication Chart)

b) Power supply is available in all the three phases, which is indicated by the pilot lamps provided in the panel board. (Switch on the Rotary Switch in the Panel Board).

c) All electrical fuses in the Panel Board are intact.

d) All the electro-magnetic brakes are functioning properly.

e) All obstructions to the movement of the rope and equipment are removed.

f) The Hand-Operation dogging-clutch is fully released away from the driving shaft wherever applicable.

g) All Pinion, wheel ,Sprocket are properly lubricated.

h) All bolts and nuts are properly tightened.

i) No foreign materials are trapped between the moving parts.

4. OPERATION

A. ELECTRICAL

The hoist unit is fitted with a Panel Board. Open the Panel Board using the key supplied. Switch on the power supply. Check the power supply in all the phases

Check the voltage in all the phases using the Voltmeter provided in the Panel Board and ensures that the required voltage is available for starting of the motor. For raising the

gate, press the push button, **Raise / Forward**. Carefully watch the functioning of the hoist. The current flowing through the circuit can be measured using the Ammeter provided in the Panel Board. Any abnormal working of hoist unit indicates that there is obstruction/fouling against the free operation of hoist/gate. The hoist is to be stopped immediately by pressing the push button **Off** and the obstruction is to be removed. The hoist is to be restarted only after removal of all obstructions.

By pressing the push button for **Off**, the gate can be stopped in any desired position within its limits. After stopping the hoist motor, wait for a few minutes to observe whether the gate leaf is creeping down. If so, it may be due to improper holding of the brake shoes on the break drum coupling. The brake shoes can be adjusted by tightening the nuts and check nuts. In no case, over tightening is recommended, as the break drum coupling will not freely rotate when the motor is switched on, resulting in overloading of motor. In any case, the motor should not be reversed all of a sudden. Allow sufficient time for the motor to come to a halt, before re-starting/changing direction of the rotation of the motor. The gate can be lowered by pressing the push button for **Lower / Reverse**.

B. HAND OPERATION

Switch off the power supply in the Panel Board by turning the handle of the rotary switch. Engage the sliding clutch connecting the hand operation drive shaft with the motor shaft. Disengage the brake by turning the handle. The hoist can be operated by rotating the handle of the hand operation. The operation of the hoists and gates are to be done by trained and skilled operators under the supervision of a qualified Engineer.

5. TROUBLE SHOOTING

A. Motor

1.	Motor fails to start	a. No main supply	Check power supply
		b. Single phasing of power circuit	Check blown fuses or dead line and replace if necessary
		c. Single phasing of motor starter	Ensure that all finger contacts of starter make contact simultaneously when closed
		d. Tripping of overload protecting device or open circuit of contacts	Ensure that the system is not overloaded, if not try to close the protecting device
2.	Motor vibrates	a. Ball bearing damaged, indicated through rattling noise of the machine during running	Replace the bearing
3.	Motors slows down or stops	a. Phase drop out	Switch off and check the fuses, replace if necessary
4.	Fuses blow out when motor starts	a. Fuses too weak	Replace with correctly rated fuse
		b. Short circuit in motor stator winding	Check for short circuit and rewind if necessary

B. Electro-magnetic Brake

1.	Brake does not hold	a. Clearance of brake Shoes with brake drum Coupling too much	Adjust the clearance with the help of feeler gauge
		b. Brake liner worn out	Replace complete liner set
		c. Faulty solenoid coil	Replace the coil

A. Lifting Beam

1.	Lifting beam does not dehook the element when lowered	a. Hook of lifting beam is Not clearing off the pin	Lower the lifting beam by one or two inches to clear off the pin
2.	Lifting beam is not hooking the element	a. Lifting beam is not Sufficiently lowered to Clear off the pin	Lower the lifting beam by one or two inches to clear off the pin
		b. Lifting beam is out of Position	Position the chain pulley block properly and lower the lifting beam

6. *LIST OF DRAWINGS*

I. Emergency Gate :

General arrangements	5139/SH/01/2016.(R4)
General arrangements(Dummy Gate)	5139/SH/02/2017.(R0)
Details of Guide shoe assembly	5139/SH/03/2017.(R0)
Schematic diagram of control panel	5416/SK/1006/17.(R0)

OPERATING INSTRUCTIONS OF RADIAL GATES

CONTENTS

I. RADIAL GATE

1. General

The operation should be conducted by educated and responsible personnel only. Before any operation, the operator should ensure that the electric power is available. The operator should also ensure that each member of the equipment is tightly fitted in its correct position. Automatic protection has been provided with equipment, the operator should also pay his careful attention to the movement of gates during operation so as to avoid any overloading of the equipment under jamming condition. If any control does not operate properly or adjustment or repairs seem to be needed or any defect is found, the operator should stop the operation and inform it to the officers in charge with a request of inspection or repairing. Wherever there is any doubt as to safely, the operator shall stop and not operate the equipment until safety has been assured.

Dated and detailed records should be kept so as to be readily available to the officers in charge. The repairing procedure will depend on the extent of damage. Therefore, the repairing procedures shall be prepared by the maintenance staff at the time of inspection of the equipments. Complete inspection of the equipments or structures shall be performed at intervals as generally defined in these instructions.

2. TECHNICAL DATA

2.1 Principal dimensions:-

Clear width and height - 10.97 m x 6.40 m

2.2 Gate speed:-

Raising and lowering with motor V = 0.30 m/min

3. OPERATION

During floods or other-wise the gate/gates shall be operated electrically. Manual operation may be used in case of power failure. The operation shall be performed in the following manner:

3.1 The gates shall be operated from local control panels located on hoist bridge.

3.2 Three push buttons namely 'Raise', 'Lower' and 'stop' have been provided in control panels for gate operation.

3.3 The 'Raise' push button is to be pressed while the gate is required to be raised. Similarly 'Lower' push button may be pressed for lowering of the gate. For stopping motion of the gate during its raising or lowering, push button 'stop' may be pressed. Once the push button 'Raise' or 'Lower' is pressed, the motion of gate will automatically be arrested in its extreme allowed raised or lowered position respectively by means of limit switch unless the 'stop' push button is pressed for any intermediate position of the gate.

3.4 In the event of electric power failure, the gate may be operated with the help of emergency hand operating mechanism provided with the hoist. For manual operation, the hand operating lever should be first engaged with the shaft.. After manual operation has been completed, the lever should be brought back to its normal position so as to keep the emergency hand operating mechanism disconnected with the motor shaft.

3.5 In case the gate is found to be sticking in any position during operation or making unusual sound 'Stop' push button should immediately be pressed. The gate then should be operated in reverse direction for some time and then again in the desired direction, If still the gate is stuck-up, the operator should press the 'stop'

push button and report the matter to his superiors for necessary action. The gate should be put into operation again only after finding out the cause of trouble and attending the same.

3.6 During the period of gate not required to be operated, the main isolating switch should be kept in 'Off' position and should be brought to 'On' position just before operating the gate.

II. HOIST

1. General

1.1 Any work and / or repairs respectively on the hoist unit should only be carried out if:

1.1.1 The hoist main switch is turned off

1.1.2 A caution plate indicating " do not switch", "danger", suspends from the main switch.

1.1.3 The gate is resting on the bottom.

1.2 During the first months after initial operation and after repairs have been carried out be sure to check that;

1.2.1 All key connections are tight.

1.2.2 No belts have worked themselves loose.

1.2.3 No bolt locks are damaged.

2. Maintenance

2.1 Lubrication, general:-

During lubrication, care should be taken that

2.1.1 All lubrication points and nipples are clean

2.1.2 Bare shafts and pads are always greased and coated with anticorrosive paint.

2.1.3 The application of grease to the lubrication points is carried out regularly and the grease must come out laterally from the bearing

2.1.4 Large bearings are sufficiently supplied with grease.

2.1.5 All joints, bolts and movable parts are oiled from time to time.

2.1.6 The friction disk and brake shoes are free from oil and dust.

2.2 Lubrication of the spur gear:

The gear shall always be filled with oil up to the oil level mark. After 100 operating hours respectively at least after approximately 6 weeks the first change of oil should take place. Future oil changes after the gears have well been set in, should take place every half year. When changing the oil, it should be drained in warm condition and the casing should be subsequently thoroughly be flushed with SHELL oil J1. Only afterwards the gear should be re-filled with SHELL HDL. Filling amount = 4 litres.

2.3 Lubrication of tooth flanks on open spur gear transmissions:

2.3.1 After assembly is completed and if no more soiling is expected, the tooth flanks are to be cleaned with carbon tetra chloride or benzene and to be lubricated with a brush.

2.3.2 Damaged spots on the lubricating film shall be repaired immediately.

2.4 Lubrication of the ropes:

2.4.1 Wire rope shall be lubricated before operation or every six months with Shell Cardium Compound D or Surett-15 or equivalent lubricant.

2.4.2 Wire rope shall be replaced when any strand is found broken. Even if no damages are seen for rope it shall be tested once in 5 years for the breaking strength. If the results are found less than the required value the rope shall be replaced with new one.

2.5 Lubrication of the roller chain:

The roller chain for operating the position indicator should be frequently oiled and be cleaned from time to time.

2.6 Lubricant:

It is advisable to use the recommended lubricants. The use of other makes of equal qualities is permissible.

2.7 If the limit switches for repair purposes are being uncoupled from the hoist unit, attention should be paid that the switches are operating at the foreseen positions.

III. Operation of the Hoist unit:

1. Worm gear

   The bearing temperature during operation should be checked from time to time by placing the hand on it.

2. Movement of the gates.

   Motor driven : Raising and Lowering

   Hand operated : Raising and Lowering

3. Electrical drive:

   Before starting with the operation be careful that:

   3.1. The stopping brake is ready to be used

   3.2. The shaft stub for hand operation is provided with a protection cover.

   3.3. The protection cover should be properly bolted.

4. Hand operation drive:

   Before operation, please check that:

   4.1. The brake is released.

   4.2. A danger sign is placed to the switch

   Cabinet reading "do not switch", "danger". After the raising and lowering movement by hand, attention should be paid that the brake is again under power and the protection cover again be bolted.

IV. Description of the electrical control

1. PERIODICAL MAINTENANCE & ADJUSTMENTS OF MOTOR

1.1 MOTOR:

All the motors, brake system, control panel and limit switches shall be overhauled once in every year preferably before monsoon , and after monsoon. All the components shall be checked in detail for the electrical parameters. If any components are seen damaged shall be repaired/ replaced so as to ensure smooth operating of the equipments.

1.1.1 The ventilators of gear box should be cleaned after every six months.

1.1.2 The bearings of electric motor should be grease lubricated once in six months. The grease to be used shall be Lithium based multi-purpose grease, grade III to IS 1002/ 1955.

(i) Shell multipurpose grease II (ii) Esso multipurpose H. Every three years, the complete grease charge should be removed, the bearings and housings washed with petrol to which a few drop of oil have been added and thoroughly dried; all old grease replaced by now grease.

It is important to note that only required quantity of grease should be put into the bearings as too much grease may also cause overheating in the same way as too little grease.

1.1.3 The brake lining adjustment should be checked after every three months and it should be free from grease, oil and humidity. To compensate for lining wear, it shall be roughened as and when required.

1.1.4 Before operation or every six months, the hoist shaft alignment should be checked and a heavy gear lubricant of a good grade should be added or charged in flexible couplings.

1.1.5 All bolts & nuts of couplings should be checked every six months and ensured that they are neither loose nor damaged.

1.1.6 Greasing of all bearings, plummer blocks, hoist drum bearings and gears/pinions should be done before operation or every six months and old grease should be pressed out.

1.1.7 The insulation resistance of windings of motors shall be tested weekly during rainy season by means of a megger and where it is found to drop below 1MOhm/KV with a minimum of 1MOhm/KV the motor should be dried out and then put into service. If weak insulation becomes a regular feature, the winding should be given a coat of good insulating varnish after the machine has been dried out.

1.1.8 Every six months, the gate should be put into operation to ensure proper functioning of all components. Also exposed surfaces of embedded parts and gates should be cleaned of all rust and foreign material.

The following should be checked specifically and rectification done if necessary:

(a) To ensure proper alignment of guides, seal seats, guide rollers and rubber seals.

(b) To ensure that rubber seals and stainless steel seal seat is no damaged. If found damaged, the same should be replaced by new seals.

(c) All the bolts and nuts (fasteners), specifically load bearing/ carrying fasteners shall be inspected once in every year. If any damages/ rusting are seen the same shall be replaced with new fasteners.

(d) To ensure that there is no crack or other defect in the welds. Defective welding should be chipped out and it should be re-welded.

(e) To ensure that gate slot is completely clean.

(f) To ensure that there are no cracks or slackness around anchorages and concrete around anchorages.

(g) All the rubber seals shall be checked and if required shall be changed when any damages are seen/ leakage are raise then the permissible value. However if no damages are noticed the seals shall be checked in detail once in every five years.

(h) To ensure that drainage holes on horizontal girders are not blocked.

(i) To ensure that no bearing is abnormally heated.

1.1.9 Appropriate repair should be carried out wherever excessive pitting and other surface damages are noticed in gates and embedded parts surfaces atleast once in a year.

1.1.10 Excessive sand and/or silt should not be allowed to be deposited on Upstream side of skin plate. To ensure this, periodic flushing should be carried out.

1.1.11 Water leakage in closed position of gate should be checked every six Months and if so necessary, gate seals should be replaced by new ones.

1.1.12 Paint on all surfaces should be maintained in good condition by Repainting when necessary.

OPERATING INSTRUCTIONS OF INTAKE GATE

I. Intake Gate

II. Hoist

III. Operation

I INTAKE GATE

1. General

The Intake opening is closed by a fixed wheel gate.

Principal dimensions:-

Clear width and height	-	2.44 m x 3.66 m
Width of span	-	2.87 m

Gate speed:-

Raising and lowering with motor	V = 1.52 m/min
Emergency lowering	V = 2.44 m/min
Hand drive from position 0 to 2	V = 0.0195 m/min at 20turns per min of hand crank
from position 2 to topmost position	V = 0.153 m/min at 20turns per min of hand crank

2. Position of the gate

2.1 Maintenance position

Lower edge of the gate 8 ¾ inch above level +2690.00 ft.

2.2 Position of readiness

Lower edge of gate 12 ft. 9 inch above bottom

3.3 Filling position

Lower edge of gate 2 inch above bottom

3.4 Gate closed

Lower edge of gate rests on bottom.

3.5 During emergency lowering the speed is being decelerated at position " Gate lower edge 0.3048 m above bottom"

4. Maintenance of the intake gate:-

4.1 Thorough checking at least once a year

4.2 Faulty water sealing rubber to be repaired or replaced as thickly as possible.

4.3 Lubrication

The gate rollers fitted with DEVA sleeves should be thoroughly lubricated at least once a year.

II. HOIST

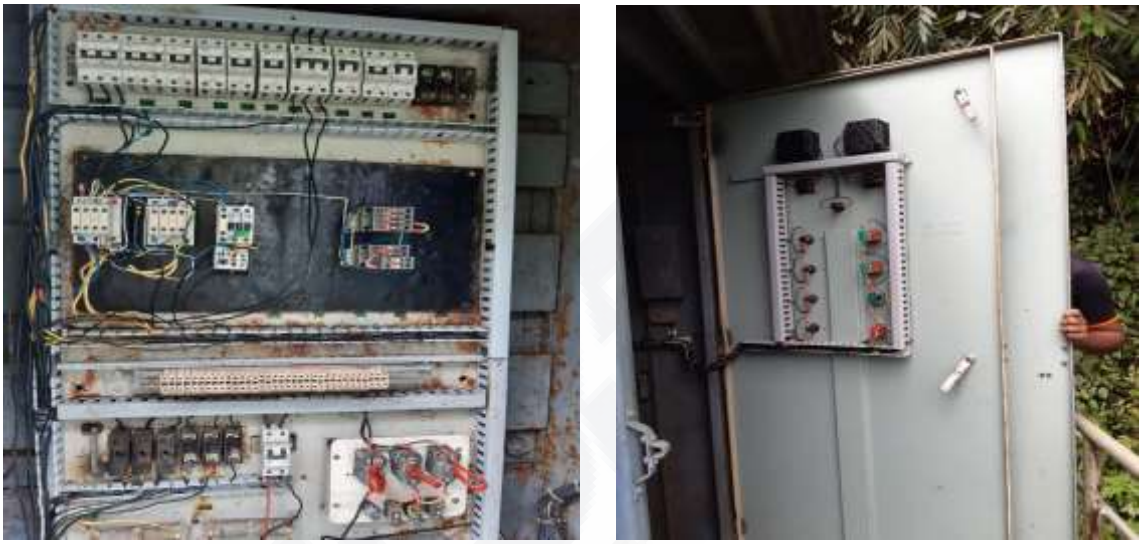


Fig 2 Control panel of intake gate

1 General

1.1 Any work and / or repairs respectively on the hoist unit should only be carried out if:

1.1.1 The hoist main switch is turned off

1.1.2 A caution plate indicating " do not turn on", "danger".

1.1.3 The gate is resting on the bottom.

After completion of repair work, care should be taken to turn the main switch on again, as otherwise heating during stands still of the electric unit is not operating.

1.2 During the first months after initial operation and after repairs be sure to check that;

1.2.1 All key connections are tight.

1.2.2 No belts have worked themselves loose.

1.2.3 No bolt locks are damaged.

2. Maintenance

2.1 Lubrication, general:-

During lubrication, care should be taken that

2.1.1 All lubrication points and nipples are clean

2.1.2 Bare shafts and pads are always greased and coated with anticorrosive paint.

2.1.3 The application of grease to the lubrication points is carried out regularly and the grease must care out laterally from the bearing

2.1.4 Large bearings are sufficiently supplied with grease.

2.1.5 All joints, bolts and movable parts are oiled from time to time.

2.1.6 The friction disk and brake shoes are free from oil and dust.

2.2 Lubrication of the spur gear:

The gear shall always be filled with oil up to the oil level mark. In order to exclude impurities, the oil is to be poured in through a fine mesh filter when the gear is at stand still. Above 4 weeks after the year's initial operation the oil should be drained off, and carefully cleaned and filled up with new oil.

After the first year of operation or the first 20 or 30 hours of operation, a change oil is necessary. Subsequent changes of oil need then be carried out at 2 or 3 yearly intervals.

2.3 Lubrication of tooth flanks on open spur gear transmissions:

2.3.1 After assembly is completed and if no more soiling is expected, the tooth flanks are to be cleaned with carbon tetra chloride or benzene and to be lubricated with a brush.

2.3.2 Damaged spots on the lubricating film shall be repaired immediately.

2.3.3 The tooth flanks of the pair of spurs for the control generator mechanism (made of steel and plastic) are to be kept clean, but are not to be lubricated.

2.4 Greasing of the cable :

2.4.1 After 100 to 250 lifting cycles, the cable has to be removed, thoroughly cleaned and new grease should be applied.

2.4.2 At the same time, the number of broken wires should be checked. The rope shall be exchanged if 15% of the visible wires are broken at the worst spot.

2.5 Lubrication of the roller chain:

The roller chain for operating the limit switches and the position indicator should be frequently oiled and be cleaned from time to time.

2.6 Lubricant:

It is advisable to use the recommended lubricants on lubrication chart 57.24.1 8394/120. The use of other makes of equal qualities is permissible.

2.7 Maintenance of the lowering brake

The brake should always be installed in such a way that, when the brake shoes are closed the weight lever lies horizontally. The brake should be checked at intervals of six months as to its condition ready for operation.

2.8 Maintenance of the stopping brake

The brake should always be installed in such a way that, the Shoes do not grind when in the lifted position and fit tightly when closed. When the brake is closed the anchor must still have 20 to 30 mm play underneath, so that the brake shoes can follow when the brake lining becomes worn.

2.9 Installation of the limit switches

Should the limiting switches be disconnected from the Hoist for repair work, care should be taken that the switches turn properly in exactly the position provided.

III. Operation of the Hoist unit:

1 Gears

An increase of the spur gear's temperature of 40 to 45^0 C above the room temperature is permissible. Any further increase indicates faults in the gears

2 Ways of raising and lowering.

Motor operation	:	raising and lowering
Emergency operation	:	Only lowering
Hand operation	:	Only raising.

3 Electrical drive:

Before starting with, the operation be careful that:

- The stopping brake and the regular brake are ready for operation.
- The control lever for releasing the stopping brake is at " Motor"
- The lever is securely locked.
-

4 Hand operation :

Before operation, please check that

- The switch lever for releasing the stopping brake is at "Hand"
- The lever is securely locked.
- A warning notice "do not switch on", "danger" is on the switch box.
- When raising the position "Filling position" the hand crank should be put on the driving shaft marked "From 0 to 2" on the Hoist. After raising the gate to position "Filling Position" the lifting procedure must be interrupted for the period of filling the tunnel (pressure balance on the gate)
- For further raising the hand winch should be put on the driving shaft marked "From 2 to top most position" on the hoist.
- The position of the gate at any time is shown on the scale of the position indicator.

- The hand crank may only be turned in the direction indicated on the hoist by an arrow (Clockwise)
- It is pointed out that by manual operation the gate can only be raised, lowering of the gate is not possible (slip-back lock). After raising by hand care should be taken to set the switch lever for disengaging the stopping brakes at "Motor".

ANNEXURE 7

MAINTENANCE SCHEDULE

KERALA STATE ELECTRICITY BOARD			Legend											
MAINTENANCE SCHEDULE			Daily		Weekly		Monthly		Quarterly		Half yearly		Yearly	
			D		W		M		Q		H		Y	
Sl. No	DEVICE	Lubricating Oil /Grease	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
I	HOISTING MACHINERY OF INTAKE AND RADIAL GATES													
1	Gear wheels	Applying cardium compound												Y
2	Plummer Block Bearings, Bush bearings of the driving shaft, Bush bearings of the shaft of rope drum, Manual operation bushing point, Position indicator bushing point, Manual operation chain, Position indicator Chain	Greasing												Y
3	Gear box	Oil filling/changing							HY					HY
4	Machinery and covers	Painting		Y										

5	Pins, rope sockets, rope clamps etc	Check up							HY					HY
	Manual operation bushing point	greasing							HY					HY
	Position indicator bushing point	greasing							HY					HY
	Manual operation chain	greasing							HY					HY
	Position indicator chain	greasing							HY					HY
6	Panel boards	Checking all relays, cleaning, drying, heating, rectification as per fault indicator							HY					HY
II	SPILLWAY RADIAL GATES (5 Nos)													
1	Guide roller	greasing							HY					HY
2	Wire ropes	Applying cardium compound												Y
3	Rubber seals	Checking for leaks						Y						
4	Radial Gates	Trial operations		HY				HY						
5	Radial Gates	Painting	Once in two years											
III	INTAKE GATE													
1	Guide roller, Moving parts	Greasing							HY					HY

2	Wire ropes	Applying cardium compound												Y
3	Moving parts	Greasing							HY					HY
4	Seals	Checking by close visual examination												Y
5	Intake Gate	Trial operations												Y
6	Intake Gate	Painting	Once in two years											
IV	TURBINE PUMPS													
1	Electrodes	Cleaning	M	M	M	M	M	M	M	M	M	M	M	M
2	Pumps	Operation	M	M	M	M	M	M	M	M	M	M	M	M
3	Panel board	Checking all relays, cleaning, drying, heating, rectification as per fault indicator	M	M	M	M	M	M	M	M	M	M	M	M
VII	DAM SAFETY INSPECTION													
1	Formed and foundation drain hole observation		M	M	M	M	M	M	M	M	M	M	M	M
2	Seepage measurement, 'V' notch		D	D	D	D	D	D	D	D	D	D	D	D
3	Measurement of pressure gauge.		M	M	M	M	M	M	M	M	M	M	M	M
4	Abutment, Dam & Fillet inspection and gallery inspection		M	M	M	M	M	M	M	M	M	M	M	M
5	U/s & D/s dam inspection		W	W	W	W	W	W	W	W	W	W	W	W
6	Inspection and Health status report preparation		Q			Q			Q			Q		

7	Jungle clearance		Q			Q			Q			Q		
8	Providing lighting arrangements		W	W	W	W	W	W	W	W	W	W	W	W
9	Gallery, drain and drain hole cleaning			Y										
10	Climatological and hydrological data collection		D	D	D	D	D	D	D	D	D	D	D	D
11	Security arrangements		Round the clock											
12	Reservoir Inspection		W	W	W	W	W	W	W	W	W	W	W	W