Operation and Maintenance Manual for MOOZHIYAR Dam State of Kerala

Doc. No. DSO_O&M_MOOZHIYAR_DAM
KSEBL_11_v1.0

DRIP
Dam Rehabilitation & Improvement Project

KSEB

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

PAGE KEPT BLANK

Government of Kerala

Operation and Maintenance Manual

Moozhiyar Dam

Prepared

Sd/-

Deputy Chief Engineer (Civil)
Dam Safety & DRIP

Approved

Sd/-

Chief Engineer (Civil)
Dam Safety & DRIP

Kerala State Electricity Board Ltd
Pallom, Kottayam.

November 2019

Government of Kerala
Kerala State Electricity Board Ltd
Dam Safety Organisation

Disclaimer

This *Operation and Maintenance Manual for MoozhiyarDam* 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 dam and appurtenant structures.

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

For any information, please contact:
The Chief Engineer (Civil)
Dam Safety & DRIP
Kerala State Electricity Board Ltd
Pallom P.O., Kottayam
Kerala - 686007
Email: cedamsafety@kseb.in, cedamsafety@gmail.com

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),
KSEB Ltd,
Kerala

PAGE KEPT BLANK

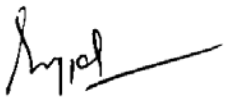
Foreword

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

Team Involved in preparing this O & M Manual of Moozhiyar dam

Review and Approval

Smt. Supriya S	Chief Engineer (Civil- Dam Safety & DRIP), KSEB Ltd, Pallom, Kottayam
Smt. Preetha R	Deputy Chief Engineer (Civil- Dam Safety & DRIP), KSEB Ltd, Pallom, Kottayam

Manual Prepared

Sri. Joji George Mathew	Executive Engineer, Research & Dam Safety Organisation, KSEB Ltd, Pallom, Kottayam
Dr. Susan Abraham	Asst Executive Engineer, Research & Dam Safety Organisation, KSEB Ltd, Pallom, Kottayam
Smt. Krupa Sara Thomas	Post Graduate Engineer

Field Officers associated in giving Data

Executive Engineer, Assistant Executive Engineers, Assistant Engineers and Sub Engineers of Dam Safety Division, KSEB Ltd, Kakkad

PREFACE

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

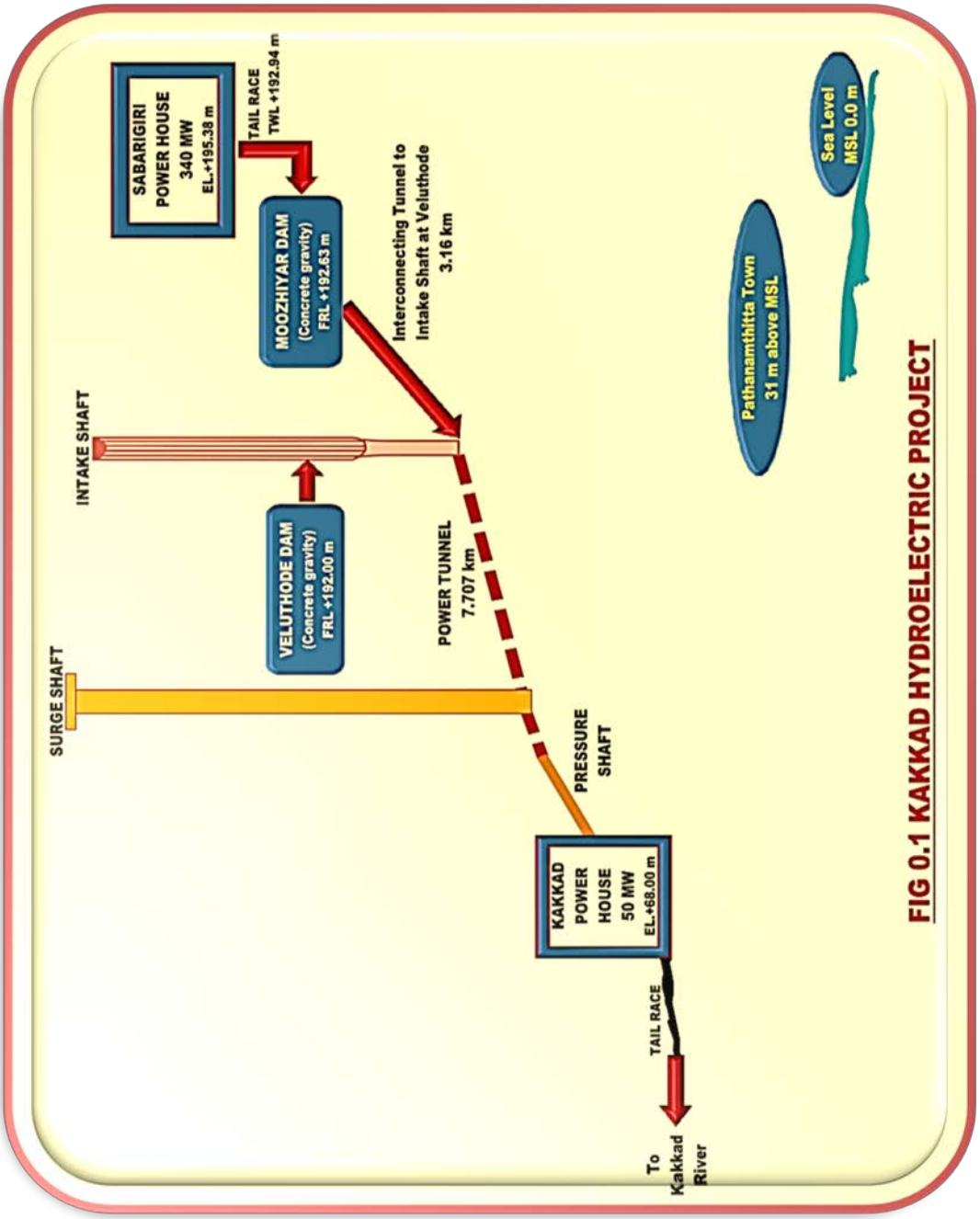
Central Water Commission has published the Guidelines for the development of New Manual and Updating of Existing Manual vide CDSO_GUD_DS_03_v1.0 Page xii January 2018.Accordingly KSEB Ltd is developing and updating the Operationand Maintenance Manual of Dams under their ownership for a healthy dam safety management system.

Moozhiyar dam under KSEB Ltd do not have a comprehensive Operation and Maintenance Manual. Hence an attempt is made here to prepare the manual as per the new guidelines by CWC. Sabarigiri HEP is the major hydro power project implemented in Pamba basin. Kakkad HEP with an installed capacity of 50 MW is also a power project in Pamba basin. The tail water of Sabarigiri HEP discharges in to Moozhiyar stream, a tributary of Kakkad River. At the downstream of the confluence of tail race of Sabarigiri HEP, a dam is constructed across Moozhiyar stream to divert the tail water of Sabarigiri HEP to Kakkad Power Station. In addition to the tail water from Sabarigiri, the yield from own catchment of Moozhiyar and yield of Veluthodu stream by creating a Forebay dam across Veluthodu stream and connecting with the tunnel from Moozhiyar to Kakkad Power Station are utilized in Kakkad HEP for power generation. The project was commissioned in 1999.

A flow chart of Kakkad HEP is given in the next page for reference.

This Operation and Maintenance Manual is prepared for the Moozhiyar dam of Kakkad HEP.

PAGE KEPT BLANK


SABARIGIRI POWER HOUSE 340 MW EL.+195.38 m
TAIL RACE TWL +192.94 m
MOOZHIYAR DAM (Concrete gravity) FRL +192.63 m
Interconnecting Tunnel to Intake Shaft at Veluthode 3.16 km
INTAKE SHAFT
VELUTHODE DAM (Concrete gravity) FRL +192.00 m
POWER TUNNEL 7.707 km
SURGE SHAFT
PRESSURE SHAFT
KAKKAD POWER HOUSE 50 MW EL.+68.00 m
TAIL RACE
To Kakkad River
Pathanamthitta Town 31 m above MSL
Sea Level MSL 0.0 m
FIG 0.1 KAKKAD HYDROELECTRIC PROJECT

The following acronyms are used in this publication:

LIST OF ACRONYMS

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

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF BASIC DRAWINGS IN ANNEXURE 1

LIST OF ANNEXURES

Chapter 1

General Information

1.1 Introduction

Sabarigiri HEP is the major hydro power project implemented in Pamba basin. Kakkad Hydroelectric Project is the second stage development of Pamba river basin. This scheme utilises the tail race water from Sabarigiri power station discharging to Moozhiyar River and water from the tributaries of Kakkad river viz. Moozhiyar and Veluthode. After the downstream of the confluence of tail race channel of Sabarigiri HEP with Moozhiyar, a dam is constructed across Moozhiyar stream as part of Kakkad HEP and is the main reservoir of this project. Thus, in addition to the tail water from Sabarigiri, the yield from own catchment of Moozhiyar is also utilized in the Kakkad HEP for power generation.

The tunnel which leads water from Moozhiyar to Kakkad Power Station crosses Veluthodu stream, a tributary of Kakkad River. The yield of Veluthodu stream is also diverted to the Kakkad power house by creating a small impoundment after constructing a small diversion dam across Veluthodu which is the second reservoir of the Project and connecting this reservoir with the tunnel from Moozhiyar to Kakkad Power Station. After power generation, water from Kakkad power station is released to the Kakkad River. The project was commissioned in 1999.

The investigation works of Kakkad HEP were taken up after the completion of the Sabarigiri HE Project. Hence the roads and buildings constructed for Sabarigiri provided access and accommodation facilities to the investigation team. Moozhiyar Diversion dam is accessible by a pacca road from Pathanamthitta leading to Moozhiyar Power station. The site survey of the Diversion Dam at Moozhiyar was completed in 1961-63.

1.2 Purpose, Location, Description of the Project

Kakkad Hydro Electric Project

The Kakkad (Sabarigiri Tail Race) scheme is formed by the formation of two small reservoirs at Moozhiyar and Veluthode, having a total storage capacity of 2.856 Mm^3, connected by an Inter connecting tunnel of length 3168 m. The power tunnel 7925.10 m long, internal diameter 4.15 m takes off from the Forebay reservoir lead the waters to the Pressure shaft

which bifurcate near the power House feeding the two machinesof 50 MW (2 x 25) installed capacity to generate a firm power 30 MW corresponding to 262 MU per year.

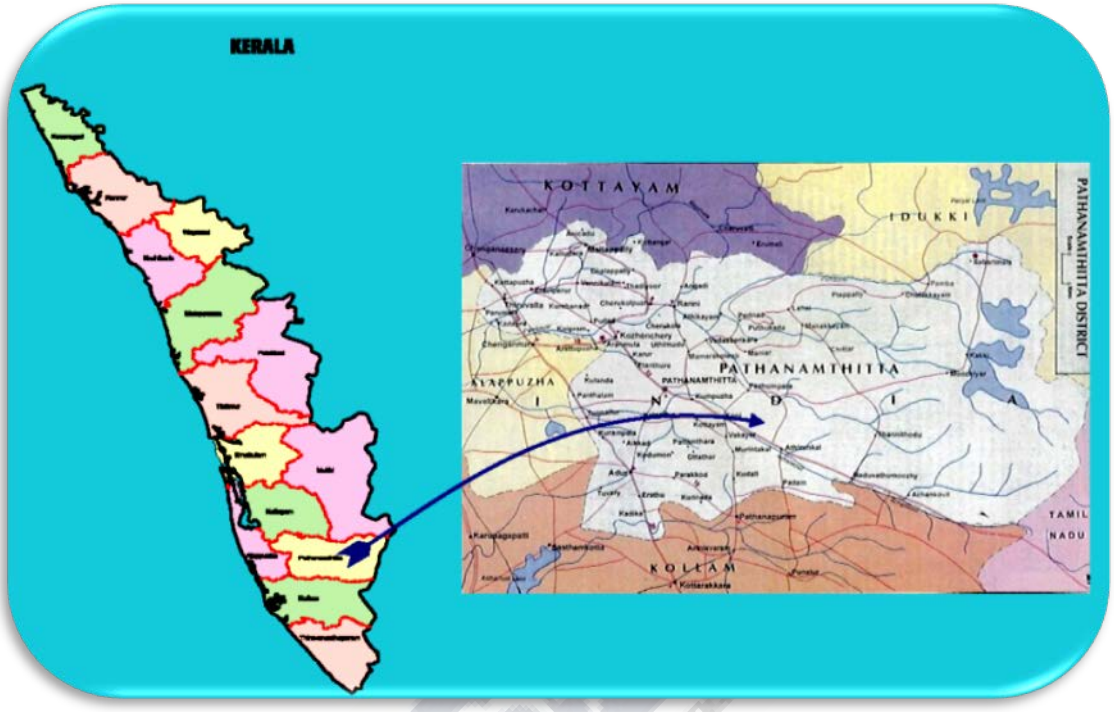


Fig 1.1 Index Map

Location:

The Project is situated at Seethathode Panchayath in Pathanamthitta District of Kerala State and is accessible by road from the District head quarter via Vadasserikkara- Chittar. The index map and Google map of Kakkad HEP are given in **Fig 1.1** and **Fig 1.2** above.

Fig 1.2a Google Map showing the Project

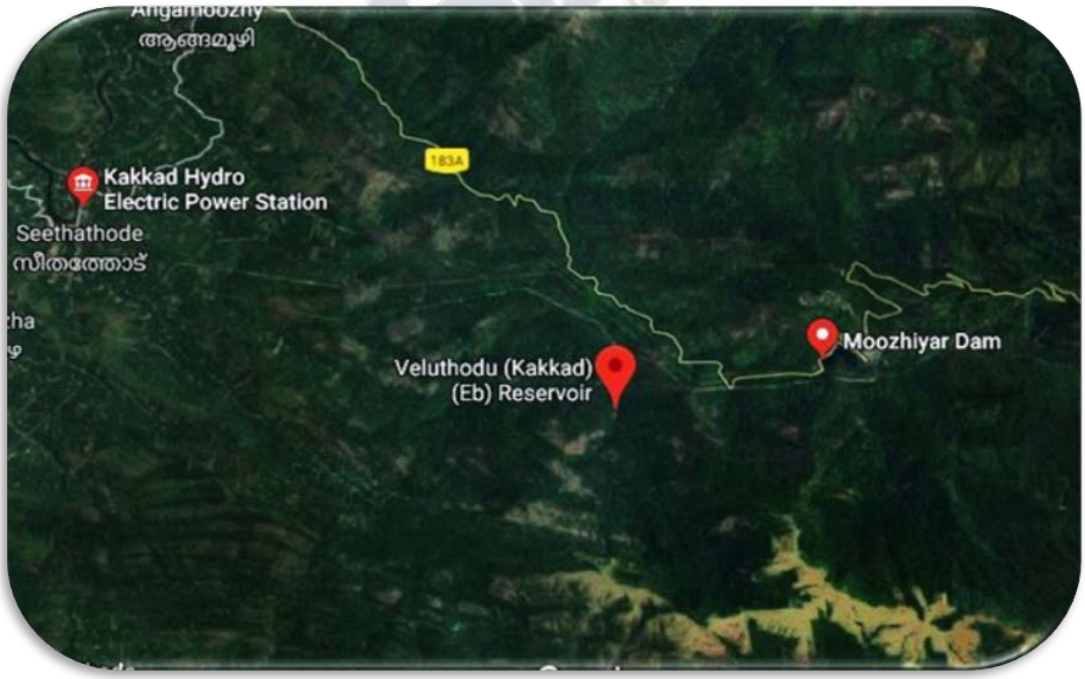


Fig 1.2b Google Map showing the Project

Kakkad project includes the following**:**

1. A Concrete straight gravity dam 30.04 m high above the deepest river bed and 176.50 m long with gated spillway across River Moozhiyar, about 1.6 km downstream of Sabarigiri Power station.
2. A concrete straight gravity ungated diversion dam 20.50 m high above the deepest river bed and 107 m long across Veluthode which diverts water through the water conductor system of Kakkad HEP.
3. A water conductor system consisting of an intake from Moozhiyar reservoir, a lined interconnecting tunnel 3.168 km long and 4.15 m finished diameter, a vertical intake from Veluthode reservoir, a lined power tunnel 7.925 km long and 4.15m finished diameter, a restricted orifice surge shaft of 16 m finished diameter, a lined pressure shaft 687.57 m long with bifurcation at Power House end.
4. A surface Power House with two machines each of 25 MW capacity located on the left bank of Kakkad River at Seethathode.

A schematic diagram of the project is outlined below in **Fig 1.3**.

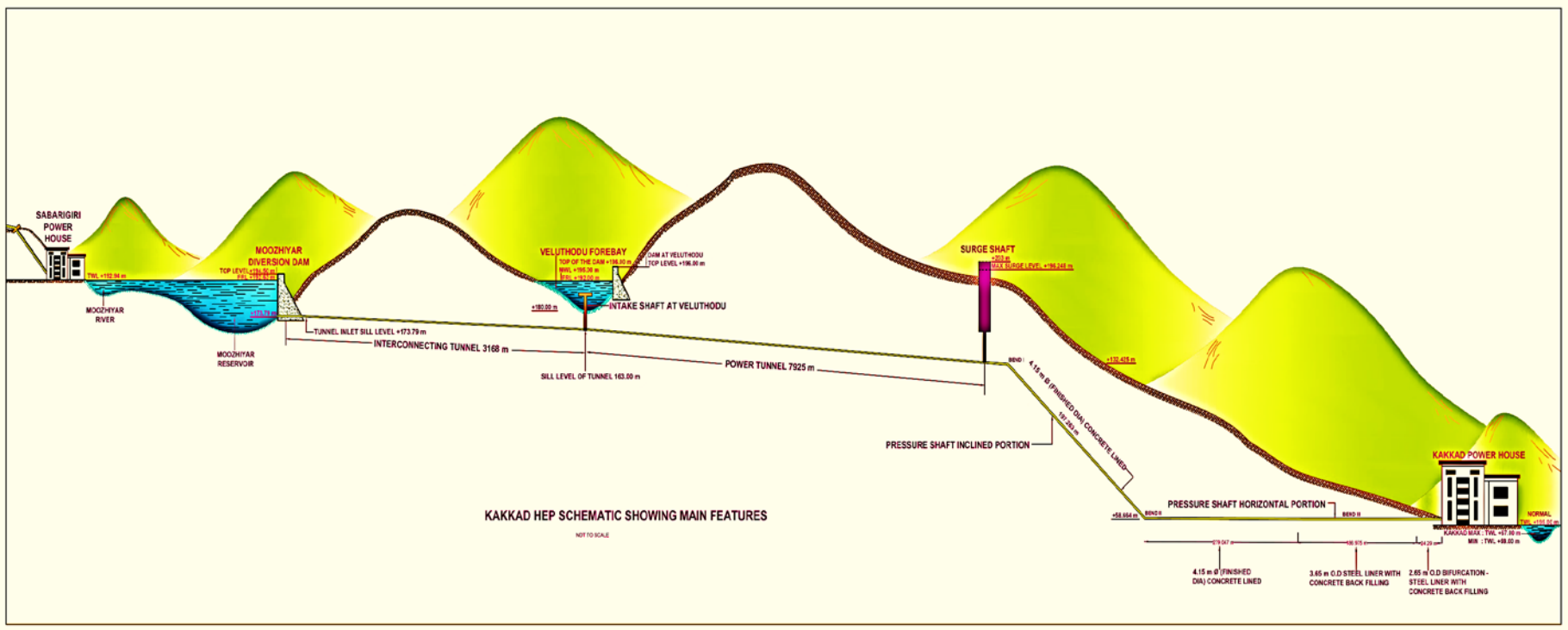


Fig 1.3 Schematic Diagram of the Project

SALIENT FEATURES OF THE PROJECT

A	Name of dam	-	Moozhiyar dam
	Type of dam	-	Concrete gravity
	Name of the river where the dam is built, sub- basin	-	Moozhiyar River
	River basin	-	Pamba River basin
	Catchment area at Dam site	-	28.75 km^2
	Deepest River Bed Level	-	164.46 m
	Top level of dam	-	194.50 m
	Maximum Water Level (MWL)	-	192.94 m
	Full Reservoir Level (FRL)	-	192.63 m
	Minimum Draw Down Level (MDDL)	-	181.36 m
	Height above deepest foundation	-	34.17 m
	Height above deepest river bed	-	29.91 m
	Bottom width at maximum section	-	28.18 m
	Length of Dam at Top	-	176.50 m
	No and size of Radial Gates	-	3 Nos (H-6.70 m x W-7.62 m)
	Crest level of spillway	-	186.53 m
	Spillway capacity	-	730.25m^3/s
	Gross storage at FRL	-	1.50 Mm^3
	Design Flood		500.64 m^3/s
	Live storage at FRL	-	1.16 Mm^3
	Dead storage	-	0.34 Mm^3
	Water spread area at FRL	-	0.15 km^2
	Downstream slope	-	0.74 H : 1V from El + 189.00 m
	Upstream slope	-	0.1 H : 1V from El + 170.00 m
	Size of disperser valve	-	1500 mm with 28.03 m^3/s
	Diameter of outlet pipe	-	2000 mm
B	**Name of dam**	**-**	**Veluthode dam**
	Type of dam	-	Concrete gravity
	Deepest River Bed Level	-	175.50 m

	Top level of dam	-	196.00 m
	Maximum Water Level (MWL)	-	195.00 m
	Full Reservoir Level (FRL)	-	192.00 m
	Crest level of spillway	-	192.00 m
	Spill way length (single bay)	-	20 m
	Maximum spillway discharge at FRL	-	312.90 m^3/s
	Height above deepest foundation	-	22.00 m
	Length of dam at top	-	107.00 m
	Gross storage at FRL	-	0.67 Mm^3
	Live storage at FRL	-	0.607 Mm^3
	Water spread area at FRL	-	6.35 Ha
	No. of scour sluice	-	1 No
	Size of scour sluice	-	1.80 m x 2.70 m
	Size of sluice gate	-	1.80 m x 2.70 m
C	**Water conductor system**		
a)	**Intake at Moozhiyar Reservoir**		
	Location	-	8 m upstream of Moozhiyar dam with centre line parallel to dam axis
	Inlet sill level	-	173.79
	Length	-	23 m
	Size and shape	-	Rectangular to circular 4.15 m diameter
	Type of lining	-	Steel lining
b)	**Intake at Veluthode Reservoir (Vertical Shaft)**		
	Location	-	25 m upstream of Veluthode dam with vertical centre line
	Inlet sill level	-	186
	Length	-	18.85 m
	Diameter	-	4.15 m
	Type of lining	-	concrete lining

c)	**Inter connecting tunnel**		
	Size and shape	-	4.15 m finished diameter, Circular
	Length	-	3168.01 m
	Inlet sill level	-	173.79 m
	Exit sill level	-	163.00 m
	Type of lining	-	Steel lining 67 m, concrete lining 3101 m
	Lining thickness	-	250 mm
	Maximum discharge	-	47.19 Cumecs
	Maximum Velocity	-	3.49 m/s
d)	**Power tunnel**		
	Size and shape	-	4.15 m diameter, Circular
	Length	-	7925.10 m
	Inlet sill level	-	163.00 m
	Exit sill level	-	129.325 m
	Type of lining	-	Steel lining 114 m, Concrete lining 7811.10 m
	Maximum flow	-	47.19 cumecs
	Maximum Velocity	-	3.49 m/s
e)	**Surge Shaft**		
	Type	-	Restricted orifice
	Size and shape	-	16 m dia Circular
	Top level of surge shaft	-	+203.00 m
	Maximum upsurge level	-	+196.248 m
	Minimum down surge level	-	+154.453 m
	Bottom level of surge shaft	-	+129.325 m
f)	**Expansion Gallery**		
	Bottom level	-	+ 192 m
	Top level	-	+200 m
	Size	-	6 m x 8 m
	Length	-	50 m

	No and size of orifice	-	2 No, 2.13 m dia, circular shaped
	Control gate	-	Vertical lift gate (fixed wheel type)
	Lining	-	RCC, 30 cm thick up to El. 191.00 m and 60 cm thick above El. 191.00 m
g)	**Pressure shaft**		
	Total length	-	687.57 m
	Finished section	-	4.15 m for 476.31 m length, 3.60 m for 187 m length, 2.60 m for 24.26 m bifurcated portion
	Type of lining	-	Steel lining 266.83 m, concrete lining 420.74 m
h)	**No of Adits**	-	7 nos
	Size and shape	-	3.00 m, D-shaped
i)	**Length of Adits**		
	Adit I	-	303.00 m, I C tunnel and power tunnel at Chorakakki
	Adit II	-	18.85 m Vertical Shaft
	Adit III	-	231.51 m at Veluthode
	Adit IV	-	607.72 m at Pannikunnu
	Adit V	-	225.216 m at Seethakuzhy
	Adit VI	-	190 m at Surge
	Adit VII	-	51.75 m at Power House
	Plugging of Adits- I, III, V and VI Plugging with provision of access door & Adit IV and VII- solid plugging.		
j)	**Power House**		
	Installed Capacity	-	50 MW
	No. of Machines	-	2
	Type of Machine	-	Francis Turbine Vertical Shaft
	Capacity of each machine	-	25 MW
	Overall size of Power House	-	44.50 m x 24.60 m
	Unit spacing	-	14 m c/c
	Service bay length	-	14.90 m

	Width of transformer deck	-	24.60 m
	Power House yard level	-	+ 68.00 m
	Generator floor	-	+ 66.00 m
	Centre line of runners	-	+ 57.00 m
	Bottom most level of excavation	-	+50.00 m
	Nominal tail water level	-	+59.60 m
	Minimum tail water level	-	+59.00 m
	Maximum tail water level	-	+67.00 m
	Average gross head	-	132.60 m
	Capacity of main hook of EOT Crane	-	100 T
	Capacity of auxiliary hook	-	20 T
	Type of scroll case	-	Steel fabricated
	Type of draft tube	-	Single pier draft tube
k)	**Width of tail race channel**	-	7 m
	Length of channel	-	100 m
	Firm power draft	-	28.40 cumecs
	Rated turbine output	-	25.86 MW
	Discharge for rated output	-	22.58 m^3/s
	Maximum turbine output	-	28.45 MW
	Transmission line	-	110 KV Double circuit from Seethathode to Pathanamthitta

Cost and benefits

The project was estimated to cost 150 crores with annual net revenue on firm power @ Rs.1.36/unit as Rs. 36.5 crores which corresponds to a net average return of the order of 24%. The annual energy generation on a firm basis will be 262 MU and secondary energy generation will be 7 MU making a total of 269 MU per year.

1.3 Background Details of the Project

The proposal utilizes the tail race water from Sabarigiri Power House at Moozhiyar for power generation originated along with the conception of Sabarigiri H E Scheme itself. After completing the investigations of the Sabarigiri Project, the initial investigations were done for utilization of the tail race waterindependently or combined with the waters of Pamba, Azhutha and Kakkad Rivers. Later it was finalized for utilizing the tail race water alone. Different alternatives for the dam site were proposed and studies were made to select a suitable alignment for the dam. Trial bore holes were taken to ensure the rock availability and levels of hard rock.

Temporary coffer dam and a diversion channel were needed at Moozhiyar for diversion of waters since there is perennial flow in the river due to the tail race discharge from Moozhiyar Power House. After completion of the river sluice, this arrangement was dispensed with. The non- overflow section have a top width of 6.4 m with a road way that cross over to the Moozhiyar power house. The bridge over the spillway section will accommodate both the road-way and the hoisting platform for the radial gates.

During the Field season of 1970-71, Geologist conducted the geological investigations of Kakkad H E Project. The dam site chosen is the same as considered in the geological report having more favorable rock conditions. Foundation excavation was done manually using Jack hammers, wagon drills and modern explosives for rock blasting. Muck removal was arranged using earthmoving and haulage equipments.

The construction of the project was commenced during 1980. The project was delayed beyond expectation due to so many factors. The overall working days/ actual working days, at various sites in this project varied from 5 to 9 years, out of the total 18 years. The two generating units were commissioned in 1999.

a. Date of Starting the construction : 1980

b. Date of Completion : 1999 March

c. Name of Design Agency : KSEB Ltd

d. Name of Contractor : M/s HCC Ltd., Bombay

e. Major accidents/incidents if any : No major accidents reported during construction

1.4 Salient Features of Moozhiyar Diversion Dam

The diversion dam at Moozhiyar is of straight gravity type in concrete. The deepest foundation level is 160.33 m and the dam is 34.17 m high. Google view of Moozhiyar dam is shown in **Fig 1.4**.

Fig 1.4 Google map view of Moozhiyar dam

Photographs showing downstream and dam top view of Moozhiyar dam are given in **Fig 1.5a, 1.5b** and **Fig 1.5c**.

Fig 1.5a Downstream View of Moozhiyar Dam

Fig 1.5b Moozhiyar Dam top

Fig 1.5c Moozhiyar Dam Reservoir

Maximum non overflow and overflow section of dam are given in **Fig 6a & 6.b**

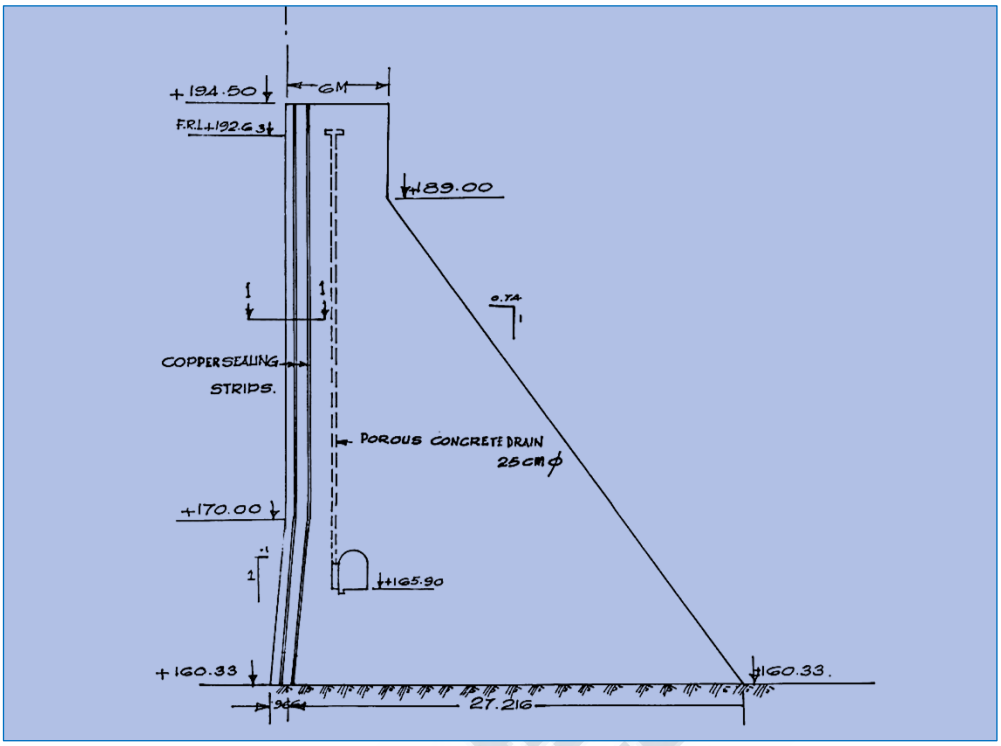


Fig 6a Maximum non overflow section of Dam

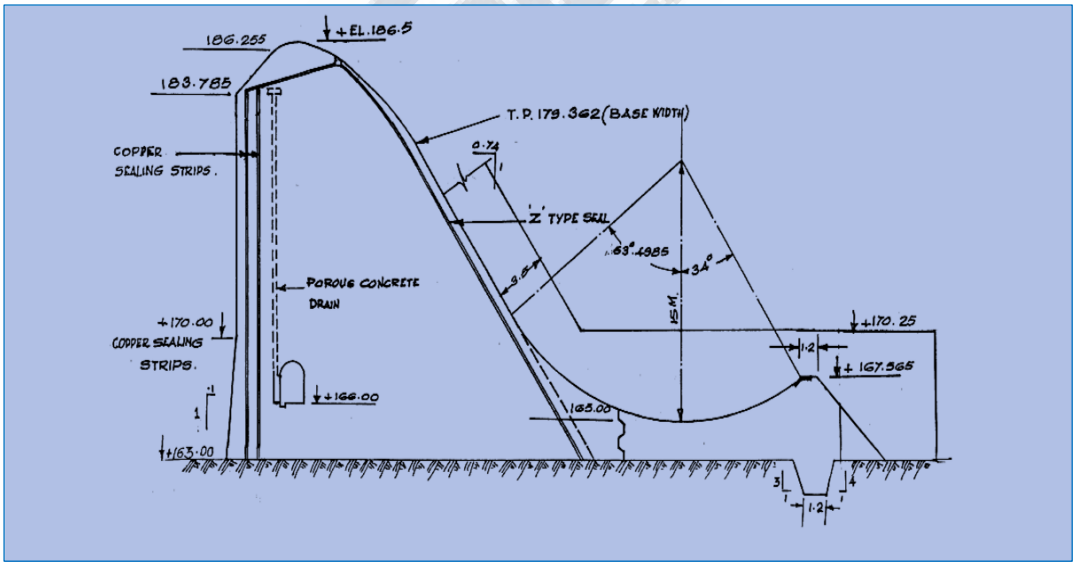


Fig 6b Overflow section of Dam

Spillway

The spillway consists of 3 spans of 7.62 m across River Moozhiyar, about 1.6 km downstream of Sabarigiri Power station and is provided with radial gates of size 7.62 m x 6.70 m which can be operated both by electrically and manually. The total spillway capacity of all bays is 730.25

m^3/s and outlet sluices are 28.03 m^3/s. The dam is constructed with 10 blocks and spillway is provided in blocks 4, 5 & 6 with Ch.92 to Ch.63. Photograph showing downstream spillway of Moozhiyar dam is given in **Fig 1.7.** Section through the spillway is given in **Fig 1.8.**

Fig 1.7 Spillway of Moozhiyar dam

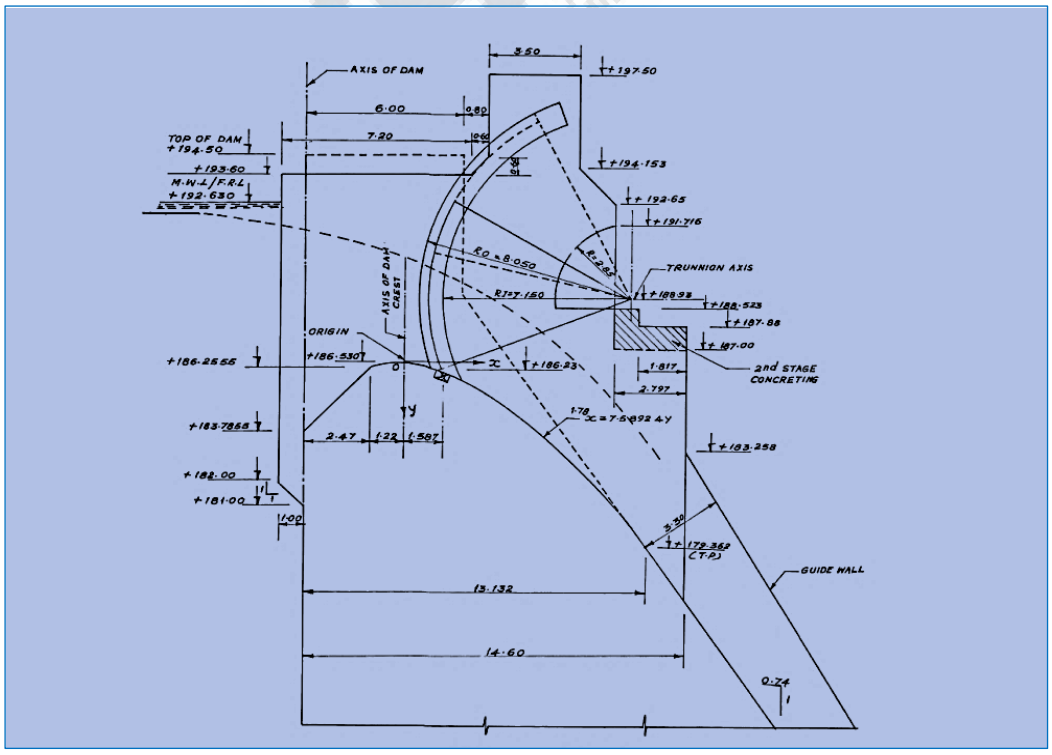


Fig 1.8 Section through spillway of Moozhiyar dam

Galleries

There is drainage cum inspection gallery of 1.52 m width and 2.13 m height in the dam with suitable drain outlets and access gallery. The water collected in the gallery is drained out through two numbers 60 cm x 60 cm outlet conduits. The drainage and grout gallery are located 3.048 m (10 ft) downstream from the axis of the dam and follow the profile of the natural ground surface.

River sluice

There is a river outlet in Block no.6 of Moozhiyar dam operated with the gate arrangement of size 1.80 m x 2.25 m. The emergency gate controlling the disperser valve of size 1.5 m is a vertical lift type, having a capacity of 15 T. The discharge capacity of the sluice is 28.03 m^3/s.

A general layout of the dam showing the various blocks, spillway, intake, sluice and trash racks are given in **Fig. 1.9** below**.**

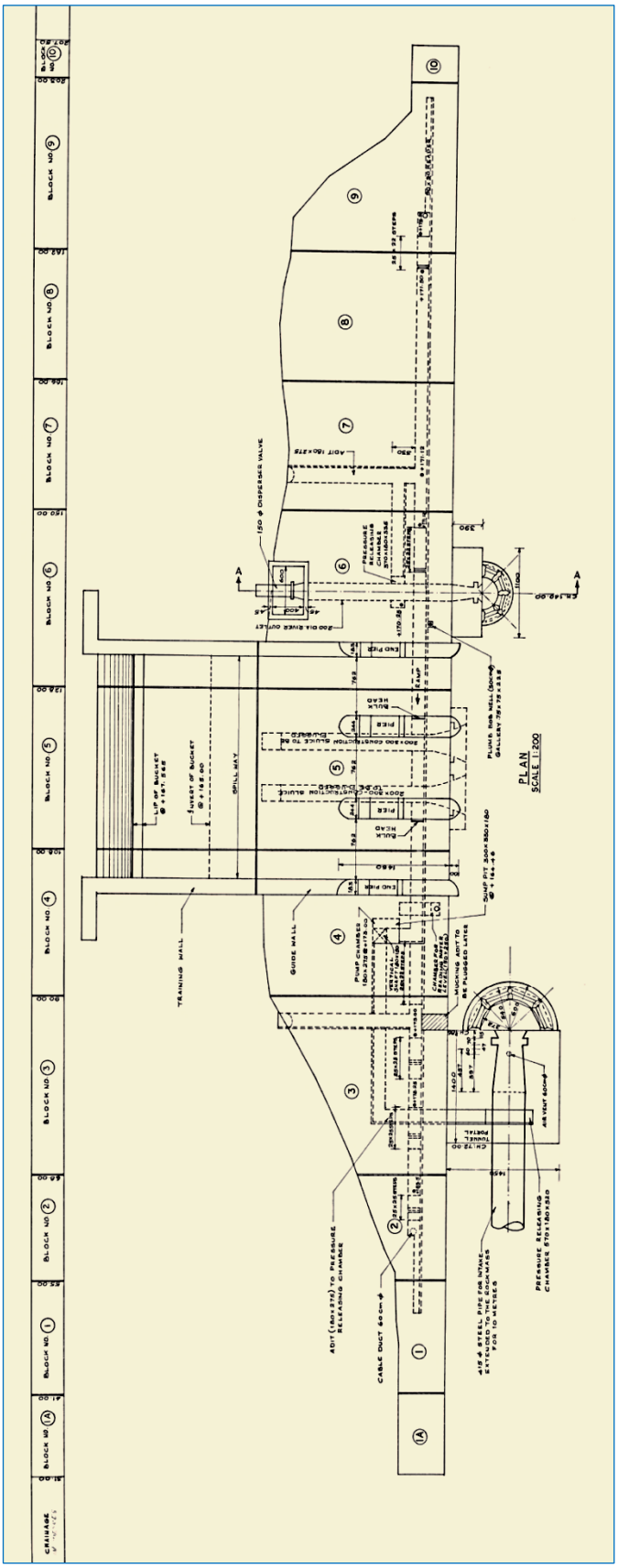


Fig. 1.9 Plan of the dam showing various blocks, spillway, intake & sluice

Water conductor system

Water conductor system of Kakkad HEP consist of an intake from Moozhiyar reservoir, a lined ***interconnecting tunnel*** 3.168 km long and 4.15 m finished diameter, a vertical intake from Veluthode reservoir, a lined ***power tunnel*** 7.925 km long and 4.15 m finished diameter, a restricted orifice surge shaft of 16 m finished diameter, a lined ***pressure shaft*** 687.57 m long (266.83 m steel lined and 420.74 m concrete lined) with bifurcation at Power House end. A photograph showing the intake structure and gate is **Fig. 1.10**.

Fig 1.10 Intake Gate of Moozhiyar dam

1.5 Assignment of Responsibility

Kerala State Electricity Board Ltd is the owner and has the final authority and responsibility for the operation and maintenance of the dam. Identification of all areas of responsibilities connected with the operation and maintenance of the dam are covered in this section. The officer's responsibilities for the various functions are identified by their designation and, in particular, the responsibilities of operating personnel are specifically identified including the regularly scheduled duties which staff personnel are required to perform as outlined.

Project Administration Office	-	Chairman & Managing Director, KSEB Ltd
Chief Controlling Officer	-	Chief Engineer (Civil – DS & DRIP)
Authority of Spillway and Flood releases	-	Chief Engineer (Civil – DS & DRIP), KSEB Ltd
Operation and safety of the dam	-	Deputy Chief Engineer, Research & Dam Safety Organization, Pallom, KSEB Ltd.
Controlling and Operation Officer at dam site	-	Executive Engineer, Dam Safety Division No. I, Seethathode.
Recording reservoir data, inspection, maintenance	-	Executive Engineer, Dam Safety Division No. I, Seethathode.
Dam Health Engineer	-	Executive Engineer, Research & Dam Safety Division No. I, Seethathode.
Recording reservoir data, inspection, monitoring and maintenance at site	-	Assistant Executive Engineer, Dam Safety Sub Division, Seethathode.
Dam operation, inspection, monitoring and maintenance officer at dam site	-	Assistant Engineer, Dam Safety Sub Division, Seethathode.

1.5.1 Roles and Responsibilities of the AEE and AE during Monsoon

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

1. Coordinate with the Asst Engineers and get the information on inflow status, reservoir level and to bring it to the notice of the EE/Dy. CE.

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

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

4. Assist the EE/ Dy. 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.

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.

7. Submit to the EE/ Dy. 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 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 in case of excessive seepage/leakage in any specific blocks and porous drains.

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

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

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

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

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

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

17. Assist AEE/EE to coordinate with the Generating staff of Kakkad Powerhouse downstream in the operation and power generation.

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

1.5.2 Roles and Responsibilities of the EE during Monsoon

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

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

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

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

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

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

7. Submit to the Dy. 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 Dy. 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 Dy. 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, ensure that the 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 Dy. CE in case of any untoward incidents or malfunctioning of the gates of excessive seepages, leakages etc.

1.5.3 Roles and Responsibilities of the Deputy Chief Engineer during Monsoon

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

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

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

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

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

1.6 Collection & Reporting of Dam and Reservoir Data

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

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

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

Table 1.1 Daily Reservoir Data

The daily reservoir status is collected as in the above format (**Table 1.1**) and is submitted to the Chief Engineer. Since Moozhiyar is a small reservoir of gross storage 1.5 Mm^3 and power generation at Kakkad HEP mainly depends on the tail race discharge of SGHEP, the inflow/outflow computation based on generation is not realistic.

Records/Logbooks of the operations at Moozhiyar 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.
- Testing/operation of Outlet gates, valves and associated controls.
- Maintenance activities carried out.
- Reservoir and dam inspections.
- Unusual conditions or occurrences.
- Safety and special instructions.
- Names of officers and staff carrying out inspections and maintenance.

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

Reservoir water surface elevation	This is collected daily and hourly during monsoon
Reservoir inflow	This is calculated daily
Spillway outflow	This is calculated during spill
River releases	The tail water release is measured at Power House and fed to the Kakkad river.
Irrigation, water supply and hydropower releases	The reservoir water is used for power generation and the tail water is released to the Kakkad river after generation.
Weather related data	Collected and reported daily
Surveillance/Security arrangements	Provide 5 securities at the check post near dam (1 Head Constable and 4 Constables). Also 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	The spill way is designed for a flood of 730.25m^3/s. There are 3 Nos of radial gates for spillway operation.

and outlet works	Take record of actual operations. Maintained at field office`
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.
Safety and special instructions	Safety equipment are available
Names and addresses of official visitors	Record of inspections maintained at office

1.7 Public Utilities and Safety

As safety of Project Staff is of prime concern, safety instructions & protection measures at the dam are to be followed by all staff / project personnel. Inspection bungalow and Canteen are located nearly 5 km from the dam.

Distance to the nearest medical assistance: A private nursing home and a Govt. health centre are available at Angamoozhy, 13 km away from the dam.

Police station is located at Angamoozhy, 13km away from the dam.

Safety equipment like first aid kit and fire extinguisher are available at the dam site.

1.8 Restricted Areas

Certain areas of the dam and reservoir are restricted for entry of the general public. The purpose of restrictions is for security of the dam, public safety and uninterrupted safe operation of the dam. Warning boards are installed in the prohibited area near dam.

Following are the restricted areas:

- Spillway gates and hoists at Dam top
- U/s areas of reservoir.
- Energy dissipation areas d/s of spillway & sluices/outlets
- Power tunnel Intake area, Trash Rack area
- Entry to dam foundation gallery
- Dam site colonies and offices.

1.8.1 Dam safety surveillance including instrumentation

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

V notch is provided for seepage measurement. Some new digital instruments are also proposed under DRIP.

Security Arrangement Existing - Kerala Police Force (5 Shifts per day)
(Head Constable - 1 No and Police Constable- 4 No)

1.9 Staff position, Communication & Warning System

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

A hierarchy of organizational structure for the control and safety of Moozhiyar dam is outlined below in **Fig 1.11**.

Fig 1.11 Dam Safety Organisation Structure for Moozhiyar Dam

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

Designation and office address	Contact number and e-mail
Chief Engineer Civil (Dam safety & DRIP), KSEBLtd, Dam Safety Organization, Pallom, Kottayam	Ph: 9496018719, 9446008964 e-mail: cedamsafety@kseb.in, cedamsafety@gmail.com
Deputy Chief Engineer, Research & Dam Safety Organization, Pallom	Ph: 9446008492, 0481-2432290, 9496011540 e-mail: dirroplm2@gmail.com
Executive Engineer, Dam Safety Division No. I, Kakkad	Ph: 9446008424 e-mail: ddrdskkds@gmail.com

Assistant Executive Engineer, Dam Safety Sub Division, Seethathode	Ph: 9496011955 e-mail:aeedssdmzhr@gmail.com
Assistant Engineer, Dam Safety Sub Division, Seethathode	Ph: 9496011953 e-mail:aeedssdmzhr@gmail.com

Warning system-Mike announcement, Newspaper and Television are used for providing warning to the downstream areas during floods.

Spillway flood releases

The Kakkad and Sabarigiri Power stations will be operated integrally such that the releases from Pamba- Kakki Reservoirs are so regulated together with the waters of Moozhiyar catchment so that it is utilized for maximum generation of power in the system. But the water level in the Moozhiyar Dam will rise up, if the Kakkad Power station is not in operational condition and during the flood season also, the expectation of flood is high. In such a case, warning for opening of spillway gates is given as water level reaches 190.00 m level. Warning is given in local media regarding the possible opening of spillway gates continuously until the reservoir level comes under control. Also intimations are given to Disaster Management, District Administrations, and Police Department etc. Spillway gates are opened by keeping the FRL at 192.63 m level based on the Gate Operation Manual.

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

Water from the reservoir is mainly used for power generation at a 2 x 25 MW at power house of KSEB Ltd. The water released from the Kakkad Power station is used for power generation at Ullumkal Power station (IPP) & Karikkayam Power station managed by private agencies. Thereafter, the water flows into the Maniyar reservoir owned by Kerala Irrigation Department for power generation in the Maniyar power station, operated by M/s Carborandum Universal Ltd.

Routine inspection

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

Maintenance

Routine maintenance is carried out for Spillway radial gates, Intake gates, river outlet gate, and Disperser Valve before the onset of monsoon. Details are given under the Chapter **Project Maintenance**.

1.10 Distribution of Operation & Maintenance Manual

The following officers/ field staff at different levels in the Division under the supervision of Deputy Chief Engineer, Research & Dam Safety Organization, KSEB Ltd, Pallom and administrative control of Chief Engineer, Dam Safety Organization, KSEB Ltd, Pallom are entrusted with the specific responsibility for carrying out O & M activities for Moozhiyar dam.

1) Executive Engineer, Dam Safety Division No. I, Kakkad
2) Asst. Executive Engineer, Dam Safety Sub Division, Seethathode
3) Assistant Engineer, Dam Safety Sub Division, Seethathode
4) Personnel in charge of works of the Dam

The offices/officers to which the O & M Manual of Moozhiyar dam is to be distributed are:

Sl. No	Name of Office	No of Manuals
1	Dam Safety Division No. I, Kakkad	1
2	Dam Safety Sub Division, Seethathode	1
3	Deputy Chief Engineer, Research & Dam Safety Organization, KSEB Ltd, Pallom	2
4	Office of the Chief Engineer, Dam Safety Organization, KSEB Ltd, Pallom	1
5	Office of the Director (Generation – Civil), Vydyuthi Bhavanam, Thiruvananthapuram.	1

1.11 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.

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

1.12 Typical Schedule of Duties

Schedule of duties/inspections to be carried out for the operation and maintenance of the dam by the concerned official are tabulated below in **Table 1.2**.

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 etc.	Daily	Sub Engineer/Dam operators on contract

2	Record water surface elevation, reservoir inflow and spillway discharge.	Daily (Hourly during monsoon)	Sub Engineer/Dam operators on contract
3	Record meteorological data, Record releases from outlets/sluices (as and when necessitated)	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 etc.	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 etc.	Fort nightly	Assistant Executive Engineer
9	Check security and safety devices, logbook and site register for the above information.	Fort nightly	Assistant Executive Engineer
10	Check stand by generator (DG Sets), Drainage systems, 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 etc.	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 ventilation system, cleaning of control panel boards.	Monthly	Assistant Engineer
17	Check outlet works, updating operating instruction, check gate air vents, clean gate control switchboxes, check operation of gates, grease gate hanger/dogging	Quarterly	Executive Engineer
18	Check condition of trash rack of intake structure, Check condition of Outlet works & its Energy Dissipation Arrangement, Check operation of Valve house	Quarterly	Executive Engineer
19	Check condition of spillway, log and safety boom, Check for debris in inlet channel, Check operation of gates, Check for damages in spillway glacis, energy dissipation arrangement, d/s area etc, Check and clear spillway bridge drains, Clean inside of motor control cabinet.	Quarterly	Executive Engineer
20	Check for adherence to instrumentation schedule, Record pertinent information in Operation of Gates, Check condition of V-notch/seepage measuring devices, Check hydro mechanical components.	Quarterly	Executive Engineer
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 CWC and uploading into DHARMA.	Half yearly	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	Five Yearly	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 1.2 Schedule of duties/inspections

1.13 Hydro-Mechanical Inspections / Checks

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

Chapter 2

Project Operation

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

2.1 Basic Data

Kakkad HEP 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 Moozhiyar dam involves regulation of its reservoir as per project specific requirements. This includes the use of area capacity curves and design flood, both are described below.

2.1.1 Dams

Moozhiyar Dam: Moozhiyar dam is 176.50 m long at road level and the top width is 6.40 m. The deepest foundation level is 160.33 m and the top of the dam is 194.50 m. The FRL and MWL of the dam are 192.63 m and 192.94 m respectively. The live storage above the dead storage level of 181.36 m is 1.16 Mm^3. The dam is divided into 10 blocks. The dam has a catchment area of 28.75 Sq km.

The effects of back water from the dam on the discharge level in the tail race of the SGHEP Power house were studied and fixed at 192.63 m. Since the maximum tail race water level of Sabarigiri Power station is 192.94 m, the FRL at 192.63 m can be maintained during almost the entire period. The MWL is 192.94 m with the elevation of the top of spillway gate fixed accordingly. The dam is constructed in 10 blocks.

The reservoir has a gross storage capacity of 1.50 Mm^3 up to FRL and 1.55 Mm^3 up to MWL. With the top of dam at El. 194.50 m, an actual board of 5 ft above MWL (192.94 m) is provided. The downstream and upstream sectional elevation of dam, showing its members and important levels are as shown in **Drg 2.1** and **Drg 2.2** of **Annexure 1**. A typical cross-section of the dam is also given in **Fig 2.1**.

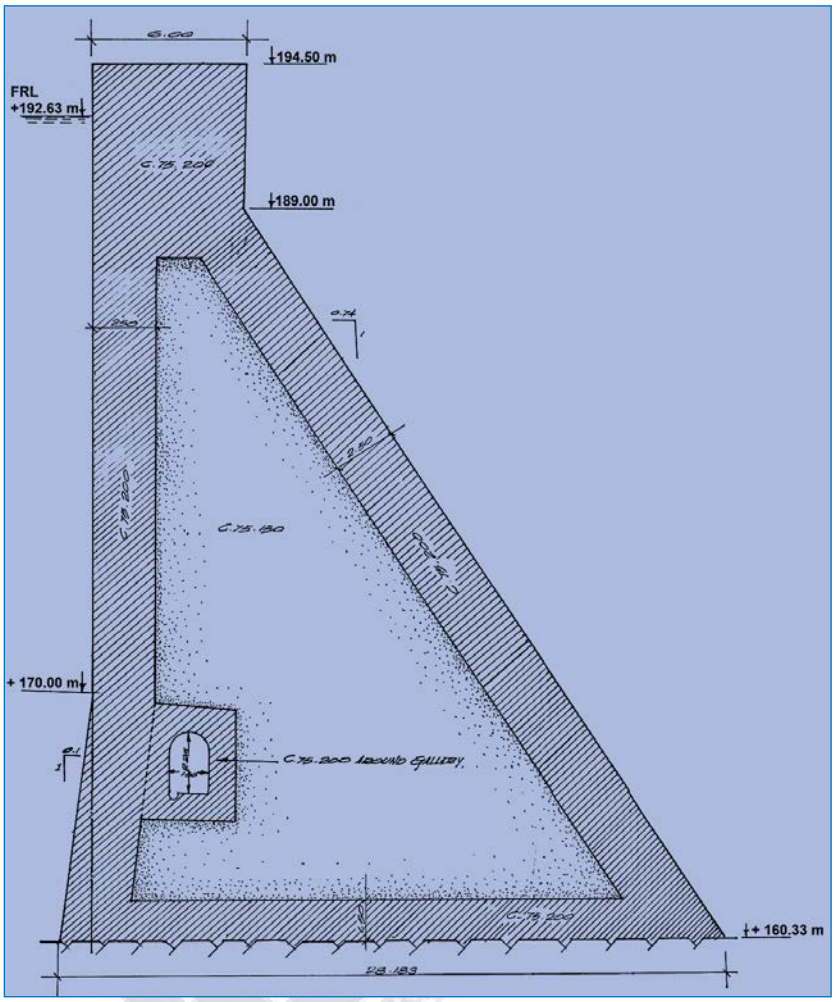


Fig 2.1 Cross-section of Moozhiyar dam

2.1.2 Spillway

The spillway of Moozhiyar consists of 3 spans of, with two intermediate single piers. The single piers extend downstream as guide walls up to certain distance in the spillway and end piers as training walls below. The elevation of the crest of the spillway is 186.53 m and FRL is 192.63 m, i.e., nearly 6 m above the crest. As the tail water level of the Sabarigiri HEP is at 192.94 m, water above the FRL of +192.63 m cannot be permitted. Hence both Sabarigiri and Kakkad Power houses are operated in such a way that the excess water above the FRL is spilled through the spillway provided at Moozhiyar Dam. The spillway is provided with radial gates of size 7.62 m x 6.70 m which can be operated both **electrically and manually**. The gate operation platform is at an elevation of 197.45 m. The gates are operated and tested in every season when the water is below the crest level. The drawing showing the cross sectional plan, sectional elevation, intake, trash rack and river outlet of Moozhiyar dam are given in **Drg 2.3**

and **Drg 2.4** of **Annexure 1**. The cross section of spillway crest and bucket is given in **Drg 2.5** of **Annexure 1.** A section of the dam through the overflow portion of spillway is given below in **Fig 2.2**. Photograph showing the spillway is given in **Fig 2.3** below.

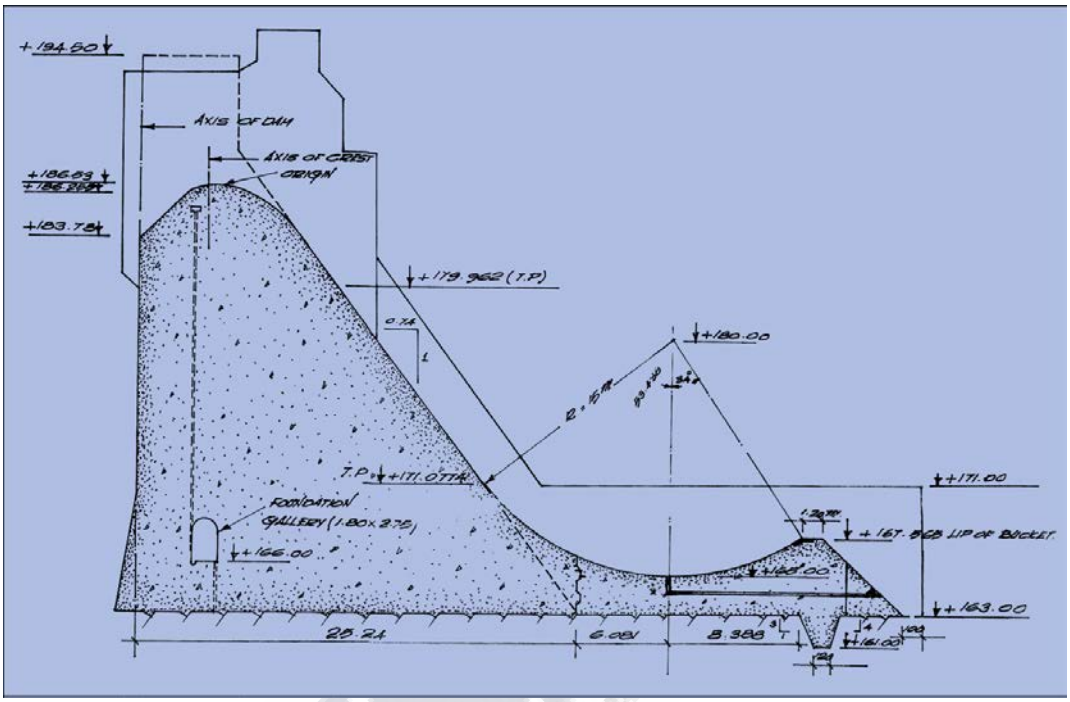


Fig 2.2 Section of the dam through the overflow portion of spillway

Fig 2.3 Spillway of Moozhiyar Dam downstream view

2.1.3 Outlet arrangements

There is a river outlet in Block no. 6 of Moozhiyar dam operated with the gate arrangement of size 1.80 m x 2.25 m. The emergency gate controlling the disperser valve of size 1.5 m is a vertical lift type, having a capacity of 15 T. The discharge capacity of the sluice is 28.03 m^3/s. The cross-section showing the disperser valve house and details of intake are shown in **Drg 2.6** & **Drg 2.7** of **Annexure 1**. The sectional plan and elevation of river outlet and trash rack arrangement is shown in **Drg 2.8 & Drg 2.9** of **Annexure 1**. Photo of the disperser valve from downstream is given in **Fig 2.4** below. Valve and starter of the disperser are given **Fig 2.5a** and the valve when opened first after installation in **Fig 2.5b.**

.

Fig 2.4 Disperser valve downstream

Fig 2.5a Starter and Valve of Disperser

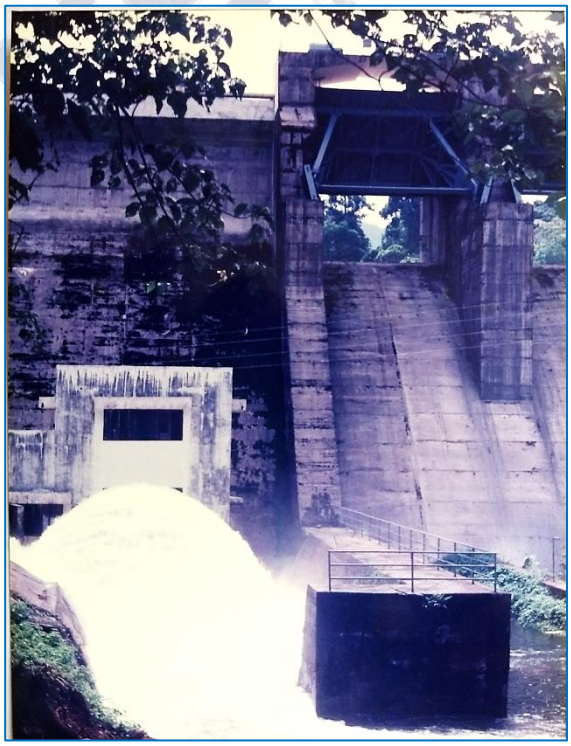


Fig 2.5b Disperser valve when opened first

The emergency gate and its hoisting system for disperser valve were supplied by M/s Kerala Electrical & Allied Engineering Company Ltd., a government undertaking firm. The sluice gate Hoist is shown in **Fig 2.6**.

Fig 2.6 Sluice Gate Hoist

2.1.4 Elevation Capacity Curve

The area and capacity curve of Moozhiyar dam during design is shown in **Fig 2.7** and tabulated in **Table 2.1**. The elevation capacity (storage) curve for Moozhiyar dam based on **Table 2.1** is shown in **Fig 2.8**.

Reservoir Level (in ft)	Reservoir Level (in m)	Storage (in Mcft)	Storage (in Mm^3)	Remarks
540	164.59	0.000	0.0000	
541	164.90	0.002	0.0001	
542	165.20	0.004	0.0001	
543	165.51	0.006	0.0002	
544	165.81	0.008	0.0002	
545	166.12	0.010	0.0003	

546	166.42	0.030	0.0008	
547	166.73	0.050	0.0014	
548	167.03	0.070	0.0020	
549	167.34	0.090	0.0025	
550	167.64	0.112	0.0032	
551	167.94	0.152	0.0043	
552	168.25	0.202	0.0057	
553	168.55	0.252	0.0071	
554	168.86	0.312	0.0088	
555	169.16	0.381	0.0108	
556	169.47	0.461	0.0131	
557	169.77	0.541	0.0153	
558	170.08	0.621	0.0176	
559	170.38	0.721	0.0204	
560	170.69	0.825	0.0234	
561	170.99	0.935	0.0265	
562	171.30	1.055	0.0299	
563	171.60	1.175	0.0333	
564	171.91	1.305	0.0370	
565	172.21	1.445	0.0409	
566	172.52	1.595	0.0452	
567	172.82	1.745	0.0494	
568	173.13	1.895	0.0537	
569	173.43	2.085	0.0590	
570	173.74	2.253	0.0638	
571	174.04	2.443	0.0692	
572	174.35	2.643	0.0748	
573	174.65	2.868	0.0812	
574	174.96	3.093	0.0876	
575	175.26	3.338	0.0945	
576	175.56	3.588	0.1016	
577	175.87	3.858	0.1092	

578	176.17	4.148	0.1175	
579	176.48	4.448	0.1260	
580	176.78	4.748	0.1344	
581	177.09	5.068	0.1435	
582	177.39	5.408	0.1531	
583	177.70	5.778	0.1636	
584	178.00	6.168	0.1747	
585	178.31	6.568	0.1860	
586	178.61	6.988	0.1979	
587	178.92	7.438	0.2106	
588	179.22	7.918	0.2242	
589	179.53	8.408	0.2381	
590	179.83	8.905	0.2522	
591	180.14	9.428	0.2670	
592	180.44	9.978	0.2825	
593	180.75	10.578	0.2995	
594	181.05	11.198	0.3171	
595	**181.36**	**11.858**	**0.3358**	**MDDL**
596	181.66	12.538	0.3550	
597	181.97	13.238	0.3749	
598	182.27	13.968	0.3955	
599	182.58	14.738	0.4173	
600	182.88	15.518	0.4394	
601	183.18	16.318	0.4621	
602	183.49	17.158	0.4859	
603	183.79	18.018	0.5102	
604	184.10	18.898	0.5351	
605	184.40	19.778	0.5601	
606	184.71	20.678	0.5855	
607	185.01	21.618	0.6122	
608	185.32	22.598	0.6399	
609	185.62	23.598	0.6682	

610	185.93	24.658	0.6982	
611	186.23	25.718	0.7283	
612	**186.54**	**26.798**	**0.7588**	**Crest Level**
613	186.84	27.893	0.7898	
614	187.15	29.018	0.8217	
615	187.45	30.138	0.8534	
616	187.76	31.238	0.8846	
617	188.06	32.338	0.9157	
618	188.37	33.463	0.9476	
619	188.67	34.678	0.9820	
620	188.98	35.998	1.0193	
621	189.28	37.198	1.0533	
622	189.59	38.398	1.0873	
623	189.89	39.648	1.1227	
624	190.20	41.048	1.1623	
625	190.50	42.788	1.2116	
626	190.80	44.243	1.2528	
627	191.11	45.703	1.2942	
628	191.41	47.163	1.3355	
629	191.72	48.623	1.3769	
630	192.02	50.088	1.4183	
631	192.33	51.688	1.4636	
632	**192.63**	**53.288**	**1.5089**	**FRL**
633	**192.94**	**54.888**	**1.5543**	**MWL**
634	193.24	56.488	1.5996	
635	193.55	58.088	1.6449	

Table 2.1 Moozhiyar Reservoir Characteristics

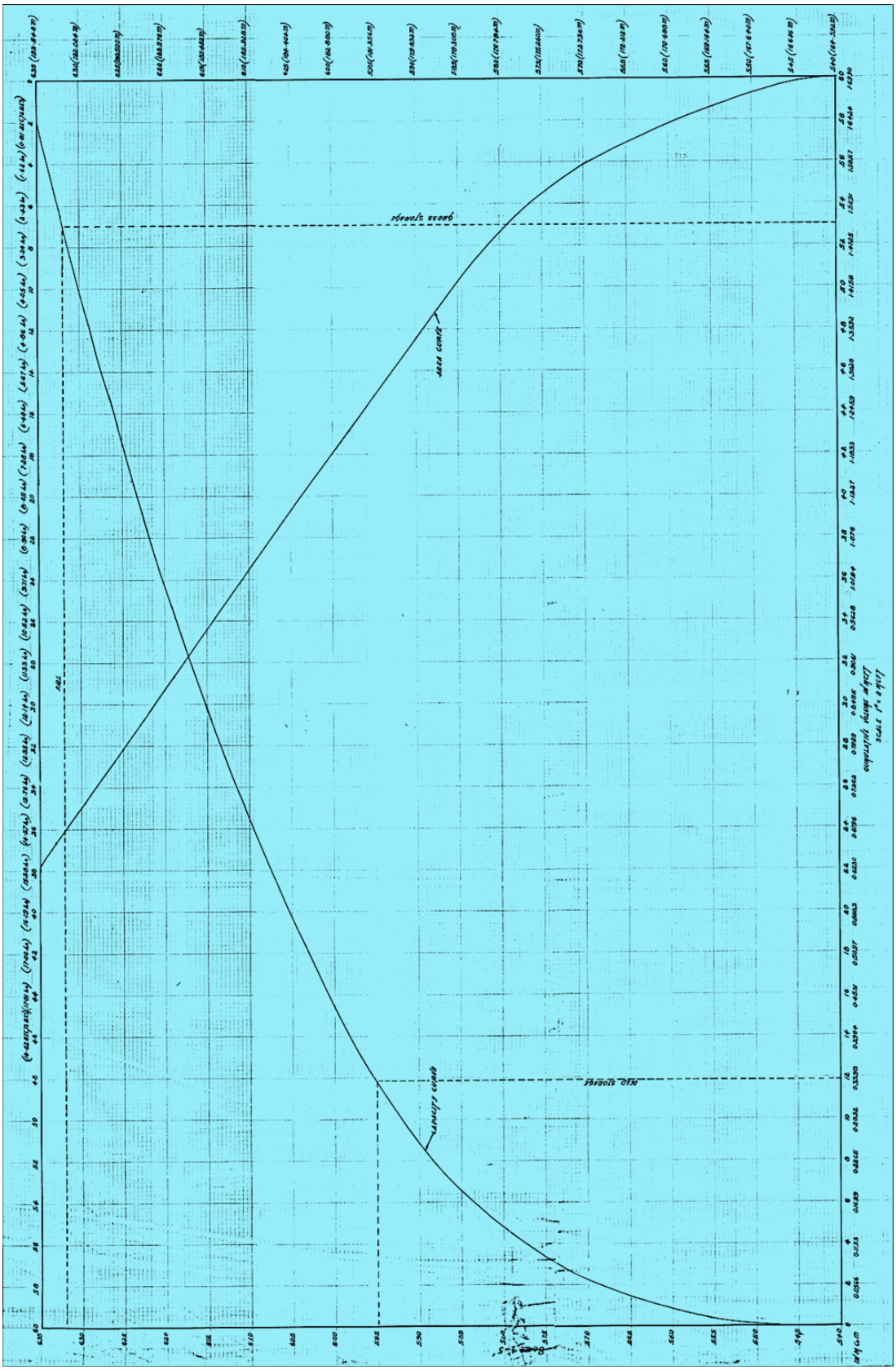


Fig 2.7 Area Capacity Curve

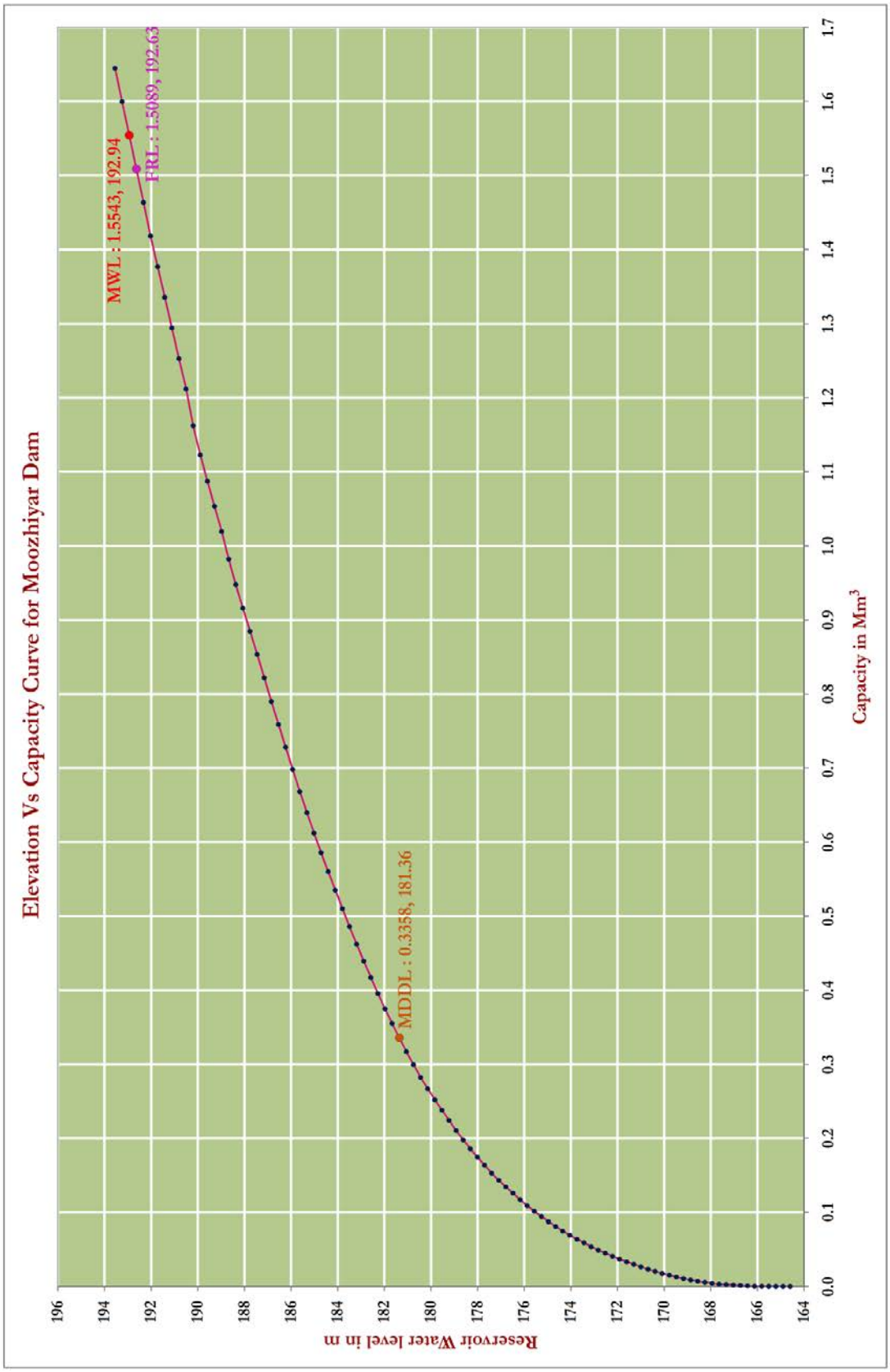


Fig 2.8 Elevation- CapacityCurve

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. Kakkad HE Project was designed in such a way that both Kakkad and Sabarigiri Power are operated integrally and the releases from Sabarigiri Power House is regulated together with the waters of Moozhiyar catchment so as to utilize maximum generation of power in the system. Hence the release through the spillway may happen whenever unprecedented flash flood from the small tributaries like Saipinthodu, Thottakuzhy etc. (upstream of the Moozhiyar Dam site) occur. In such occasions, the spillway shutters/gates are opened keeping the water level at FRL or below.

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 where rainfall of 484 mm and 751 mm respectively was recorded.

The second historical flood occurred during August 14 to 17 in 2018 which resulted in record inflow in to the reservoir. The SW monsoon of the year 2018 in the state was similar to that of 1924 Devikulam storm. Kerala experienced an abnormally high rainfall from 1 June 2018 to 19 August 2018 which resulted severe flooding in 13 out of 14 districts in the State. It is seen that the 2-day and 3-day rainfall depths of 15-17, August 2018 rainfall in Pamba, Periyar and Bharathapuzha sub-basins are almost comparable to the Devikulam storm of 16-18, July 1924. For the entire Kerala, out of 758.6 mm rainfall from 1 August 2018 to 19 August 2018, about 414 mm rainfall occurred in just three days viz. 15-17, August 2018, which created severe flooding in the State, while the same during 16-18, July 1924 was 443 mm. The 3-day rainfall of 14-16, August 2018 at Moozhiyar dam site was 422 mm.

Recently heavy flash flood occurred on 14.08.2018 at 10.40 pm and the situation was managed by opening the gates. Moozhiyar spillway gates were opened during 2018 for flood control. (Gate No. 1 for 2.00 m, Gate No. 2 for 1.00 m and Gate No. 3 for 1.00 m were opened to release 107.68 cumecs). The maximum spill discharge of the year was 11.893 Mm^3 on 15.08.2018.

2.2.2 Design Flood and Features Related to Safety

The Kakkad Scheme was conceived even when the integrated Pamba - Kakki (Sabarigiri) scheme was proposed for utilizing the tail waters of Sabarigiri Power House for Power Development further down on Moozhiyar. From the working table prepared for 16 years from 1956-57 to 1971-72 for the integrated operation of Kakkad and Sabarigiri Power stations, it is seen that a firm power draft of 28.40 cumecs will be available for utilization at the Kakkad Power House, generating 262 MU of energy annually .

Hydrology

Moozhiyar or Kakkad River is one of the major tributaries of Pamba River in the downstream reaches. Kakkad River originates at an altitude of +1040 m at the ridge that separates Kakki River with Kakkad River. The catchment area is delineated from the Kakki lake catchment by a ridge. The catchment area of Moozhiar reservoir is approximately 28.75 sq km. In addition to this, that from the diversion weir Upper Moozhiyar earth dam (9.77 sq km) which diverts the water into Kakki-Anathode Reservoir is also considered. Thus the total catchment area considered for flood estimation is 36.52 sq km (14.1 sq miles). The gross storage volume is estimated at approximately 1.5 Mm^3 only as the Dam is intended mainly to divert the tail water from 300 MW Moozhiyar Power House and no storage as such is envisaged. Moozhiyar Dam is 34.17 m high from deepest foundation level. The catchment area falls between $9^0$15' N & $9^0$20' N latitude & $77^0$0' E & $77^0$10' E longitude.

Flood calculation based on the Project Report (Jan 1973)

Ryve's formula is used to calculate the maximum flood discharge considering the 100 year flood peak. The original flood was estimated as 449 m^3/s using Ryve's empirical formula with Ryve's constant 2700. In addition to this there is a tail race discharge of 54.37 m^3/s also from Sabarigiri Power House to Moozhiyar Reservoir.

$$Q=CA^{2/3}= 2700 \times 14.1^{2/3}= 15760 \text{ cusec (449.27 cumec)}$$

Adding the peak tail discharge from Sabarigiri Power station = 1920 cusec (54.37 cumec)

Total= 17680 cusec (500.64 cumec)

Hydrology review carried out in DRIP

The revised design flood of Moozhiyar reservoir is reviewed under DRIP as per FER 5 (a) & (b) published by Central Water Commission and IS 11223. The physiographic parameters like

length of longest stream, equivalent slopes etc are found out from GTS maps. The total catchment area considered for flood estimation is 36.52 sq km including that of Upper Moozhiyar. The length of longest stream is 13.16 km and equivalent stream slope is 81.01 m/km. The average tail water level at downstream is 166 m. The base flow is worked out at the rate of 0.15 m^3/s per square km of the catchment area of the basin. The base flow is arrived at as 5.48 m^3/s. Thus the revised flood of Moozhiyar reservoir is estimated as 624.64 m^3/s. The rate of inflow including tail race discharge of Sabarigiri HEP comes out as 729.01 m^3/s. The existing spillway discharge capacity is 730.25 m^3/s. Hence this spillway can discharge the revised flood without exceeding the full reservoir level. The revised design flood has been reviewed and approved by the State Level Committee constituted vide B.O. (FTD) No. 1022/2014(MG/Dam Safety/DRIP/2008) TVPM dated 25-03-2014 as this dam's design flood comes under the SPF category.

2.2.3 Hoisting Arrangements for Radial Crest Gates

The spillway of Moozhiyar dam consists of 3 nos. radial gates supplied and erected by M/s Kerala Electrical & Allied Engineering Company Ltd., a government undertaking firm. The spillway hoist bridge and general layout are given in **Drg 2.10, Drg 2.11** & **Drg 2.12** of **Annexure 1**.

Operation of radial gates:

The operation of the radial gates can be done either by **electrically/manually**. After observing the parameters like, quantity of inflow on account of sudden rainfall likely to happen, the height of gatesto be raised is assessed first. This total height of opening is equally distributed to the all threegates. Gate No.2 is opened first to a unit height on the basis of requirement. Then Gate No.1 is operating to the same height as that of Gate No.2 and finally Gate No.3. The further increase in openings is also performed in the similar manner. The closing of the gates are to be done in the reverse manner of that of opening. The spillway general arrangement from downstream is given in **Fig 2.9**. The hoist system for operating the radial gates is shown in **Fig 2.10**.

Fig 2.9 General View of Spillway Hoist Bridge

The gates shall be operated as per the instructions and detailed procedure as described in the gate operation manual included in **Annexure 2**.

Fig 2.10 Moozhiyar Dam Spillway Hoist Mechanism

2.3 Normal Operation of the Reservoir

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

- Instructions for operating control mechanisms.
- Instructions for operating the reservoir in accordance with operation rule curve.
- General instructions for the safe operation of the dam and appurtenances.

The following aspects also need to be included:

- Releases to be made for various purposes round the year including releases to be made as per Inter-State Agreements/ MOU's with various States/Agencies/Projects, riparian releases etc.
- Rule curves.
- Inflow forecasting
- Flood release procedure

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

2.3.1 Operation of Control Mechanisms

3 phase electric supply is available at dam site. During periods of heavy rain fall and storm, probability for power failure or lack of sufficient voltage is quite frequent. For obtaining uninterrupted three phase electric supply of sufficient voltage required for the operation of shutters, a 40 KVA Diesel Generator set is installed near the dam. The DG set will be kept ready, after checking its fuel quantity, circuits, and change over system, etc.

Radial Gate Operations for flood release

The gates are being opened only after intimating higher officials, District Disaster Management Authority, Police & Revenue Department. Mike announcement regarding the spill are being intimated to habitants on downstream sides of river course. Intimation to the public is also being given through Visual Medias. Also a control room is opened at the dam top itself during flood season on reaching reservoir level at 191.00 m for achieving better monitoring of water levels and gate operations.

The spillway gates hoist motors are having **5 HP** capacities.The details of the gate are given in the table below.The gate is designed to be raised or lowered to any position between fully closed and opened. It is advisable to raise the gate 1.5 m below the maximum level noted and only in very rare and exceptional case the gate is to be opened up to the maximum level. In normal operating conditions, the gate may be raised up to 3 m above sill level. The operation of gatesshall be carried under supervision of a qualified engineer and as per the instructions given in the manufacturer's manual attached as **Annexure 2.** Photographs showing the hoist mechanism are given in **Fig 2.11a, 11b & 11c**.

Radial crest gates		
• **Gate structure**		
Type of gate	:	Spillway radial crest gates
Sizeof gate		
a. Clear span	:	7.62 m
b. Height	:	6.70 m
c. Radius	:	7.62 m
Elevations		
a. Sill	:	186.23 m
b. Trunnion	:	188.93 m
c. Top of gate	:	192.93 m
d.Bottom of gate when fully raised	:	192.63 m
• **Hoist**		
Capacity of Hoist	:	25 T
Motor		
a. Speed	:	1000 rpm
b. HP	:	5 HP
c. Supply	:	440 Volts, 3 phase
Electro-magnetic brake	:	200 mm dia., 440 V, single phase type
Speed of operation	:	0.473 m /min (approx.)
Seal	:	Bronze cladded rubber seal

Fig 2.11a Radial Gate hoist mechanism

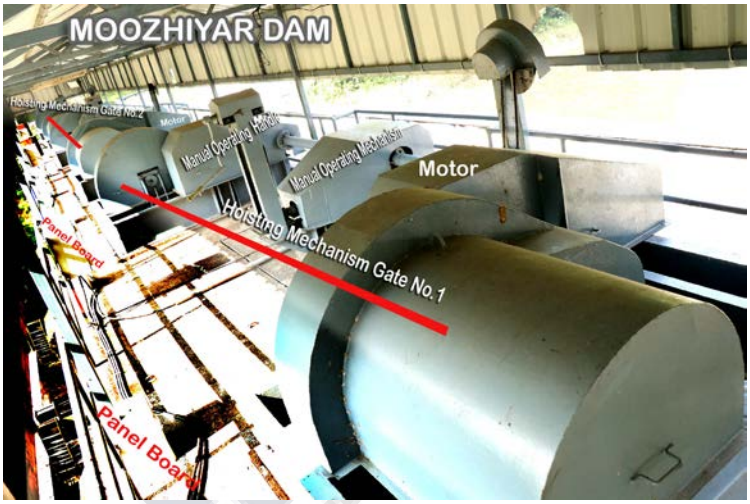


Fig 2.11b Radial Gate hoist mechanism

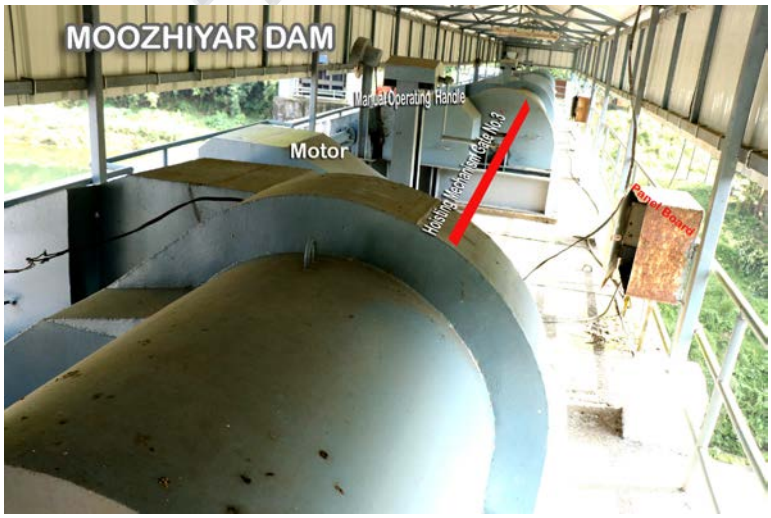


Fig 2.11c Radial Gate hoist mechanism

Emergency Gate

The Emergency gate is provided for river outlet. This vertical gate is designed to operate under unbalanced head condition. It is recommended that the gates are kept either fully closed or fully opened position. Before raising/lowering of gate, ensure that all precautionary measures have been taken. The operation of gates shall be carried under supervision of a qualified engineer and as per the instructions given in the manufacturer's manual attached as **Annexure 2.** The emergency sluice gate hoist motor has **5 HP** capacity. Sluice gate hoisting structure and mechanism are given in **Fig 2.12a & 2.12b**. The details of the gate are tabulated below.

Emergency gate (River outlet gate)		
Type of gate	:	Fixed wheel type
Weight of gate	:	3.36 MT (approx.)
Type of seal	:	Teflon cladded rubber seal
Type of wheel bearing	:	Spherical roller bearing
Capacity and type of Hoist	:	15 T., Rope drum type
Lowering or raising speed	:	0.9 m /min (approx.)
Electro-magnetic (solenoidoperation) brake with B.D coupling	:	150 mm dia., 440 V, single phase type
Motor		
a. Speed	:	950 rpm
b. HP	:	5 HP
c. Supply	:	440 Volts, 3 phase 50 Hz

Fig 2.12a Sluice Gate Hoist Structure

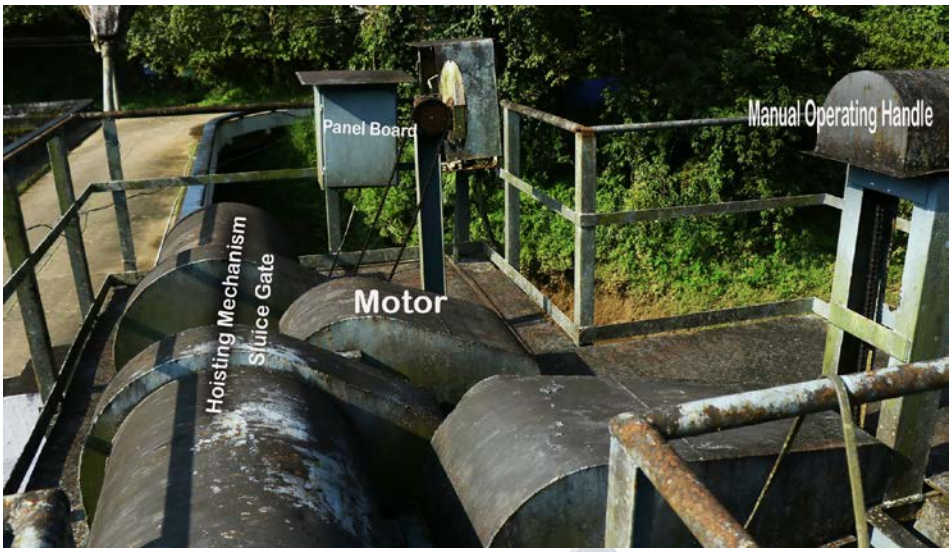


Fig 2.12b Sluice gate hoist mechanism

Intake gate

This vertical gate provided at the intake i.e. at the IC tunnel inlet and is designed to operate under unbalanced head condition. The intake hoist motor is having **10 HP** capacity. The operation of gates shall be carried under supervision of a qualified engineer and as per the instructions given in the manufacturer's manual attached as **Annexure 2**. The intake gate and general arrangement of hoisting mechanism are given in **Fig 2.13a & 2.13b**. The details of the gate are tabulated below.

Power intake gate		
Type of gate	:	Fixed wheel type
Weight of gate	:	9.4 MT (approx.)
Type of seal	:	Teflon cladded rubber seal
Type of wheel bearing	:	Spherical roller bearing
Capacity and type of Hoist	:	25 T., Rope drum type
Lowering or raising speed	:	1.0 m /min (approx.)
Electro-magnetic (solenoidoperation) brake with B.D coupling	:	200 mm dia., 440 V, single phase type
Motor		
a. Speed	:	960 rpm
b. HP	:	10 HP
c. Supply	:	440 Volts, 3 phase 50 Hz

Fig 2.13a Intake gate and hoist

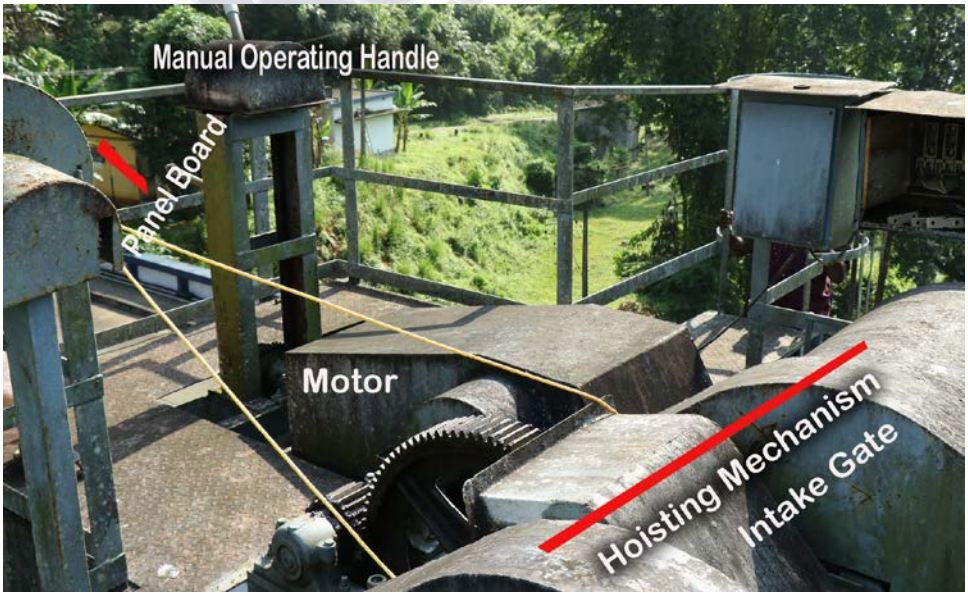


Fig 2.13b Intake gate hoist mechanism

2.3.2 Operation of the Reservoir

Moozhiyar reservoiris operated as a storage dam where no spilling of water over the spillway will normally be permitted until FRL is reached. But as mentioned earlier Kakkad and Sabarigiri Power stations are operated integrally such that the releases from Pamba and Kakki Reservoirs are regulated together with the waters of Moozhiyar catchment so as to generate maximum power in the system. But the water level in the Moozhiyar Dam will rise up, if the Kakkad Power station is not in operational condition and during the flood season also, the expectation of flood is high. In such a case, warning for opening of spillway gates is given as water level reaches 190.00 m. Since this is a small reservoir of gross capacity 1.5 Mm^3 and inflow/outflow computations are not realistic based on generation, no rule curve is prepared for this dam.

Sanction shall be obtained from District Collector, Pathanamthitta for spilling the water. As the reservoir capacity is small and the reservoir is formed at the tail race of SGHEP and meant to be operated in tandem with Kakkad HEP, which has its intake from Moozhiyar reservoir, there is possibility of release from dam in case of tripping of any Generators at the downstream Kakkad HEP. Hence release may have to be made after giving sufficient notice to District Collector.

The reservoir water is released through spillway gates on reaching the required level of operation. The spillway crest level is EL. 186.53 m. The total spillway discharge (free discharge) through spillway gates (3 Nos) for different reservoir levels under full opened condition is tabulated in **Table 2.2** and is given in **Fig 2.14a**. Discharge (Rating) curve through single spillway for different reservoir levels with different gate openings is given in **Fig 2.14b** and tabulated in **Table 2.3**.

Spillway discharge through one gate in m^3/s	Total Spillway discharge (3 gates) in m^3/s
0.00	0.00
4.98	14.95
11.28	33.85
18.66	55.97
26.95	80.86

36.07	108.22
45.94	137.82
56.49	169.47
67.68	203.04
79.47	238.40
91.81	275.44
104.69	314.07
118.07	354.22
131.94	395.81
146.26	438.77
161.02	483.06
176.20	528.61
191.79	575.38
207.77	623.32
224.13	672.39
243.44	730.33

Table 2.2 Free Spillway Discharge

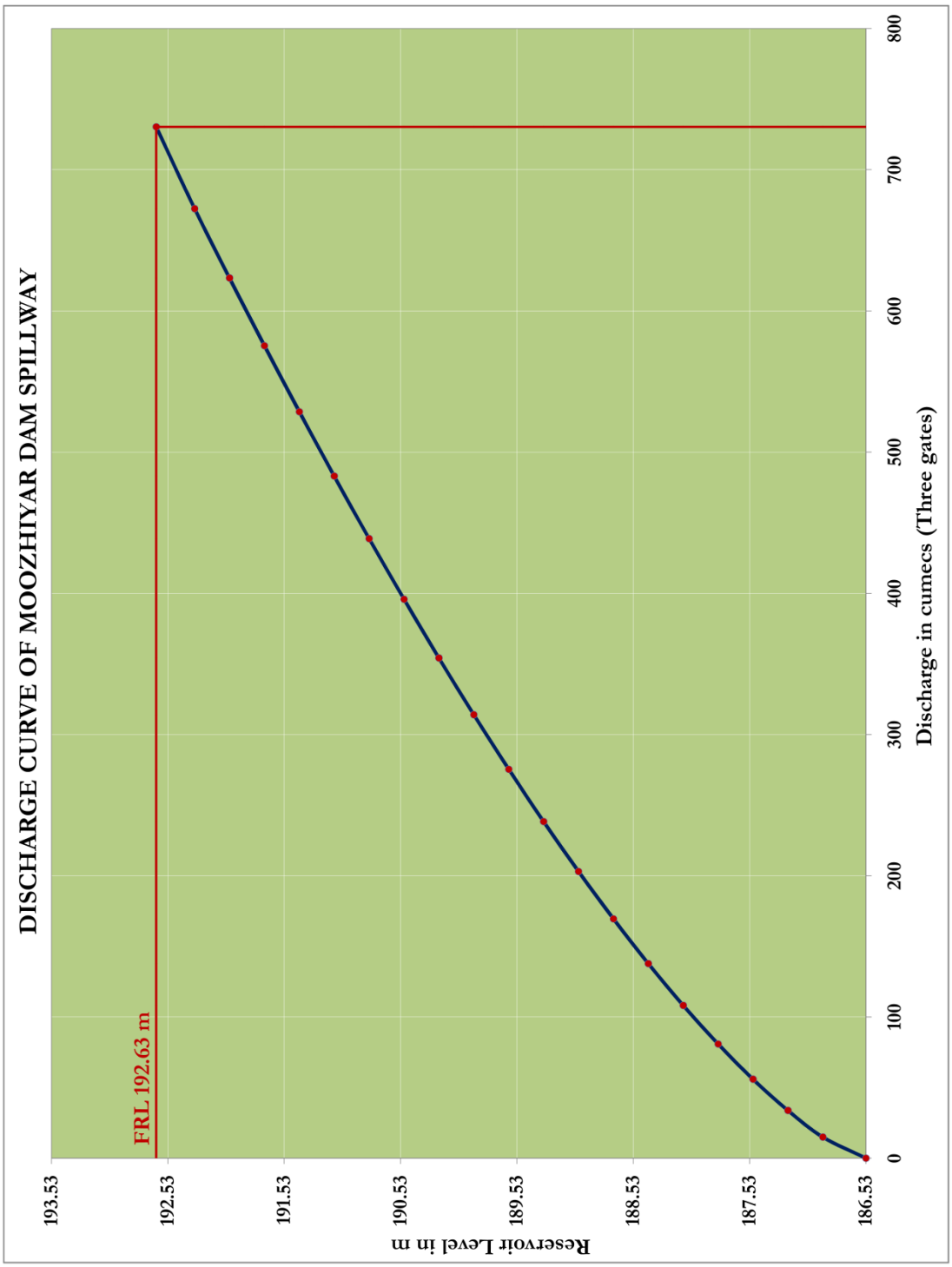


Fig 2.14a Free Discharge through Spillway Gates

Moozhiyar - Discharge through a single spillway gate for different gate openings and reservoir levels										
Reservoir Level (m)	Gate opening (m)/Bottom level of gate (+m)									
	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3
	186.83	187.13	187.43	187.73	188.03	188.33	188.63	188.93	189.23	189.53
186.53 (Crest level)	0.00									
186.60	3.08									
186.90	4.98									
187.20	6.31	11.28								
187.50	7.39	13.69	18.66							
187.80	8.33	15.71	21.99	26.95						
188.10	9.16	17.48	24.84	31.12	36.07					
188.40	9.92	19.07	27.37	34.73	40.99	45.94				
188.70	10.63	20.53	29.67	37.95	45.30	51.55	56.49			
189.00	11.28	21.89	31.78	40.90	49.17	56.50	62.75	67.68		
189.30	11.89	23.15	33.75	43.62	52.73	60.99	68.31	74.55	79.47	
189.60	12.47	24.35	35.59	46.17	56.03	65.12	73.36	80.67	86.90	91.81
189.90	13.02	25.48	37.33	48.56	59.12	68.96	78.04	86.27	93.57	99.79
190.20	13.55	26.55	38.99	50.82	62.03	72.57	82.40	91.46	99.68	106.97
190.50	14.05	27.58	40.56	52.98	64.80	75.98	86.51	96.32	105.37	113.57
190.80	14.53	28.56	42.07	55.03	67.43	79.22	90.40	100.90	110.70	119.73
191.10	15.00	29.51	43.51	57.00	69.94	82.31	94.09	105.25	115.74	125.52
191.40	15.44	30.42	44.90	58.89	72.35	85.27	97.63	109.39	120.52	130.99
191.70	15.87	31.29	46.24	60.71	74.67	88.11	101.01	113.34	125.08	136.20
192.00	16.29	32.14	47.53	62.46	76.90	90.84	104.26	117.14	129.45	141.17
192.30	16.69	32.96	48.78	64.15	79.05	93.47	107.39	120.78	133.64	145.93
192.63	17.12	33.83	50.11	65.95	81.34	96.26	110.70	124.64	138.07	150.96

Moozhiyar - Discharge through a single spillway gate for different gate openings and reservoir levels										
Reservoir Level (m)	Gate opening (m)/Bottom level of gate (+m)									
	3.3	3.6	3.9	4.2	4.5	4.8	5.1	5.4	5.7	6.1
	189.83	190.13	190.43	190.73	191.03	191.33	191.63	191.93	192.23	192.63
186.53 (Crest level)										
186.60										
186.90										
187.20										
187.50										
187.80										
188.10										
188.40										
188.70										
189.00										
189.30										
189.60										
189.90	104.69									
190.20	113.18	118.07								
190.50	120.85	127.05	131.94							
190.80	127.93	135.19	141.38	146.26						
191.10	134.54	142.72	149.97	156.15	161.02					
191.40	140.76	149.76	157.93	165.17	171.34	176.20				
191.70	146.66	156.41	165.39	173.55	180.78	186.93	191.79			
192.00	152.27	162.71	172.44	181.42	189.56	196.77	202.92	207.77		
192.30	157.64	168.72	179.14	188.86	197.82	205.95	213.15	219.29	224.13	
192.63	163.29	175.03	186.16	196.63	206.40	215.42	223.62	230.91	237.15	243.44

Table 2.3 Discharge through single spillway

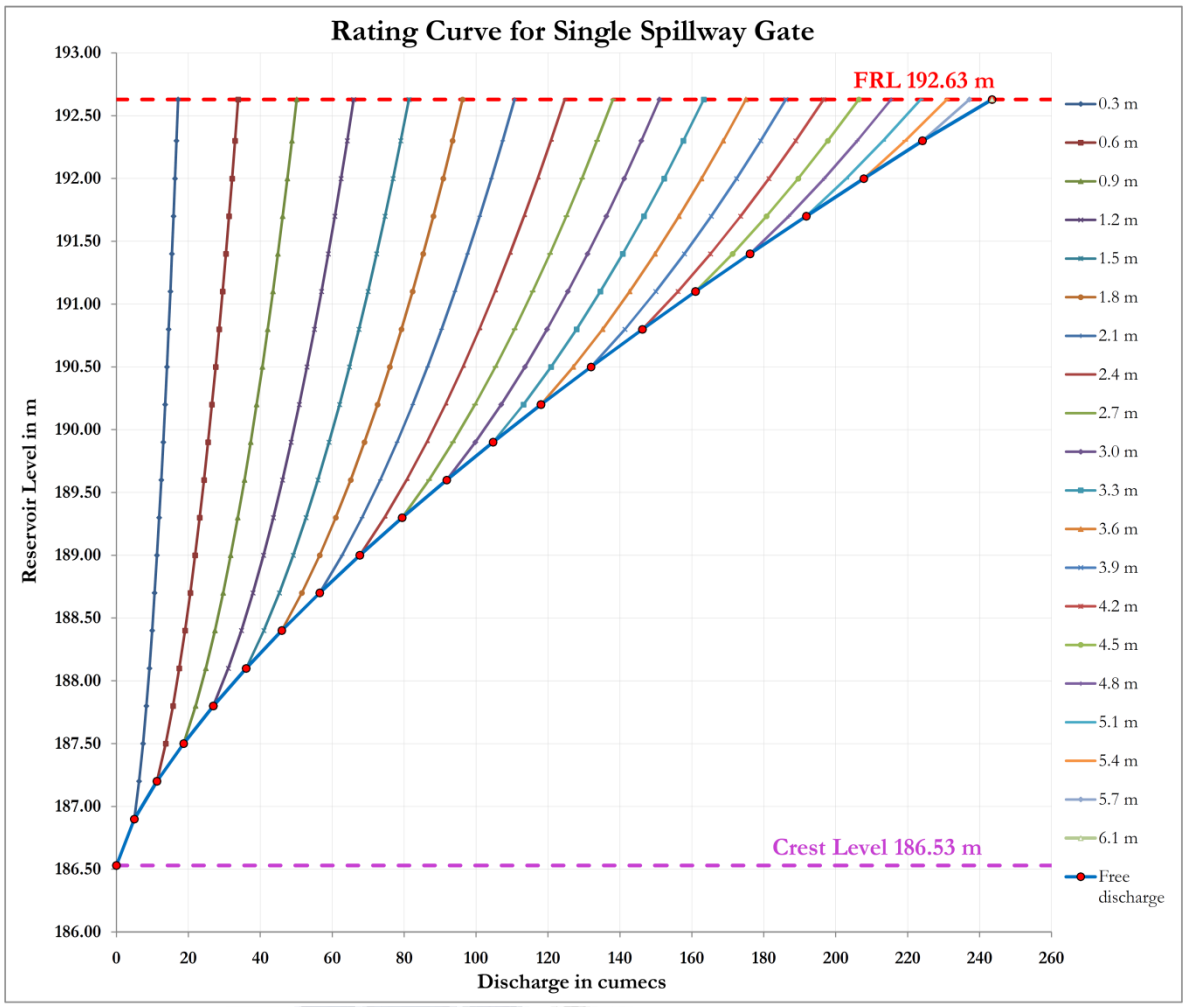


Fig 2.14b Discharge curves for Single Spillway Gate

2.3.3 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 Mm^3 in order to create some dynamic flood cushion for moderating the floods of lower return periods particularly in the early period of monsoon. Accordingly, rule curve for major reservoirs under KSEBLtd considering the historic inflow after the filling of reservoir and the power demand during respective months are prepared.

The gross storage capacity of Moozhiyar dam is only 1.53 Mm^3 and Kakkad HEP is designed as a tail race scheme of Sabarigiri HEP. The reservoir water is being diverted through IC Tunnel for power generation at Moozhiyar Power house. Water from the Forebay dam Veluthodu is also drawn through a vertical shaft to join the IC tunnel discharge from Moozhiyar reservoir for power generation at Kakkad HEP. The Kakkad and Sabarigiri Power stations are operated integrally such that the releases from Pamba and Kakki reservoirs regulated together with the waters of Moozhiyar catchment are utilized for maximum generation of power in the system. The bed level of the Moozhiyar stream at the Diversion Dam site is 164.46 m. The maximum tail water level of the Sabarigiri Power station with Pelton installation is +192.94 m. To avoid tail race encroachment the, FRL is restricted to +192.63 m and the live storage is only 1.16 Mm^3. The peak discharge from Sabarigiri alone is at the rate of 54.368 cumecs.

As mentioned in **Cl 2.3.2**, the water level in the Moozhiyar Dam will rise up, if the Kakkad Power station is not in operational condition and due to the flash flood from upstream. Hence the expectation of flood is high in this reservoir and cannot be predicted based on inflow/outflow computations. Thus spillway gates are to be operated based on site specific conditions met with and reservoir operation cannot be regulated with a rule curve. Hence no rule curve is prepared for this dam.

2.3.4 Safety Aspects

The spillway gates are operated step by step after assessing the reservoir water level and inflow and the sequencing is defined in **Cl.2.2.3**.

2.3.5 Flood Release Procedure

The flood water is released through spillway gates based on the operation manual of gates and flood routing studies given in the hydrology review**.** There are three spillway gates in Moozhiyar dam. The sequence of operation of spillway gates is Gate no. **2, 1, 3**. i.e., Gate No.2 is opened first to a unit height on the basis of requirement. Then Gate No.1 is operated to the same height as that of Gate No.2 and finally Gate No.3. The further increase in openings is also performed in this manner.

During flood season, alert as mentioned in **Cl.2.3.2** is issued for opening of spillway gates on reaching FRL or below. But in the light of the Kerala Flood 2018, the flood release

operations of Moozhiyar reservoir is revised by the KSEB Ltd vide B.O (FTD) No. 444/2019 (DGC/AEE-II/Dam Safety/2019 dt 03.06.2019. Accordingly, alert for spilling of water are fixed as 190.00 m**.** After giving warning at 190.00 m, further warning is given in local media including TV etc., regarding the possible opening of spillway gates continuously. Also intimations are given to Disaster Management, District Administration, and Police Department etc. before opening the Spillway gates.

2.3.6 Reservoir Capacities

The Gross storage and the Live Storage of the reservoir at FRL are1.53 $Mm^3$and 1.16 Mm^3 respectively and the details are given in **Table 2.1**.

2.3.7 Climate

The area experiences moist tropical climate with moderate temperature and heavy rainfall. The average annual rainfall in the basin in general varies from 266.7 cm (106 inches) in the coastal reaches to about 444.5 cm (175 inches) in the high lands. During the two monsoons, almost 90% of the annual rainfall is precipitated. The period January to April is comparatively dry during which the balance 10% of the rainfall in the year occurs. The South-West monsoon which occurs from middle of May to September accounts for the bulk of the rainfall.

2.3.8 Inflow forecasting/Methodology

There is no inflow forecasting system at present in Moozhiyar dam. Even though, normally the reservoir level rises during South West monsoon and North- East monsoon, the inflow at the reservoir mainly depends on the generation from the Sabarigiri Tail Race and from the nearby free catchment. A methodology for working out the inflow is not firmed up.

2.3.8.1 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 Moozhiyar reservoir for a rate of rise in reservoir level of 1 cm/hour. This table can be put to use for easy interpolation. Once the inflow is known the outflow and gate opening required to maintain the water level can be computed.

2.3.9 Summary of Flood Regulation Procedure

The flood regulation procedures at Moozhiyar damcan 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 sluices, spillway, IC Tunnel etc.)
3. Estimate the inflow
4. Determine the gate opening as the case maybe.
5. Open the required number ofgates to the extent required to maintain constant reservoir level. i.e., release is equal to the inflow.

2.3.10 Emergency Operation

The Emergency operation will be carried out following the Emergency Action Pan (EAP). The Emergency conditions are outlined in **Chapter 4** under **Cl.4.2.1** on Immediate Maintenance. The EAP together with this Manual will be available at site at all times. Summary of alert conditions during Emergency are given in **Annexure 7**.

2.4 Power Generation

The Kakkad and Sabarigiri Power stations will be operated integrally such that the releases from Pamba - Kakki Reservoirs (after generation from Sabarigiri HE Project) together with the waters of Moozhiyar catchment are regulated in such a manner for maximum generation of power in the system.

The surface Power House is located on the left bank of Kakkad River at Seethathode. There are two generating units of 25.00 MW each. The turbines are of vertical Francis type manufactured by BHEL. A firm power draft of 28.40 cumecs will be available for utilization at the Kakkad Power House, generating 262 MU of energy annually.

The installed capacity of the Kakkad project is 50 MW (2 x 25 MW) with firm power 30 MW. The water released from the Kakkad Power station is used for power generation at Ullumkal Power station (IPP) & Karikkayam Power station and flows into the Maniyar reservoir owned by Kerala Irrigation Department for power generation in the Maniyar power station, operated by M/s Carborandum Universal Ltd.

2.4.1 Power Outlets

The intake structure is provided in the dam location Block No.3 as in **Fig 2.15a** below with the invert level at 173.79 m. A photograph of the same is given in **Fig 2.15b.** Bell mouth entry is provided for smooth transition and is protected with trash screens. The intake opening is rectangular and has a size of 4.88 m x 6.40 m which then transforms in to circular section of size 4.15 m. The intake gate provided at the entrance is operated by an electrically driven hoist housed in a chamber over the shaft above the FRL. Details of Power intake is given in **Drg 2.13** of **Annexure 1**.

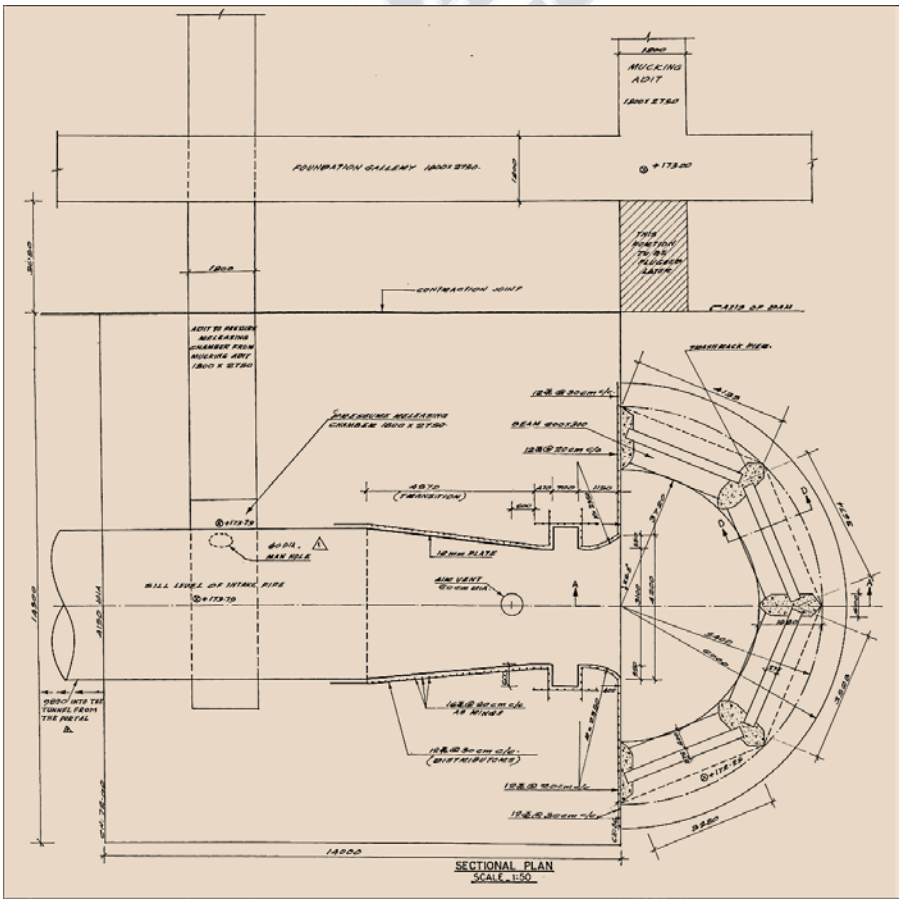


Fig 2.15a Power Intake and Trash rack

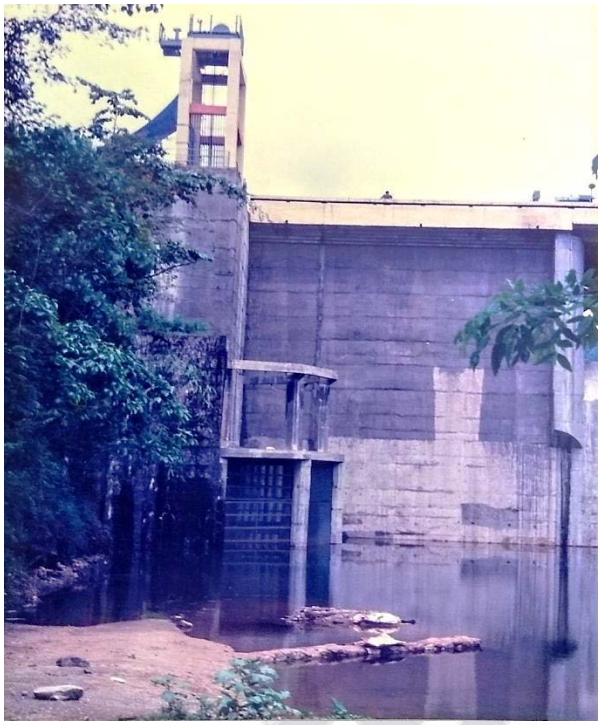


Fig 2.15b Power Intake and Trash rack

Trash-rack structure

Trash rack arrangements are provided at the intake tunnel, in a semicircular pattern around the tunnel mouth supported by R.C.C. columns and ribs and also for the disperser valve inlet and is given in **Drg 2.12** and **Drg 2.13** of **Annexure 1.** A photo graph of intake trash rack is given in **Fig 2.16.**

Fig 2.16 Moozhiyar Dam Trash rack at intake

2.4.2 Power Tunnel

All the tunnel length is lined throughout with the cement concrete with an average thickness of 25 cm. Slope of the tunnel is 1 in 200 (approx). Normal and maximum velocity of flow is 1.58 m/s and 3.5 m/s. On completion of the work of power tunnel, trial run was done for one of the machines of power house during 1999, after filling the power tunnel. The water conductor system starts with a lined interconnecting tunnel 3.168 km long of 4.15 m finished diameter from Moozhiyar Intake to a vertical intake shaft from Veluthode reservoir, followed by a lined Power tunnel 7.925 km long of 4.15 m finished diameter, which connects with a restricted orifice surge shaft of 16 m finished diameter. The water is taken through a lined pressure shaft 687.57 long (420.74 m concrete lined and 266.83 m steel lined) with bifurcation at Power House end. Photograph of circular shaft at Veluthode Forebay is given below in **Fig 2.17** .This vertical intake is located 25 m upstream of Veluthode dam dia 4.15 m and length 18.85m. The location of vertical shaft with respect to IC tunnel, Veluthode dam and power tunnel is given in **Fig 2.18**. The details are given in **Drg 2.14, Drg 2.15a** and **Drg 2.15b** of **Annexure 1**.

Fig 2.17 Intake shaft at Veluthode reservoir

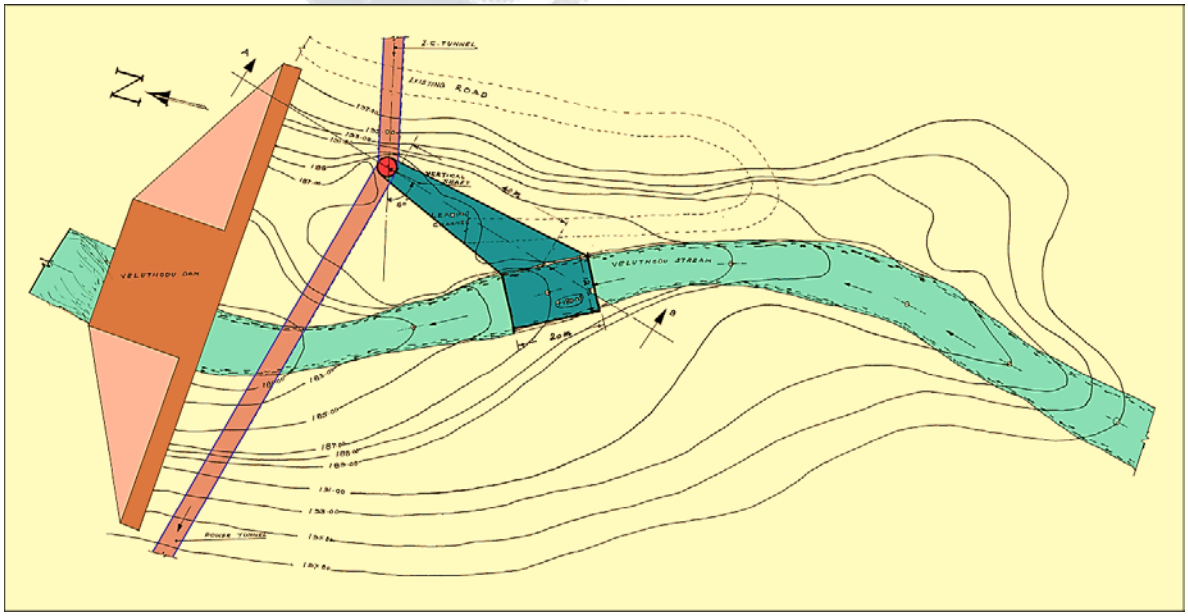


Fig 2.18 Location of Intake shaft at Veluthode reservoir

2.4.3 Surge Shaft

The surge shaft is a restricted orifice of 16.00 m diameter with two number circular shaped orifices of 2.13 m diameter. Vertical lift gate is provided as control gate. Photograph showing the surge shaft gallery is given in **Fig 2.19**.

Fig 2.19 Surge Shaft

The bottom level at the center of the surge shaft is +129.325 m. Top level of the surge shaft is +200.00 m. Maximum and minimum upsurge level +196.248 m and +154.453 m respectively. Expansion gallery of size 6.00 m x 6.00 m for 50.00 m length is provided to accommodate the surplus water during upsurge. The bottom and top level is at +192.00 m and +200.00 m. Section through surge shaft with details is given in **Fig 2.20**. The plan and sectional plan of surge shaft are given in **Drg 2.16a** and **Drg 2.16b** of **Annexure 1**.

2.4.4 Pressure Shaft

From the surge tank one low pressure tunnel takes off having 4.15 m diameter for 476.31 m length, 3.60 m diameter for 187 m length and 2.60 m diameter for 24.26 m bifurcating at the power house end to feed two machines.

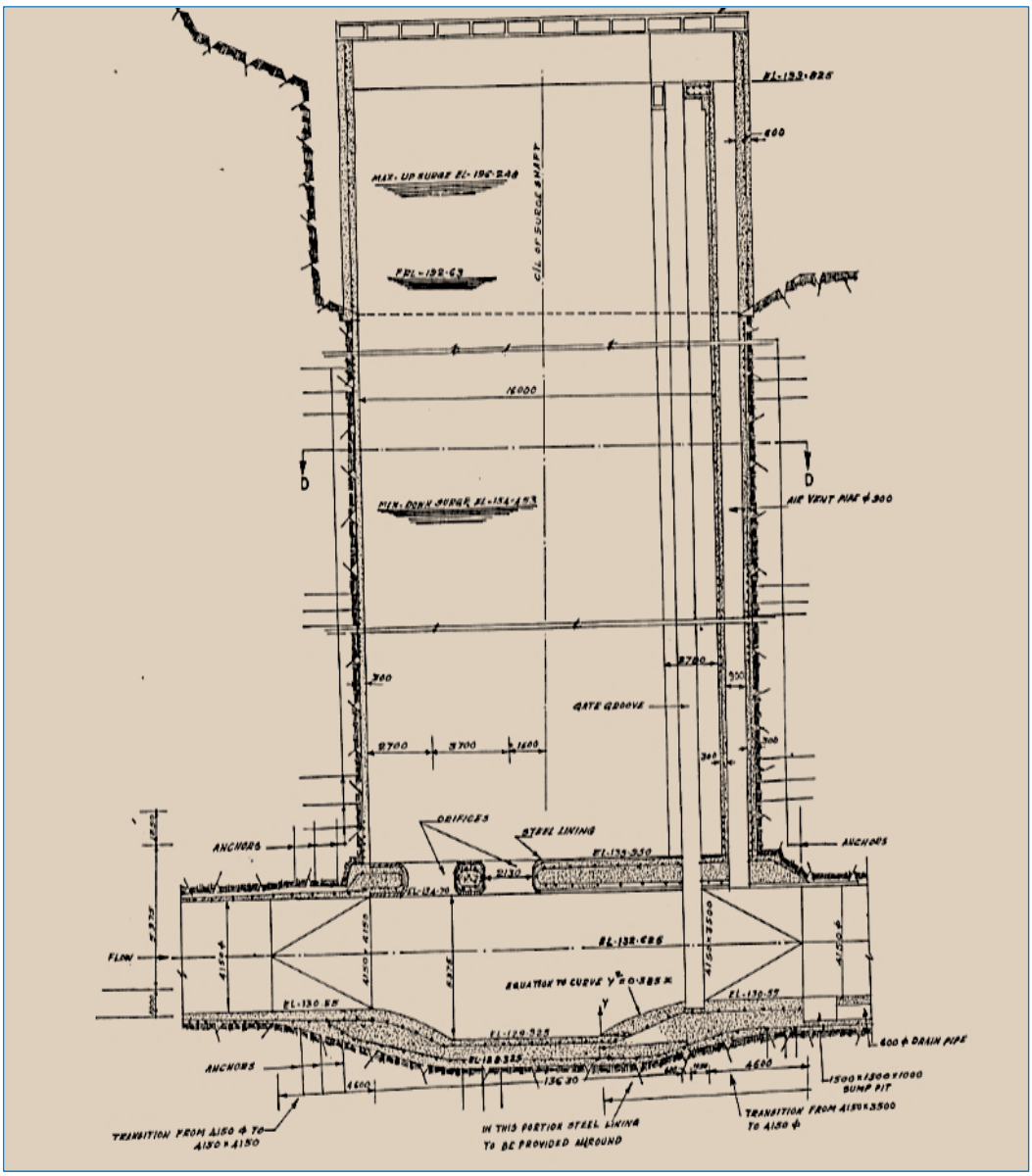


Fig 2.20 Section through Surge shaft

2.4.5 Initial Filling of Reservoir

The Reservoir was initially filled during 1999. First power tunnel filling was started from 07.05.1999 onwards and the trial run of the machines was done successfully. The commissioning of the machines of the Power House was done in 1999 and they were put into commercial operation in the same year.

2.5 Record Keeping

The records regarding dam and appurtenant structures including detailed drawings and construction details are kept at the field office. Essential documents as per the dam safety guidelines are kept at the dam site office.

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/ releases through IC Tunnel.
6. Water audit register
7. All operating procedures

Chapter 3

Project Inspection

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

3.1 Types of inspections

Four different types of dam safety inspections are available for being carried out at Moozhiyar Dam. These include, but not limited, to the following:

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

The frequency of each type of inspection depends on the condition of the dam and dam safety regulations, etc. Typical inspection elements and the detail of the safety inspections are provided below. More detailed descriptions are given in the 'Guideline for Safety Inspection of

Dams' (CWC 2018). A comprehensive health checklist **(Annexure 6)** for recording the status of each item being inspected and the overall condition of the equipment along with any consequential risks on the health of the dam is required to be maintained.

3.2 Comprehensive Evaluation Inspections

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

- General assessment of hydrologic and hydraulic conditions, review of design flood, flood routing for revised design flood and mitigation measures.
- Review and analysis of available data of dam design including seismic safety, construction, operation maintenance and performance of dam structure and appurtenant works.
- Evaluation of procedures foroperation, 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 Moozhiyar dam consists of five major parts:

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

3.2.1 Details to be provided to DSRP before inspection.

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

- General information and Scope of the Project
- Emergency preparedness
- Details of key personnel
- Hydrology - (both Original and design flood review study)
- Reservoir operation and regulation plan
- Basic data and Issues related to safety of dam
- Problems if any during construction
- Drawings of dam, spillway, gates and appurtenant structures
- Seismicity aspects & details
- Status of the instrumentation
- Construction History
- Geological Report including Special problems at site and their treatment
- Field Inspection- Observation & recommendation regarding Remedial Measures
- Dam Incidents and Reservoir filling details

Dam Incidents and Reservoir filling

First power Tunnel filling was started from 07.05.1999 onwards and the trial run of the machines was done successfully. The commissioning of the machines of the Power House was done in 1999 and they were put into commercial operation in the same year.

3.2.2 Field Inspection – Observation & recommendation regarding Remedial Measures

Based on the field inspection, remedial measures recommended by the DSRP are to be undertaken. Various project components to be inspected shall include but will not be limited to;

a) Dam

1. Upstream face
2. Downstream face
3. Top of dam
4. Structural behavior as observed visually and as per evaluation of instrumentation data (any visible cracking, deflections etc.)
5. Seepage assessment
6. Condition of natural/excavated slopes in the abutments, both on u/s and d/s.
7. Any specific problems/deficiencies

b) Spillway

1. Civil structure
2. Energy Dissipation Arrangements (EDA)
3. Spill channel, drop structures etc. if any.
4. Condition of EDA and its performance
5. Spillway Gates & Hoists
6. Downstream safe carrying capacity of river / channel.

c) River / Canal Outlets

1. Civil structures
2. Outlet Gates, Hoists & Controls
3. Conduits/ Outlets through Embankment dams and sluices through Masonry/ Concrete dams (Condition, problems etc.)
4. Trash racks, if any
5. Separate energy dissipation arrangements, if any.

d) Review of Sedimentation of the Reservoir.

1. Assessment of sedimentation and its effect on flood routing, operation/life of reservoir.

e) Flood Hydrology

1. Extent & sufficiency of data available
2. Method used for estimating the design flood.
3. Design flood review study.
4. Flood routing studies with the revised flood
5. Adequacy of free board available

f) Miscellaneous services /facilities

1. Access Roads / Bridges / Culverts
2. Elevators
3. Stand by power arrangements
4. Flood forecasting arrangements, if any
5. Communication facilities (Telephone, Satellite, Wireless, Mobile etc.)

g) Hydraulic Model studies, if any new studies carried out.

h) Earlier reports of experts / DSRP etc., if any, as annexures.

i) Photographs of dam project showing problem areas.

3.2.3 Components involved

A comprehensive evaluation inspection of a dam will typically consist of five components:

1. Project records review (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 etc.).
2. Visual inspection or field examination of the dam and its appurtenant works & Preparation of a detailed report of the inspection.
3. Education and training of the dam owner on the issues observed during dam inspection, identification of potential dam failure modes & to carryout additional field investigations & laboratory testing as required. Dam owners should be made part of the inspection process so that they take ownership of the results and are committed to implementing the recommended remedial measures.
4. Design studies e.g. review of design flood, checking of the adequacy of spillway capacity, freeboard requirements, dam stability, any special study as required & submission of the report.

3.3 Scheduled Inspections

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

The purpose of scheduled inspections is to keep the dam and its appurtenant structures in good operating condition and to maintain a safe structure. As such, these inspections and timely maintenance will minimize long-term costs and will extend the life of the dam. Scheduled inspections are performed more frequently than comprehensive evaluation inspections to detect at an early stage any development that may be detrimental to the dam. These inspections involve assessing operational capability as well as structural stability and detection of any problem 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 (Dam Inspection Report is recommended).

Scheduled inspections include the following components as a minimum:

- Review of past inspection reports, monitoring data, photographs, maintenance records, or other pertinent data as may be required
- Visual inspection of the dam and its appurtenant works
- Preparation of a report or inspection brief, with relevant documentation and photographs. The report should be filed in the dam owner's project files.

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

Detailed checklists are required to ensure the health of the dam and to ensure that it continues to operate in satisfactory and safe condition. The proforma to be used for inspection should be the one enclosed in the Doc No. CDSO_GUD_DS_07_ v1.0, CWC 2018 on the Guidelines for Safety Inspection of Dams.

Pre-monsoon Inspection to be carried out during	:	April - May
Post-monsoon Inspection to be carried out during	:	December - January
Inspecting Officers	:	Deputy Chief Engineer along with SPMU Executive Engineer, Field Executive Engineer, Concerned field Assistant Executive Engineer and Assistant Engineer
Preparation of Inspection Report	:	Executive Engineer, Field (Dam Health Engineer)
Submission of Pre-monsoon Inspection Report	:	Before June 30th
Submission of Post-monsoon Inspection Report	:	Before January 15th
Checking and approval of report	:	Deputy Chief Engineer, SPMU
Uploading corrected document in DHARMA	:	Executive Engineer, Field

3.4 Special (Unscheduled) Inspections

Special inspections may need to be performed to resolve specific concerns or conditions at the site on an unscheduled basis. Special inspections are not regularly scheduled activities, but are usually made before or immediately after the dam or appurtenant works have been subjected to unusual events or conditions, such as an unusually high flood or a significant earthquake. These inspections are to be carried out by teams to be constituted by State DSO after an initial assessment based on informal inspection carried out by project personnel reveal dam safety related concerns like cracking in the dam, damages, erosion/ scour, undermining/ piping/ sink holes/ liquefaction or any such undesirable feature. A special inspection may also be performed during an emergency, such as an impending dam breach, to evaluate specific areas or concerns. They are also made when the ongoing surveillance program identifies a condition or a trend that appears to warrant a special evaluation. Special inspections should focus on those dam components that are affected by the unusual event and should include at least three elements:

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

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

Further the following activities are also recommended to minimize the adverse impacts of an earthquake

- Regular field drills at dam site to make the site officials aware of their roles and responsibilities during and after an earthquake event and thereby to upgrade the earthquake response system
- Securing communication lines by having a redundancy in the system by way of availability of different types of telecommunication systems (viz. mobile phone, wireless, satellites, telephone etc.) at dam site.
- Securing adequate fuel for at least 3 days (viz. petrol, diesel) for the emergency power generators and other essential supplies like food, water, fire wood etc.
- Installation of seismometers in a dam and development of a data sharing system.

3.5 Informal Inspections

An informal inspection, is a continuing effort by on-site personnel (dam owners/operators and maintenance personnel) performed during their routine duties. Informal inspections are critical specially to keep an eye on to 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 Moozhiyar dam site are supposed to conduct informal inspections on routine basis. These people are the 'first-line of defense' in assuring safe dam conditions, and it is their responsibility to be familiar with all aspects of the dam. Their vigilance while walking across the dam for inspection / surveillance, checking the operating equipment, and noting changes in conditions may prevent serious mishaps or even dam failures.

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

Chapter 4

Project Maintenance

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

4.1 Maintenance Plan

A basic maintenance schedule for the various monitoring components prepared for Moozhiyar dam based on manual of operating parts, frequent inspections, priority, and interval for Moozhiyar dam shows the tasks to be performed and how frequently that is to be inspected/observed and repaired **(Annexure 5)**.

4.2 Maintenance Priorities

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

4.2.1 Immediate Maintenance

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

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

Although the remedy for some critical problems may be obvious (such as clearing a blocked spillway or repairing the spillway gates so that they are in working condition), the problems listed above generally demand the services of experienced engineers/expert panels familiar with them design, construction and maintenance of dams. 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 from the dam and restoring any eroded areas.
- Repair of defective gates, valves, and other hydro-mechanical equipment.
- Repair any concrete or metal components that have deteriorated.
- Cleaning of the choked drainage holes in the dam body/ foundations in concrete / masonry dams.
- Repair any damages on spillway glacis, piers, energy dissipaters, training/divide walls, downstream areas etc.
- Controlling any heavy seepage in the foundation/ inspection galleries in Concretedams from drainage holes.
- Repairs of any cracks/cavities/joints in concretedam.
- However many of these works will require the services of experienced engineers/expert panels.

4.2.2.2 Routine Maintenance

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

- Any routine repair to concrete or metal component.
- Observation of any springs or seepage areas in shear zones, faults etc., comparing quantity and quality (clarity) with prior observations.

- Monitoring of downstream development which could have an impact on the dam and its hazard category.
- Maintenance of Electrical & Hydro-Mechanical equipment and systems eg. Servicing of spillway gates, hoisting arrangementsand gates/hoist of outlet works/sluices & stand by generator.
- Maintaining proper lighting at dam top, galleries, etc.
- Monitoring of seepage in galleries.
- Monitoring/ cleaning & removal of leached deposits in porous concrete / formed drains in dam body and foundation drainage holes.
- Maintenance of all dam roads & access roads.
- Operation of electrical and mechanical equipment and systems including exercising gates & 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

Moozhiyar Dam top paved with concrete is designed so that it can allow heavy vehicles to pass through since Moozhiyar Power House is on the upstream of the dam site of approximately 6 km away. Also vehicles are permitted after security checking at Dam check posts.

4.3.2 Controlling Vegetation

Removal of vegetation around the dam and adjoining premises is done 2 times in a year.

4.3.3 Masonry / Concrete dams & spillways

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

- Cracking in concrete (potential causes are alkali – aggregate reaction, thermal stresses because of heat of hydration or temperature variations, foundation problems).
- Damages on spillway glacis, spillway piers, training/divide walls, energy dissipaters, downstream areas (probable causes are cavitation, abrasion, un-symmetrical flows, unfavorable down-stream conditions)
- Vegetation growth in spillways, spill channel, approach channel etc.
- Seepage in Galleries and on d/s face of the dam.
- Cleaning and removal of leached deposits from choked drainage holes in the dam body/foundations.
- Repair to upstream face of masonry dams in case the pointing is damaged, leading to increased seepage.
- 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

The civil and HM components of outlet provided in Moozhiyar Dam are detailed in **Cl.2.2.4** and the operation and maintenance are detailed out in the manufacturer's manual attached as **Annexure 2**. The outlet conduits should be inspected thoroughly once a year. Common problems are improper alignment (sagging), separation and displacement at joints,

cracks, leaks, surface wear and loss of protective coatings, corrosion and blockage. Problems with conduits occur most often at the joints. Hence, special attention should be given to them during inspection. The joints should be checked for gaps caused by elongation or settlement and loss of joint-filler material. Open joints can permit erosion of embankment material or cause leakage of water to the embankment during pressure flow. The outlet should be checked for signs of water seepage along the exterior surface of the pipe. A depression in the soil surface over the pipe may be a sign that soil is being removed from around the pipe.

As regards to Hydro-mechanical works, appropriate paragraphs in this chaptermay be referred. If routine inspection of the Hydro-Mechanical Equipment shows the need for maintenance, the work should be completed as soon as possible.

Painting of metallic components of gates and valves shall be done as explained below. Provision for timely maintenance shall be given in every year for applying cardium compound and greasing to wire ropes so as to ease the operation and life.

4.3.5 Trash Racks

Trash racks are provided at the power intake as well as for the river outlet intake as detailed in the previous chapter. This may become clogged with debris or trash reducing their discharging capacity. The head losses through clogged trash racks also increase. Maintenance of trash racks includes periodic inspections for rusted and broken sections and repairs are made as needed. Trash racks should be checked during and after floods to ensure that they are functioning properly and to remove accumulated debris periodically as per site requirements.

4.3.6 Spillway Radial Gates & Hoisting Equipment

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

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

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

4.3.6.1 Radial Gate

The main components of these gates are as under;

a) Embedded Parts:

- Common Anchorages (Bonded Anchorages)
  - Sill beam Assembly
  - Wall plate Assembly
  - Horizontal Anchor Rods
  - Trunnion Girder
  - Trunnion girder chairs
  - Vertical rods
  - Thrust block (If tie between trunnion is not used)

- Independent Anchorages (Unbonded Anchorages)
  - Sill beam assembly
  - Wall plate assembly
  - Anchor girders
  - Load Anchors / Tie flats
  - Yoke girders
  - Rest plate
  - Vertical rods etc.
  - Thrust block (If tie between trunnion is not used)

b) Radial Gate Leaf:

- Common Anchorages (Bonded Anchorages)
  - Skin plate
  - Side guide and seal assembly
  - Vertical stiffeners
  - Horizontal Girders

- Horizontal Girder Bracings
- Arm Assembly
- Trunnion
- Trunnion pin
- Trunnion Bush
- Trunnion Bracket
- Tie between trunnion and thrust Block

➢ Independent Anchorages (Un bonded Anchorages)

- Lifting Bracket
- Skin plate
- Side guide and seal assembly
- Vertical stiffeners
- Horizontal Girders
- Horizontal Girder Bracings
- Arm Assembly
- Trunnion
- Trunnion pin
- Trunnion Bush
- Trunnion Bracket
- Tie between trunnion or Thrust block

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

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

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

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

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

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

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

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

c) **Gate structures:**

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

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

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

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

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

d) **Embedded Parts:**

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

ii) The guide roller pins shall be lubricated.

e) **General Maintenance:**

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

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

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

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

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

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

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

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

viii) Wire ropes should be properly lubricated.

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

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

xi) Flexible couplings should be adjusted if required.

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

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

xiv) The list of essential spare parts to be kept available should be reviewed and updated periodically. The condition of spares should be checked periodically and protective coating given for use.

4.3.6.2 Vertical lift fixed wheel and Slide Gates

These gates are provided in spillways, outlet works, sluices etc. for controlling/regulating the flow. The main components of these gates are as under;

i). Embedded parts:

- Sill beam assembly
- Top and side seal seats
- Roller track
- Side guide
- Dogging arrangement

ii). Gate Parts:

- Skin plate Assembly
- End Verticals
- Horizontal girders
- Vertical Stiffeners
- Roller assembly
- Seal Assembly
- Side guide assembly
- Lifting Arrangement

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

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

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

iii. 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.

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

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

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

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

viii. Where filling valves are provided as part of the gate structure, all the nuts, bolts, check nuts etc. should be tightened.

ix. All welds shall be checked for cracks/ damages. Any weld that might have become defective should be chipped out and redone following the relevant codal provisions. Damaged nuts, bolts, rivets, screws etc. should be replaced without delay.

x. The filling-in valves allow passage of water when it is lifted by lifting beam & crane due to creation of space between stem seat and exit passage liner. The springs and associated components should be checked periodically for damages and replaced if necessary.

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

xii. The wheel pin shall be coated with corrosion resistant compound.

xiii. All nuts and bolts shall be tightened.

4.3.7 Maintenance of Electrically operated fixed hoists

For obtaining uninterrupted three phase electric supply of sufficient volts required for the operation of shutters, a 40 KVA Diesel Generator set is installed.

General Instructions:

a. 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.

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

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

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

4.3.8 Maintenance of Electrical components 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 connector should be tried by hand to make sure that it operates freely.

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

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

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

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

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

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

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

x) Do not lubricate the contacts.

xi) Examine earth connections and motor leads.

xii) Examine motor windings for overheating

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

xiv) Examine control equipment

xv) Examine starting equipment for burnt contacts

xvi) Check and tighten all nuts and bolts

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

xviii) Lubricate the bearings

xix) Overhaul the controllers

xx) Inspect and clean circuit breakers.

xxi) Wipe brush holders and check bedding of brushes.

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

xxiii) Check the insulation resistance of the motor between any terminal and the frame. If the measured resistance is less than the prescribed value, then steps shall be taken to dry- out the motors either by passing a low voltage current through the 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.

4.3.9 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.

4.3.10 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.

The metal parts of the gates were painted by zinc rich primer and epoxy. The hoist motor parts were painted using synthetic enamel paint. This was arranged under DRIP works.

Surface Preparation and Painting of HM Works

i) Protection of painted surfaces is considered essential for protection & enhancement of service life. Gates, their embedded parts, gate leaf, hoists and its supporting structures need to be protected against corrosion due to climatic condition, weathering, biochemical reaction and abrasion etc. This equipment is likely to deteriorate or get damaged to any extent that the replacement of parts may become necessary and such replacement may become difficult and costly.

ii) Surface preparation & Painting requirements:

Painting for hydro-mechanical works is to be carried out as prescribed in IS 14177 for both newly manufactured as well as old & used gates, hoists and associated works after proper surface preparation. The preparation includes thorough cleaning, smoothing irregular surfaces,

rusted surfaces, weld spatters, oil, grease, dirt, earlier applied damaged layers of primers/ paint by use of mechanical tools, by use of solvents, wire brush etc. The sand / grit blasting process is used for surface preparation to a level of Sa 2½ of the Swedish standard.

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

a) The following surfaces are not to be painted unless or otherwise specified:
   - Machine finished or similar surface
   - Surfaces which will be in contact with concrete
   - Stainless steel overlay surfaces.
   - Surfaces in sliding or rolling contact
   - Galvanized surfaces, brass and bronze surfaces.
   - Aluminum alloy surfaces

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

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

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

a) Embedded Parts:
   - The prescribed primer shall be applied as soon as the surface preparation is complete and prior to the development of surface rusting and within the specified time prescribed by Indian Standards or the Paint Manufacturer. In case there is lapse of considerable time beyond the prescribed time limit, the surfaces shall be again cleaned prior to priming.
   - Two coats of zinc rich primer with epoxy resin shall be applied to all embedded parts surfaces which are not in contact with concrete and shall remain exposed to atmosphere or submerged in water to obtain a dry film thickness of 75 microns.
   - This shall be followed by three coats at an interval of 24hours of coal-tar blend epoxy resin so as to get a dry film thickness of 80 microns in each coat. Total dry film thickness of paint shall not be less than 300 microns

b) Gates:

• Primer Coat:

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

• Finished paint:

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

v) Hoist and supporting structure:

a) Structural components:

Primer coats of zinc phosphate primer shall be applied to give a dry film thickness of 40±5 microns.

Final Coats: One coat of alkalized based micaceous iron oxide paint to give a dry film thickness of 65 ± 5 microns followed by two coats of synthetic enamel paint confirming to IS 2932 – 1974 to give a dry film thickness of 25 ± 5 microns per coat. The interval between each coat shall be 24hours. The total dry thickness of all coats of paint including the primer coat shall not be less than 175 microns.

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

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

Finished coats: The finished paint shall consists of three coats of aluminum paint confirming to IS2339 – 1963 or synthetic enamel paint confirming to IS 2932 – 1977 to give a dry film thickness of 25±5 microns per coat to obtain a total minimum dry film thickness of 125 microns.

c) Machined surfaces:

All machined surfaces of ferrous metal including screw threads which will be exposed during shipment or installation shall be cleaned by suitable solvent and given a heavy uniform coating of gasoline soluble removable rust preventive compound or equivalent.

Machined surfaces shall be protected with the adhesive tapes or other suitable means during the cleaning and painting operation of other components.

vi) Application of paint:

- Mix the contents thoroughly as directed by paint manufacturer before and during use.
- Painting at shop can be done by any of the three methods namely Brush / roller, Conventional spray, Airless spray etc.

The paint can be made to suit the adopted method. But once the gate and equipment is in erected position the general method adopted is only brush / roller. In case of spray lot of precautions are to be taken.

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

Appendix A – Brushing of paint

Appendix B – Spraying of paint

Appendix C – Spray painting defects: Causes and remedies.

Removal of old paint / rust and carrying out fresh painting:

The carrying out of fresh painting is to be considered under the following conditions:

- The rusting is noticed all over the surface or
- Rusting is severe or
- Cracking and blistering has damaged the primer coat exposing the metal and is noticed all over the surface or
- The paint film has eroded badly, scrap off entire paint film to the base metal and carry out fresh painting.

Note: In case of maintenance and renovation: Refer IS 14177 (Part II) – 1971 for checking and repainting.

vii) Removal of old paint for repainting:

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

a) Wire brushing, Scraping, and chipping. Sand papering or cleaning with steel wool or abrasive paper
b) Power tool cleaning
c) Flame cleaning
d) Sand blasting or shot blasting and

e) Chemical rust removal.

Note: The method of application shall be decided based on conditions existing. After cleaning, painting is to be carried out as originally proposed.

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

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

a) The following steps are involved in inspection of painting:
   - General inspection before and during painting
   - Viscosity test of paints
   - Paint thickness test – using Elco-meter.
   - Inspection of general appearance of finished work.

b) General:

   The aim of inspection and testing is to ascertain whether the recommended practice is being employed correctly during every stage of application and whether the final results fulfill the object of painting. Any test carried out should be of non – destructive nature or, if it is of destructive nature, it should be either restricted to areas which can be restored without marring the general appearances or be such that it is possible to restore easily without necessitating a complete repetition of the work.

c) Inspection of surfaces prior to painting: Inspection methods will depend on whether it is to be painted for the first time or is to be repainted.

d) New Works (Not previously painted): The following shall be decided by inspection:
   - The method of pre cleaning feasible or recommended;
   - The intermediate protective treatments to be applied, if found necessary;
   - The final painting schedule and the specifications for the paint for ensuring the particular performance;
   - The method of application, whether by brush, roller or spray.

e) Old Work (Which requires repainting):

   The following shall be decided by inspection:
   - Whether the entire existing paint requires removal; and/or
   - Whether repainting without paint removal would be adequate.

4.3.11 Access Roads

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

The dam is situated 6 km away from Moozhiyar staff colony. The entry to the dam is through black topped/ bitumen tarred road.

4.3.12 General Cleaning

For proper operation of spillways, outlet valves, inlet and outlet structures, stilling basin/energy dissipation arrangements, IC Tunnel dam slopes, trash racks, debris control devices etc., regular and thorough cleaning and removal of debris is necessary. Cleaning is especially important after large floods, which tend to send more debris into the reservoir.The dam has two numbers of horizontal galleries. The dam top road and these galleries are to be cleaned regularly.

4.4 Materials and Establishment Requirements during Monsoon

Materials required during monsoon period for both immediate maintenance and preventive maintenance must be stocked in adequate quantities for emergency situations that may arise. At Moozhiyar Dam, round the clock patrol is to be carried out during monsoon period. At the same time the manpower requirements during monsoon period are to be enhanced. Details of manpower are given below in table.

Present Manpower		
Designation	**Moozhiyar Dam**	**Remarks**
Executive Engineer	1	The dam safety officers and staff concentrate fully on monsoon related dam operation & monitoring works during monsoon period. The dam safety O & M works are generally executed during the off monsoon period.
Assistant Executive Engineer	1	
Assistant Engineer	1	
Sub Engineer	2	
Security Staff	As mentioned in **Cl.1.8.1**	

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

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

4.5 Preparation of O&M budget

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

i) **Establishment Cost of Regular Staff** - Salaries and allowances, Bonus, Medical reimbursement, LTC, Leave encashment, Pension benefits, etc. (as applicable).

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

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

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

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

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

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

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

A summary table for the O&M budget is given below in **Table 4.1.**

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	Vehicle expenses			
5	Maintenance of office & colony complex			
	Sub-total - a			

b.	**Works**			
1	**Civil works**			
1.1	Concrete / masonry dam			
1.2	Sluices in concrete / masonry dams			
1.3	Approach / inspection roads within dam area			
2	**Hydro-Mechanical works**			
2.1	Spillway gates & hoists			
2.3	Sluices in concrete/masonry dams - service/emergency gates & hoists			
3	**Electrical works**			
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 / dieselgenerator			
3.5	Remote control			
4	**Instrumentation**			
5	**Miscellaneous works**			
6	**Salary of workcharged staff including all benefits**			
7	**Materials to be stored before monsoon**			
	Sub-total - b			
c.				
1	**Contingency (10%) on Sub-total of a & b**			
2	**Tools &Plants**			
	Sub-total - c			
	Total Annual Cost			

Table 4.1 Summary Table for Annual O&M Budget

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, and
- Before and after photographs.

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

Chapter 5

Instrumentation and Monitoring

A dam's instrumentation furnishes data for deciding if the structure is functioning as intended and provides continuous monitoring to warn of any unsafe developments or phenomena that can lead to dam failure by drawing information from a wide spectrum of instruments and procedures, ranging from simple to complex. The program must be based on prevailing geotechnical conditions at the dam, and must include consideration of the hydrologic and hydraulic factors present before and after the project is in operation. Instrumentation designed for monitoring potential deficiencies at dams must consider the threat to life and property that the dam presents. Thus, 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. Continued monitoring is important to monitor the efficacy of the remedial works carried out. The involvement of personnel with experience in the design, installation, regular monitoring, and evaluation of an instrumentation system is of prime importance to the success of the program.

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

5.1 Instrument Types and Usage

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

- movements (horizontal, vertical, rotational and lateral)
- pore pressure and uplift pressures
- water level
- seepage flow
- water quality
- temperature
- Crack width

- seismic activity
- weather and precipitation data
- stress and strains

In Moozhiyar Dam, the existing Pendulum is not at all in working condition. For conducting the instrumentation studies Pendulum, Pore Pressure meter, Joint meter, Resistance Thermometer etc., are proposed under DRIP.

Now only seepage through the foundation drain holes and body drain holes are observed.The status of instrumentation in Moozhiyardam is given in the **Table 5.1.**

STATUS OF INSTRUMENTATION IN MOOZHIYAR DAM			
Sl. No.	**Name of the Instruments**	**Existing**	**Proposed under DRIP**
1	V Notches	2	0
2	Automatic Weather Station	0	1
3	Automatic Reservoir Water Level recorder/Gauges	1	1
4	Total Station	1	0
5	Permanent Bench Marks	0	1
6	Survey Markers (Target Points)/settlement plates	0	10
7	Uplift Gauges / Pore Water Pressure Gauges	0	5
8	Plumb Line	1	1
9	Thermometer	0	2

Table 5.1 Instrumentation Present Status & Proposal

5.2 Parameters monitored

5.2.1 Water Level

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

5.2.2 Seepage Flow

Seepage is measured with V notches.

Seepage assessment

In Moozhiyar dam there are 34 Nos vertical drain holes and 21 Nos foundation drain holes. The seepage measured during the recent past is tabulated below in **Table 5.2**.

Seepage details of Moozhiyar dam from 2014 to 2019		
Date	Water Level in m	Seepage in lit/min
25.03.2014	188.10	71.40
22.04.2014	191.60	78.00
20.05.2014	190.50	69.00
05.06.2014	depleted	reservoir depleted
29.07.2014	185.30	75.00
25.08.2014	186.00	72.00
11.09.2014	189.20	82.20
20.10.2014	186.50	82.80
29.11.2014	187.55	90.60
22.12.2014	187.00	82.80
28.01.2015	187.10	79.20
20.02.2015	188.55	70.20
23.03.2015	187.00	78.00
23.04.2015	188.70	86.40
22.05.2015	188.25	80.40
22.06.2015	186.50	83.40
23.07.2015	186.00	80.40
24.08.2015	186.00	81.60
29.09.2015	184.40	58.80
21.10.2015	185.50	63.00
26.11.2015	188.50	73.20
22.12.2015	186.90	61.80
22.01.2016	187.10	79.20
22.02.2016	188.55	70.20
17.03.2016	186.50	72.00
22.04.2016	187.00	78.60

20.09.2016	186.30	78.00
25.10.2016	186.50	78.00
17.11.2016	186.00	72.00
25.01.2017	186.40	60.00
09.03.2017	187.45	61.00
25.03.2017	187.40	60.00
28.04.2017	187.30	65.34
31.10.2017	188.05	45.74
17.11.2017	188.40	61.81
22.12.2017	187.45	56.76
23.01.2018	184.80	46.28
21.02.2018	186.00	42.10
27.03.2018	184.00	57.22
16.04.2018	186.40	59.34
23.05.2018	188.10	53.94
12.06.2018	182.90	45.16
18.07.2018	192.63	84.15
31.08.2018	188.80	50.34
26.09.2018	185.00	42.02
30.10.2018	189.25	53.29
29.11.2018	185.50	44.69
18.12.2018	186.50	45.63
31.01.2019	185.85	40.23
28.02.2019	187.90	51.34
30.03.2019	184.70	66.50
29.04.2019	186.70	66.36
29.06.2019	182.90	62.12
29.07.2019	185.00	40.62
29.08.2019	186.00	43.07
25.09.2019	186.15	57.48
30.10.2019	185.10	25.07

Table 5.2 Seepage details of Moozhiyar dam from 2014 to 2019

5.2.3 Water Quality

The quality of water including pH value is tested monthly at Regional Analytical laboratory, Ernakulam earlier. The test was not conducted recently.

5.2.4 Weather Conditions

The rainfall data are collected from the rain gauge installed near to the Dam site maintained by the Kerala Irrigation Department. But a full equipped weather station can sense all weather conditions. Automated weather station is proposed under DRIP.

5.3 Frequency of Monitoring

Frequency of measurement for different parameters is indicated in the tabular form below:

Sl No	Parameter	Frequency
1	Water Level	Daily
2	Seepage	Monthly
3	Rainfall	Daily
4	Water Quality	Monthly

5.4 Data Processing and Evaluation

The steps required to process and evaluate data, whether collected manually or automatically, are the same. Instrument data should be processed and evaluated according to the procedures established by the monitoring program. Accumulation of instrument data by itself does not improve dam safety or protect the public.Interpretation of data, so collected, needs to be carried out judiciously. Help of experienced personnel from the concerned field from Institutes / manufacturers / instrument suppliers could prove to be useful.

5.4.1 Data Collection

Data collected manually should be recorded on the data sheets prepared as part of the monitoring program. Complementary data, such as air temperature, reservoir level, reservoir temperature, recent precipitation, and other information or observations that may be important in evaluating the instrumentation data should be noted on the data sheets. Data collection for the dam is carried out on daily, fortnightly / monthly basis as the case may be.

5.4.2 Data Presentation

All data should be summarized in graphical form. All plots should include sufficient previous data to identify any long-term trends. Furthermore, the plots should be self-explanatory.

5.4.3 Data Interpretation

Data should be reviewed for reasonableness, evidence of incorrectly functioning instruments, and transposed data. Several checks for reasonableness can be made on all data. The magnitude of data should be near the range of previous data. Data that are significantly different may be incorrect. All data will have scatter from instrument error, human error, and from changes in natural phenomena such as temperature, wind, and humidity. The true accuracy of data will not be apparent until a significant number of readings have been taken under a variety of conditions. All data will follow trends, such as decreasing with time or depth, increasing with time or depth, seasonal fluctuation, direct variation with reservoir or tail water level, direct variation with temperature, or a combination of such trends.

Interpretation of data is carried out as per standard practice & on monthly/six monthly/yearly basis or as decided by design authorities for this dam.

Interpretation of data, so collected, needs to be carried out judiciously. Help of experienced personnel from the concerned field from Institutes / manufacturers / instrument suppliers could prove to be useful.

5.4.4 Dam Performance Evaluation

The purpose of instrumentation and monitoring is to maintain and improve dam safety. The data should be used to evaluate whether the dam is performing as expected and whether it provides a warning of developing conditions that could endanger the safety of the dam. All data should be compared with expected behavior based on the basic engineering concepts. Variations from expected behavior may suggest development of conditions that should be evaluated. All data should be compared with design assumptions. If no unusual behavior or evidence of problems is detected, the data should be filed for future reference. If 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 case-by case basis. Possible actions include:

- Performing detailed visual inspection;
- Repeating measurements to confirm behavior;
- Re-evaluating stability using new data;
- Increasing frequency of measurements;
- Installing additional instrumentation;

- Designing and constructing remedial measures;
- Operating the reservoir at a lower level; and
- Emergency lowering of the reservoir.

Due to the flood of August 2018, some rectification works were required to be done.

5.4.5 Methods of Behavior Prediction

Each dam is a unique structure and has its own special conditions of siting, design, construction and operation. Rigorous methods of prediction have been developed over the years. These methods apply the laws of physics to problems of slope stability, foundation stability and rock deformation. Modern solutions use finite element or finite difference models run on computers. Such numerical analyses are expensive and for that reason are generally used only for larger dams. Special analyses are made when investigations reveal weak materials or other anomalies**.**

5.5 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, upon each visit to the dam site, should examine it visually – walking along the dam alignment and looking for any signs of distress or unusual conditions.

PAGE KEPT BLANK

Chapter 6

Previous Rehabilitation Efforts

6.1 Issues with the dam

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

- Maintenance of road at left bank and right bank to gallery of Moozhiyar dam
- Extension of concrete retaining wall of right side and left bank to protect the left bank road at downstream of Moozhiyar dam
- Painting of intake gate, emergency gate and disperser valve of Moozhiyar dam
- Repairs to the radial gates of Moozhiyar dam
- Repair works to the spillway bucket of Moozhiyar dam
- Construction of monitoring cabin nearMoozhiyar dam
- Construction of cat walk way across the spillway gate piers of Moozhiyardam
- Pressure washing the downstream face and painting parapet &allied structures of dam
- Providing hand rails along the steps in the gallery of Moozhiyar dam
- Supply and commissioning of high mast with cost effective lighting system with accessories
- Reaming of internal drainage system of Moozhiyar dam
  a) Reaming of foundation drain holes inside the gallery with bit of appropriate size to required depth:FD 2/1-7.90 m, FD 3/1-7.10 m, FD 3/2-15.75 m, FD 3/3-15.80 m, FD 3/4-15.10 m, FD 4/1-8.30 m, FD 4/2-17.30 m, FD 4/3-16.00 m, FD 5/1-16.12 m, FD 5/2-12.10 m, FD 6/1-17.75 m, FD 6/2-12.50 m, FD6/3-16.90 m, FD 6/4-11.36 m, FD 7/1- Not reamed, FD 7/2-8.05 m, FD 8/1-17.10 m, FD 8/2- 17.50 m, FD 8/3-13.50 m, FD 9/1-14.50 m
  b) Reaming of body drain holes inside the gallery: The reaming was attempted for 4 no's of body drain holes for lengths 0.95 m to 1.50 m but it was fully chocked with concrete and hence the work was stopped.

- Supply and commissioning of High Mast lights
- Protective roofing to the hoist of radial gates of Moozhiyar dam
- Construction of a building for generator room at the premises of Moozhiyar dam
- Supply, installation, testing and commissioning of Diesel Generator sets
- Supplying and fixing Panel Board with accessories at Moozhiyar dam and providing electrical supply from the Panel Board to various gate of Moozhiyar dam DG set , High Mast light etc
- Providing and fixing retro reflective sign boards

The surge gate of the project and hoisting mechanism are not functioning properly. There are some maintenance works including overhauling, repairs of adit and surge gates and painting of the structures which are to be carried out urgently.

The photographs showing the DRIP works are given below:

Painting of Moozhiyar dam before and after

Pressure washing the downstream face before and after

Construction of monitoring cabin

After construction of monitoring cabin

During - Extension of concrete retainingwall of L/B road at

After - Extension of concrete retaining wall of L/B road at downstream

Before - Extension of concrete retainingwall of R/B road at

After - Extension of concrete retaining wall of R/B road at downstream

Before - Repairs to the radial gates

After - Repairs to the radial gates

Before - No roofing to the hoist of radial gates

After - Protective roofing to the hoist of radial gates


Spillway catwalk before and after

Repair works to the spillway bucket

Generator room

After - Construction generator room

High mast lighting system

Retro reflective sign boards

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. Updating information in the O & M Manual should be done whenever major changes like construction of an additional spillway, construction of dam on the upstream etc take place.

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

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

PAGE KEPT BLANK

References

1. **CWC Guidelines for preparing O & M Manual of Dams DSO_GUD_DS_03_v1.0 Page xii January 2018**
2. **CWC Guidelines for Safety Inspection of Dams CDSO_GUD_DS_07_v2.0 Page B4-B45 January 2018**
3. **'Guidelines for Operation of Reservoirs' (IS 7323:1994)**
4. **'Hydraulic Design of High Ogee Overflow Spillways' (IS 6934:1998)**
5. **Criteria and Guidelines for Evacuating Storage Reservoirs, Sizing Low Level Outlets and Initial Filling of Reservoir**
6. **Notification for Strengthening of Alarm and Warning System for Safety of People from Sudden Release of Water from Dams Issued by National Disaster Management Authority (October 2015).**
7. **Hydrology Review Report for DRIP 1**
8. **Project Screening Template for DRIP 1**