Operation and Maintenance Manual
For Sengulam Dam
State of Kerala

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Operation and Maintenance Manual for Sengulam Dam

Prepared by the Dam Safety Organisation

Kerala State Electricity Board Ltd

(A Government of Kerala undertaking)

State of Kerala

Front Cover Photographs: Downstream and Upstream views of Sengulam dam.

Operation and Maintenance Manual

Sengulam Dam

Approved by

Chief Engineer (Civil-Dam Safety & DRIP)

Dam Safety Organisation

Kerala State Electricity Board Ltd Pallom, Kottayam.

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Kerala State Electricity Board Ltd
Dam Safety Organisation

Disclaimer

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

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Message

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

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

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

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

Bibin Joseph,
Director Generation (Civil),
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Foreword

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

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

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

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

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PREFACE

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

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

Sengulam dam under KSEBL 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. The Sengulam HEP of KSEBL commissioned in 1954 includes one main dam located at Sengulam and is of Masonry gravity type. The power house of SHEP, located at Vellathooval, generate 48 MW under a net head of 341.36m. A flow chart of Sengulam HEP is given in the next page for reference.

This Operation and Maintenance Manual is prepared for the Sengulam dam of SHEP.

Flowchart of Sengulam Hydro Electric Project

LIST OF ACRONYMS

The following acronyms are used in this publication:

AAR	Alkali-Aggregate Reaction
ACI	American Concrete Institute
ASTM	American Society for testing Materials
CDSO	Central Dam Safety Organization
CWC	Central Water Commission
CWPRS	Central Water and Power Research Station
DDMA	District Disaster Management Authority
DHARMA	Dam Health and Rehabilitation Monitoring Application
DRIP	Dam Rehabilitation and Improvement Project
EAP	Emergency Action Plan
FSCT	Federation of Societies for Coatings Technology
HCC	Hindustan Construction Corporation Ltd
IS	Indian Standard
KERI	Kerala Engineering Research Institute
KDSA	Kerala Dam Safety Authority
KSEBL	Kerala State Electricity Board Ltd
KWA	Kerala Water Authority
NCDS	National Committee on Dam Safety
NCSDP	National Committee on Seismic Design Parameters
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
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

Team Involved in preparing this O & M Manual of Sengulam Dam

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References

1. CWC Guidelines for preparing O & M Manual of DamsCDSO_GUD_DS_03_v1.0 Page xii January 2018
2. CWC Guidelines for Safety Inspection of Dams CDSO_GUD_DS_07_v2.0 PageB4-B45 January 2018
3. 'Guidelines for Operation of Reservoirs' (IS 7323:1994)
4. 'Hydraulic Design of High Ogee Overflow Spillways' (IS 6934:1998)
5. Technical Completion Report of Sengulam HEP
6. Project Screening Template of Sengulam HEP

Chapter 1
General Information

1.1 Introduction

The Sengulam Hydro Electric Project is a small project located in Idukki district, Devikulam Taluk, Kunjithanni Village, Vellathooval Gramapanchayath, Kerala State. The latitude is 10^0 00' 39.62" and longitude is 77^0 01' 57.95" . The installed capacity of the Project is 48 MW. Water required for power generation is stored in a very small reservoir created by constructing a dam across Sengulam stream, a small tributary of Mudirapuzha River. Height of the dam is 26.82m above lowest river bed. The year of completion of dam is 1954. The nearest airport is Nedumbassery (Kochi international airport) whereas the nearest railway station is Aluva. From Nedumbassery/Aluva, this Project can be accessed via Perumbavoor – Kothamangalam – Adimaly - Anachal road route (100km, approx.)

The Sengulam Hydro Electric Project was commissioned in 1954. The Head works of Sengulam Hydro Electric Project consists of the dam located two miles below the Pallivasal Power House. The dam is a straight massive rubble masonry structure throughout. The reservoir formed by the dam is a balancing reservoir for the water brought from upper reaches. It commands an independent catchment of 5.18 sq. km and impounding capacity of 0.71Mm^3. The water spread area at FRL of 847.65m is 0.29 sq.km. The length of Dam is 143.26m at road level. The top width of dam is 4.80m. The maximum width at foundation level is 19.20m. The spillway is ogee type with three vents of 1.80 m x 4.80 m with internal pier of 30 cm thick. No gate is provided over the spillway. The spillway crest and buckets are made in concrete. There is a scour sluice of 600 mm diameter controlled by a valve located in the foundation gallery and an Emergence gate on u/s face of the dam. Suitable trash racks are also provided for the scour sluice. A drainage cum inspection/foundation Gallery runs through the length of dam with an access opening from the downstream side of the dam. In this gallery suitable drain holes for release of uplift pressure from the dam foundations and Porous drain holes from the dam top to the gallery are provided for intercepting the seepage from the dam face.

Since the Sengulam Hydro Electric Project is a tail race development project, there is no independent catchment except 5.18 sq. km of balancing reservoir. The Kundala and Madupetty reservoirs in the upper reaches of the Mudirapuzha and the yield of 129.75 sq. km uncontrolled catchment provides continuous discharge of 7.36m^3/s at RA Head works. But the water conductor system of the Pallivasal HE Project is designed only for a capacity of 6.80m^3/s. Hence the remaining

0.56m^3/s spill over the head works and flow into the river Mudirapuzha which is tapped in the collecting tank along with the tail race of Pallivasal Power House collected by a pickup weir. Thus, the Sengulam Project is supplied with the continuous discharge of 7.36 m^3/s. The water from Sengulam reservoir is diverted through a water conductor system to the Powerhouse of SHEP located at Vellathooval on the right bank of Mudirapuzha River. After generating power, the water is released to Mudirapuzha River itself.

1.2 Purpose, Location, Description of the Project

Sengulam Hydro Electric Project Location

The project is located in Idukki District of Kerala State. The location of the dam site is at Sengulam near Anachal. The location of dam is at latitude 10^0 00' 39.62" N and longitude 77^0 01' 57.95" E. The Dam is located at Kunjithanny Village and Power House is situated in Vellathooval Villige. Both sites are situated in Vellathooval Panchayath, Devikulam Taluk of Idukki District of Kerala State. The dam site is located along the sides of Anachal Vellathooval road, 2 km form Anachal Jn. The Power House is located along the side of Adimali Rajakkad road near to Vellathooval town. Approximate distance of dam from Adimaly to Dam site is about 12km. The nearest airport is Nedumbassery (Kochi international airport) whereas the nearest railway station is Aluva. From Nedumbassery/Aluva, this Project can be accessed via Perumbavoor-Kothamangalam-Adimaly-Anachal road route (100km, approx.)

The index map and route map of Sengulam HEP are given in **Fig 1.1 and Fig 1.2**.

Fig 1.1 Index Map

Fig 1.2 Index Map District wise

1.2.1 MAIN FEATURES OF THE WATER FEEDING SYSTEM TO SENGULAM RESERVOIR AND SENGULAM HEP:

PRINCIPAL FEATURES OF SENGULAM HYDRO ELECTRIC PROJECT		
Collecting Tank		El - 838.16, Size - 33.5 x12.19m
Control Gate		Two Nos, Size - 3.50x2.05m Each
I	**Power Channel No.I and Pump Forebay**	
	Length	423.65m consisting of RCC Cut and Cover, RCC Open Chanel and Aqueduct, Fore bay, capacity 1M Cft
II	**Pump and Pumping Main**	
	Pumps	Three Nos Manufactured by M/s Suler Eros Ltd., Switzeland
	Type	Vertical Shaft, Semiaxial of Capacity 150 cusecs each
	Height Through which water is Pumped	9.14m from El 835.72 to 844.86m
	Head Pumped	12.19m.(Since the FRL of balancing reservoir is 847.65
	Motors Make	Brown Boveri
	Output	1020 HP
III	**Pumping Main (Steel)**	
		207.76m long from Pump House to the Inlet of Tunnel I with 3 pipes, 1.39m diameter for a length of 44.19m from Pump House and one pipe 2.29m diameter for the balance length, woth venturi tubes, sluice, air valves etc.
IV	**Tunnel No.1**	
	Length	1755.56m
	No. of bends	3
	Finished Sectional area	6.69m^2
	Lining	30.32cm thick cement concrete
	Maximum Flow	400 cusecs
	No. of ADITs	One
	Control Gate at Exit	1No - Size 2.97x 2.82m
V	**Power Channel No II**	
	Open Channel	Length 518.16m
VI	**Sengulam Dam(Balancing Reservoir)**	
	Catchment Area	5.18 sq.km
	Capacity	0.71 Mm^3
	Bed Level	830.54m
	Crest level of Spillway	847.65m
	FRL	847.65m
	MWL	849.49m
	Road Level	850.10m
	Water Spread area at MWL	0.328 sq.km
	Water Spread area at FRL	0.29 sq.km
	Maximum length of Dam	143.26m
	Maximum width at base	19.20m
	Width at top	4.8m
	Maximum height above deepest foundation	26.82m
	Type of Dam	Straight Gravity
	Materials used	Rubble masonry in cement mortar
	Masonry contents	0.184 Mm^3
	Spillway	Ogee type with 3 Vents eacg 4.80x1.80m
	Maximum flood discharge	70.78m^3/s

VII	**Power Channel No.III**	
		Open Channel391.65m long with intake works at the inlet of RC Conduit
	Control gate at Intake works	1 No. 2.97x2.82m
	Intake level	842.12m
	Sectional Area	6.69m^2
VIII	**Tunnel No.II**	
	Inlet level	842.12m
	Length	1778.42m
	No. of bends	Four
	Finished Sectional area	6.69m^2
	Lining	20.32 cm th. Cement concrete
	Maximum flow	600 cusecs
IX	**Low Pressure Pipe Line**	
	Length	829.40m
	Internal diameter	2.59m
	Shell Thickness	15.88mm
	No. of Anchors	8
	Maximum velocity	3.35m/s
X	**Surge Shaft**	
	Sill Level	775.07m
	Static water level	847.30m
	Surge level	849.74m
	Level of Crest	850.35m
	Height	74.98m
	Diameter	2.59m from sill to El 803.41
		4.74m from 803.41 to 839.38m
		9.14m from 839.38 to 850.35m
XI	**High Pressure Pipe Line**	
	No. of Line	Two
	Internal Dia	1.47m
	Distribution lines	4 Nos
	Distribution Diameter	1.07m
	Total length	957m
	Maximum Velocity	5.18m/s
	Shell thickness at beginning	12.7mm
	Shell thickness at Lowest portion	38.1mm
	No. of Anchors	11
	Butterfly Valve	2 Nos. of the self closing automatic type and of diameter 1.47m
	Veturi tubes	2 Nos.
	Air Valve	2 Nos.
	Air Shifting Valve	2 Nos.
	Hand operated Valve	2 Nos.
	Hydrulicaly operated Valve	4 Nos
XII	**Power House**	

	RCC Strucure	Size 69.80x13.41x 13.71m
	Power House Equipments	
	Turbine	Four Nos. Multiple Pelton Wheel type
	Manufactured and Erected by	M/s English Electric Company
	Capacity	Each 18000 HP
	Maximum Static Head	365.74m
	Normal net Head	341.36m
	Alternators and Switchgear	Manufatured and Erected by M/s English Electric Company
	Numbers	Four Nos.
	Generating Capacity	Each 12000 KW
	Generating Voltage	11,000 V
	Transformers	Manufatured and Erected by M/s English Electric Company
	Numbers	Four
	Capacity	14,125 KVA, 66/44 KV
	Over Head Electric Travelling Crane Manufactures	M/s Herbert Morris Ltd, Loughborough.
	Number	One
	Lifting Capacity	70 MT

Table 1.1 – Main Features of Sengulam Hydro Electric Project

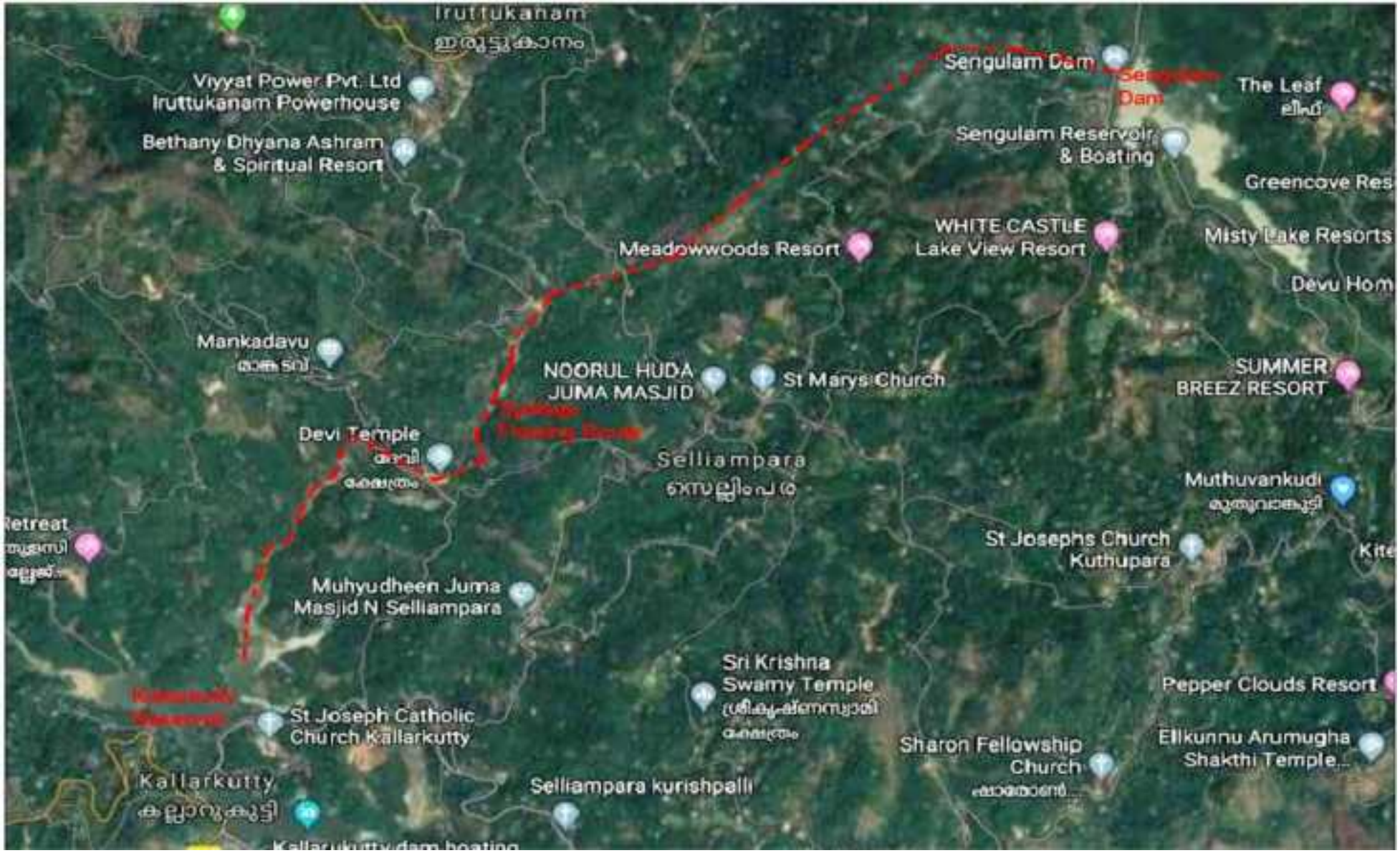

Fig 1.3 Spillway Water from Sengulam Dam – Flowing Route

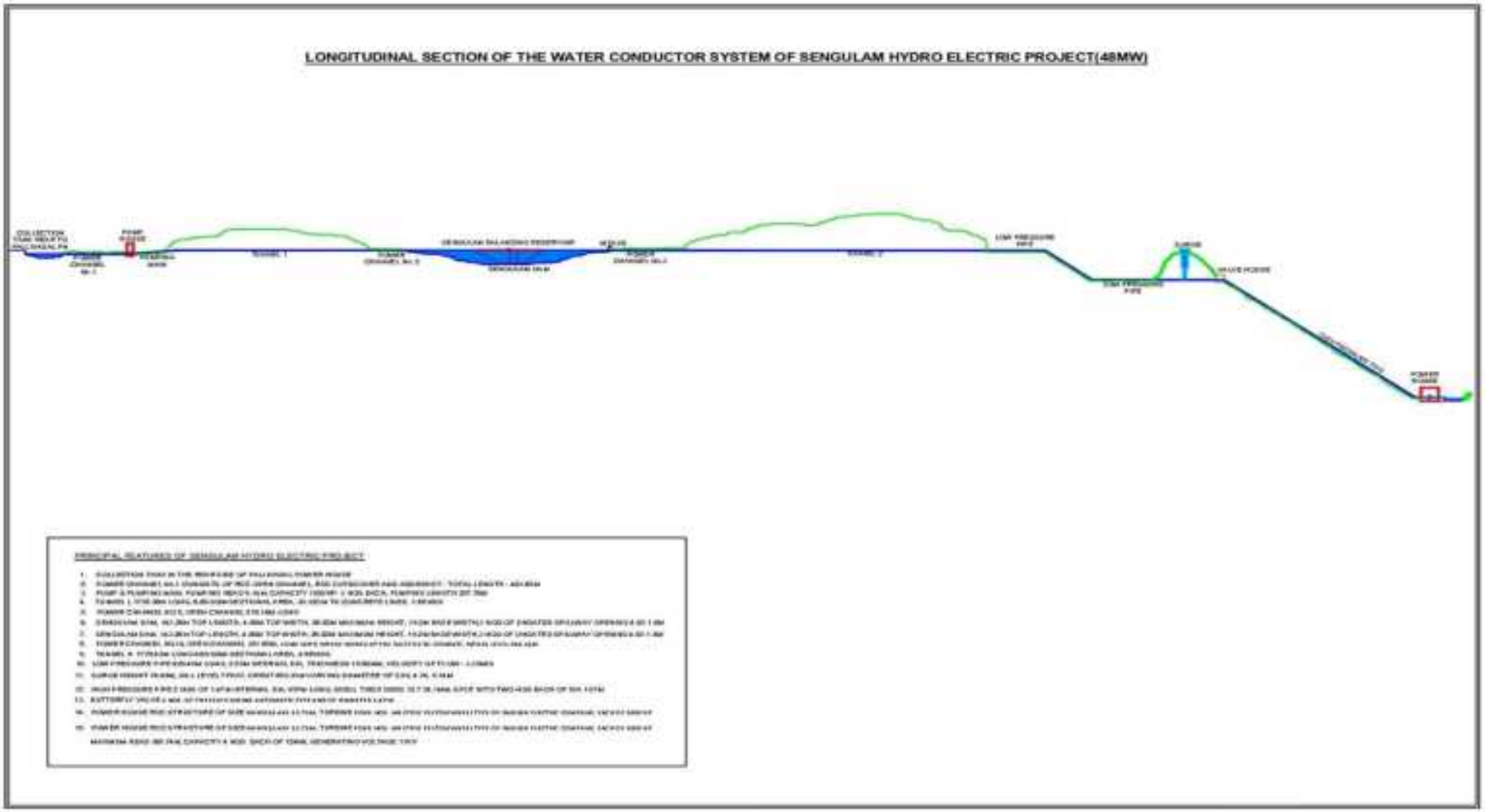

Fig 1.4 Longitudinal Section of the water Conductor System - Sengulam HEP

Fig 1.5 Longitudinal Section of the water Conductor System of Sengulam HEP from SBR to Power House

Main Components of the Project

1.2.2 The Reservoir

Sengulam dam is intended to store water for Sengulam HE Project. The Project utilises the tail water of Pallivasal Power House. The tail water of Pallivasal HE project collected in the fore bay near the power house is pumped over a head of 9.14 m and carried to Sengulam balancing reservoir through a tunnel of 1728.20m length. The water conductor system from the reservoir to power house consists of 1759m long power tunnel, 808 m long Low pressure Pipe and 960m long twin penstock. These penstock pipes bifurcate and feed 4 machines of 12MW each. Tail water is released to Mudirapuzha River.

1.	Water Spread Area	0.29 Sq km.
2.	Catchment Area	5.18 Sqkm)
3.	Maximum per day Rainfall recorded	36cm
4.	Full Reservoir Level (FRL)	+847.65 m above MSL
5.	Minimum Drawdown level (MDDL)	+846.00 m above MSL
6.	Effective Storage at FRL	0.3903 Mm^3
7.	Net head at power house	341.36 m

Table 1.2 – Hydrology Details of SHE Project

Fig 1.6 Sengulam Reservoir - Google view

1.2.3 The Dam

The Head works of Sengulam Hydro Electric Project consists of the dam located two miles below the Pallivasal Power House. The dam is a straight massive rubble masonry structure throughout. The reservoir formed by the dam is a balancing reservoir for the water brought from upper reaches. It commands an independent catchment of 5.18 sq. km and impounding capacity of 0.71Mm3. The water spread area at FRL of 847.65m is 0.29 sq. km. The length of Dam is 143.26m at road level. The top width of dam is 4.80m. The maximum width at foundation level is 19.20m. The spillway is ogee type with three vents of 1.80m x 4.80m with internal pier of 30cm thick. No gate is provided over the spillway. The spillway crests and bucket portion are made in concrete. There is a scour sluice of 600 mm diameter controlled by a valve and an Emergency gate. Suitable trash racks are also provided for the scour sluice. Drainage cum inspection Gallery runs through the length of dam with an access opening from the downstream side of the dam. In to this gallery suitable number of drain holes for release of uplift pressure from the dam foundations and Porous drain holes from the top of the dam to gallery are provided. The general arrangement, layout, upstream elevation etc. are appended in **annexure I and drgs. 2 and 3.**

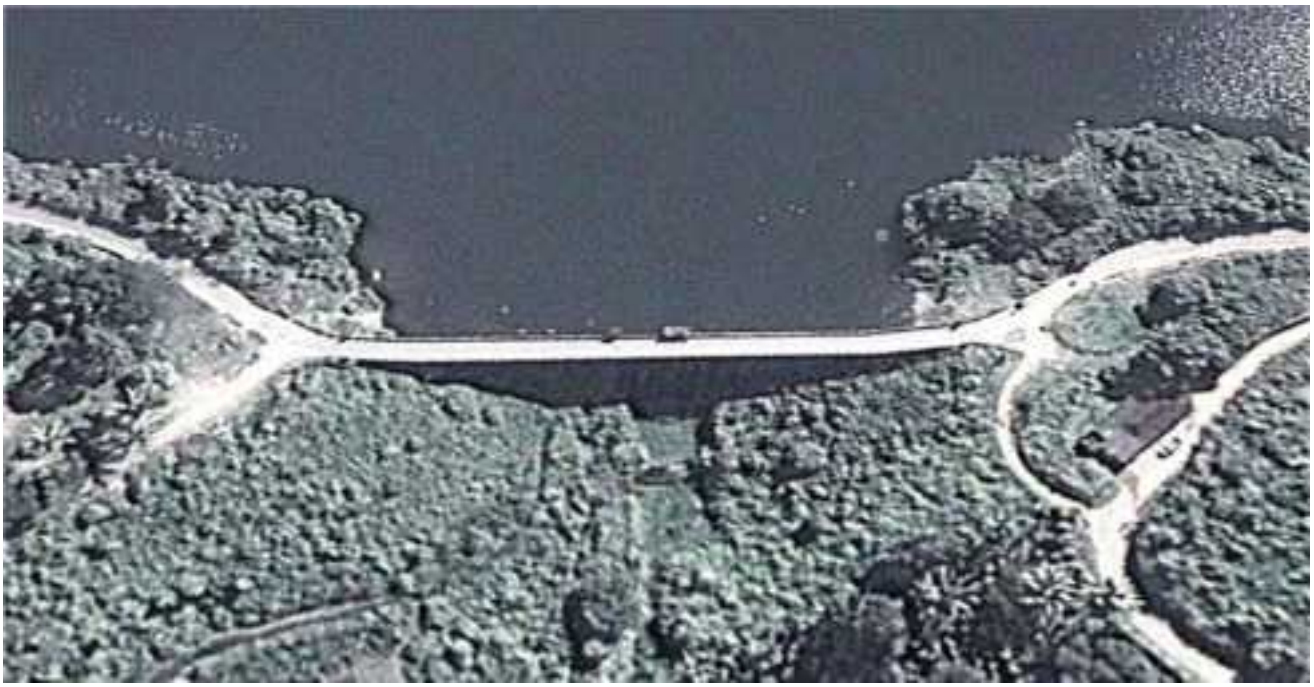

Fig 1.7 Sengulam Dam - Google view

1.2.4 Water Conductor System

The water conductor system of the Sengulam Hydro Electric Project consists of two parts. First is to convey the tail race water from Pallivasal power house and excess water from Muthitrapuzha near to the pallivasal power house to Sengulam balancing reservoir and later is to convey the water from Sengulam balancing reservoir to the Power House located at Vellathooval. These are described below.

1.2.4.1 Diversion Channel

The spillover from the RA head works (0.57m^3/s) and flow into the river Muthirapuzha which is taped in the collecting tank along with the tail race of Pallivasal Power House collected by a pickup weir. The diversion works at Muthirapuzha contains 1) a diversion weir, 2) a Diversion channel and 3) collecting tank. Diversion weir, located just above the Pallivasal power house is to divert the part of the run off of the river in to the colleting tank for the requirement of Sengulam Power House. The weir is a straight massive rubble masonry structure throughout.

Diversion channel is to convey the water from the river to the collecting tank. The intake arrangements with a sluice gate is provided at a commencing point

The size of the collecting tank at the downstream and close to the Pallivasal power house is 33.53m x 12.19 m with floor level at EL 838.16. The tail race of Pallivasal power house and the diverted water is collected in this tank and carried through a covered conduit to pump fore bay. It has an emergency spillway controlled by two gates of size 3.5 x 2.06 m. This is meant to spill the water collected in the tank if the pumping fails, thus avoid flooding of Pallivasal Power house.

1.2.4.2 Power Channel No. I

The first part of water feeding system to Sengulam Hydro Electric Project is power channel No.1. This is to carry water from the collecting tank to the pump house. It has total length of 423.65 m. The first reach of this channel is constructed as a covered conduit to accommodate the channel 1 in the limited space between the transformer yard and the river. Next to this is open channel with a level aqueduct in the middle to cross a stream. The RCC covered conduit and the RCC open channel before the aqueduct are of 3.35 x 1.52 m in cross section. The open channel after the aqueduct is of the same size with rubble masonry side walls and concrete flooring.

Power channel No.1 ends in pump fore- bay having a capacity of 1.0 Mcft. Over flow section is provided for the power channel at its end for the escape of surplus water from the channel.

Fig 1.8 – Pickup Weir near to Pallivasal PH to collect spillover from RA Head Works

Fig 1.9 Collection arrangement near Pallivasal PH to collect water from pickup weir and tail race

Fig 1.10 – RCC Aqueduct as a part of Power Channel No.1 to convey water to pump house

1.2.4.3 Pump House and Pumping system

The pumping system of the project is intended to carry water brought to pump fore- bay, from collecting tank, to Tunnel No,1. It is of steel pipe having 207.56 m length from pump house to inlet Tunnel No.1. From pump house, 3 Nos. of 1.4 m diameter pipes start and after running for a length 44.19m join together underneath an anchor to form a single pipe of dia. 2.29 m for the remaining length. It is designed for a capacity of 450 cusecs. Height through which water is pumped, is 9.14m.ie from Elevation +835.72 to +844.86. The pumping pipe is supported at intervals by saddles of rubble in cement mortar at the junction of the pumping main and tunnel No.1. There is 600 mm finished diameter shaft as air vent.

The pump house is of RCC column beam structure. The floor level of the pump house is +840.90m. Three Nos. vertical shaft semi-axial pumps of capacity 4.25 m^3/s each are installed. The motor coupled to pumps is of 1020 HP. There are arrangements to screen the water before entering the pump units.

Fig 1.11 – Pump House at Pallivasal to pump the water to Tunnel No.1

Fig 1.12 – Pumping line from Pump House to Tunnel 1

1.2.4.4 Tunnel No.1

Tunnel No.1 carries the water pumped in to it to the Sengulm Balancing Reservoir. The Tunnel is designed to carry a maximum flow of 400 cusecs. The total length of the Tunnel is 1755.56m with three bends. The general shape of tunnel is horse shoe, with a cross sectional area of 6.69 sq. m. The average lining thickness is 20.32 cm. The Tunnel ends in a power channel No.2. at the exit and the flow is controlled by a gate of size 2.06 m x 2.82 m.

1.2.4.5 Power Chanel No.2

This channel is at the exit of tunnel No.1 at Anachal. It is trapezoidal in cross section with dimensions of average size of 7.62 x 4.57 m

1.2.4.6 Sengulam Dam

The Head works of Sengulam Hydro Electric Project consists of the dam located two miles below the Pallivasal Power House. The dam is a straight massive rubble masonry structure throughout. The reservoir formed by the dam is a balancing reservoir for the water brought from upper reaches. It commands an independent catchment of 5.18 sq. km and has impounding capacity of 0.71 Mm^3. The water spread area at FRL of 847.65 is 0.29 sqkm. The length of Dam is 143.26m at road level. The top width of dam is 4.80 m. The maximum width at foundation level is 19.20m. The spillway is ogee type with three vents of 1.80m x 4.80m with internal pier of 30cm thickness. No gate is provided over the spillway. The spillways crest and bucket portion are made in concrete. There is a scour sluice of 600 mm diameter controlled by a valve and an Emergency gate, not operational at present. Suitable trash racks are also provided for the scour sluice. Drainage cum inspection Gallery runs through the length of dam with an access opening from the downstream side of the dam. In the gallery suitable drain holes are provided in the dam foundations and Porous drain holes from the top of the dam to gallery.

Fig 1.13 – Sengulam Dam - an Upstream View

Fig 1.14 – Intake of Sengulam Dam

Fig 1.15 – Close up view of Intake Hoisting arrangements

1.2.4.7 Power Chanel No.3

The channel from balancing reservoir to the tunnel No 2 is called power channel No.III. It consists of two parts. 1) an open channel with base width of 5.49 m and side slope of 2 to 1 for a length of 391.65 m. 2) RC conduit of horse-shoe shape 2.44 x 2.74 m with cross s sectional area of 6.69 m^2 for a length of 259 m.

An intake arrangement with control gate of size 2.97 x 2.82 m is provided in the beginning of RC conduit. Flow in the Muthuvankudy stream is diverted in the power channel no.3 by an underground RCC pipe conduit. Necessary trash rack arrangements are also provided at Intake.

1.2.4.8 Tunnel No.2

The tunnel o 2 of the Sengulam Project is horse shoe shape in section connecting the power channel No 3 to Low Pressure pipe line. It is lined in concrete all around and is 1778.42m in length of which the last 47.70 m is a pipe tunnel. It is designed for a flow of 16.98 m^3/s. The area of section of the finished lined tunnel is 72sqft. The average thickness of tunnel lining is 30.32 cm. There are four bend in the alignment of the tunnel. The tunnel runs through the hard rock for its entire length.

1.2.4.9 Low Pressure Penstock (LPP)

This item is a special feature of the project. The saddles along the hill are not strong enough to take pressure tunnel with insufficient rock cover, hence this arrangement to carry the water through pipe line following more or less the same contour is made. The total length of LP pipe is 829.4 m. Out of 829.4 m, a length of 56.84 m is in the beginning and 102.08 m between the last anchor and surge chamber are steel pipe concreted in- side circular- shaped tunnel. The intention to have the LPP to the no.2 tunnel at exit side for 56.84 m is to have a proper bonding of LPP with the tunnel. The remaining length of LPP is of steel pipe laid over ground fixed by anchors and supported by saddles. The LP pipe is 2.59 m dia. and 15.88 mm shell thickness.

There are eight anchor blocks along the LPP line. Anchor blocks are located at different points on the LPP line, where ever there is a change in alignment either vertically or horizontally. Anchor Nos 2, 5 &7 have compound bends, Anchor Nos 3, 1 and 8 are simple bends and the remaining anchor say 1, 4 and 6 are straight anchors. The maximum vertical deflection are 19^0 13' 38" down words and 19^0 19' 31" upwards in anchor no 5 and 7 respectively. The distance between center lines of anchors varies from 69.13 m to 127.15m. The shortest distances is between anchors 1 & 2 and longest is between 7 & 8. In every anchor block there is Dutch man in the upstream portion and expansion joint in the downstream portion. Each pipe piece is supported by single saddle.

Fig 1.16 – LPP coming out from Tunnel 1 - Close up view

Fig 1.17 – Low Pressure Pipe

1.2.4.10 Surge shaft

The surge chamber in Sengulam water conduit system is located at the end of LPP tunnel. It is at "elkunnu" where only the proper site close to water conductor system was available. The total height of chamber is 75.07 m. The surge shaft of Sengulam project is of simple type. No gallery or ventilating duct is provided. The surge chamber consist of

1 a box chamber with approximate dimensions of 4.57 x 2.44 x 5.79 m
2. a vertical circular shaft in rock with dia. of 2.59 m from about elevation +782.8 to +803.41m
3. a transition from about elevation 780.99 to +782.08. This section to transform the box chamber to the circular shaft of 2.59 m dia.
4. a vertical shaft of 4.57m dia from el 803.41 to El 839.38 i.e. up to ground level.
5. RCC Circular over ground well of 9.14m dia from El 803.41 to 850.35m.

Trash rack arrangements are provided inside the surge shaft covering. The bell mouth of the High Pressure pipe to screen the debris that flows through the LPP. The whole shaft is lined. The thickness of lining varies from 22.86 cm to 45.70 cm. Over the RC Super Structure, there is a landing platform formed by cantilevering from the vertical wall towards the inside, which by a steel ladder erected on the side of the wall.

Fig 1.18 – LPP Entering to Surge Shaft Hill

Fig 1.19 – Surge Shaft

Fig 1.20 Butterfly valve

1.2.4.11 High Pressure Penstock (HPP)

Two Nos. high pressure pipes each 957.03 m long, start from surge shaft and run through tunnel for a length of 98.95 ft. and emerges out. From this point the HPP have a steep gradient up to anchor No.9. From Anchor No.9, the penstock deviates and passes through independent anchors. The first line bifurcates in to distributors at anchor No.11 and second line bifurcates in Anchor No.10a and ends in the turbine. Between anchor 9 and 10, the penstock line cross a valley through a RCC inclined bridge of 30.48 m length.

The diameter of pipe is 1.47 m. Thickness of the penstock varies from 12.7 mm at beginning to 38.1 mm at the bottom end. The maximum capacity of each pipe is 300 cusecs and is designed for a maximum velocity of 5.18 m/s.

There are three sets of valves installed at the penstock pipes of which the vales at top portion are butterfly valves. Besides the butterfly vale, there is a 45.72 cm air valve provided at the top of each penstock immediately below butterfly valve.

At the bottom of penstock route and inside the power house, there are 106.68cm/91.44cm hydraulic valves one in each penstock feeder. Outside the power house, hand operated sluice valves, one each in the feeder are installed.

The HPP line has 9 anchor blocks; in addition to the two independent anchors for line No.1 known as 10 and 11, and one for second line, known as 10a. Anchor blocks No. 1, 4, 6 & 9 have compound bend. Anchor No. 3, 5 & 8 are simple bends, whereas, Nos. 3 and & are of intermediate anchors. The distance between anchor blocks varies from 48 m to 117.74 m. A Dutchman and expansion joint are placed at the upstream and downstream of each anchor blocks. The pipe between anchor blocks are supported by saddles.

Fig 1.21 – High Pressure Pipe (Penstock)

Pipe Fig 1.22 – Venturimeter arrangement in High Pressure Pipe line

Fig 1.23 – HPPs approaching Power House Building

1.2.4.12 Power House

The Power House is located on the right bank of the Mudirapuzha River at Vellathooval, about 9.66 km downstream of Pallivasal Power Station., and about 14.5 km south west of Chithirapuram. The building is a framed RCC structure with hollow cement concrete block masonry walls. There are four Multiple Pelton wheel type turbines of 18,000 HP capacities each, in machine hall, coupled to 4 Nos 12,000KW, 11 KV AC generators with all its controlling and protective devices and governing arrangements. The maximum static head on turbine is 365.74 m. The power house is 69.80 x 13.41 x 13.71 m with generator floor level at 486.13m. Size of control annex is 19.50 x 6.10m.

1.2.4.13 Transformer Yard

Transformer yard at Vellathooval is located partially on rock and partially on filled up earth. The yard is wide and is formed at level 486.13m at the river side and 485.98m at the cutting sides. 14.125 KVA 66/11 KV Transformers (4 Nos. one for each generating unit) and the outdoor switchgear of the power station are located in the transformer yard. The spacing of transformer is 11.89 m.

1.3 Background Details of the Project and New Schemes

After the preliminary works like investigation, preparation of DPR etc., the work was completed in 1954. The total estimate was amounting to Rupees 3,64,73,000/-.

Sengulam HE project is one among the oldest Power Station in Kerala which is operational since 1954. Installed capacity of the scheme is 48 MW (4x12 MW). The Power Station is now being operated as peak load station since the availability of water to the scheme is limited. Main source of water to the scheme is the tail race water of Pallivasal HE project. The tail race water is conveying to the balancing reservoir of Sengulam HEP by pumping.

The storage capacity of Sengulam balancing reservoir is $0.7Mm^3$ only. The MDDL of the reservoir is +844.9m and FRL +847.65m.

In order to enhance the inflow into Sengulam HEP, it was decided to divert the Western Kallar River flowing to Kallarkutty reservoir of Neriamangalam HEP to Sengulam Balancing Reservoir (SBR). Accordingly Sengulam Augmentation Scheme (SAS) was proposed. The scheme is now under construction.

The Ramaswamy Ayer (RA) Head Works of Pallivasal H.E. Project often spills during monsoon due to low storage capacity of the reservoir. Pallivasal Extension Scheme (PES) is planned for the maximum utilization of the inflow of R.A Head works. The scheme is now under construction.

Due to the implementation of above two schemes, there will be excess water in Sengulam balancing reservoir (SBR) since its storage capacity is very less ($0.7\ Mm^3$). The MDDL of this dam is +844.9 m and FRL is +847.65 m.

In addition to the schemes mentioned above, there are proposals to divert upper Rajamala AR to the catchment of Pallivasal HEP. This in turn will increase the inflow to SBR. The Upper Sengulam HE project is proposed to utilize this water also.

Since the commissioning of the above mentioned schemes under construction stage and investigation will be at different period, the project is also proposed in stages. The structural components of the project are designed to the full capacity 48 MW. The installed capacity in stage-1 is limited to 24 MW.

1.4 Sengulam Dam and Reservoir:

Sengulam dam is intended to store water for Sengulam HE Project. The Project utilises the tail water of Pallivasal Power House. The tail water of Pallivasal HE Project collected in the fore bay near the power house is pumped over a head of 9.14 m and carried to Sengulam balancing reservoir through a tunnel of 1728.20 m length. The reservoir formed by the dam is a balancing reservoir for the water brought from upper reaches. It commands an independent catchment of 5.18 sq. km and impounding capacity of 0.71 Mm^3. The water spread area at FRL of 847.65 is 0.29 sq.km.

The Head works of Sengulam Hydro Electric Project consists of the dam located two miles below the Pallivasal Power House. The dam is a straight massive rubble masonry structure throughout. The length of Dam is 143.26 m at road level. The top width of dam is 4.80 m. The maximum width at foundation level is 19.20 m. The spillway is ogee type with three vents of 1.80 m x 4.80 m with internal pier of 30 cm thick. No gate is provided over the spillway. The spillways crest and up tuned buckets etc. are made in concrete. There is a scour sluice of 600 mm diameter controlled by a valve and an Emergency gate. Suitable trash racks are also provided for the scour sluice. Drainage cum inspection Gallery runs through the length of dam with an access opening from the downstream side of the dam. In this gallery suitable drain holes are provided in to the dam foundations and porous drain holes from the top of the dam to the gallery.

Fig 1.24 Upstream view of Sengulam dam

Fig 1.25 Sengulam Reservoir

1.5 Assignment of Responsibility

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

Project Administration Office	Chairman & Managing Director, KSEB Ltd.
Chief Controlling Officer	Chief Engineer (Civil – Dam Safety & DRIP), KSEB Ltd
Authority of Spillway operations and Flood releases	Chief Engineer (Civil – Dam Safety & DRIP), KSEB Ltd
Operation and safety of the dam	Deputy Chief Engineer, Research & Dam Safety Organization, Pallom, KSEB Ltd.

Controlling / Operation Officer at dam site	Executive Engineer, Research & Dam Safety Division No. IV, Pambla.
Reservoir operations, inspection & maintenance	Executive Engineer, Research & Dam Safety Division No. IV, Pambla.
Dam Health Engineer	Executive Engineer, Research & Dam Safety Division No. IV, Pambla.
Recording reservoir data, inspection, monitoring and maintenance at site	Assistant Executive Engineer, Research & Dam Safety Sub Division, Pambla.
Handling Dam operations, inspection, monitoring and performing duties as Maintenance Officer at dam	Assistant Engineer, Research & Dam Safety Sub Division, Pambla.

1.5.1 Roles and Responsibilities of the AEE and AE during Monsoon

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

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

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

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

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

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

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

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

drains.

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

10. 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.

11. 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.

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

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

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

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

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

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

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

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

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

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

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

condition.

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

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

9. 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.

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

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

1.5.3 Roles and Responsibilities of the Chief Engineer during Monsoon

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

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

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

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

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

1.6 Collection & Reporting of Dam and Reservoir Data

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

- Reservoir water surface elevation.
- Reservoir inflow.
- outflow.
- Weather related 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 1.3: Daily Reservoir Data

Instruction is given to the Executive Engineer for daily collection and reporting of inflow and outflow data in a standard Proforma as in **Table 1.3** above to the Deputy Chief Engineer.

Date	Water Level (m)	Previous Year Same day Water Level (m)	Rainfall (mm)	Previous Year Rainfall (mm)	Storage (Mm^3)	Generation	Gross Inflow (Mm^3)	PH discharge + Losses (Mm^3)	Spill (Mm^3)	Net Inflow (Mm^3)	Remarks

Table 1.4: Daily Reservoir Status

On collecting the details in the above format, a daily reservoir status is submitted to the Chief Engineer as in the **Table 1.4**.

Records/Logbooks of the operations for the following activities at Sengulam 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 record
- Attendance statement during normal operations – both during monsoon and non- monsoon periods.
- Operations of the gates, valves and outlet works.
- Operating hours of mechanical equipment.
- Testing/operation of Outlet gates, valves and associated controls.
- Maintenance activities carried out.
- Reservoir and dam inspections.
- Unusual conditions or occurrences.
- Safety and special instructions.
- Names of officers and staff carrying out inspections and maintenance.

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

Reservoir water surface elevation	This is collected daily
Reservoir inflow	This is calculated daily
Outflow	This is calculated daily
River releases	The tail water is released to Mudirapuzha and is reached to the small reservoir for Vellathooval SHEP
Weather related data	Collected and reported daily
Surveillance/Security arrangements	Provided at one security cabin at right bank of dam and one near Intake structure. The Security duty was arranged through M/s KEXCON. CCTV surveillance will be provided soon to cover the dam area and adjoining premises.
Water quality	The quality of water is to be tested.
Attendance statement during normal operations	Both during monsoon and non-monsoon period maintained at field office.
Operations of the gates and outlet works	The spill way is designed for a safe discharge of $70.8 m^3/s$. The spillway is ogee type with three vents of 1.80m x 4.80m with internal pier of 30cm thick. No gate is provided over the spillway. There is a scour sluice of 600mm diameter controlled by a gate valve at foundation gallery and emergency gate at the entry of sluice.
Operating hours of mechanical equipments	Maintained at field office
Testing/Operation of spillway gates and associated controls	No spillway gates are provided
Testing/operation of Outlet gates, valves and associated	Maintained at field office
Maintenance activities carried	Details maintained at field office
Reservoir and dam inspections	Periodically inspected and details maintained at field office
Unusual conditions or occurrences, including acts of vandalism	Details maintained at field office
Attendance statement at dam during emergency operations	Details maintained at field office

Changes to normal operating procedure	Details maintained at field office
Communication network checks	Network i s available at Dam site.
Safety and special instructions	Safety equipment are available
Names and addresses of official visitors	Record of inspections are 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. IB is provided near to the Power House at Vellathooval. The Anachal Vellathooval road passes through the dam top of Sengulam. The Sengulam dam is about two km from Anachal. Frequent bus services are available in day time on this route.

Distances to the nearest medical assistance is available at Vellathooval (6km) and Adimaly (14 km). Government community health center is also available at Chithirapuram, about 6 km from dam site. Police station is located at Vellathooval which is near to the Power House site of Project. Two nos. of main private hospitals with almost all medical facilities are also available at Kothamangalam which is around 65 km from dam site. Safety equipment like safety shoe, helmet, safety belt, first aid kit and fire extinguisher are available at the dam site.

1.8 Restricted Areas

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

1.8.1 Dam safety surveillance including instrumentation

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

V- Notch is provided for seepage measurement.

Security Arrangement exists through - M/S KEXCON - 3 Shifts per day
(Ex Service military Persons)

1.9 Staff position, Communication & Warning System

The number & description of operating unit personnel posted/placed at different locations of the dam are noted in supporting documents and are 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 satellite phones, wireless sets etc. Basic facilities warning system like sirens are available.

A hierarchy of organizational structure for the control and safety of Sengulam dam is outlined below in **Fig 1.26**

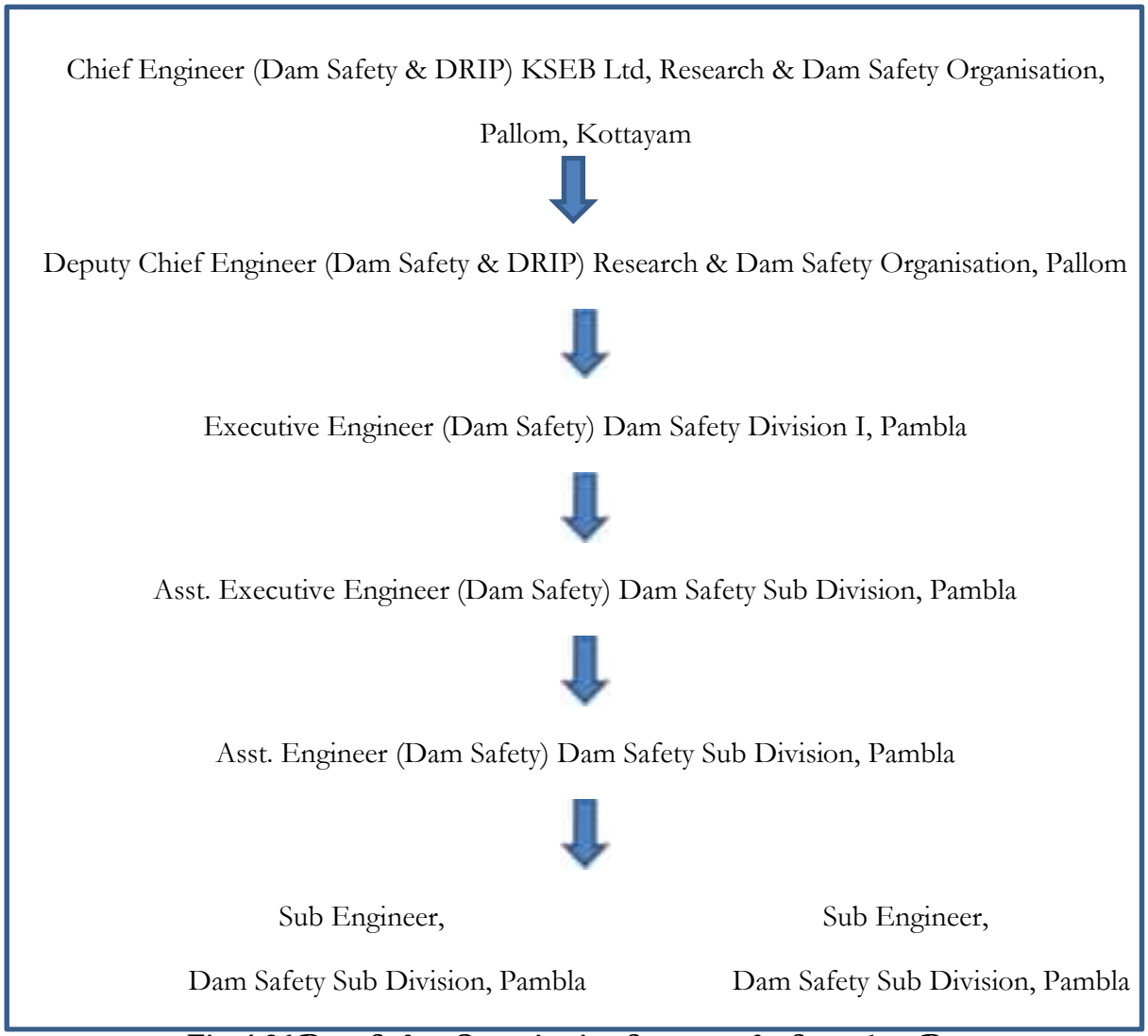

Fig. 1.26 Dam Safety Organisation Structure for Sengulam Dam

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

Designation and office address	Contact number and e-mail
Chief Engineer Civil (Dam safety & DRIP), KSEB Ltd, Dam Safety Organization, Pallom, Kottayam	Ph: 9496018719, 9446008967 0481 2951300 cedamsafety@gmail.com
Deputy Chief Engineer, Research & Dam Safety Organization, Pallom	Ph: 9446008492, 0481-2432290, 9496011540 e-mail: dirroplm2@gmail.com
Executive Engineer, Dam Safety Division No. IV, Pambla	Ph: 9446008421 e-mail: eerdspambla@gmail.com
Assistant Executive Engineer, Dam Safety Sub Division, Pambla	Ph: 9496011802 e-mail:aeedspambla@gmail.com
Assistant Engineer, Dam Safety Sub Division, Pambla	Ph: 9447981054 e-mail:aeedspambla@gmail.com

Table 1.5 Hierarchy of Controlling Officers of Sengulam dam

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

Spillway flood releases

Sengulam reservoir was being operated as per 'Guidelines for Operation of Reservoirs' (IS 7323:1994). Sengulam is only a balancing reservoir having a live storage capacity of 0.3903Mm^3. Hence different warning level as in the case of storage reservoir was not fixed. The dam has not equipped with spillway shutter and the water coming above the FRL is freely flowing to downstream via the uncontrolled spillway. The downstream portion of the Sengulam dam is almost all cultivated land with thick vegetation. The main sources of water to Sengulam reservoir is the pumping water from tail race of Pallivasal. The inflow from its own catchment is negligible. Hence it is possible to keep the water level below FRL by adjusting the pumping from Pallivasal. Generally, the water level in the reservoir is kept below FRL by planning the generation to avoid spillage.

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

The water from Sengulam reservoir is mainly used for power generation of 48 MW at Vellathooval power house of KSEBL around 15 Km from Adimaly. The tail water from power house is available for the Vellathooval Small Hydro Electric Project.

1.10 Supporting Documents & Reference Material

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

- Detailed drawings of the Project
- Emergency Action Plan (EAP)
- Latest Hydrology Review Report
- Latest DSRP Report
- Flood forecasting and operating criteria - Not Available
- Agreements with user agencies
- Power station operation plan
- Administrative procedures
- Maintenance schedules
- Gate Manufacturer's manual and drawings – Not available
- Regional communication directory
- Instrumentation reports / results

1.11 Typical Schedule of Duties

Schedule of duties/inspections to be carried out for the operation and maintenance of the dam by the concerned official are tabulated below in **Table 1.6.**

Sl. No.	Component/ Duty	Frequency	Personnel
1	Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of foundation and abutments, Galleries, Spillway and its energy dissipation arrangements, Power Intake	Daily	Sub Engineer/Dam operators on contract
2	Record water surface elevation, reservoir inflow and spillway discharge.	Daily (Hourly basis during monsoon)	Sub Engineer/Dam operators on contract

3	Record meteorological data, Record releases from outlets /sluices	Daily	Sub Engineer/Dam operators on contract
4	Check security and safety devices, Complete logbook / site register which include the above information.	Daily	Assistant Engineer
5	Record seepage from drainage systems, Gallery drains etc. and record meteorological data.	Weekly	Sub Engineer/Dam operators on contract
6	Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of foundation and abutments, Galleries, Spillway and its energy dissipation arrangements, Power Intake	Weekly	Assistant Engineer
7	Check stand by generator (DG Sets), Drainage systems, Gallery drains etc.	No DG Set installed	Assistant Engineer
8	Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of foundation and abutments, Galleries, Spillway and its energy dissipation arrangements, Power Intake	Fort nightly	Assistant Executive Engineer
9	Check security and safety devices, logbook and site register which include the above information.	Fort nightly	Assistant Executive Engineer
10	Check stand by generator (DG Sets), Drainage systems, Toe drains, Gallery drains etc.	No DG Set Installed	Assistant Executive Engineer
11	Measuring devices, communication devices, status of instruments, vegetation growth	Fort nightly	Assistant Executive Engineer
12	Check Sign/Warning display boards near vulnerable locations	Fort nightly	Assistant Executive Engineer
13	Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of foundation and abutments, Galleries, Spillway and its energy dissipation arrangements, Power Intake	Monthly	Executive Engineer

14	Check measuring devices/Instruments, Security and safety devices, Communication Devices, Status of Vegetation growth, – rectification, if needed.	Monthly	Executive Engineer
15	Check Sign/Warning display boards near vulnerable locations	Monthly	Executive Engineer
16	Replace fuse light bulbs, Inspect to maintain ventilation system, cleaning of control panel boards.	Monthly	Assistant Engineer
17	Check outlet/intake works, updating operating instruction, check gate air vents, clean gate control switchboxes, check operation of gates, grease gate	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, 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-	Quarterly	Executive Engineer
	Notch/ seepage measuring devices, Check hydro mechanical components.		
21	Inspection of Spillway & outlet works, hydro mechanical components (all gate , valves and their hoist / operating machinery),Check paint on gates, steel surfaces for any damages / corrosion , weld joints, Check mechanical hoist bearings and flexible coupling bearings, Check gear systems, Exercise gates and valves, Check pressure release valve, Check lubrication of gate rollers, Check rubber seals and seal clamp bar.	Half yearly (Pre and Post Monsoon)	Deputy Chief Engineer along with Executive Engineer in charge of dam

22	Submission of Inspection report to State DSO, CWC and uploading into DHARMA.	Half yearly	Chief Engineer/ Deputy Chief Engineer
23	Comprehensive inspections	Annually	Dam Safety Authority along with Dam Owners
24	Inspect dam and gate structures, trash racks and stilling basin / energy dissipation arrangement, which normally are underwater (by dewatering or by divers/ROV as necessary). Review Dam operation procedures and EAP and update as necessary.	Five Yearly	Chief Engineer/ Deputy Chief Engineer
25	Comprehensive inspection of performance of the dam and gate structures and reservoirs, trash racks and stilling basin /energy dissipation arrangement.	Ten Yearly	DSRP

Table 1.6 Schedule of duties/inspections

1.12 Hydro-Mechanical Inspections / Checks

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

Chapter 2

Project Operation

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

2.1 Basic Data

The Sengulam dam 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.

2.1.1 Dam

The Head works of Sengulam Hydro Electric Project consists of the dam located 3.2 km below the Pallivasal Power House. The dam is a straight massive rubble masonry structure throughout. The reservoir formed by the dam is a balancing reservoir for the water brought from upper reaches. It commands an independent catchment of 5.18 sq. km and impounding capacity of 0.71 Mm^3. The water spread area at FRL of 847.65 is 0.29 sq. km. The length of Dam is 143.26 m at road level. The top width of dam is 4.80 m. The maximum width at foundation level is 19.20 m. The spillway is ogee type with three vents of 1.80 m x 4.80 m with internal piers of 30 cm thick each. No gate is provided over the spillway. The spillway crest and buckets are made in concrete. There is a scour sluice of 600 mm diameter controlled by a Valve located in the foundation gallery and an Emergency gate on u/s face of the dam. Suitable trash racks are also provided for the scour sluice. Drainage cum inspection Gallery runs through the length of dam with an access opening from the downstream side of the dam. In this gallery suitable drain holes from the foundation gallery floor and Porous drain holes from the top of the dam are provided.

2.1.2 Spillway

The spillway of Sengulam Dam is ogee type with three vents of 1.80 m x 4.80 m with internal piers each of 30 cm thickness. No gate is provided over the spillway. The spillway crest and buckets are made in concrete. There is a scour sluice of 600 mm diameter steel pipe controlled by a valve operational from foundation gallery and an Emergency gate at u/s face of the dam. Suitable trash racks are also provided for the scour sluice.

The spillway length is 16.76 m including training walls of 0.76 m width. It is between

chainage 95.85 m and 112.62 m, from left to right flanks. The zero chainage is 36.57 m is further left of the commencement of left core wall. The location of the spillway is not in the center of the valley but slightly towards the right flank. The spillway section is designed allowing full uplift and foundation is on sound rock. Release drains for 100 mm diameter at 4.57 m apart are taken to 6.10 depth in the rock. Drainage holes from foundation gallery floor for release of uplift water pressure and porous drains from dam top to crown of the gallery to trap seepage are provided.

The spillway portion is divided in to three spans of 4.87 m clear with 30 cm thick partition piers. The spillway bridge is in RCC. The bridge accommodates 4.57 m wide roadway between kerbs. The top level of road way is 850.11 m. The operating platform for emergency gate is provided alongside on left of the spillway bridge on cantilevering platform towards upstream of the dam.

Fig 2.1 Photograph Showing un-gated Spillway Arrangements of Sengulam Dam

2.1.3 River Outlet Arrangements

A scour vent of 600 mm internal diameter is provided at chainage 104.24 m and is normal to the axis of the dam. The invert level of the scour pipe is 832.06 m where the bell mouth ends. The bell mouth is for 0.84 m length and it widens out to 1.14 m diameter. It is lined with cut stone masonry. A trash rack is installed in front of the bell mouth between levels 831.38 and 833.51 m. The trash rack is permanently fixed to RC Slabs both at top and bottom. The trash rack is made with M.S Flats arranged at 50 mm centers. They are fixed to steel frame works. A hand operated valve is installed on the scour vent pipe in the gallery to facilitate operations of the valve. The tail

end of the scour pipe is tilted slightly upwards for a length of 1.83 m, the tilt being 30 cm. A drain pipe of 50 mm dia. is also provided at tail end to drain the invert portion of scour vent.

The scour vent is controlled by a vertical lift type emergency gate of 1.30 x 1.30 m at mouth of the vent, but is located inside the trash rack. The gate is intended to be in the closed position except during emergency. The emergency gate and hand operated valve are supplementing each other. The gate is operated by hand operated winch provided at the cantilever platform near the spillway bridge. The rolling surface of the groove is lined with "L" iron 75 x 75 x 6 mm.

Fig 2.2 Hoisting winch of emergency gate

Fig 2.3 Hand operated wheel valve for scour vent in the inspection gallery

The river outlet arrangement is not operational at present.

2.1.4 Elevation Capacity Curve

The area and capacity curve of Sengulam Reservoir has not much significance because Sengulam reservoir is only a balancing reservoir and thus the possibilities of spilling are very rare. The only readings available are storage at MDDL, FRL and MWL. The details and graph are shown below.

Storage Details of Sengulam Reservoir			
Sl No.	Water Lelel (m)	Storage (Mm^3)	Remarks
1	846.00	0.3197	MDDL
2	847.65	0.7100	FRL
3	849.49	1.3000	MWL

Table 2.1 Storage Details of Sengulam Reservoir

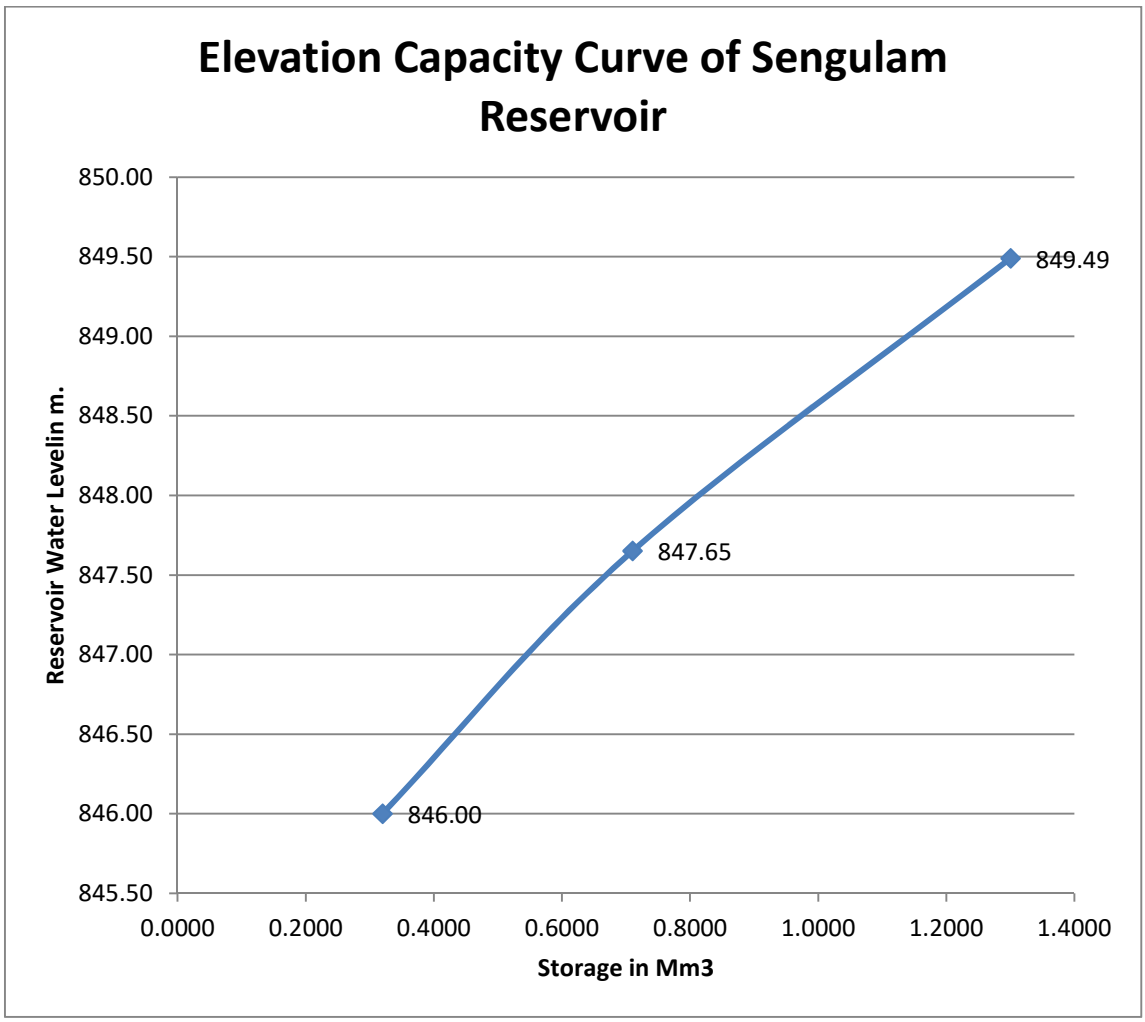

Fig 2.4 Elevation Capacity Curve

2.2 Operation Plan

An effective operation plan and schedule is required for the safe project operation for which the project specific features shall be known. The salient features of the dam are given in Chapter 1.

2.2.1 Data of the historic floods

As per historical records, the maximum flood observed in Western Ghats was during 1924. The center of the storm of the 1-day rainfall of 17th July 1924 and 2-day rainstorm of July 16- 17 was located at Devikulam in Kerala in which rainfall of 484 mm and 751 mm respectively was recorded. The second historical flood occurred during August 14 to 17 in the year 2018, which resulted in record inflow in to the reservoir. The SW monsoon of the year 2018 in the State similar to that of 1924 Devikulam storm, Kerala experienced an abnormally high rainfall from 1 June 2018 to 19 August 2018 which resulted in severe flooding in 13 out of 14 districts in the

State. It is seen that the 2-day and 3-day rainfall depths of 15-17, August 2018 rainfall in Pamba, Periyar and Bharathapuzha sub-basins are almost comparable to the Devikulam storm of 16-18, July 1924. For the entire Kerala, out of 758.6 mm rainfall from 1 August 2018 to 19 August 2018, about 414 mm rainfall occurred in just three days viz. 15-17, August 2018, which created severe flooding in the State, while the same during 16-18, July 1924 was 443 mm. The 3-day rainfall of 15-17, August 2018 at Sengulam dam site was 550.4 mm. The 4 –day rainfall of 15-18, August 2018 at Sengulam dam site was 605.40 mm.

Rainfall Details of Sengulam Dam from June 2018 to May 2019 are given below.

RAINFALL DATA 2018-2019

(in mm)

NAME OF RIVER BASIN			PERIYAR									
NAME OF STATION			SENGULAM DAM SITE									
DATE	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19
01	-	1.60	7.00	3.10	5.50	5.60	-	-	-	-	-	-
02	-	4.10	-	-	16.30	5.70	-	-	-	2.80	-	-
03	2.20	29.80	4.10	-	14.80	-	-	-	-	-	-	-
04	1.30	-	-	-	20.30	-	-	-	-	-	-	-
05	8.10	-	-	-	20.60	-	-	-	-	-	-	-
06	-	-	4.30	-	2.80	-	-	-	-	-	-	-
07	7.50	5.70	21.80	-	-	-	-	-	-	-	-	8.20
08	22.40	16.60	68.40	-	-	-	-	-	-	1.50	-	-
09	31.40	86.20	247.80	-	16.40	-	-	-	-	-	-	-
10	90.40	48.90	56.60	-	2.90	13.60	-	-	12.80	6.80	35.00	-
11	75.20	62.00	72.50	-	-	-	-	-	-	-	-	-
12	79.40	29.80	10.90	-	-	-	-	-	-	-	-	1.50
13	40.10	47.00	55.00	-	-	-	-	-	-	-	-	-
14	31.10	40.60	96.40	-	46.90	-	-	-	-	-	-	24.20
15	1.10	32.20	176.90	-	-	-	-	-	-	-	-	5.60
16	-	93.80	231.50	-	12.30	1.50	-	-	-	-	-	4.30
17	12.20	24.20	142.00	-	13.50	122.80	-	-	3.10	-	-	8.20
18	-	61.60	55.00	1.50	-	-	-	-	-	-	-	4.40
19	11.40	21.80	26.90	-	3.10	-	-	-	-	1.60	-	-
20	14.10	60.40	9.50	12.30	8.40	50.90	-	-	-	-	1.50	-
21	19.10	16.20	8.20	-	61.20	-	-	-	-	-	89.90	-
22	5.10	7.80	-	-	4.40	-	-	-	-	-	-	-
23	7.10	8.20	-	-	16.30	-	-	-	-	-	11.00	1.50
24	1.30	33.80	-	53.60	-	-	1.40	-	-	-	1.60	5.60
25	-	100.50	-	6.40	-	-	-	-	-	-	41.80	8.20
26	7.60	21.80	-	1.50	-	-	-	-	-	-	3.20	-
27	1.40	2.90	-	1.60	-	-	-	-	-	-	-	-
28	11.20	-	16.60	4.50	-	-	-	-	-	-	-	1.60
29	5.40	10.80	4.10	24.30	-	-	-	-		-	-	-
30	-	-	-	21.90	-	-	-	-		-	1.50	1.50
31		11.20	-		-		-	-		-		7.20
TOTAL	**486.10**	**879.50**	**1,315.50**	**130.70**	**265.70**	**200.10**	**1.40**	**0.00**	**15.90**	**12.70**	**185.50**	**82.00**
									Total Annual Rainfall:		**3575.10**	

Table 2.2 Rainfall details of Sengulam Reservoir

2.2.2 Design Flood and Features Related to Safety

The revised design flood, as per method I, is estimated as 121.36 m^3/s. By method II the revised design flood is 129.73 m^3/s. Hence the highest value is considered as the revised design flood of Sengulam Dam. The original design flood of Sengulam was 71 m^3/s. The revised design flood has exceeded the original design flood. The storage of Sengulam Reservoir between FRL (0.71 Mm^3) & MWL (1.30 Mm^3) is about 0.59 Mm^3. The peak flood value occurs at tp = 0.81 hours. The peak corresponds to a single instant. Due to lower time of concentration, the rising limb will be steep and peak of the hydrograph will be sharp. The duration at which the hydrograph ordinate exceeds 71 m^3/s will be less than 1 hr. The maximum accumulation expected due to difference between revised design flood & original design flood for a duration (max) of 1 hr. is ((129.73-71)X3600/10^6)) 0.21 Mm^3. As the accumulation is far below the available storage, the spillway can safely dispose the revised design flood.

The design flood is re-worked out as per the comments of CPMU (dtd.19.08.'14) and obtained as 145m^3/s. The reservoir can safely accommodate this flood without the water level rising beyond the MWL.

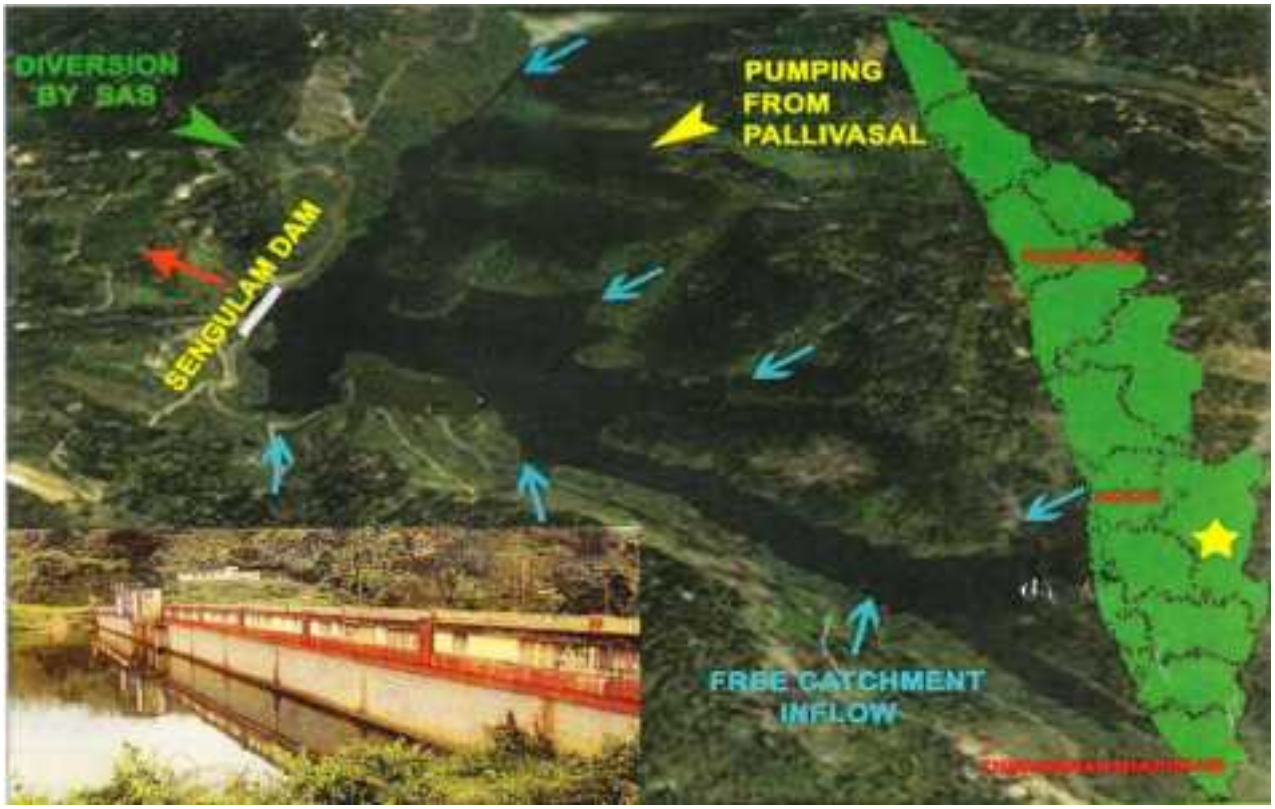

Fig 2.5 Inflow details of Sengulam Balancing Reservoir

2.3 Normal Operation of the Reservoir

No Spillway Gates are provided for Sengulam Dam.

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.
- 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
- 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 Power Intake

At the end of the cut and cover channel, the intake chamber is constructed. This chamber has a reinforced cement concrete mat having a size of 6.4x9.14m at foundation. The foundation is constructed such that the top of its mat and the bottom of the base slab of cut and cover are in the same level i.e.. at 842.73 m. The base slab of cut and cover structure is keyed in to this mat. The intake chamber is in the form of a well of 2.97 m inside diameter with staining of 60 cm built with rubble masonry in cement. This chamber is built with RCC construction at bottom and rubble masonry in cement well from RL. 845.47 m. A bell mouth to ease the water into the cut and cover section is also there below the wall. The bell mouth curved with the RCC sides and top. RCC side walls having a thickness of 120 cm are suitably curved outwards to form the bell mouth. In front of bell mouth 2 RCC posts 45 x 45 cm are constructed at 7.16 m apart in the line 3.05 m shifted from the bell mouth. This is to accommodate the trash rack. Two inter mediate RCC post of special shape 91.44 x 45.72 cm maximum also were constructed. The intake mouth 8.38 x 6.70 m has its bed level at the same level as that of invert level of the bell mouth. The roof slab is also RCC having 84 cm thickness. The intake well is connected to the left bank of the channel by means of a bridge 18.28 m long, having 6 spans of 3.05m centre to centre. The top level of the bridge is 850.10m.

A trash rack 6.7 m long and 3.05 m wide was proposed in front of the bell mouth. RCC vertical posts have been cast for fitting the trash rack but at later stage it was decided to provide a

temporary trash rack. Necessary fittings have been made to form this trash rack in the bell mouth portion. The trash rack has to be cleaned frequently.

The control gate provided in the intake structure is 2.90 x 2.82 m. The gate is of sliding type. The operation of this gate is arranged by means of dual worn geared cast iron hood stake. The Intake shutter can be operated both electrically and manually as per requirements.

Fig 2.6 Photograph Showing Intake Channel

Fig 2.7 Intake trash rack

2.3.2 Operation of the Reservoir

The Sengulam Balancing reservoir was being operated as per 'Guidelines for Operation of Storage Reservoirs (IS 7323:1994). No spilling of water over the spillway will normally be permitted because the water level can be kept under the FRL by adjusting the pumping from Pallivasal pump house as per the requirements at Power Station. Hence no rule curve was prepared for this dam. The downstream area of the Sengulam Dam in which spilled water would be flowing was fully cultivated land with thick vegetation. Hence the inhabitants residing at the downstream area of dam have been agitating . In case of any unavoidable situations, the water can be spilled with necessary precautions and after giving wide publicity viz, mike announcement, TV, Radio, local channels if any etc. Also local authorities like concerned villages, panchayaths, police station, District Disaster Management Authority etc. are to be informed at appropriate time.

2.3.3 Rule Curve

The live storage capacity of Sengulam reservoir is only 0.3903$Mm^{3.}$ Water from Sengulam balancing reservoir is used for generating electricity utilizing tail water from Pallivasal Hydro Electric Project, at power house located at Vellathooval and the tail race water is discharged to the river Mudirapuzha . The water then flows to the Vellathooval Small HEP's reservoir.

2.3.4 Flood Release Procedure

Generally, the water level in reservoir is kept below the FRL by adjusting the pumping from u/s project. If any unavoidable situations are created due to natural calamity or any other such incidents, the excess water can be permitted to flow out through the un-gated spillway vents provided at Dam structure after giving wide publicity and taking proper precautions.

2.3.5 Reservoir Capacities

The Gross storage of the reservoir 0.71 Mm^3 and the Live Storage is 0.3903 Mm^3 at FRL of +847.65 m and the details are given in **Table 2.1.**

2.3.6 Climate

Sengulam balancing reservoir and its allied catchment receives comparatively good rains almost throughout the year. It is observed that the rains contributed by South-West monsoon are comparatively heavier than the rain precipitation during North- East monsoon. The maximum one day rainfall reported is 36 cm.

2.3.7 Inflow forecasting/Methodology

There is no inflow forecasting system at present in Sengulam dam.

2.3.8 Emergency Operation

Emergency Action Pan (EAP) to take care of any eventualities has been prepared and is available.

2.4 Power Generation

Sengulam Power House is located in Vellathooval, Vellathooval village, Devikulam Taluk around 15 Km from Adimaly. The Power Station was commissioned during 1954 with Four Generating units of 12 MW each coupled to Horizontal Shaft Multiple Pelton Wheel turbine of M/s English Electric Company. After power generation, water from the power station is released to the Mudirapuzha river itself. The total installed capacity of the station is 48 MW.

2.4.1 Trash-rack structure

Trash rack 6.7 m long and 3.05 m wide was provided at the beginning of Power Channel No.3. RCC vertical posts have been cast for fitting the trash rack but at later stage it was decided to provide a temporary trash rack. Necessary fittings have been made to form this trash rack in the bell mouth portion. The trash rack is cleaned frequently.

2.4.2 Intake structure - See details at **2.3.1** Power Intake

2.4.3 Tunnel

There are two tunnels in the Sengulam HEP, i.e. one from Pallivasal H E P to Sengulam balancing reservoir, as feeding tunnel, named Tunnel- I and the other one is from Sengulam balancing reservoir to the Low Pressure Pipe (LPP) starting at Elkunnu named Tunnel-II. The Tunnel- I has a total length of 1755.56 m with three bends. The Tunnel-I has 6.69 sq. m. finished sectional area. The concrete lining thickness of the tunnel is 20.32 cm and the maximum flow in the tunnel is 11.33 m^3/s. There is one ADIT provided for Tunnel- I to facilitate tunnel driving.

Tunnel- II is used to convey water from Sengulam Balancing reservoir to LPP starting point. The Tunnel- II also has 6.69 m^2 finished sectional area and 20.32 cm concrete lining thickness. The total length of Tunnel is 1778.42 m and has four bends. The maximum flow permitted in Tunnel- II is 16.99 m^3/s. The inlet level of Tunnel- II is 842.12 m.

2.4.4 Low Pressure Pipes (LPP)

The low pressure pipe Starts from end of Tunnel- II and ends at Surge shaft. The LPP has an internal diameter of 2.59 m and shell thickness of 15.89 mm. No. of Anchors for LPP are eight and its total length is 829.40 m. Maximum velocity in LPP is 3.35 m/s.

2.4.5 Surge Shaft

The surge chamber in Sengulam water conduit system is located at the end of LPP. It is at "elkunnu" where only the proper site close to water conductor system was available. The total height of chamber is 75.07 m. The surge shaft of Sengulam project is of simple type. No gallery or ventilating duct is provided.

2.4.6 High Pressure Pipe

The HPP of the Sengulam HEP runs from the Surge shaft to Power house at Vellathooval. There are two nos. of HPP and have an internal diameter of 1.47 m each. The total length of HPP is 957m. Number of distributers in HPP are 4 and each has an internal diameter of 1.07 m. Two no of self-closing automatic type butterfly valves are provided in a valve house located near to the starting portion of HPP. The shell thickness at starting portion is 12.7 mm and end portion is 38.10 mm. The maximum velocity in HPP is 5.18 m/s.

2.4.7 Initial Filling of the Water conductor system

First full impoundment was done in 1954.

2.5 Record Keeping

The records regarding dam and appurtenant structures including detailed drawings and construction details are kept at the field office. Essential documents as per the dam safety guidelines are kept at the dam site office. Also the Rainfall data and Reservoir level are available. 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. Power releases.
4. Water audit register to be maintained for estimating the inflows on hourly basis during monsoon and daily basis during non-monsoon by accounting all the releases/outflows and the incremental change in storage in the reservoir.
5. 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 sent to higher offices. The current practice of Inspection at Sengulam dam envisages Deputy Chief Engineer in presence of Executive Engineer of site to carryout pre-monsoon and post-monsoon inspections as per CWC guidelines in the format issued by CWC. 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, CWC2018 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 for 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 Sengulam dam is given below. Note that for uploading Inspection Data into DHARMA, the Inspection Instructions & Forms given in the above mentioned Guideline for Safety Inspection of Dams must be used. This Chapter provides guidance on carrying out other inspections.

3.1 Types of inspections

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

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

The frequency of each type of inspection depends on the condition of the dam and State DSO regulations, 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 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) was constituted under DRIP for determining the condition of the dam and appurtenant works. The panel will undertake safety evaluation of the dam. The terms of reference of the comprehensive dam safety evaluation shall include but not limited to;

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

A comprehensive evaluation inspection of Sengulam dam consists of five major parts:

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

3.2.1 Details to be provided to DSRP before inspection

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

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

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

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.

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 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 pages B3-B45.

3.4 Special (Unscheduled) Inspections

Special inspections may need to be performed to resolve specific concerns or conditions at the site on an unscheduled basis. Special inspections are not regularly scheduled activities, but are usually made before or immediately after the dam or appurtenant works have been subjected to unusual events or conditions, such as an unusually high flood or a significant earthquake. These inspections are to be carried out by teams to be constituted by state DSO after an initial assessment based on informal inspection carried out by project personnel reveal

dam safety related concerns like cracking in the dam, damages, erosion/ scour, undermining/ piping/ sink holes/ liquefaction or any such undesirable feature. A special inspection may also be performed during an emergency, such as an impending dam breach, to evaluate specific areas or concerns. They are also made when the ongoing surveillance program identifies a condition or a trend that appears to warrant a special evaluation. Special inspections should focus on those dam components that are affected by the unusual event and should include at least three elements:

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

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

3.5 Informal Inspections

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

Operators, maintenance crews, or other staffs who are posted at Sengulam 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 stretch. 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 Sengulam dam based on manual of operating parts, frequent inspections, priority, and interval for Sengulam dam is attached as **Annexure VI**. This shows tasks to be performed and how frequently that is to be inspected/observed and repaired.

4.2 Maintenance Priorities

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

4.2.1 Immediate Maintenance

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

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

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

4.2.2 Preventive Maintenance

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

4.2.2.1 Condition Based Maintenance

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

- Remove all vegetation and bushes by roots from the dam surfaces, restoring any eroded areas.
- Repair of defective gates, valves, and other hydro-mechanical equipment.
- Repair any concrete or metal components that have deteriorated.
- Cleaning of the choked drainage holes in the dam body/ foundations in concrete / masonry dams.
- Repair any damages on spillway glacis, piers, energy dissipaters, training walls, downstream areas etc.
- Repairs on u/s face of masonry dams in case the pointing of masonry joints is damaged resulting in increased seepage
- Controlling any heavy seepage in the foundation/ inspection galleries in Concrete / masonry dams from drainage holes.
- Repairs of any cracks/cavities/joints in concrete /masonry dams/structures.
- However many of these works will require the services of experienced engineers/expert panels.

4.2.2.2 Routine Maintenance

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

- Any routine repair to concrete or metal component.
- Observation of any springs or seepage areas 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 gates (Intake and Emergency gates), hoisting arrangements of gates, valves of outlet works/sluices & stand by generator.

- Maintaining proper lighting at dam top, galleries, etc.
- Monitoring of seepage in galleries of the dam.
- Monitoring/ cleaning & removal of leached deposits in porous concrete / formed drains in dam body and foundation drainage holes.
- Maintenance of all dam roads & access roads.
- Operation of electrical and mechanical equipment and systems including exercising gates
- To keep the gate slots clear of silt/debris.
- Maintenance/testing of monitoring equipment (instruments) and safety alarms.
- Testing of security equipment.
- Testing of communication equipment.
- Any other maintenance considered necessary.

4.3 Procedures for Routine Maintenance

4.3.1 Controlling Damage from Vehicular Traffic

Since the roadway from Anachal to Vellathooval is passing through the dam top, it is difficult to restrict the Vehicular traffic above the dam. Any damages noticed are repaired as soon as possible.

4.3.2 Controlling Vegetation

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

4.3.3 Masonry / Concrete dams & spillways

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

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

Vertical lift gates are provided in intake tower of the Sengulam dam for controlling the flow and at upstream face / bell mouth entry of Scour vent pipe. 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 immediately.

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

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

iv) Hoisting connection of the gate leaf should be lubricated where ever 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) 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.

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

ix) All nuts and bolts shall be tightened.

Outlet valve

Sl. No	Outlet valve	Frequency
1	Regular inspection of components of valve to be carried out to ensure that there is no unusual development/ observation	Half Yearly
2	Seals to be checked. If the seals are required to be replaced the same shall be carried out.	Half Yearly

Lubrication of moving parts

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

Lubrication chart

Sl. No.	Item	Lubricant	Periodicity	Remarks
	Hoist of emergency gate			
1	Motor bearing, Rope drum bearing, Manual operation bearing, Indicating Mechanism, Teeth of Gears	Grease	Once in every 6 months	
2	Brake liner, Geared coupling, Gear box	Gear oil	Once in every 6 months	Regular check of oil level is to be made and replenish with oil if necessary
3	Worn reducers of hoist	Gear oil	Once in every year	
4	Gear box	Gear oil	Once in every 6 months	
	Emergency Gate			
1	All pinion and gear wheels, guide shoes in the gate elements and lifting rollers, pulleys / Pulley pin	Grease	Once in every 3 months	
2	Wire rope	Cardium compound	Once in every year, preferably before the onset of monsoon	

4.3.5 Trash Racks

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

4.3.6 Spillway Radial Gates & Hoisting Equipment

No Spillway gates are provided

4.3.7 Maintenance of electrically operated fixed hoists of intake gate

i) General Instructions:

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

ii) Inspection and Maintenance

The aspects to be inspected and maintained periodically for ensuring proper operation of 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. Check the overload relays for proper functioning.

xvii. 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.

xviii. 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.

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

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

xxi. 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 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 connector and see when the contact tips of one of the connector units are touching, it is impossible to get the contact tips of the other unit to touch.

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

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

x) Do not lubricate the contacts.

xi) Examine earth connections and motor leads.

xii) Examine motor windings for overheating

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

xiv) Examine control equipment

xv) Examine starting equipment for burnt contacts

xvi) Check and tighten all nuts and bolts

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

xviii) Lubricate the bearings

xix) Overhaul the controllers

xx) Inspect and clean circuit breakers.

xxi) Wipe brush holders and check bedding of brushes.

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

xxiii) Check the insulation resistance of the motor between any terminal and the frame. If the measured resistance is less than the prescribed value, then steps shall be taken

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

xxv) Over haul the motor, if required.

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

xxvii) Check resistance or earth connections.

xxviii) Check air gap.

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

b) Solenoid Operated Brakes

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

ii) The magnet stroke should be reset to compensate for wear. Re-adjust the brake when the magnet stroke reaches the value given on the instruction plate.

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

iv) Examine all electrical leads and connections.

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

vi) The pins should be tightened.

4.3.9 Maintenance of Metal Gate Components

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

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 are 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:

- <u>Primer Coat:</u>

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:

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

d) 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.

e) 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.

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

To 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, to 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.

viii) 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 amounts to no painting and deteriorate faster than the original one.

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

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.

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.

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.

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.

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.

4.3.10 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 was executed under DRIP.

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

4.4 Materials and Establishment Requirements during Monsoon

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

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

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

4.5 Preparation of O&M budget

The O&M budget for Sengulam 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)

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

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

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

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

vii) **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 / diesel generator			
3.5	Remote control			
4	Instrumentation			
5	Miscellaneous works			
6	Salary of work charged 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. The extent and nature of the instrumentation depends not only on the complexity of the dam and the size of the reservoir, but also on the potential for threat to life and property losses downstream. The involvement of personnel with experience in the design, installation, regular monitoring, and evaluation of an instrumentation system is of prime importance to the success of the program.

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

5.1 Instrument Types and Usage

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

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

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

Sengulam dam is not instrumented with any of instruments like Pendulum, Pore Pressure meter, Joint meter, Resistance Thermometer etc. "V" notch is the only Instrument for Sengulam dam. There are 19 Vertical body drain holes (porous drains) and 18 nos. of foundation drain holes provided in the Sengulam dam. All drain holes are monitored regularly.

5.2 Parameters monitored

5.2.1 Water Level

Water level gauge is provided at the left 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 in the foundation gallery with V notches installed in the gallery drain.

5.2.3 Seepage assessment

In Sengulam dam the porous drains and foundation drain holes are connected to the common drain in foundation gallery at Elevation 831.50m. The collected water is drained outside the dam by gravity flow. Total seepage is measured using three nos. of "V" notches fixed in the inspection gallery.

5.2.4 Seismic Activity

The project area falls in zone III of the seismic zone map of India. The dam is required to be safe using the appropriate seismic coefficients in the BIS code and as approved by NCSDP. Historical significant earthquake events in the near vicinity are as under

Event 1: Date: 1998, Epicenter: Nedumkandam, Magnitude: 4.5 and

Event 2: Date: 1/07/2001, Epicenter: Erattupetta, Magnitude: 5.13

There is no Seismic observatory or accelerographs installed at Sengulam Dam.

5.2.5 Weather Conditions

The rainfall data are measured with rain gauges.

5.3 Frequency of Monitoring

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

5.4 Data Processing and Evaluation

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

5.4.1 Data Collection

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

5.4.2 Data Presentation

On monthly basis.

5.4.3 Data Interpretation

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

5.4.4 Dam Performance Evaluation

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

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

- Performing detailed visual inspection;
- Repeating measurements to confirm behaviour
- 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
- Emergency lowering of the reservoir

5.5 Methods of Behavior Prediction

5.5.1 Visual Observations

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

5.5.2 Monitoring Results

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

"V" Notch Readings of the Sengulam Dam -2019			
Sl No.	Date	Water Level (m)	Seepage (litre/minutes)
1	01.01.2019	846.65	1.90
2	15.01.2019	846.60	1.90
3	01.02.2019	846.60	1.65
4	15.02.2019	846.60	1.95
5	01.03.2019	846.75	2.05
6	15.03.2019	846.70	2.15
7	01.04.2019	846.50	2.00
8	15.04.2019	846.70	2.20
9	01.05.2019	846.70	2.10
10	15.05.2019	846.65	2.20
11	01.06.2019	846.65	2.15
12	15.06.2019	846.70	2.30
13	01.07.2019	846.45	2.20
14	15.07.2019	846.40	2.10
15	01.08.2019	846.60	2.10
16	15.08.2019	846.60	2.20
17	01.09.2019	846.80	2.30
18	15.09.2019	846.70	2.20
19	01.10.2019	846.70	2.00
20	15.10.2019	846.75	2.00
21	01.11.2019	846.75	1.90
22	15.11.2019	846.70	2.30
23	01.12.2019	846.70	1.90

Table 5.1 – "V" notch readings

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 were given for undertaking rehabilitation works/remedial measures for improving the structural safety and security performance of the Dam. Accordingly the following works were carried out under DRIP I.

1	Reaming foundation and body drain holes and drilling new body drain holes
2	Construction of a security guard room/operators cabin at Sengulam dam top
3	Construction of a security guard room/operators cabin at Sengulam intake
4	Pointing d/s face after pressure washing and Painting of allied structures
5	Protective wall behind the intake tower including drain, Protective fencing around intake structures including locking arrangements
6	Chipping carpet of road to intake and dam gallery
7	Providing steps at D/S right bank, including hand rail
8	Providing welcome board, information board, sign board on both end of dam
9	Fencing Boards land on D/s area of Sengulam dam
0	Treatment of u/s face of dam
11	Arrangements for electrical operation of intake gate
12	Installing one number high mast light
13	Installing CCTV
14	Installing electronic automatic rain gauging system
15	Dam break analysis
16	Purchase of speed boat for inspection

Table 6.1 - Previous Rehabilitation Efforts made

The photographs showing the DRIP works are given below:

Fig 6.1 Photograph showing Newly Constructed Security cabin at Right Bank of Dam

Fig 6.2 Photograph showing Automatic Water level recorder

Fig 6.3 Photograph showing Sluice Wheel Valve

Fig 6.4 Approach road to foundation gallery and newly constructed steps from dam top to gallery along the d/s face of dam, as visible from dam top.

Fig 6.5 Security Guard Room on right bank of the Sengulam dam.

Fig 6.6 Photograph showing Intake

Fig 6.7 Photograph showing Roofing works of Intake

Fig 6.8 Photograph showing High mast light at Dam top and Painting of dam body

Fig 6.9 Newly constructed Security guard room near Intake and entrance gate along with fencing seen in the background.

Fig 6.10 View of rehabilitation works at Intake area

Fig 6.11 View of security fencing and entrance gate in the project area.

Fig 6.12 Raised and cut pointing for Dam body at downstream face of Dam

Fig 6.13 Newly constructed Steps to Dam gallery from right bank of Dam top

Fig 6.14 Construction of Retaining Wall and deep trench near Intake site.

Chapter 7

Updating the Manual

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

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

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

Annexure XI
Glossary

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Dam owner - the Central Government or a State Government or public sector undertaking or local authority or company and any or all of such persons or organizations, who own, control, operate or maintain a specified dam.

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

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

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

Design flood - see spillway design flood.

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

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

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

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

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

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

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

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

Earthen dam or earth filled dam - see embankment dam.

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

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

Emergency spillway - see spillway.

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

Failure - the uncontrolled release of water from a dam.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Internal Erosion - see piping.

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

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

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

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

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

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

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

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

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

Morning glory spillway - see spillway.
One-Hundred Year (100-Year) Exceedance Interval - the flood magnitude expected to be equalled or exceeded on the average of once in 100 years. It may also be expressed as an exceedance frequency, i.e. a percent chance of being exceeded in any given year.
Operation - the administration, management, and performance of maintenance activities necessary to keep a dam safe and functioning as planned.

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

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

Overflow dam - a dam designed to be overtopped.

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

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

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

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

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

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

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

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

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

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

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

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

Program — any authorized activity used to implement and carry out goals, actions, and

objectives contained within the authorizing legislation.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Rock fill Dam - see embankment dam.

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

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

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

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

Service/Regulating gate (regulating valve) - a gate or valve that operates under full pressure and flow to throttle and vary the rate of discharge.

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

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

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

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

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

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

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

Sluiceway - see low-level outlet.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Upstream Blanket - see blanket.

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

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

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

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