OPERATION AND MAINTENANCE MANUAL

PERUMTHENARUVI DIVERSION WEIR

Doc. No. O&M _ Per _Div. Weir_KSEBL_22

Kerala State Electricity Board Limited

Chief Engineer (Civil-Dam Safety & DRIP)

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LIST OF ACRONYMS

The following acronyms are used in this publication:

AE	Assistant Engineer
AEE	Assistant Executive Engineer
CWC	Central Water Commission
DDMA	District Disaster Management Authority
DHARMA	Dam Health and Rehabilitation Monitoring Application
DRIP	Dam Rehabilitation and Improvement Project
Dy CE	Deputy Chief Engineer
EAP	Emergency Action Plan
EE	Executive Engineer
IS	Indian Standard
KSEBL	Kerala State Electricity Board Ltd
KWA	Kerala Water Authority
NDSA	National Dam Safety Authority
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RCC	Reinforced Cement Concrete
SDSO	State Dam Safety Organization

References

1. Guidelines for preparing O&M Manual of Dams (DSO_ GUD_ DS_ 03_ v1. 0 January 2018) published by CWC.
2. CWC Guidelines for Safety Inspection of Dams (CDSO_GUD_DS_07_v2.0 January 2018)
3. Guidelines for Operation of Reservoirs (IS7323:1994)
4. Hydraulic Design of High Ogee Over flow Spillways (IS6934:1998)
5. Technical Completion Report of Perumthenaruvi SHEP

DISCLAIMER

This *Operation and Maintenance Manual for Perumthenaruvi Diversion Weir* 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 weir and appurtenant structures.

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

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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. Dam Safety Act, 2021 also mandates that the dam owner shall ensure that a well-documented operation and maintenance manual is kept at each of the specified dams and are followed at all times. Accordingly, Kerala State Electricity Board Limited is developing and updating the Operation and Maintenance Manual of Dams under their ownership for a healthy dam safety management system.

Operation and Maintenance Manual of Perumthenaruvi dam project under KSEBL is prepared as per the guidelines by CWC. The Perumthenaruvi HEP of KSEBL was commissioned on 23.10.2017.

The Perumthenaruvi small hydroelectric project is a run-off the river scheme in river Pamba (known as “Pambayar”) of Pamba basin. The scheme envisages the utilization of water from 442 Sq km catchment of Pamba and Azhutha river for electricity generation under a net head of 17.33 m and Power House to be located on the left bank of Pamba river downstream of Perumthenaruvi falls. The catchment area comprises of that of Azhutha river, below the Azhutha diversion scheme at Peerumade and the lower reaches below the dam sites of Pamba & Kakki of Sabarigiri HE Project.

This Operation and Maintenance Manual is prepared for the Perumthenaruvi Diversion Weir under Perumthenaruvi SHEP.

Chapter 1 : General Information

1.1 Introduction

Perumthenaruvi Small Hydro Electric Project with an installed capacity of 6 MW (2 x 3 MW) is a run off the river scheme in Pamba river basin. The scheme utilises water from a free catchment of 465 Sq. km of Pampa river downstream of Pamba and Kakki dams and spill from Pamba and Kakki – Anathode reservoirs. The project is located in Pathanamthitta District of Kerala. The Project was commissioned in the year 2017.

It consists of the Diversion Weir of length 227.5 m, a reservoir having a pondage of 1 Mm3, Power Channel of length 462 m, Fore bay of 22 m dia., Two Penstock pipes of length 9.25 m and 3.2 m dia. each, power house of dimension 19m x 18m x 10.5m etc.

Water from the reservoir is primarily utilized for Power Generation. Expected annual generation from the project is 25.77 MU. Water after generating power, is diverted to the river at immediate downstream and is used for Irrigation and drinking water purpose.

1.2 Project Location

Perumthenaruvi Small Hydro Electric Project is situated in Naranammoozhy and Vechoochira Gramma Panchayat and Naranammoozhy and Kollamula Villages of Ranni Taluk. It is about 10 km away from the famous pilgrim centre Erumeli. The nearest Railway station is Chengannur which is 54 km away from project site. Nearest Airport is Trivandrum International Airport which is about 140 km from the project site. Geographic coordinates of the weir location is 9^0 24' 44" North & 76^0 52'48" East. Location of Power House is 9^o24'42" North and 76^o52'30" East. The Project site can be accessed from Mukkoottuthura Jn. in Sabarimla Road. The Project area is approximately 5 km from Mukkoottuthura Jn. The nearest town is Ranni which is about 18 km from the Project site. A location map of the project is shown below;

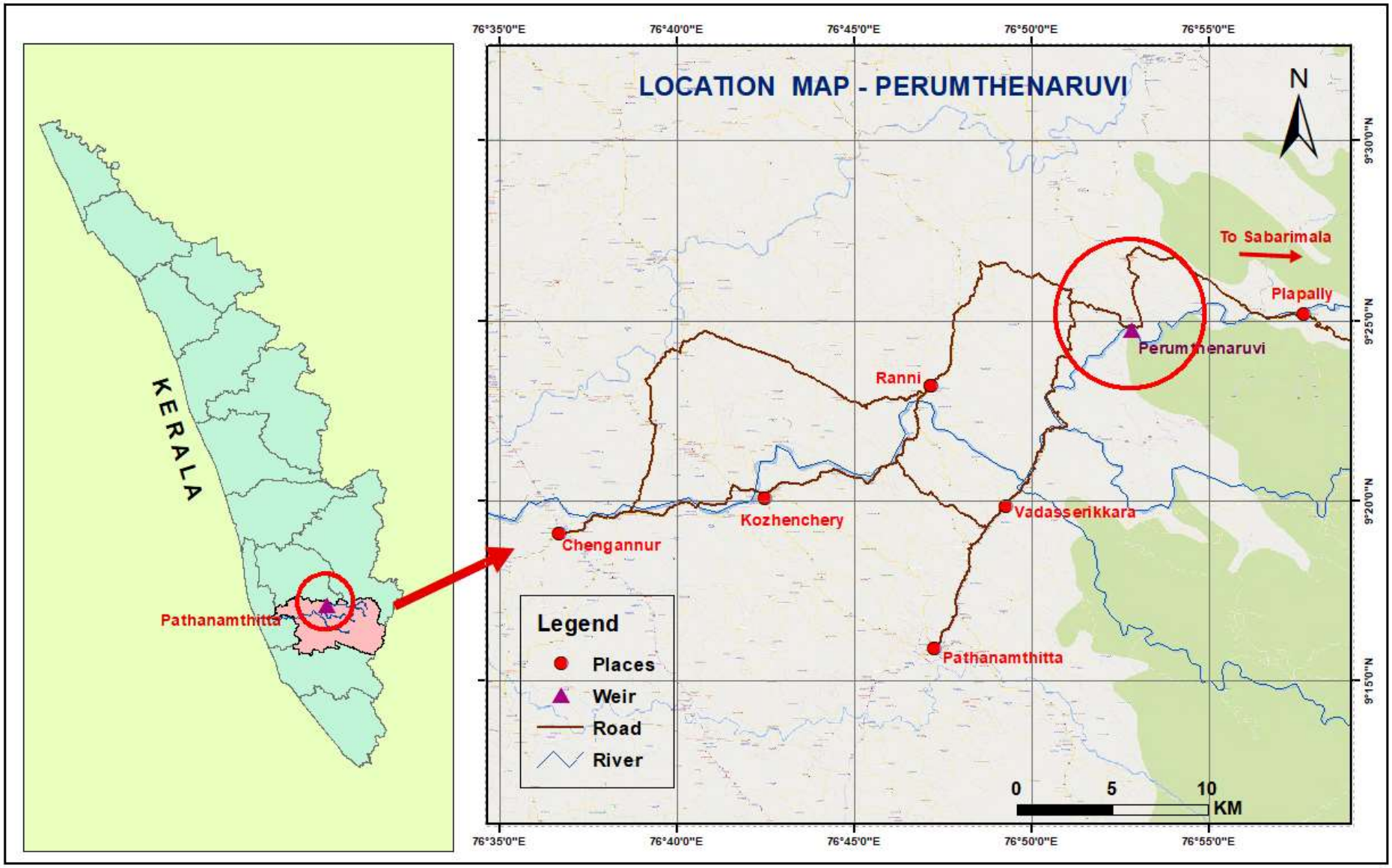

Fig: 1.1 : Location Map

1.3 Salient Features

Location		
State	:	Kerala
District	:	Pathanamthitta
Taluk	:	Ranni
Panchayat	:	Naranammoozhi & Vechoochira
Place	:	Perumthenaruvi Access
Road	:	Erumeli-Mukoottuthara-Chathanthara10Km
Rail	:	Nearest Railway station is at Chengannur 54 Kms away
Airport	:	Thiruvananthapuram, 140 Kms away
Geographical Co-ordinates Weir		
Latitude	:	9 º 24'44"N
Longitude	:	76 º 52'48"N
Power House		
Latitude	:	9 º 24'42"N
Longitude	:	76 º 52'30"N
River/Catchment		
Basin	:	Pamba
River	:	Pamba
Hydrology		
Catchment area	:	442 Sq.Km Average Annual Rainfall
Average Annual Rainfall	:	3427mm
Average Annual Yield	:	1014 Mm^3
Design Flood (Original)	:	2662 Cumecs (as per PMP Atlas 1998)
Design Flood (Revised)	:	4156 Cumecs (as per PMP Atlas 2015)
Component Structures		
Diversion Weir		
Type	:	Concrete Gravity Weir
Total length of weir	:	227.50m
F.R.L	:	+51.000m
M.W.L	:	+55.200m
Reservoir area at F.R.L	:	30.499 Hectare
Reservoir area at M.W.L	:	54.302 Hectare
Storage Capacity	:	1Mm3
Overflow Section(Spillway)		
Type	:	Un-gated Ogee Weir
Length of spillway	:	131.50m
Crest level	:	+51.00m Height of overflow section
Height of overflow section	:	7.00 m

General bed level	:	+46.00 m
Average firm rock level	:	+44.00 m
U/S face	:	Vertical
Head over crest (design)	:	4.20m
Discharge capacity at MWL through spillway & sluices	:	2665.60 m^3/s
Dam Top Bridge		
Number of spans	:	10 Nos
Number of bridge piers	:	9Nos 1.2 m width
Width of bridge	:	3.40m
Deck slab level	:	56.500m
Non-Overflow section		
Length	:	96.00m
Length at Right Bank	:	40.50m
Length at Left Bank	:	55.50m
Top level of weir	:	56.50m
Top width of weir	:	3.40m (Right bank).2.40m+0.50m over hanging on either side(Left bank)
U/s profile	:	Vertical
D/s profile	:	Vertically down to +51.00 m and a slope of 0.7 H/1.0 V
Scour		
Location	:	Left bank
Size of Scour Sluice	:	2Nos,2.00 mx4.00 m
Sill level of scour	:	+46.00 m
Discharge capacity of Scour at MWL	:	150 Cumecs.
Power Channel		
Intake	:	3 Nos opening at left bank, 3.00mx4.50m
Sill level of intake	:	+47.00m
Type	:	Rectangular RC Channel
Design discharge	:	44.000m^3/sec
Maximum velocity	:	1.97m/sec
Length of channel	:	452.50m
Bottom width of channel	:	5.75m
Depth of flow	:	3.70m
Intake transition	:	15m width to 5.75m width, 20.85m long
Bed level of transition	:	+46.700m
Side slope of channel	:	0.25H to 4.50V
Starting bed level at Ch 20.00m	:	46.9
Bed slope	:	1 in 1200

Bed level near fore bay Ch 461.00	:	46.533
Surplus escape length	:	100.00m
Surplus weir crest level	:	+50.95 m
Discharge through surplus escape in the channel at MWL	:	264 Cumecs
Fore bay		
Type	:	R .C.C. Circular
Inner diameter	:	22.00m
Wall thickness	:	0.50m
Full supply Level	:	+50.45m
MDDL	:	+47.00m
Top level	:	+53.50m
Bottom level	:	+29.20m

Surplus escape at exit of Power channel

Over flow weir length	:	+25.40m
Over flow Weir crest level	:	50.70m
Length of Over flow Channel	:	63.50m

Intake structure and trash rack arrangement at fore bay

Type of intake structure	:	3 sluices through weir with bell mouth at entrance
Height of bell mouth	:	5.34m
Width of bell mouth	:	4.48m
Type of trash rack arrangement	:	Vertical
Penstock		
Length	:	9.25m
Diameter of Penstock	:	2Nos,3.2m
Thickness of the shell	:	12mm, IS2002
Design discharge	:	44.00Cumecs
Design Velocity	:	2.74m/sec
Hydro Mechanical Components		
Type of channel intake gate	:	Vertical Lift Gate
Service Gates	:	3 Nos
Emergency Gates	:	1 No
Hoist Arrangement Service gates:	:	Electrically operated 15 Ton Capacity Mono Rail Mounted travelling trolley type
Emergency gate:	:	Manually operated 15 Ton Capacity Mono Rail Mounted travelling trolley type

Scour Sluice

Service Gates	:	2 Nos
Emergency Gates	:	1 No
Hoist Arrangement		
Service gates	:	Electrically operated 10T on Capacity Mono Rail Mounted travelling trolley type
Emergency gate	:	Manually operated 10 Ton Capacity Mono Rail Mounted travelling trolley type

Trash Rack Arrangement

Trash rack is provided covering power channel intake and scour sluice area in front of intake

Number of slots	:	7 Nos
Panels per slot	:	3 Nos
Panel Size	:	3200mm X 2100mm
Trash rack spacing	:	100mm
Scour side		
Number of slots	:	3 Nos
Panels per slot	:	3 Nos
Panel Size	:	3200mm X 2350mm
Trash rack spacing	:	100mm
Panel Size	:	3400mm X 3000mm
Penstock Intake Gates		
Service Gates (clear opening)	:	2Nos 2700mm X 3200mm
Hoist Arrangement	:	Manually operated 10 Ton Capacity Chain Block-Individual Operation
Fore bay Trash Racks		
Number of slots	:	5Nos
Panels per slot	:	3Nos
Trash rack spacing	:	50mm
Power House		
Type	:	Over ground
Building	:	Pre Engineered Building above service bay level
Overall size	:	32.20m X 24.00m X11.80m
Size of Machine Hall		
Length	:	23.54m
Width	:	19.80m
Height	:	21.00m (11.80m above Service bay)
Installed capacity	:	2x3000KW+10% (overload)
Type of Turbine	:	S-Type Axial Flow
Rated Net Head	:	17.33m

Runner Diameter	:	2060 mm
Main Inlet valve diameter	:	3200mm
Crane	:	EOT Crane 25T/5T
R.L of C/L of turbine	:	+31.300m
Sill level of TR pool	:	+26.743m
Tailrace weir crest level	:	+31.700m
Width of Tailrace pool	:	19.90m
Length of Tailrace pool	:	20.00 m
Draft Tube Gate		
Number of gates	:	2 Nos
Type of gate	:	Vertical Lift Gate
Power		
Targeted Annual Power	:	25.77 MU

1.4 Project Components

An index map and a Layout map of the Project detailing the Project components is shown below;

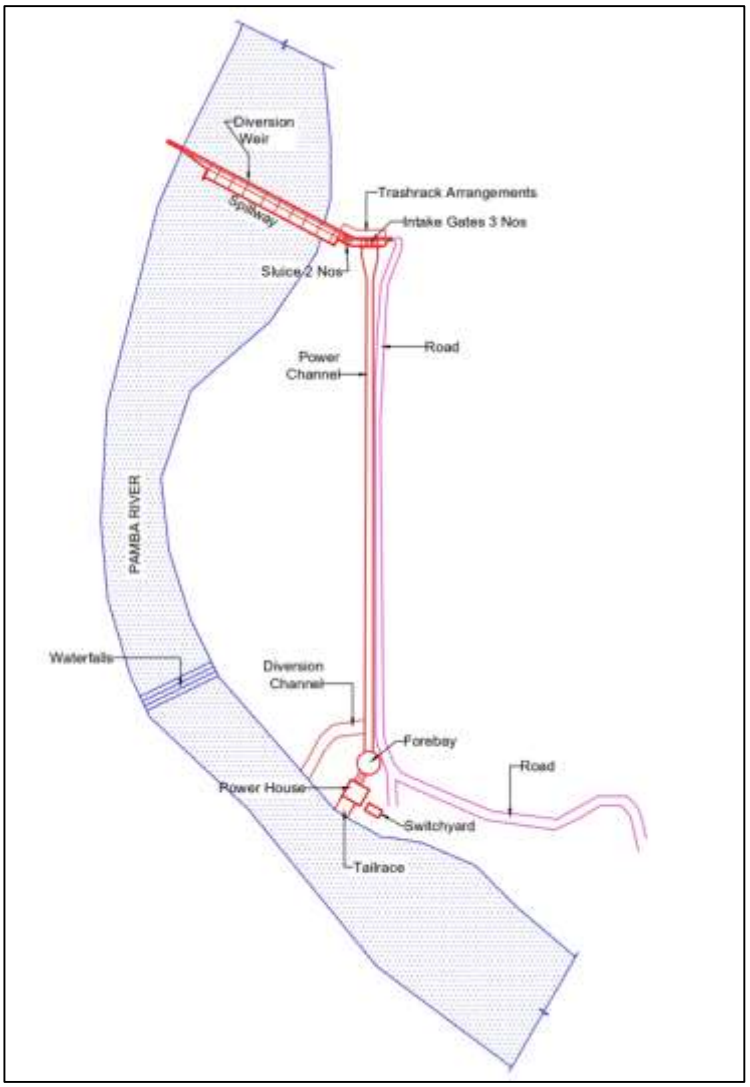

Fig 1.2 Index Map

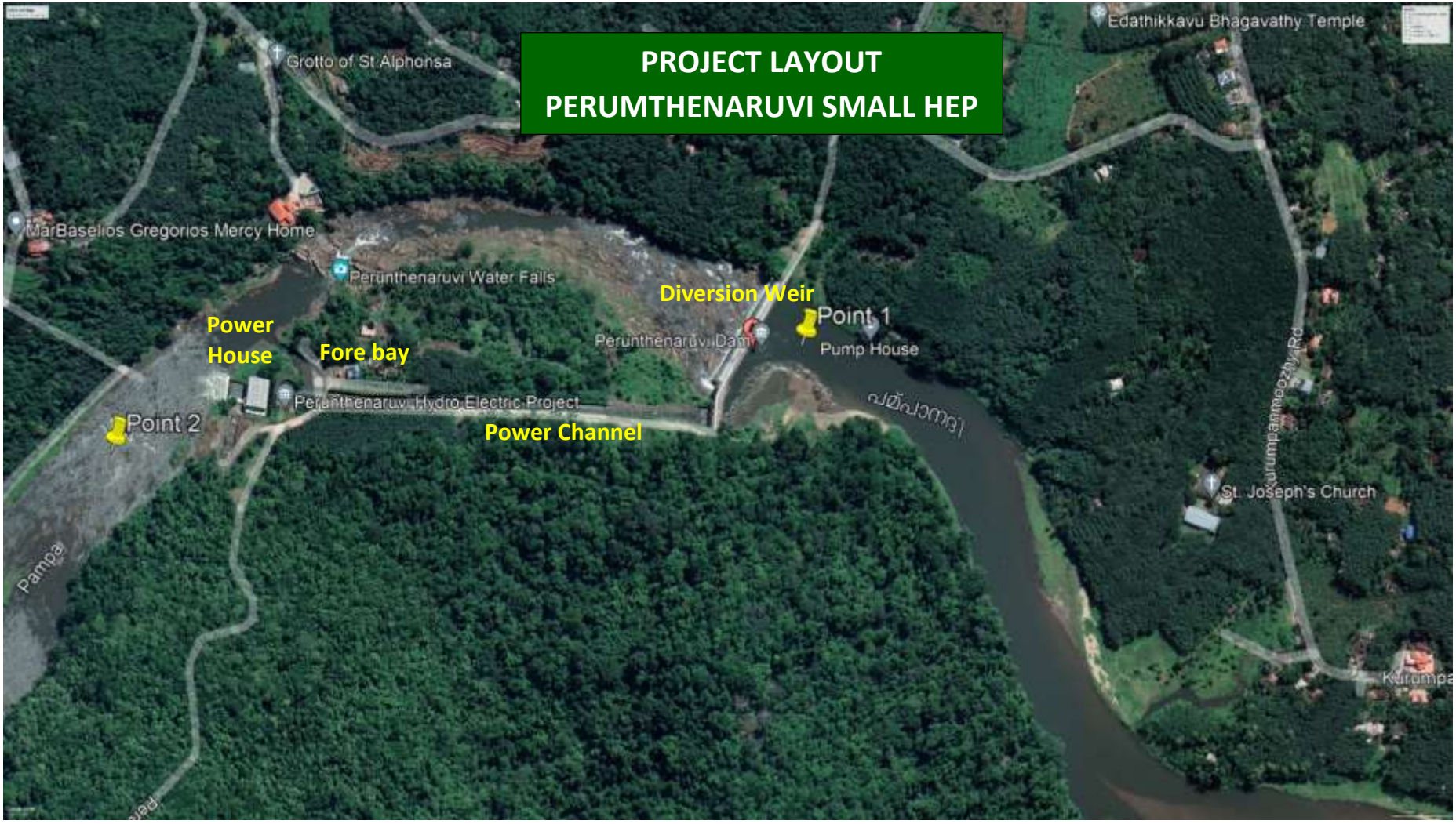

Fig: 1.3: Project Layout

Major components of the Project are;

1.4.1 Reservoir

A small reservoir having a pondage of 1 Mm3 is formed by constructing Perumthenaruvi diversion weir. Water spread area at FRL is 0.305 Sq. Km. Full Reservoir Level (FRL) is + 51.00 m and Maximum Water Level (MWL) is +55.20 m.

This reservoir helps to store water for running the project as a peak load station during lean flow period. The controlled release is done from the reservoir during summer to fulfill the demands of drinking water supply scheme downstream.

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Fig 1.4: Perumthenaruvi Reservoir Google view

1.4.2 Diversion Weir

Perumthenaruvi diversion weir is a concrete structure constructed across Pamba river as part of Perumthenaruvi Small Hydro Electric Project (2 X 3MW). The weir is constructed in 15 blocks. Major part of the weir is constructed as free over flow section without spillway gates. Stretches of 55.5m on near the left bank & 40.5m near right bank of the weir is constructed as non-overflow section. Length of overflow structure is 131.5m including piers. The crest level of weir is 51.00m. The non-overflow sections on either bank are connected by a bridge over the overflow portion with top level 56.50m. The bridge is supported by nine number of piers of width 1.2m. Pondage of the weir at FRL Is 1 Mm3 and the submergence is almost within the river width itself. The height of non over flow structure from average bed level is 10.5 m. The

height of overflow structure from average bed level is 5 m. As the maximum height of the weir is more than 10 m & pondage is 1 Mm3, the structure qualifies the requirement of a specified dam as per DSA 2021.

From chainage 174m, the weir axis tilts at 28 degrees towards upstream side. The entire portion of weir is founded over hard rock. The right bank abutment is terminated at Ch-12.00 m and a core wall of width 2.40 m is provided for abutting to the rock facing on the downstream side as per the recommendations of GSI team. Contraction joints with PVC water stops are provided between each block. 76 Nos of curtain grout holes were drilled and grouted along the river bed as per specifications and approved drawing. Permeability tests were also carried out in 7 bore holes. Upstream face of the overflow portion is vertical up to +49.360 m and there after it slopes at 1H:1V towards downstream face until it meets the ogee curve with crest at +51.000m. The tangent point of bucket curvature with weir is +47.57 m. The radius of bucket is 5.50m.

Fig 1.5: Photograph of Diversion Weir

1.4.3 Scour Sluice

Two scour sluices are provided on the left bank of over flow section to remove the silt periodically, flood control operations and to release water to the river for pumping by KWA for drinking water purpose. The sill level is at El 46 .00 m. Two service gates of size 2 m X 4 m is provided for the scour sluice. Trash rack at 10 cm spacing also provided to prevent entry of large sized materials that may cause clogging of the scour opening affecting gate operation. Each sluice is provided with one service gate slot and emergency gate slot. Electrical chain hoist with a lifting capacity of 10 Ton is provided for operating the Scour Gate. One emergency gate is also provided in one of the emergency slot and it is always in open position. The emergency gate can be shifted from one sluice to another sluice by a manually operated chain block of 10 Ton capacity with travelling trolley mounted on a mono rail.

1.4.4 Water Conductor System

The water conductor system of the Perumthenaruvi Small HEP consists of Intake arrangements with trash rack, Power Channel, Fore bay, and two Nos penstocks.

1.4.5 Intake structure and trash rack arrangements for Power Channel

Three openings of 3m x 4.5m size are provided at the intake with trash rack. The spacing of trash bars is 100 mm. The sill level of intake is +47.00m and bell mouth is provided in the intake opening. The length of intake is 8.5 m. top level of opening is +51.50m. Gates of size 3.57m X 4.65 m are provided. The gate hoisting platform is at El + 54. 00 m and is at the exit of intake block. Trash rack arrangement with 100 mm spacing of trash bars is provided to avoid entry of large sized particles into the power channel. The intake arrangement is provided Block No 14 of the Weir.

There are three intake sluices of size 3.00m x 4.50m provided in the left bank non-overflow portion to draw water from reservoir to the channel. Each sluice is provided with one service gate slot in the upstream side and emergency gate slot in the downstream side. Electrical chain hoist with a lifting capacity of 15 Ton is provided for operating the Canal Intake Gate. One emergency gate is also provided in one of the emergency slot and it is always in open position. The emergency gate can be shifted from one sluice to another sluice by a manually operated chain block of 15 Ton capacity with travelling trolley mounted on a mono rail. The operation procedures are detailed in the operations and maintenance manual.

Fig 1.6: Intake and Sluice arrangements

Fig 1.7 : Intake and Sluice arrangements. Photographs at Construction Stage

1.4.6 Power Channel

The power channel is provided in the left bank of the river. The length of RCC rectangular power channel is 461m, and 5.75m width. The bed level of the channel at intake portion is +47.00m. The F.S.L of power channel at inlet is +50.70 m . Drawings attached separately. Maximum power draft for 6000KW is 44m^3/sec. The width of channel at chainage 8.5 m is 15m. The ch. 0.0 m is the bellmouth entry point of the power outlet openings. From ch.18.5 m transition starts and the width of channel reduced to 5.75 m. The length of transition is 20.84 m. A surplus escape of 100m is provided in the channel from Ch.20 to 120m with crest level as +50.95m to escape surplus water in the power channel to the river. Bed slope of channel is 1 in 1200. The top level of channel including parapet is as note below.

From Ch 8.50 to Ch 20.00	:	+53.000
From Ch 20.00 to Ch 120.00	:	+52.300 (Left side wall , side surplus escape)
From Ch 120.00 to Ch 340.00	:	+52.300
From Ch 340.00 to Ch 415.60	:	+53.600
From Ch 415.60 to Ch 425.60	:	+54.000
From Ch 425.60 to Ch 429.60	:	+53.000
From Ch 429.60 to Ch 461.00	:	+53.500
Parapet wall	:	0.15m x 0.60 m

Fig 1.8 : Power Channel during Construction

A surplus escape of length 26 m is provided near the exit of power channel also. The crest level is 50.70 m. Length of overflow channel is 79.20 m.

The zero chainage of Power Channel (Centre line) starting from Ch.189.40 of weir axis and the centre line of Power Channel is perpendicular to weir axis. The distance between the fore bay centre and zero chainage of power channel is 472.00m. The starting portion of canal from Ch.0.00 to 8.50m is inside the dam body. The width of canal at intake is 15.00m upto Ch.18.50m and the canal transition varies from 15.00m to 5.75m at Ch.39.34m. From Ch.39.34 to Ch.461.00 at fore bay, the canal section is rectangular with bottom width 5.75m. A surplus weir is provided along the right side of Power Channel from Ch 20.00m to 120m with crest level at +50.950m. An under passage type cross drainage work is constructed at Ch 272m for diverting a natural drain from the power channel location. The catch water drain along the left side wall of power channel is also disposed to this under passage through a vertical shaft. The top of this rectangular shaft is covered with a steel grating for safety. A box culvert is constructed between Ch 425.20m and Ch 429.50m to provide access to Perumthenaruvi waterfall. An overflow weir with leading channel is provided in between the box culvert and fore bay for the release of water during load rejection.

The sill level at canal intake is +47.00m. The bed level of the canal transition is at +46.700. The bed level at Ch 20.00m is +46.90 m from there, canal bed level is in a falling gradient of 1 in 1200 until it reaches forebay tank. The transverse slope of the side wall is 0.25 H to 4.50 V. The top level of side wall is different at different locations as per drawing. There are expansion joints for the canal at Ch 31.80m, Ch 70.00m, Ch 115.00m, Ch 205.00m, Ch 250.00m, Ch 295.00m, Ch 340.00m, Ch,395.00m. PVC water stops and bitumen pad also are provided at these joints.

1.4.7 Fore bay Tank

An R.C.C circular fore bay is provided at the exit of the open channel. F.S.L at the fore bay tank is +50.45 m. Diameter of the tank is 22m. Top level is fixed at 53.50 m and bottom level is 29.20m. The fore bay tank is partly underground. The thickness of RCC wall of fore bay tank varies from 100 cm to 50 cm. MDDL of the fore bay is kept at +47.00m to avoid air entry into the penstock. The fore bay can be emptied by releasing water through the drainage arrangement provided in the penstock inside the power house. An intake structure with trash rack arrangement is provided inside the fore bay in front of penstock pipes. The spacing of trash bars is 50 mm.

Fore bay tank is situated in between power channel and penstock. It acts as a buffer tank for suppressing the fluctuations in canal inflow. It also helps to suppress the surge during load acceptance and rejection in turbine. Perumthenaruvi SHEP, diversion weir diverts water from Pamba river to the power channel and then to fore bay tank. From the fore bay tank, water passes through two separate penstock pipes to the power house. Fore bay tank is circular in shape with diameter 22m and height 24.20m and RCC wall thickness varies from 0.5m to 1m. Bottom level of fore bay is +29.20m and parapet level is +53.5m. Concrete mix for the wall is M25 MSA 20 and in penstock portion it is M20MSA20.

There are five rectangular trash racks fitted in the concrete slab at +38.20m level. Intake structures are bell mouth type with height of entry 5.34m and breadth 4.48m. Two gate slots in fore bay with two gates of size 3.75m x 3.20m control flow of water into the penstock. Sill level of the gate opening is +29.730m and level of gate hoist slab is +52.700m. Site was handed over to contractor for construction of forebay on 17.02.2012. Preliminary works started on 17.05.2012. After completing the excavation works, concreting started on 13.05.2014 and was completed in all respects on 31.03.2017. Ch 429.50m to 455.50m of the power channel adjacent to the fore bay has the surplus arrangement for diverting surplus water back in to river. The surplus arrangement also helps to maintain the forebay water level when there is a sudden load rejection in the turbine.

Width of surplus channel at the beginning (power channel side) is 26m and at the end is 6.50m. Bottom level at the beginning is +50.700m and +30.240m at the end. There are R.C.C training walls on both sides of the surplus channel. First 12m of the channel is almost horizontal and thereafter sloping towards the river. Top width of the training wall is 30cm (average) and bottom width is 60cm (average). Bottom width varies as per the height of the training wall. There is a parapet of 1m height above the training wall to prevent splash of water. Base of the surplus channel is with dry rubble packing at the bottom, a leveling course with PCC of 100mm thick and then R.C.C lining on top. Bed slope provided is 1 to 0.4. Outer wall of fore bay and power channel are joined in an anchor block of size 1000 x 1500mm. Full supply level of fore bay is +50.50m. Hand rail is provided around the deck slab in safety aspect.

Fig 1.9: Fore bay tank

Fig 1.10: Fore bay tank during Construction

1.4.8 Penstock

Two penstocks each of 3.2 m diameter and length 9.25 m is provided to carry water to the two machines. The penstocks have made with steel plates IS 2002 having thickness of 12mm. While calculating the thickness of Penstocks, provisions for water hammer is also considered. The penstocks are embedded in concrete up to yard level. Bell mouth entry is provided for the penstock pipe. The dimensions of bell mouth is 4.48 m X 5.34m. Service and Emergency gates are provided to control flow through penstock. Dimension of gate is 3.42m X 3.45 m. Two gates are manually operated using chain pulley block of 10 T capacity.

There are 13 links for connecting the gates to chain pulley. Two air vents of 600mm dia steel pipe are also provided in the fore bay for ventilating the penstock transition. A flash plate is provided in each of the vent pipe to avoid splashing of water into power house due to way unbalancing between upstream and downstream of guide vane.

Fig 1.11: Penstock during the Construction

1.4.9 Power House

The Power House is located on the left bank of the Pamba River at downstream of Perumthenaruvi Waterfalls. The installed capacity of the Power House is 2x3MW (6MW). The average annual generation is 25.77 Mu. The Power House building has a size of 32.20m (Length), 24m (Width) and 11.80m (Height above service bay). Size of machine hall is 23.54 m X 19.80 m X 21 m. Two numbers of horizontal Kaplan Turbine have been installed at the Power House. The center line of Machines are at an elevation of +31.30m from MSL.

There is a sump pit of size 3m x 2m x 2m inside the power house. Three tailrace piers are covering three downstream columns. Pier A & Pier C on either ends of tailrace consists of 2m x 2m dewatering sumps of draft tubes of unit 1 & unit 2 respectively. Tailrace can be dewatered from these sumps. Bottom level of the sump is (+) 25.750m.

Fig 1.12: Power House – Perumthenaruvi SHEP

Fig 1.13: Power House during Construction stage

Fig 1.14: Power House during Construction stage

1.4.10 Tail Race

The dimensions of tail race is 20 m X 19.9 m and Discharge in to the tail race pool is 44m3/sec. Tail water is discharged in to the river downstream of the power house at +30.00 contours available on river bed. Gates are provided in the draft tube of both machines. Size of gate is 6.25 m X 2.75 m. These gates are of manual operation using 15 Tonnes capacity chain pulley block fixed on hoisting structure Floor of tailrace weir is having a reverse slope of 1 in 4. Crest level of tailrace is at EL+31.700 which starts at Ch.68.50 and top ends at Ch.69.500m. Right side wall of tailrace pool is up to EL (+) 34.50 and right side wall is up to right yard level. There are two gates for the two draft tubes. Top level of the operating platform (deck slab) is +37.500 Sill level of the draft tube opening is at EL+26.743 and top level of the opening is at EL+ 29.211.

Discharge of water after power generation is through tailrace channel to the river. As per tender drawings, size of tailrace was 12m x 14m but due to changes in power house design size of tailrace was modified to 21m x 19.90m.

Fig 1.15: Tailrace

1.4.11 Transmission System

The power generated from this scheme can be fed in to the following circuits.

1. 11KV feeder at Asramapady-0.5KM from site
2. Kanjirappally - Erumely 11 KV feeder at Chathenthara-2KM from site
3. Ranni - Vadasserikkara 11 KV feeder at Kudamuratty-2KM from site
4. Erumely 33 KV substation (Proposed), which is about 7KM away from the P/H site by 11 KV double circuit line.

1.4.12 Switchyard

Size of the Switchyard is 20m x 10.50m and yard level is +41.00 m. There is one 8 MVA 6.6KV/33KV transformer and another auxiliary transformer of 250KVA in the switchyard. Yard was formed by constructing retaining wall around.

Fig 1.16: Switchyard

1.4.13 Access Roads

The cement concrete road from dam top and ending at Ch 425.20 m along left bank of power channel is the Power Channel Access Road. The cement concrete road starting from Panchayat road from Edathikavu and ending at Ch -12.00 of dam on right bank is the Right Bank Access Road. There is a concrete culvert constructed across a nallah at the beginning of right bank access road near the Panchayat road. Rubble retaining wall protection is provided along the stream. An entrance portal is also installed at the beginning of Right Bank Access Road. Safety hand rails are given near dam on both Right Bank Access Road and Power Channel Access Road.

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 Weir. 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 Officer	The Director (Generation – Civil), KSEB Ltd.
Chief Controlling Officer	Chief Engineer (Civil–Dam Safety & DRIP)
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. I, Kakkad.
Reservoir operations, inspection &maintenance	Executive Engineer, Research &Dam Safety Division No. I, Kakkad.
Dam Health Engineer	Executive Engineer, Research & Dam Safety Division No.I, Kakkad.
Recording reservoir data, inspection, monitoring and maintenance at site	Assistant Executive Engineer, Research & Dam Safety Sub Division, Seethathode.
Handling Dam operations, inspection, monitoring and performing duties and Maintenance- Officer at dam	Assistant Engineer, Research & Dam Safety Sub Division, Seethathode.

Table 1.1: Officers and their responsibilities

1.5.1 Roles and Responsibilities of the AE and AEE during Monsoon

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

1. Collect rainfall information in the catchment, inflow status, reservoir level and to bring it to the notice of the EE/DyCE.
2. Assist the EE/DyCE/CE to coordinate with the Revenue authorities (District Administration), to alert the downstream inhabitants and to alert DDMA to evacuate from the flood zone to prevent loss of life and live stock.
3. Assist the EE/DyCE/CE to coordinate with the CWC flood monitoring authorities on the flood condition.
4. Maintain the reservoir water level gauge register and to update on hourly basis during floods and report to EE/DyCE/Chief Engineer.
5. Submit to the EE/DyCE/CE on the inflows and outflows from the reservoir and status of the reservoir at 3 hr interval during flood or at interval as decided by competent authority/ DDMA.
6. Observe the gates and to see that floating debris are not deposited in the gate components.
7. Monitor the condition of the Welding transformers, gas cutting sets, umbrellas, toolkits, torches, chain blocks, ropes, ballies etc. on daily basis and to see that things are in place to handle any emergency situation.
8. 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.

9. Observe and ensure that the dam top, approach roads are well maintained.
10. Observe the performance of the Dam and its appurtenant structures/Gates and Hoists during flood water releases and to report to the EE/DyCE/CE in case of any untoward incidents or malfunctioning of the gates, excessive seepages, leakages etc noticed.
11. Assist EE/DyCE/CE to coordinate with the Generating staff of Perumthenaruvi Power house downstream in the operation and power generation.

1.5.2 Roles and Responsibilities of the EE and DyCE during Monsoon

1. Conduct Periodical (Pre and Post Monsoon) in sections to assess the health status of the Dam and appurtenant structures 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 Hydro Mechanical components of the Dam project such as Gates and Hoists before and after monsoon and to issue necessary instructions to the Executive Engineer.
3. Coordinate with the field Engineers to get the information in respect of rainfall and inflow status and to bring to the notice of the CE.
4. Assist the CE to coordinate with the Revenue authorities (District Administration) to alert the downstream villagers and DDMA to initiate evacuation from the flood zone to prevent any loss of life and livestock.
5. Assist the CE to coordinate with the CWC flood monitoring authorities on the flood condition.
6. Submit to the CE the status of inflows and releases from the reservoir daily or as instructed.
7. Observe the seepages in the drainage Gallery with respect to the reservoir head and record the seepages in the infiltration gallery and to immediately bring to the notice of the CE incase of excessive seepage, leakage in any specific blocks and porous drains.
8. 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.
9. Observe the dam top, embankment, approach roads are well maintained by housekeeping personnel.
10. 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 mal functioning of the gates of excessive seepages, leakages etc.

1.5.3 Roles and Responsibilities of the Chief Engineer during Monsoon

1. Coordinate with the CWC flood monitoring authorities on the flood condition.
2. Observe the performance of the Dam and its appurtenant structures/Gates and Hoists during flood water releases and to issue necessary instructions to the DyCE/EE.
3. Coordinate with the Generation wing of KSEBL regarding the power generation requirement.

1.6 Collection & Reporting of Data

Following data are collected, recorded and documented.

- Reservoir water surface elevation.
- Reservoir inflow.
- Spillway outflow.
- River releases.
- Water supply and hydropower releases.
- Rainfall data etc.

Instructions are issued to the Executive Engineer for daily collection and reporting of inflow and outflow data to the Deputy Chief Engineer in the following format.

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

Table1.2: Daily Reservoir Data

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

Table1.3: Daily Reservoir Status

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

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

The data collection and reporting shall be done as follows:

Reservoir water surface elevation	This is collected daily
Spillway out flow	This is calculated during spill
River releases	The tail water is released to Pamba River itself
Weather related data	Collected and reported daily
Water quality	Shall be tested once in 6 months
Attendance statement	Both during monsoon and non-monsoon period maintained at field office.
Operations of outlet gates	Shall be recorded
Operating hours of mechanical equipments	Maintained at field office
Testing/operation of Outlet gates, and associated controls	Maintained at field office
Maintenance activities carried out	Details maintained at field office
Reservoir and dam inspections	Periodically inspected and details maintained at field office, Circle and CEs office
Unusual conditions or occurrences, including acts of vandalism	Details maintained

Attendance statement at dam during emergency operations	Details shall be maintained at field office
Changes to normal operating procedure	Details shall be maintained at field office
Communication	Network i s available at Dam site.
Safety and special instructions	Safety equipment are available
Names and addresses of official visitors	Record of inspections maintained at office

1.7 Public Utilities and Safety

As safety of Project Staff is of prime concern, safety instructions & protection measures at the dam are to be followed by all staff/project personnel.

Sufficient accommodation facilities are available at nearby Town Ranni which is around 18 km from Weir Site. The Perumthenaruvi Diversion Weir is about five km from Mukkottuthara Jn. in Pamba - Erumeli Route. Frequent bus services are available on day time in this route.

Distances to the nearest medical assistance is available at Mukkottuthara. Government community health centre is also available at Perunad, about 10 km from weir site. Police station is also located at Perunad. Hospitals with medical facilities are also available at Pathanamthitta which is around 30 km from weir site.

1.7.1 Security Arrangements

Security arrangements are provided near dam at security check post at the dam top on left bank.

1.8 Organogram

The organogram of the officials under Dam Safety Wing responsible for the operation and maintenance of the weir and their contact details is shown below;

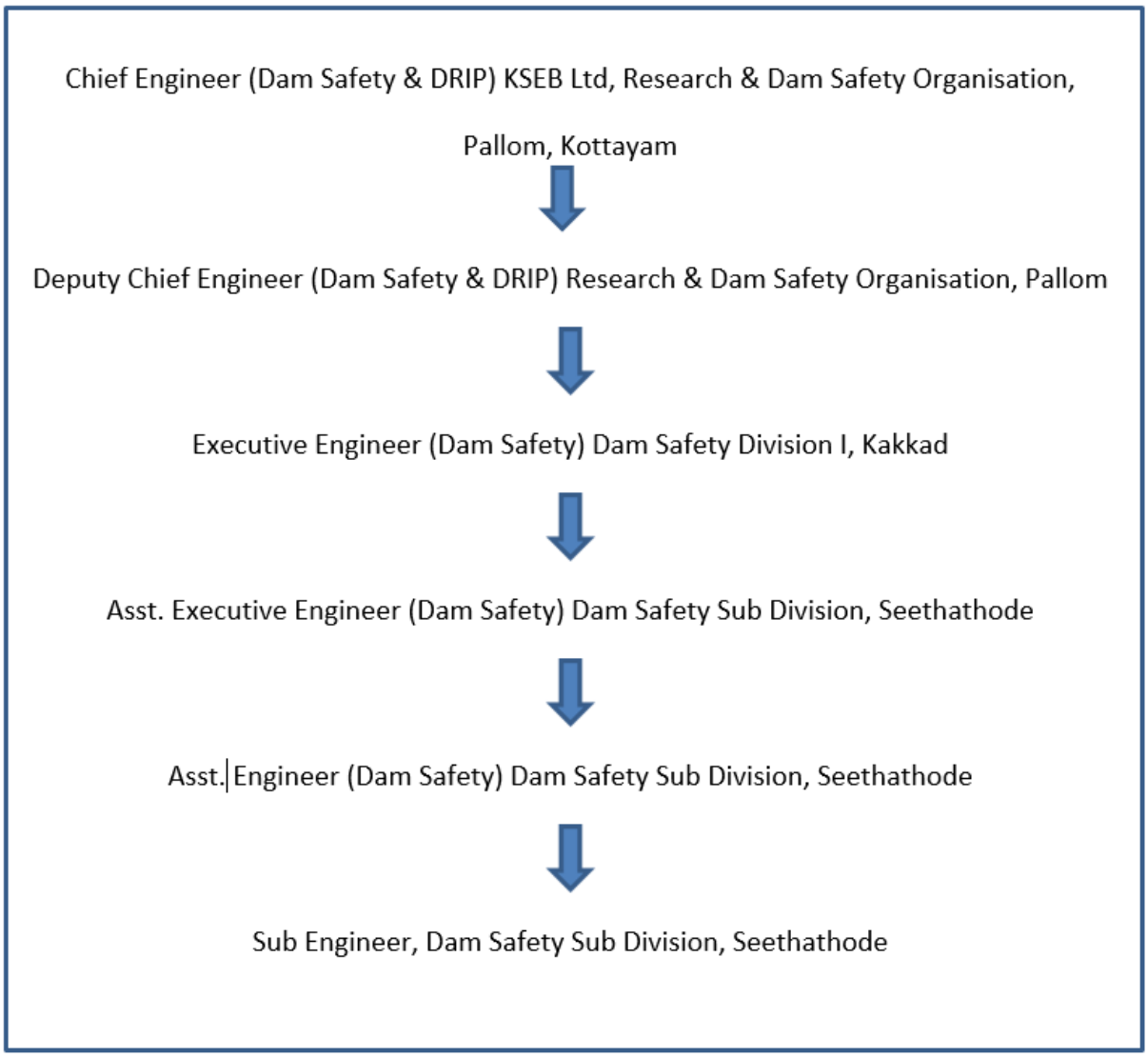


Fig.1.17: Organogram

Designation and office address	Contact number and e-mail
Chief Engineer Civil (Dam safety & DRIP), KSEBLtd, Dam Safety Organization, Pallom, Kottayam	Ph:9496018719 cedamsafety@gmail.com
Deputy Chief Engineer, Research& Dam Safety Organization, Pallom, Kottayam	Ph:9446008492,0481-2432290, 9496011540 e-mail:dirroplm2@gmail.com
Executive Engineer, Dam Safety Division No.I, Kakkad	Ph:9446008424 e-mail: ddrdskkds@gmail.com
Assistant Executive Engineer, Dam Safety Sub Division, Seethathode	Ph: 9496011955 e-mail: aee.dssdn@gmail.com
Assistant Engineer, Dam Safety Sub Division, Seethathode	Ph: e-mail: aee.dssdn@gmail.com

Table 1.4: Contact details of officials

1.9 Warning system

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

1.10 Releases through Spillway

Spillway of the weir is ungated. Water will flow freely through the spillway when the reservoir level reaches FRL/Spillway crest level. The spill water will flow through River Pamba in vechoochira, Naranammoozhy, Ranni-Perinad, Ranni-Pazhavangadi, Vadasserikkara, Ranni, Ranni-Angadi, Ayroor, Cherukole, Kozhenchery, Thottapuzhassery, Mallapuzhassery, Elanthoor, Aranmula, Koipuram, Mazhuveli, Eravipeoor panchayats of Pathanamthitta district and Chengannur municipality, Mulakuzha, Thiruvanvandoor, Pandanadu Panchayats in Alappuzha district. Flow path of the spill water is shown below;

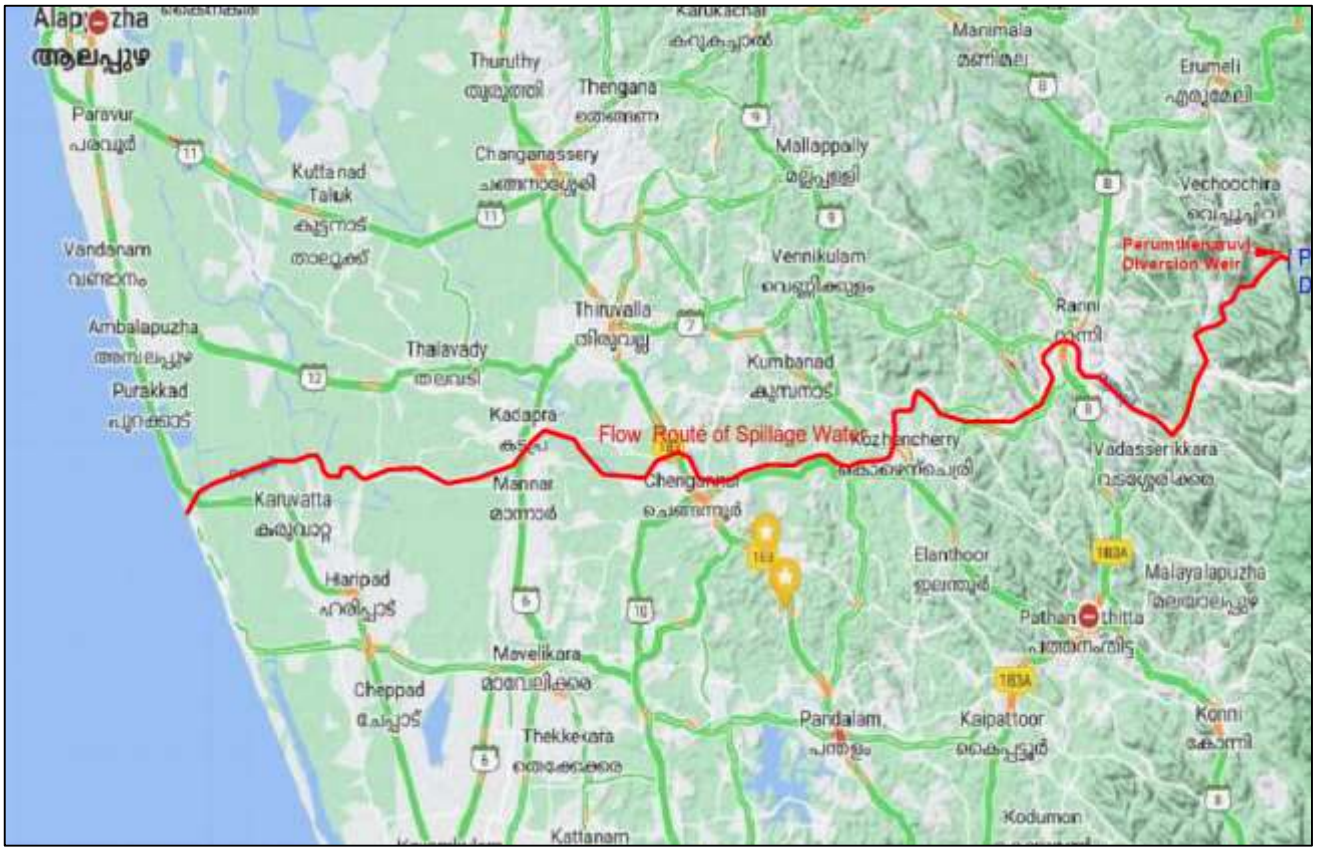


Fig 1.18: Flow path of spill water

1.11 Supporting Documents & Reference Material

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

- Detailed drawings of the Project
- Emergency Action Plan (EAP)

- Latest Hydrology Review Report
- Power station operation plan
- Administrative procedures
- Maintenance schedules
- Regional communication directory

1.12 Typical Schedule of Duties

Schedule of duties/inspections to be carried out for the operation and maintenance of the dam by the concerned officials are tabulated below in **Table1.6.**

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, Spillway and its energy dissipation arrangements, Power Intake	Daily	Sub Engineer/Dam operators on contract
2	Record water surface elevation, reservoir in flow 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. Replace fuse light bulbs.	weekly	Assistant Engineer
6	Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of foundation and abutments, Spillway and its energy dissipation arrangements, Power Intake	Fortnightly	Assistant Engineer

7	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	Fortnightly	Assistant Executive Engineer
8	Check security and safety devices, logbook and site register which include the above information.	monthly	Assistant Executive Engineer
11	Measuring devices, communication devices, instruments, vegetation growth	monthly	Assistant Executive Engineer
12	Check Sign/Warning display boards near vulnerable locations	Fortnightly	Assistant Executive Engineer
13	Visual inspection of dam including Crest of dam (Dam top), Upstream and downstream faces, visible portions of foundation and abutments Spillway and its energy dissipation arrangements,	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	Cleaning of control panel boards.	Monthly	Assistant Engineer
17	Check outlet works, updating operating instruction, check gate airvents, clean gate controls witch boxes , check operation of gates, grease gate hanger/ dogging	Quarterly	Executive Engineer
18	Check condition of trash rack of intake structure, Check condition of Outlet works& its Energy Dissipation Arrangement, Check operation of Valve house	Quarterly	Executive Engineer

19	Check condition of spillway, 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 instrument at action schedule, Record pertinent information in Operation of Gates,	Quarterly	Executive Engineer
21	Inspection of outlet works, hydro mechanical components,	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	SDSO along with Dam Owners
24	Inspect dam and gate structures, trash racks and stilling basin/energy dissipation arrangement, which normally are under water (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 rack sand stilling basin	Ten Yearly	Dam Safety Review Panel

Table 1.5: Schedule of duties/inspections

Chapter 2 : Project Operation

2.1 General

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

The Perumthenaruvi weir is an un gated overflow weir and the water level is to be monitored daily. No Control arrangements are provided for the releases through spillway. The scour sluices are to be operated when the water level raises above + 51.30 m. The surplus water entering into the power channel will be escaped through the surplus escape in the power channel. The causeway upstream of the reservoir will get submerged when the water level in the reservoir is above + 51.80 m. Normally during monsoon, the water level may raise up to +53.5 m.

2.2 Historical Data of Flood

As per historical records, the maximum flood observed in Western Ghats was during1924.The center of the storm of the 1-day rainfall of 17th July 1924 and 2-day rainstorm of July16-17 was located at Devikulam in Kerala in which rainfall of 484 mm and 751mm 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 758.6mm rainfall from 1 August 2018 to 19 August 2018, about 414 mm rainfall occurred in just three days viz. 15-17, August2018, which created severe flooding in the State, while the same during 16-18, July1924 was 443mm. There no Rain gauge stations at Perumthenaruvi Weir Site. The 3-day rainfall of 15-17, August 2018 at Moozhiyar dam site was 422mm. Rainfall Details of the Nearby Koruthode Rain Gauge Station from 2010 to 2022 attached as **Annexure III.**

2.3 Design Flood

Catchment area of the Perumthenaruvi Reservoir is 442 Sq. Km. Average Annual Rainfall received is 3427mm Average Annual Yield: 1014 Mm3. Design Flood of 2662 Cumecs is revised during 2022 as 4156 Cumecs. A copy of the revised Design Flood Review Report is attached as **Annexure II.**

2.4 River Outlets

Two number of lower level outlets (scour sluice) are provided in the weir adjacent to spillway in the left bank. Sill of the outlets is at El. +46.00 m. Two no. of service gates and one emergency gate of size 2 m x 4 m is provided for the lower level outlets. The gates are vertical lift type.

2.5 Intake Gates

Three nos. of service gates and one no. of emergency gate of size 3 m x 4.5 m is provided for the intake. Vertical life type gates are provided for the intake.

2.6 Operating Procedure of gates

All the gates shall be properly maintained for correct functioning.

The service gates of Canal Intake and Scour sluice can be operated with the help of electrical hoist provided at site. There are two three phase electric motors in each hoisting unit. The travelling trolley motor moves the hoisting unit in a horizontal direction along the monorail. The hoist motor lifts and lowers the load chain at the rate of 2.66m per minute. Care shall be taken while lifting and lowering the gates, ensure the chains are rolling easily through sprockets, there is no kinking or twisting of chains.

Refer Drawing No. PGCC/PRVI/IGHA-INTAKE GATE (Rev 3), for lifting arrangement and dogging details of Canal Intake Gate and Drawing No. PGCC/PRVI/IGHA-INTAKE GATE /SG (Rev 2) for Scour Sluice gate.

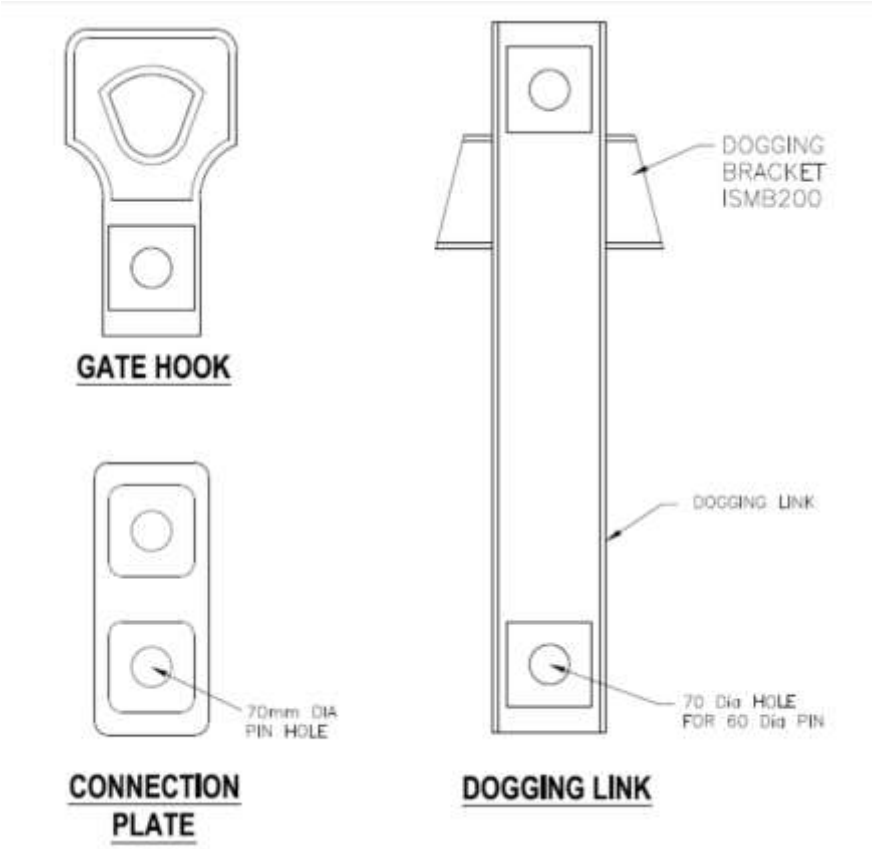


Figure 2.1: Hooking Assemblies

2.6.1 Lifting

- Before commencing every hoisting operation, ensure the chains, sprockets and trolley wheels are properly lubricated.
- In the case of service gates, position the Electrical hoist exactly vertical over the gate hook by using the lateral movement switch in the pendant control panel.

- In the case of emergency gate, position the trolley mounted chain block exactly over the gate by using the trolley chain.
- Insert the gate hook on the top most dogging link by inserting the dogging pin and lock.
- Hook the Hoist / Chain block hook on the gate hook
- Lift the gate gradually until the dogging bracket of the 2nd dogging link came out of the gate slot.
- Insert the dogging frame so that the legs properly seated on opposite sides of gate slot and the dogging bracket of 2nd dogging link rests over the dogging frame.
- Lower the hoist until the load from the topmost dogging link is removed.
- Remove the bottom dogging pin of topmost dogging link
- Remove the topmost dogging link and stack it aside
- Remove the connecting plates and stack it aside. Care shall be taken not to fall any plates or dogging pins or lock nuts into the gate slot.
- Replace the gate hook on the 2nd dogging link
- Connect the hoist hook on the gate hook and lift slightly so that the load from dogging frame is removed.
- Remove the dogging frame and lift the gate until the dogging bracket on the gate is seen outside.
- Dog the gate using the dogging frame.

2.6.2 Safety

- Only experienced operators shall be allowed to operate the gates.
- The operators shall strictly use hand protection gloves.
- The gate hook can be fitted on any hooking link with the help of dogging pin.
- Original Dogging frame shall be used while adding or removing dogging links.
- The chain shall not be tied to any member for lifting.
- The hoist and hoisting structure shall be strictly used for handling vertical loads only.
- The gate slots shall always be covered with cover plates unless any lifting operations are carried out.
- Ensure the hoists are not lifting any load beyond its safety headroom.

2.6.3 Annual Maintenance

All hydraulic gates shall be thoroughly inspected during the summer period preferably in the beginning of April every year. Annual shutdown is necessary for inspection of gate grooves, gate sluices, and bell mouths. Painting of metal inserts provided along the path of sluice opening such as bell mouth skin plates, gate embedded parts etc. shall be carried out during

the shutdown period.

Painting, repairing work of gate, changing of rubber seal, greasing, inspection of wheels, chain blocks, travelling trolley, servicing of electric motors, electric connections etc. shall be carried out through experienced agencies.

The inside of gate sluices shall be cleared off silt, pebbles and other debris.

2.6.4 Routine Maintenance

The gates shall be lifted and lowered for testing purpose once in every 3 months. The greasing of wheels, chains and other visual inspection shall be carried out during this operation. Emergency gates may be used at the time of routine maintenance to prevent the loss of water from reservoir.

2.6.5 Lubricants

Regular application of lubricant is necessary for the smooth functioning and long lasting of the moving parts such as Chain, Sprockets, Wheels etc of Manual as well as Electric Chain Hoists. The manufacturer of Electric Hoists, M/s Hercules Hoists Ltd recommended the following grade lubricants.

OIL: HP Parthan: 320 Grade.

Grease: HP MP3

2.6.6 Operation of scour gates during flooding

The scour gates must be opened when the reservoir level exceeds +53.500 m. Sudden opening of Scour gates shall be avoided. The gates shall be gradually opened step by step and one after other after giving sufficient warning to the downstream people. Both the scour gates shall be opened fully when water level exceeds +53.500 m. Always open the scour gate number S1 (adjacent to spillway) first. Complete opening of S2 gate will affect the flow into canal.

2.6.7 Stage Discharge curve of Scour Sluice.

A plot of the Stage - discharge details of Scour sluice is shown below;

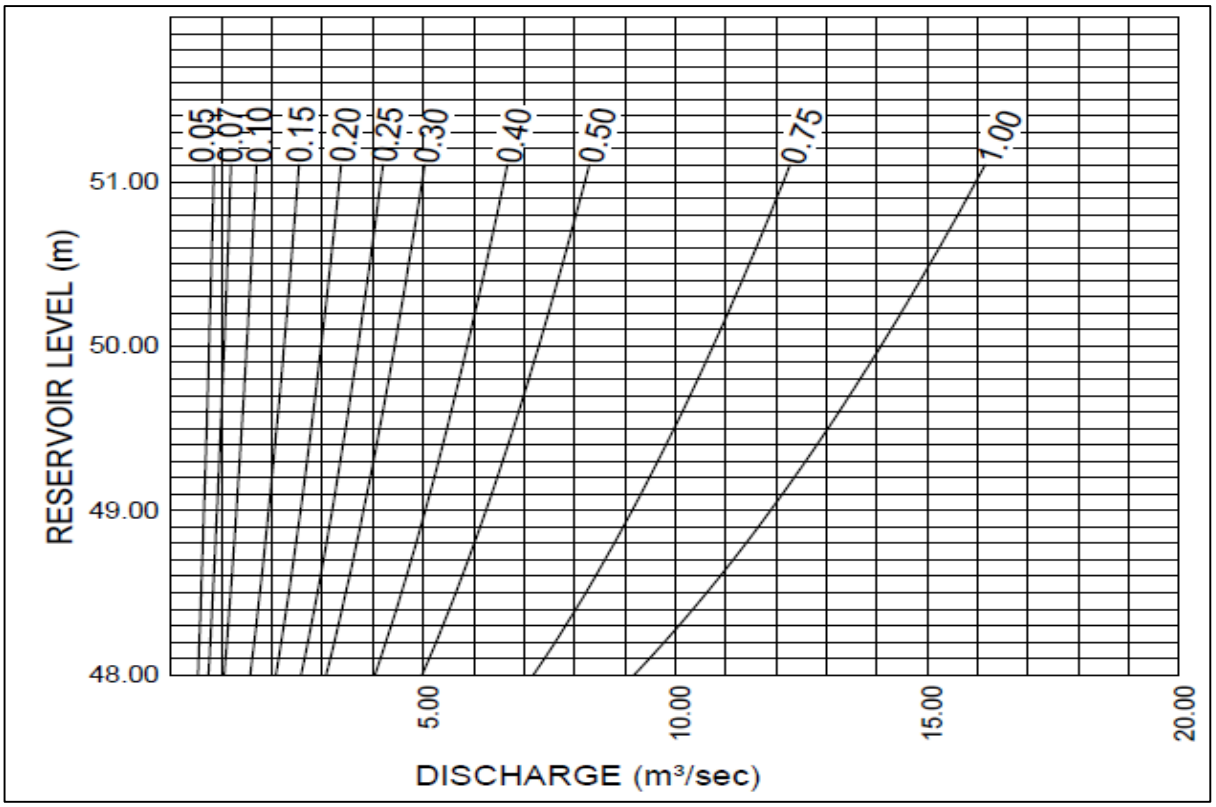


Figure 2.2: Stage discharge curve of scour sluice

2.7 Rule Curve

Rule curves with dynamic flood cushion for moderating the floods of lower return periods are provided for reservoirs having a storage of more than 200 MCM only. Hence No Rule curve is adopted for Perumthenaruvi.

2.8 Emergency Action Plan

Emergency Action Pan(EAP) is prepared and published in the web site.

2.9 Record Keeping

The records regarding dam and appurtenant structures including detailed drawings and construction details shall be kept at the field office and DSO. Also documents as per the dam safety guidelines and DSA 2021 shall be kept at the dam site office. Following records of reservoir operations shall be maintained:

1. Data of Rain gauges in the catchment area.
2. Reservoir levels on daily basis during non-monsoon and at short interval as decided during monsoon.
3. Depth of out flow over the spillway during monsoon.
4. Spillway outflows.
5. Power releases.
6. All operating procedures

Chapter 3 : Project Inspection

An effective inspection program is essential to identify problems and to keep a dam in a good and healthy condition. Inspection details and suggestions are kept at field office and reports send to higher offices. The Deputy Chief Engineer in presence of Executive Engineer and field officers shall carryout pre-monsoon and post-monsoon inspections as per CWC guidelines in the format issued by CWC. The Deputy Chief Engineer shall submit the inspection report to the Chief Engineer for onward transmission to CWC. The Executive Engineer at site shall conduct quarterly inspections and inform any remedial measures to be taken to higher ups. The inspection reports are to be uploaded in DHARMA. Also SDSO conducts pre monsoon & Post monsoon inspections. The dam comes under the specified dam category as per Dam Safety Act 2021.

3.1 Types of inspections

Safety inspections are to be carried out for Perumthenaruvi Diversion Weir as this is a specified dam as per DSA 2021. These include, but not limited, to the following:

1. Comprehensive dam safety evaluation shall be done as per DSA 2021
2. Scheduled inspections (Pre & Post monsoon inspections & other scheduled inspections)
3. Special (Unscheduled) inspections
4. Informal inspections.

The frequency of each type of inspection depends on the condition of the weir and State DSO regulations, etc. A comprehensive health checklist for recording the status of each item being inspected and the overall condition of the structures along with any consequential risks on the health of the weir and appurtenant structures is required to be maintained.

3.2 Comprehensive Evaluation Inspections

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

- General assessment of hydrologic and hydraulic conditions, review of 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, appurtenant works etc.
- 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.

3.3 Scheduled Inspections

Scheduled inspections by dam owner include pre and post monsoon inspections which include;

- 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 and also to be forwarded to NDSA & SDSO.

3.3.1 Pre and Post-Monsoon Inspection

The form and checklist provided as Annexure B to the Guidelines for Safety Inspection of Dams published by Central Water Commission, shall be followed for conducting scheduled inspections including Pre and Post Monsoon Inspections.

3.3.2 Special (Unscheduled) Inspections

Special inspections may need to be performed to resolve specific concerns or conditions at the site on a non-scheduled 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 SDSO after an initial assessment based on informal inspection carried out by project personnel reveal dam safety related concerns like cracking in the weir, damages, erosion/scour, undermining/piping/sinkholes/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.

3.4 Informal Inspections

An informal inspection, is a continuing effort by on-site personnel (dam owners 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 Perumthenaruvi Diversion Weir 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 hydro mechanical components prepared based on manual of operating parts is included in Chapter 2 - Project operation and section 4.4.2 Routine Maintenance. This shows tasks to be performed and how frequently to be inspected/observed and repaired.

4.2 Maintenance Priorities

Maintenance activities need to be prioritized. In the order of priority, they need to be included under the heads Immediate maintenance & Preventive maintenance.

4.3 Immediate Maintenance

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

- The dam is about to be overtopped or being over topped 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.

4.4 Preventive Maintenance

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

4.4.1 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 area etc.
- Repairs on u/s face of dams in case the lift joints is damaged resulting in increased seepage.
- Controlling any heavy seepage in the foundation
- Repairs of any cracks/ cavities/ joints in concrete structures.

However, many of these works will require the services of experienced engineers/ experts.

4.4.2 Routine Maintenance

Several tasks should be performed on a continuous basis. These include but 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 (muddy) 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 etc. Servicing of gates (Intake and Emergency gates), hoisting arrangements of gates, valves of outlet works/sluices
- Maintaining proper lighting at dam top.
- Maintenance access roads.
- Operation of electrical and mechanical equipment and systems
- To keep the gate slots, clear of silt/debris.
- Maintenance/testing of monitoring equipment and safety alarms.
- Testing of security equipment.
- Testing of communication equipment.
- Any other maintenance considered necessary.

4.5 Maintenance to the vertical lift gates

Vertical lift gates are provided at the intake of the weir for controlling the flow to power channel and at scour outlet. The aspects to be inspected and maintained periodically for ensuring proper operation of these gates are as under;

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

ii) The gate leaf should be thoroughly cleaned and repainted at 5year interval or as and when necessary according to the procedure or guidelines- indicated in IS: 14177 or as per the recommendations of the paint manufacturer. All drain holes provided in the gate assembly should be cleaned.

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

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

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

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

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

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

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

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

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

xii) All nuts and bolts shall be tightened.

xiii) 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 re painted, 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. Grease should be applied on friction surfaces to avoid binding. As rust is especially damaging to contact surfaces, existing rust is to be removed before periodic application of grease.

4.6 Maintenance to 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 frequently to ensure that they are functioning properly and to remove accumulated debris periodically as per site requirements.

4.7 Trash Rack Cleaning

Regular trash cleaning from the trash rack panels installed in front of the Canal Intake structure is an integral part of the functioning of turbines. There are seven Panel slots in front of intake area and three panel slots and one additional slot in scour area. The gap between trash rack bars are 100mm. The accumulation of floating trash, bottles, vegetation, bamboo stumps, decayed vegetables, domestic wastes, dead animals etc. will be prevented by the trash rack structure installed in weir to enter. Regular trash rack cleaning is necessary in monsoon days for the proper functioning of turbines.

4.7.1 Trash Rack Raking System

A mechanical trash rack raking tray is installed in front of all 10 main trash rack slots. The raking tray is suspended by wire ropes and pulley. The tray can be pulled with the help of a grip hoist available at site. The pulling operation can be done from the trash rack deck slab level. Anchoring hooks have been provided on the weir body in front of every trash rack slots for anchoring the grip hoist. There is a guide slot on the trash rack pier, which guides the trash rack raking tray in a vertical direction. Three wheels are also installed on each tray to reduce the sliding friction with trash rack bars.

4.7.2 Raking Operation

- Connect one end of the grip hoist to the hook provided in the weir body.
- Connect the other end to the middle hook in wire rope of trash rack raking system.
- Pull the rope by operating the hand liver of the grip hoist until the trash rack tray reaches to a convenient level for removing the trash manually.
- The trash may be collected manually from the deck slab level or at water level by using pontoons.
- The removed trash may be suitably disposed at a convenient location.
- The raking operation can be done one after another

4.7.3 Safety

- Only experienced divers are allowed to work in trash rack cleaning job.
- No workman is allowed to work alone in the water way.
- Do not work under a trash rack tray which is kept in a raised position.
- Personal protection devices such as safety belts, goggles, hand gloves and lifebuoys shall be used while engaging in trash rack cleaning job.

4.7.4 Maintenance

Lubricants shall be applied on the pulleys, wheels, grip hoist and other moving parts of

the raking system once in a month. Cardium compound shall be applied on the wire ropes to protect the rope from corrosion.

4.8 Maintenance of access roads

Access road surfaces must be maintained to allow safe passage of automobiles and any required equipment for servicing the dam in all 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 a long road for proper drainage. This will prolong the life of the road. Road surfacing should be repaired or replaced as per requirement.

4.9 General cleaning

For proper operation of spillways, inlet and outlet structures, energy dissipation arrangements, dam slopes, trash racks, debris control devices etc., regular and thorough cleaning and removal of debris is necessary. Cleaning is especially important after large floods, which tend to send more debris in to the reservoir.

4.10 Materials and establishment requirements during monsoon

Materials required during monsoon period for both immediate maintenance and preventive maintenance must be stocked inadequate quantities for emergency situations that may arise. Details of man power/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

4.11 Preparation of O&M Budget

The O&M budget for should essentially include the following items:

i) **Establishment Cost of Regular Staff** - Salaries and other eligible allowances,

ii) **Establishment Cost of Work charged Staff** - salaries and other eligible allowances,

iii) **Office Expenses** – Telephone/Mobile/any other Telecommunication facility, 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 etc

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, 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 access roads & basic facilities, provision for flood contingency works during monsoon, unforeseen events/ items etc.

4.12 Maintenance Records

Maintenance records are of utmost importance. A record register 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 time taken to complete the work with dates,
- Equipment and materials used, and
- Before and after photographs.
- Due date for next maintenance.

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

Chapter 5 : Instrumentation and Monitoring

Perumthenaruvi weir is a small weir with free overflow spillway. Galleries are not provided. Reservoir water level is monitored daily.

5.1 Seismic Activity

The project area falls in zone No. III of the seismic zone map of India. The weir is designed for seismic stability as per BIS 6512 Historical significant earthquake events in the near vicinity areas were under

Event1: Date: 1998, Epicenter: Nedumkandam, Magnitude : 4.5 and

Event2 : Date: 1/07/2001, Epicenter: Erattupetta, Magnitude: 5 . 1 3 which occurred before construction of the weir.

Nearest Seismic observatory is at Vallakkadavu.

5.2 Dam Performance Evaluation

Performance evaluation is to be conducted for safe normal operation before and after monsoon.

5.3 Methods of Behavior Prediction

5.3.1 Visual Observations

Observations by onsite inspection of officials (dam owners/operators and maintenance personnel) may be the most important and effective means of monitoring the performance of a dam. An officer should examine visually by walking along the dam alignment to see if any leakages, any distress, wet spots on the surface of weir, seepage from foundation etc. is there.

5.3.2 Monitoring Results

Analysis and observation of the water level, leakages, and other parameters can ascertain the behavior of the dam. Any deviation from the normal behavior needs to be resolved critically by taking required remedial measures in consultation with senior / experienced engineers.

Chapter 6 : Previous Rehabilitation Works

6.1 Works carried out

The dam was commissioned on October 2017 and no major Rehabilitation works were necessitated.

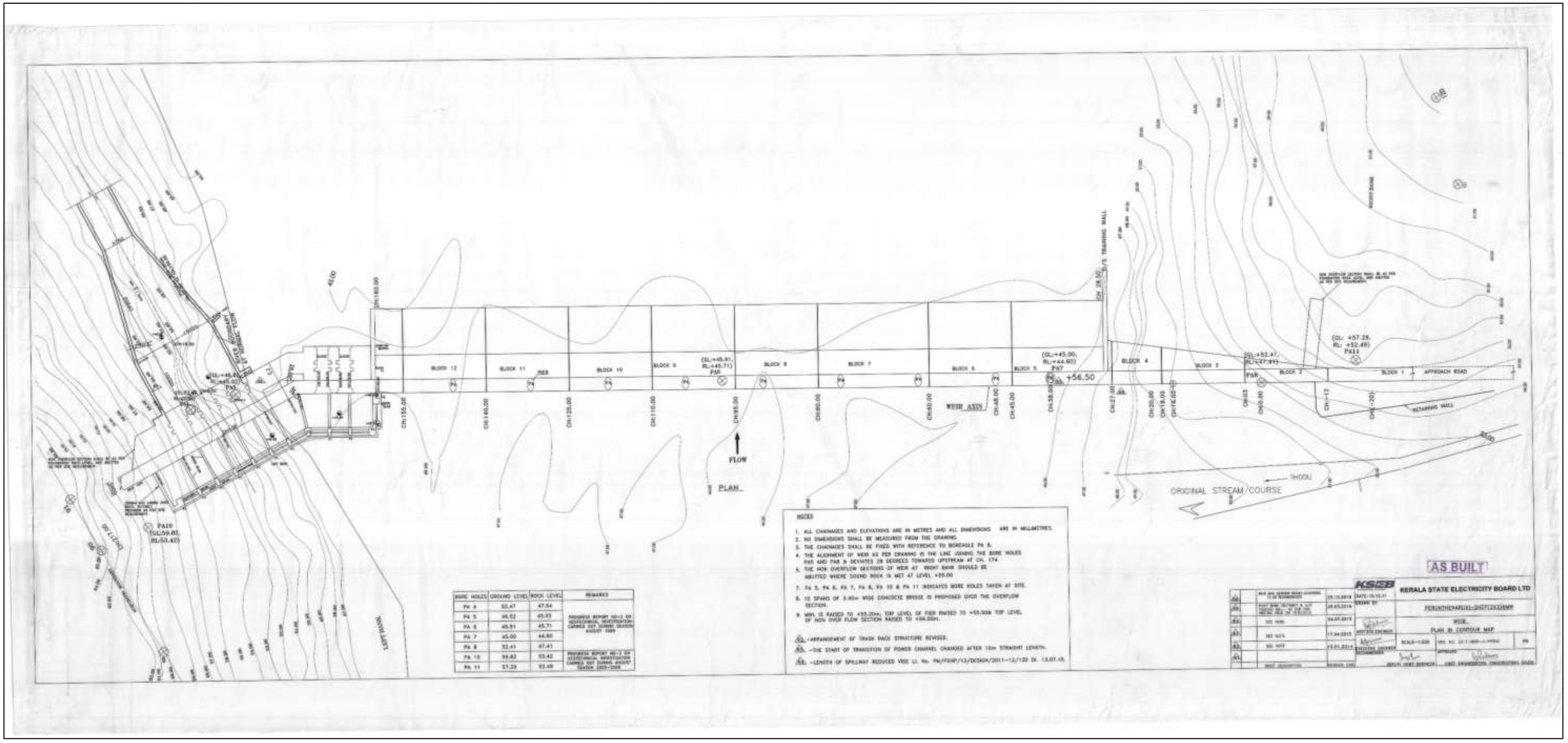
Chapter 7 : Updating the Manual

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.

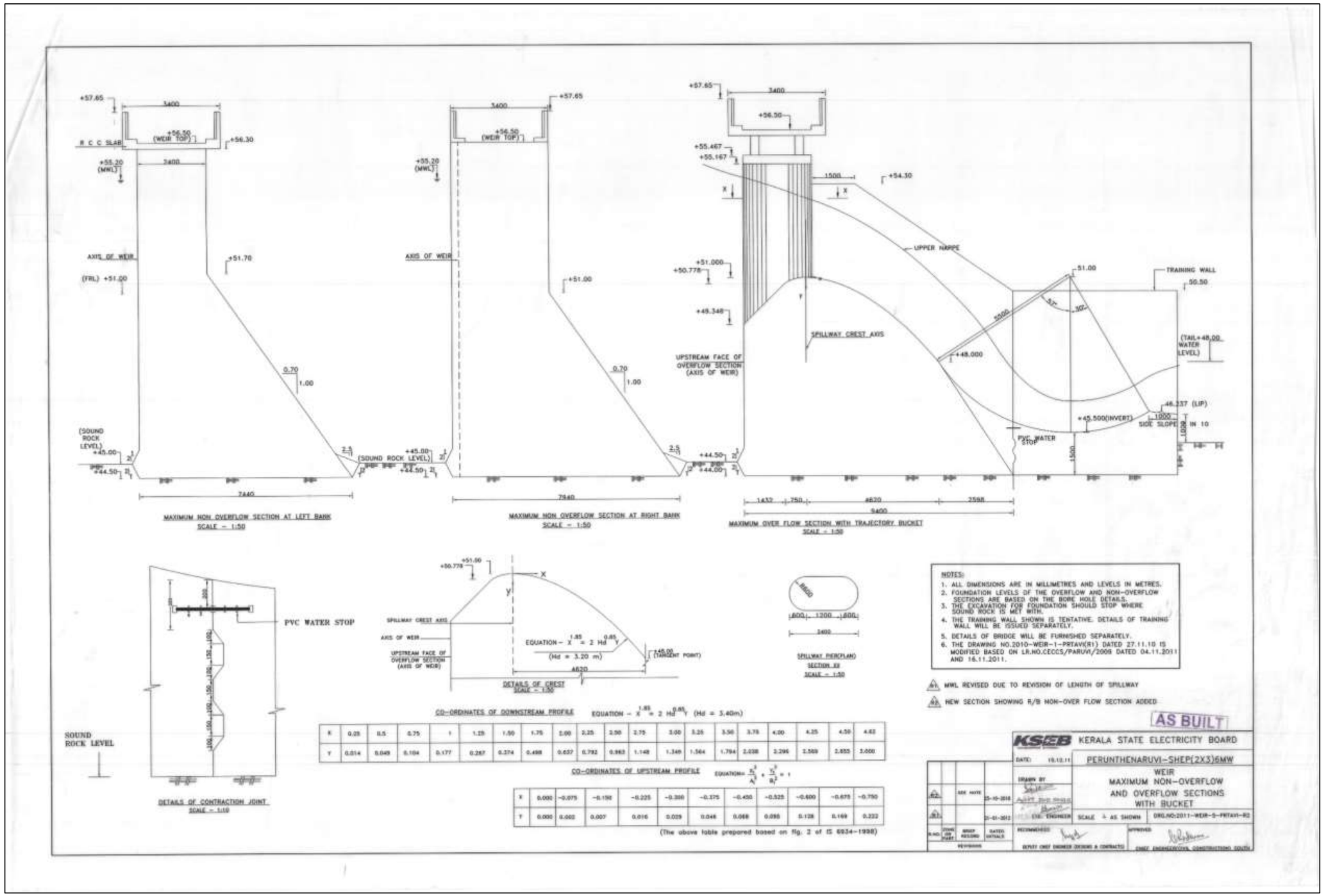
Aspects to be considered when updating the Manual must include Increase/decrease in the frequency of an inspection or the maintenance routine based on additional data/experience acquired, Changes in the operation and/or maintenance procedures based on additional data/ experience acquired, Alterations 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 maybe reviewed/ updated after every 10 years or whenever there is any change in the information given in the Manual needs updation by the respective Dam Owners.

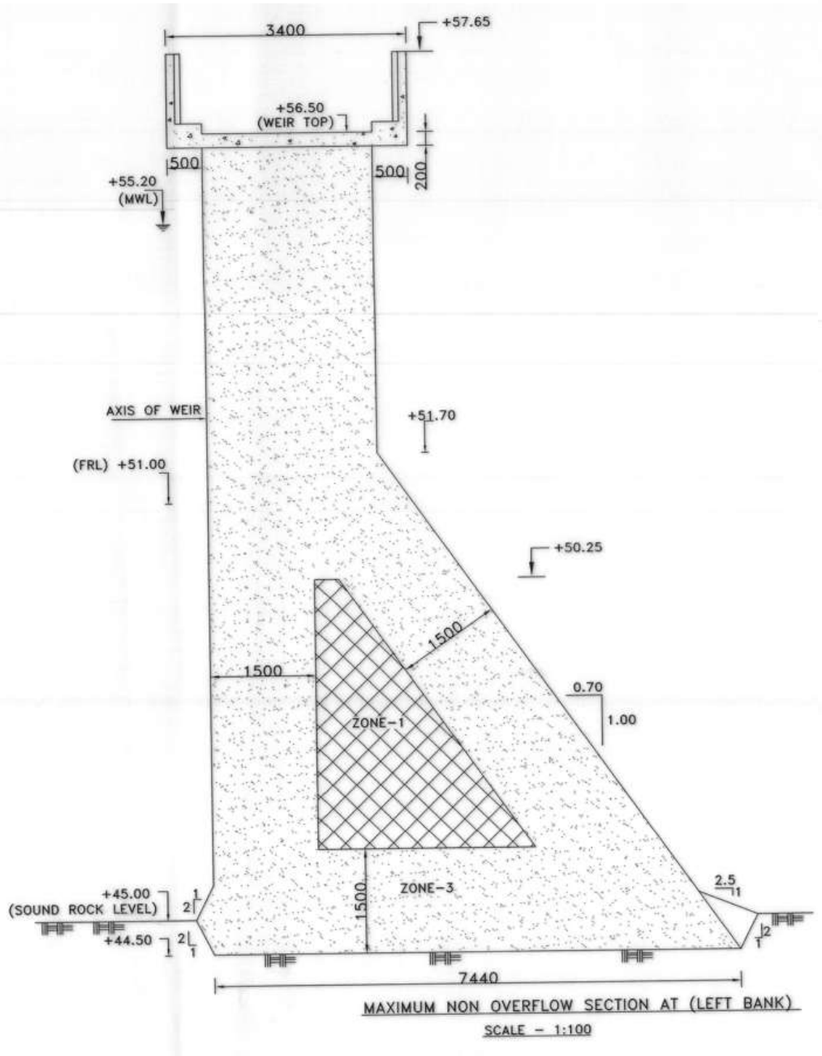
ANNEXURE I - DRAWINGS

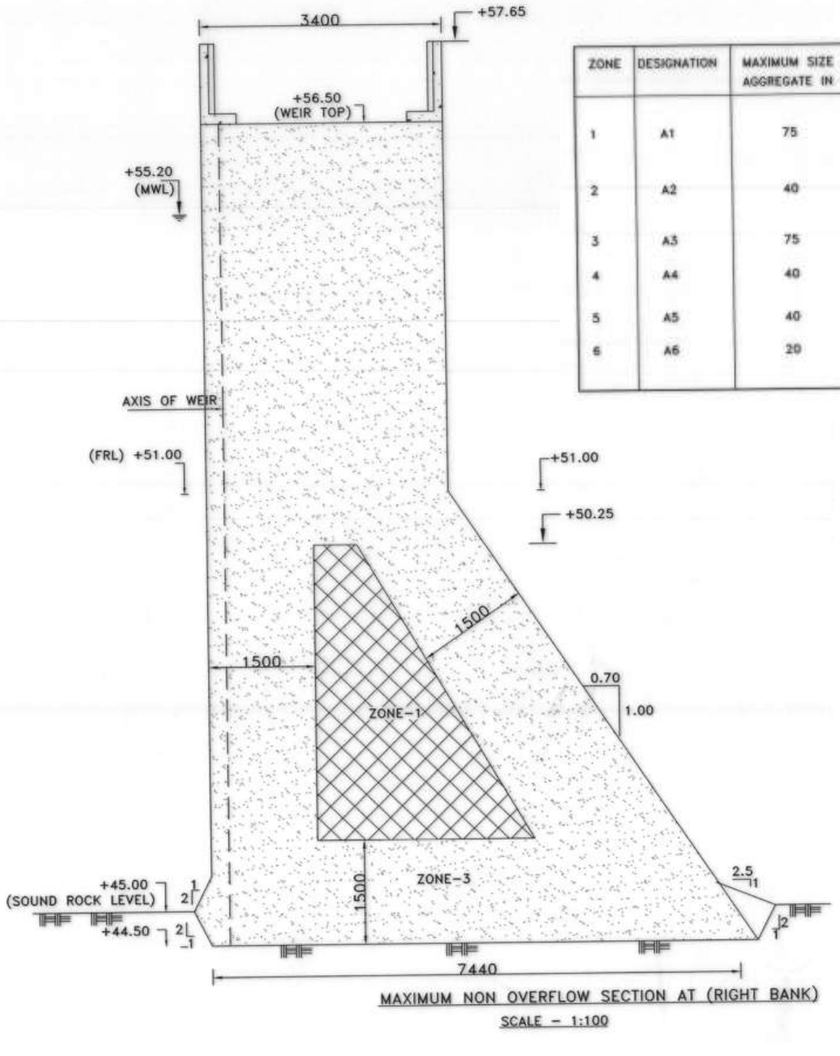


Drg 1: Plan - Perumthenaruvi Diversion Weir



Drg 2: Section - Perumthenaruvi Diversion Weir

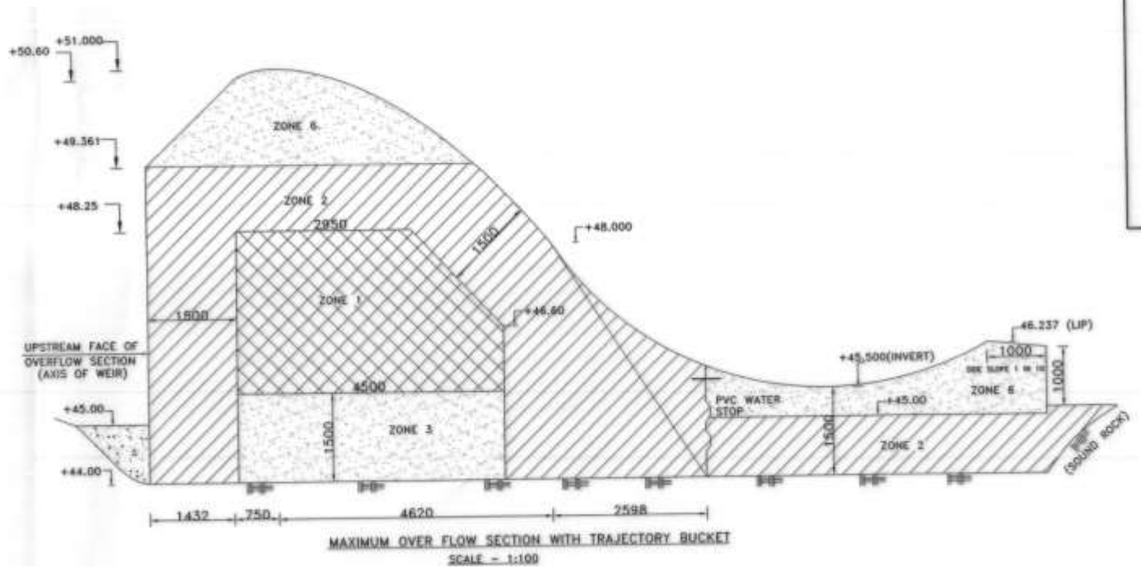




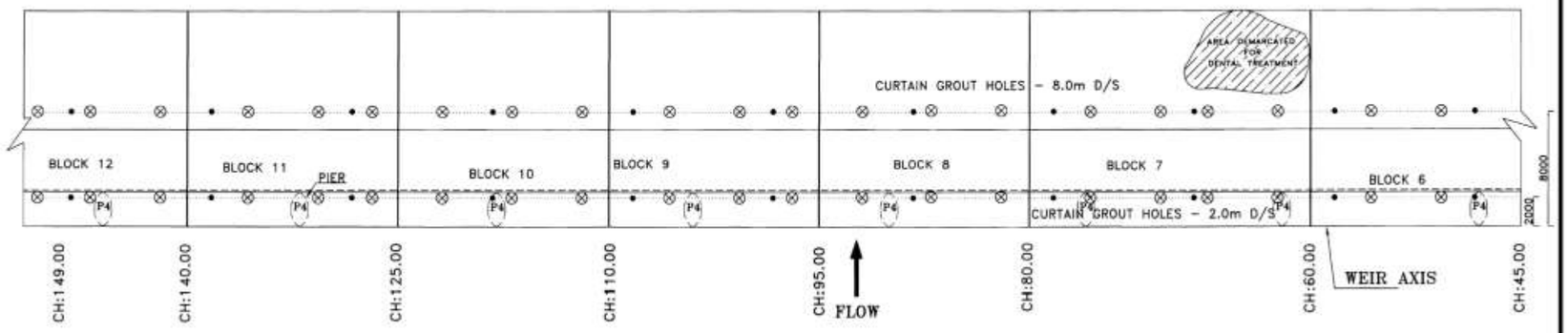
ZONE	DESIGNATION	MAXIMUM SIZE OF AGGREGATE IN MM	28 DAYS COMPRESSIVE STRENGTH OF 150 MM CUBES (Newton/Sq.mm)	NOTATION
1	A1	75	15	
2	A2	40	20	
3	A3	75	20	
4	A4	40	15	CREVICES FILLING
5	A5	40	20	TRAINING WALL,PIER
6	A6	20	20	

Drg 3- Zoning of Concrete at Overflow and Non – Overflow Sections - Perumthenaruvi SHEP

ZONE	DESIGNATION	MAXIMUM SIZE OF AGGREGATE IN MM	28 DAYS COMPRESSIVE STRENGTH OF 150 MM CUBES (Newton/Sq.mm)	NOTATION
1	A1	75	15	
2	A2	40	20	
3	A3	75	20	
4	A4	40	15	CREVICES FILLING
5	A5	40	20	TRAINING WALL,PIER
6	A6	20	20	

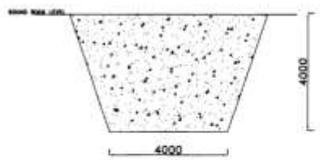


Drg 5- Zoning of Concrete at Spillway Bucket Portion - Perumthenaruvi SHEP



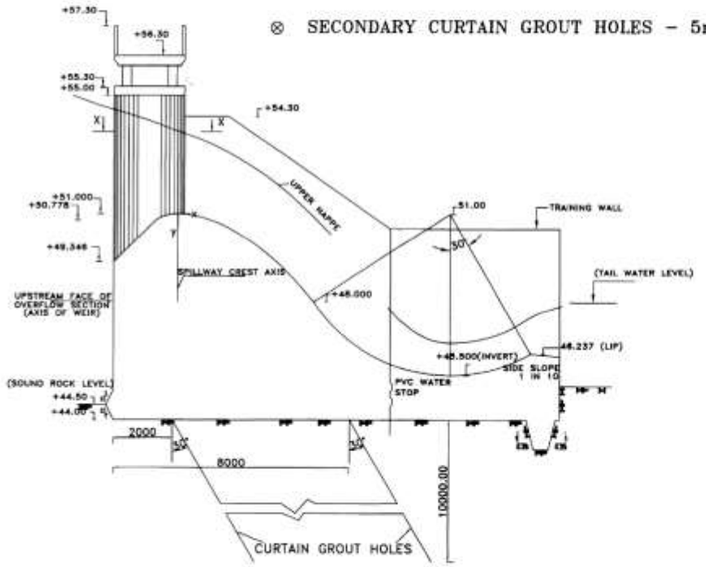
PLAN OF WEIR

SCALE – 1:200



CROSSSECTION SHOWING MAXIMUM SIZE OF DENTAL TREATMENT FROM CH.60 TO 68

- PRIMARY CURTAIN GROUT HOLES – 10.0m INTERVAL
- ⊗ SECONDARY CURTAIN GROUT HOLES – 5m INTERVAL



MAXIMUM OVER FLOW SECTION SHOWING CURTAIN GROUT HOLES.

SCALE – 1:100

NOTES

1. ALL CHAINAGES AND ELEVATIONS ARE IN METRES AND ALL DIMENSIONS ARE IN MILLIMETRES.
2. NO DIMENSIONS SHALL BE MEASURED FROM THE DRAWING.
3. THE CHAINAGES SHALL BE FIXED WITH REFERENCE TO BOREHOLE PA 8.
4. ALL DETAILS AS PER GSI REPORT (CONSTRUCTION STAGE) DATED 08.03.2013 SHALL BE ADHERED TO, BEFORE CONCRETING OF WEIR.
5. THE GROUT HOLES ARE TO BE DRILLED IN THE DOWNSTREAM DIRECTION i.e TOWARDS WESTERLY DIRECTION AT AN INCLINATION OF 30° FROM VERTICAL FOR A DEPTH OF 10.0m.
6. DENTAL TREATMENT WITH CEMENT CONCRETE M20 MSA 40 IS TO BE PROVIDED ALONG THE WEATHERED PEGMATITE ROCK OCCURING BETWEEN CH:60.0 & CH:68.00 (OFFSET BETWEEN 10.0m & 14.0m D/S.)
7. SHEAR PLANES ARE TO BE TREATED BY REMOVING THE CLAY/ GOUGE MATERIAL AND BACKFILLED WITH CONCRETE BEFORE LAYING THE FOUNDATION.
8. IN VIEW OF CLOSED SPACED RIVER PARALLEL JOINT PLANES, TWO ROWS OF CURTAIN GROUTING TO BE CARRIED OUT, AT OFFSET 2.0m D/S AND ANOTHER AT OFFSET 8.0mD/S
9. THE GROUTING HAS TO BE FOLLOWED IN A PHASED MANNER, INITIALLY PRIMARY GROUT HOLES SHALL BE PLACED AT 10.0m INTERVAL, ALL ALONG THE WEIR SITE. AFTER GROUTING THE PRIMARY HOLES, WATER LOSS TEST SHALL BE CARRIED OUT BY DEPLOYING SECONDARY HOLES AT 5.0m INTERVALS. IF THE WATER LOSS STILL PERSISTS THIS MAY BE REPORTED TO THIS OFFICE.
10. DEPTH OF DENTAL TREATMENT SHALL BE 0.3b+5 ft. WHERE b IS THE WIDTH OF WEAK ZONE IN FEET.
11. THE LOCATION OF CURTAIN GROUT HOLES CAN BE SUITABLY MODIFIED IF SITE CONDITION WARRANTS
12. CURTAIN GROUT HOLES SHALL NOT BE WITHIN 1.5 M FROM CONTRACTION JOINTS.
13. FOR MORE DETAILS REFER IS 6066–1984 &IS 11293

Ref.No.30

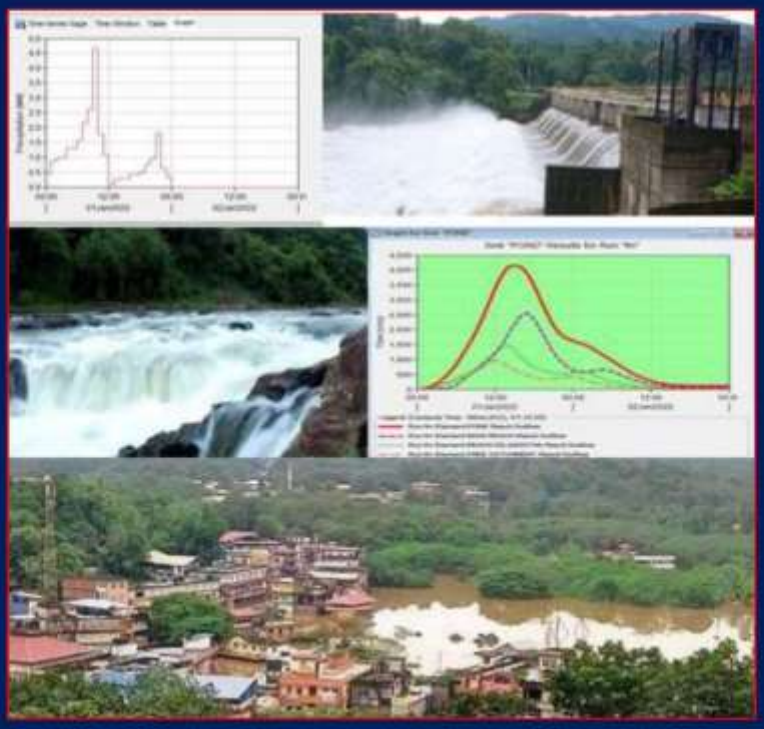
				DATE: 26.04.2013	KERALA STATE ELECTRICITY BOARD
					PERUNTHENARUVI–SHEP(2X3)MW
				DRAWN BY	WEIR
				ASST: EXE: ENGINEER	DETAILS OF CURTAIN GROUTING FROM CH:50.0m TO 149.0m
				RECOMMENDED EXECUTIVE ENGINEER	SCALE–AS SHOWN / DRG. NO: 2013–WEIR– 7 –PRTAVI
R.NO.	ZONE OR PART	BRIEF RECORD	DATED INITIALS	APPROVED	
REVISIONS				DY.CHIEF ENGINEER (DESIGNS) WITH FULL POWERS OF CHIEF ENGINEER	

Drg 6- Details of Curtain Grouting - Perumthenaruvi SHEP

ANNEXURE II - Design Flood Review

DESIGN FLOOD REVIEW

PERUMTHENARUVI DIVERSION WEIR



1/KSEBL/DFR/PERUMTHENARUVI/2022

KERALA STATE ELECTRICITY BOARD LIMITED

Chief Engineer (Civil – Dam Safety & DRIP)

December 2022

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Annexure: SUH Parameters

Report on Design Flood Review of Perumthenaruvi Diversion Weir

1. Background

Perumthenaruvi diversion weir is constructed as part of Perumthenaruvi Small Hydro Electric Project (2X3 MW). The project is located in Pathanamthitta District. The weir is constructed across river Pamba in the upstream of Perumthenaruvi falls. There are two dam projects viz; Pamba & Kakki located in the upstream region of this project. There is also a diversion from this catchment to Periyar basin from the upstream reaches of Azhutha stream, a tributary of Pamba. There is a diversion from Moozhiyar, a stream flowing on the Southern side of Kakki stream which is a tributary of Pamba, to Kakki reservoir. Diversions are there from Kullar& Gaviar two small streams, which are tributaries of Pamba and they join with river Pamba before Thriveni confluence, flowing on the northern side of Pamba stream to Pamba reservoir. Diversion from Azhutha & from Moozhiyar is not considered in the study, as the rate of diversion will be negligibly small compared to the inflow at Perumthenaruvi during extreme scenario like the one cause due to the occurrence of a rainfall with larger return period, like a storm of return period 100 years, over the basin. Controlled diversion will be there from upstream reaches of the river to Sabarigiri Power Station to the tune 50-55 m3/s, generally during monsoon from Pamba and Kakki dam Projects. Inflow to the Perumthenaruvi Project during extreme scenario will be mostly the spill from Pamba & Kakki reservoirs plus the inflow from downstream uncontrolled catchment. Azhutha is the major tributary of Pamba in the upstream reaches of Perumthenaruvi. Project lay out is shown in Figure 1.1.

Figure 1.1 : Project Layout

The length of the weir is 227.5 m. Length of overflow section is 131.5 m. Height of the structure from deepest foundation level is 12.2 m. The hydraulic head is about 7 m. Pondage is 1 Mm3. The cross section of overflow section is shown as Figure 1.2 and Plan of the Structure is shown as Figure 1.3.

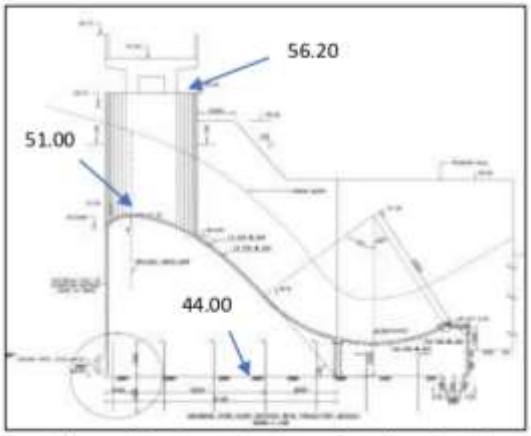

Figure 1.2 : Cross Section – Overflow Section

Design flood of the project is estimated with updated information and following the procedure laid down in Flood Estimation Report & PMP Atlas 2015 published by the Central Water Commission. DFR studies are now made as part of conducting the dam break analysis of specified dams to determine the extent of inundation and to estimate the flood hazard parameters. Flood estimation is performed using HMS Tool.

2. Project catchment

The catchment area of the project is 758 Km2. The Pamba & Kakki dams controls 293 Km2 of the catchment. The uncontrolled catchment of the project is 465 Km2. Catchment area map of the project is shown in Figure 2.1.

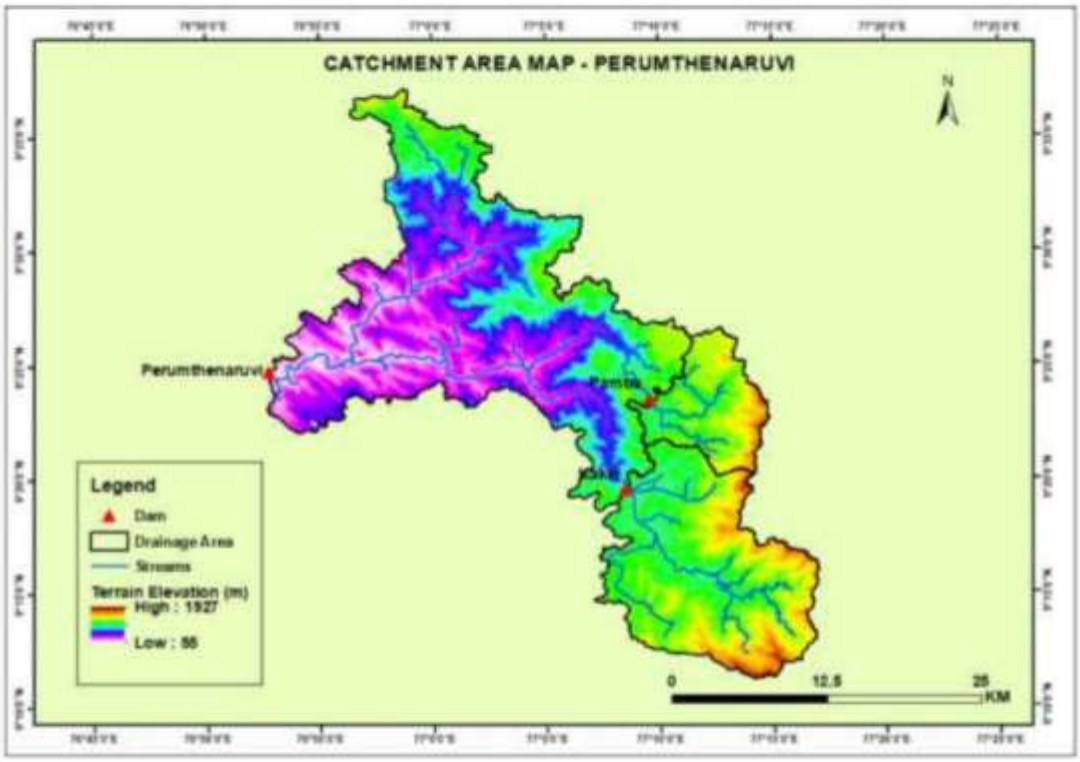

Figure 2.1 : Catchment Area Map

3. Categorisation

The hydraulic head of weir is less than 12 m and storage less than 10 MCM. Hence the design storm for the project to estimate design flood is the one with a return period of 100 years.

4. Design storm

Design storm with a return period of 100 years is taken from PMP Atlas 2015. The project catchment is superimposed over the shape file of isohyetal map of 100 yerar return period storm in GIS. The spatial average of rain fall over the catchment is estimated after rasterising the isohyets. The project catchment is divided in to four sub catchments. Sub catchment Pamba with outlet at Thriveni, Sub catchment Kakki with outlet at Thriveni, Sub catchment Azhutha with outlet at its confluence with Pamba & then the catchment downstream of Thriveni. Average rain over this sub catchments is calculated in GIS. Isohyetal map of the catchment is shown in Figure 4.1.

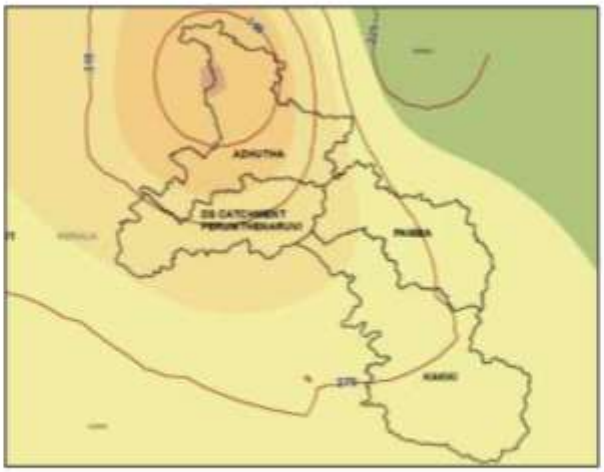

Figure 4.1 : Isohyetal Map of 100 Yr. Return Period Rainfall

Average rainfall over sub catchment Pamba is 27.38 cm. 12 hr bell distribution of rainfall is shown in Table 4.1. Hourly distribution of rain fall is shown in Table 4.2. Loss considered is 0.19 cm/hr. The rain fall excess is shown in the Table 4.3. Rainfall series after Critical sequencing is shown in Table 4.4. and Figure 4.2.

1day areal 100 Yr. RP rainfall	27.38 cm
24 hr. aerial 100 yr. RP rainfall (with 15% clock hour correction restricted to maximum 50 mm)	31.49 cm
Depth of 12 hr. bell (0.71 x 31.49)	22.36 cm

Table 4.1: 12 Hr Bell Distribution - Pamba

Time	Hourly Distribution (cm)
1	4.94
2	2.87
3	2.39
4	1.99
5	1.51
6	1.16
7	1.76
8	1.51
9	1.20
10	1.07
11	0.66
12	1.29

Table 4.2: Hourly Distribution - Pamba

Time	Hourly Rainfall excess (cm)
1	4.75
2	2.68
3	2.20
4	1.80
5	1.32
6	0.97
7	1.57
8	1.32
9	1.01
10	0.88
11	0.47
12	1.10

Table 4.3: Hourly Rainfall excess - Pamba

Time	Hourly rainfall after critical sequencing (cm)
1	0.47
2	0.57
3	0.88
4	0.97
5	1.01
6	1.32
7	1.32
8	1.57
9	2.20
10	2.68
11	4.75
12	1.80

Table 4.4: Hourly Rainfall after critical sequencing – Pamba

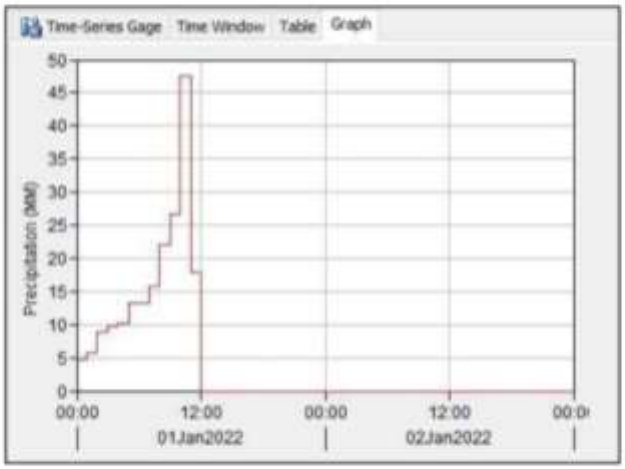

Figure 4.2: Hourly Rainfall after critical sequencing – Pamba

Average rainfall over Sub catchment Kakki is 26.98 cm. 12 hr bell distribution of rainfall is shown in Table 4.5. Hourly distribution of rain fall is shown in Table 4.6 and 4.7. Loss considered is 0.19 cm/hr. The rain fall excess is shown in the Table 4.8 and 4.9. Rainfall series after Critical sequencing is shown in Table 4.10 and Figure 4.3.

1day areal 100 Yr. RP rainfall	26.98 cm
24 hr. aerial 100 yr. RP rainfall (with 15% clock hour correction restricted to maximum 50 mm)	31.03 cm
Depth of 1st 12 hr. bell (0.71 x 31.03)	22.03 cm
Depth of 2nd 12 hr. bell (0.29 x 31.03)	9.00 cm

Table 4.5: 12 Hr Bell Distribution-Kakki

Time	Hourly Distribution of 1st 12 hrs bell (cm)
1	4.87
2	2.82
3	2.36
4	1.96
5	1.49
6	1.15
7	1.74
8	1.49
9	1.18
10	1.06
11	0.65
12	1.27

Table 4.6: Hourly Distribution of 1st 12 hr bell - Kakki

Time	Hourly Distribution of 2nd 12 hrs bell (cm)
1	1.99
2	1.15
3	0.96
4	0.80
5	0.61
6	0.47
7	0.71
8	0.61
9	0.48
10	0.43
11	0.27
12	0.52

Table 4.7: Hourly Distribution of 2nd 12 hr bell - Kakki

Time	Hourly Rainfall excess of 1st 12 Hr bell (cm)
1	4.68
2	2.63
3	2.17
4	1.77
5	1.30
6	0.96
7	1.55
8	1.30
9	0.99
10	0.87
11	0.46
12	1.08

Table 4.8: Hourly Rainfall excess of 1st 12 Hr bell – Kakki

Time	Hourly Rainfall excess of 2nd 12 Hr bell (cm)
1	1.80
2	0.96
3	0.77
4	0.61
5	0.42
6	0.28
7	0.52
8	0.42
9	0.29
10	0.24
11	0.08
12	0.33

Table 4.9: Hourly Rainfall excess of 2nd 12 Hr bell – Kakki

Time	Hourly rainfall after critical sequencing (cm)
1	0.46
2	0.87
3	0.96
4	0.99
5	1.30
6	1.30
7	1.55
8	2.17
9	2.63
10	4.68
11	1.77
12	1.08
13	0.08
14	0.24

7

15	0.28
16	0.29
17	0.42
18	0.42
19	0.52
20	0.77
21	0.96
22	1.80
23	0.61
24	0.33

Table 4.10: Hourly Rainfall after critical sequencing – Kakki

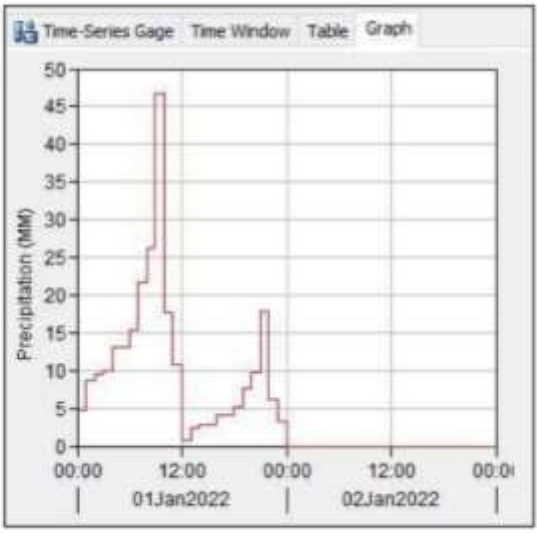

Figure 4.3: Hourly Rainfall after critical sequencing – Kakki

Average rainfall over sub catchment Azhutha is 33.84 cm. 12 hr bell distribution of rainfall is shown in Table 4.11. Hourly distribution of rain fall is shown in Table 4.12 and 4.13. Loss considered is 0.19 cm/hr. The rain fall excess is shown in the Table 4.14 and 4.15. Rainfall series after Critical sequencing is shown in Table 4.16 and Figure 4.4.

1day areal 100 Yr. RP rainfall	33.84 cm
24 hr. aerial 100 yr. RP rainfall (with 15% clock hour correction restricted to maximum 50 mm)	38.84 cm
Depth of 1st 12 hr. bell (0.71 x 38.84)	27.58 cm
Depth of 2nd 12 hr. bell (0.29 x 38.84)	11.26 cm

Table 4.11: 12 Hr Bell Distribution-Azhutha

Time	Hourly Distribution of 1st 12 hrs bell (cm)
1	6.10
2	3.54
3	2.95
4	2.45
5	1.86
6	1.44
7	2.18
8	1.86
9	1.48
10	1.32
11	0.82
12	1.59

Table 4.12: Hourly Distribution of 1st 12 hr bell – Azhutha

Time	Hourly Distribution of 2nd 12 hrs bell (cm)
1	2.49
2	1.44
3	1.21
4	1.00
5	0.76
6	0.59
7	0.89
8	0.76
9	0.60
10	0.54
11	0.33
12	0.65

Table 4.13: Hourly Distribution of 2nd 12 hr bell - Azhutha

Time	Hourly Rainfall excess of 1st 12 Hr bell (cm)
1	5.91
2	3.35
3	2.76
4	2.26
5	1.67
6	1.25
7	1.99
8	1.67
9	1.29
10	1.13
11	0.63
12	1.40

Table 4.14: Hourly Rainfall excess of 1st 12 Hr bell – Azhutha

Time	Hourly Rainfall excess of 2nd 12 Hr bell (cm)
1	2.30
2	1.25
3	1.02
4	0.81
5	0.57
6	0.40
7	0.70
8	0.57
9	0.41
10	0.35
11	0.14
12	0.46

Table 4.15: Hourly Rainfall excess of 2nd 12 Hr bell – Azhutha

Time	Hourly rainfall after critical sequencing (cm)
1	0.63
2	1.13
3	1.25
4	1.29
5	1.67
6	1.67
7	1.99
8	2.26
9	3.35
10	5.91
11	2.76
12	1.40
13	0.14
14	0.35
15	0.40
16	0.41
17	0.57
18	0.57
19	0.70
20	0.81
21	1.25
22	2.30
23	1.02
24	0.46

Table 4.16: Hourly Rainfall after critical sequencing – Azhutha

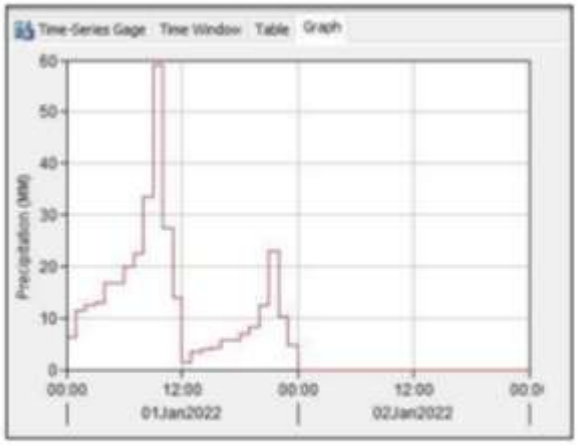

Figure 4.4: Hourly Rainfall after critical sequencing – Azhutha

Average rainfall over sub catchment downstream of Pamba and Kakki dams is 31.41 cm. 12 hr bell distribution of rainfall is shown in Table 4.17. Hourly distribution of rain fall is shown in Table 4.18 and 4.19. Loss considered is 0.19 cm/hr. The rain fall excess is shown in the Table 4.20 and 4.21. Rainfall series after Critical sequencing is shown in Table 4.22 and Figure 4.5.

1day areal 100 Yr. RP rainfall	31.41 cm
24 hr. aerial 100 yr. RP rainfall (with 15% clock hour correction restricted to maximum 50 mm)	36.12 cm
Depth of 1st 12 hr. bell (0.71 x 36.12)	25.65 cm
Depth of 2nd 12 hr. bell (0.29 x 36.12)	10.48 cm

Table 4.17: 12 Hr Bell Distribution-Downstream Catchment

Time	Hourly Distribution of 1st 12 hrs bell (cm)
1	5.67
2	3.29
3	2.74
4	2.28
5	1.73
6	1.34
7	2.02
8	1.73
9	1.37
10	1.23
11	0.76
12	1.48

Table 4.18: Hourly Distribution of 1st 12 hr bell – Downstream Catchment

Time	Hourly Distribution of 2nd 12 hrs bell (cm)
1	2.32
2	1.34
3	1.12
4	0.93
5	0.71
6	0.55
7	0.83
8	0.71
9	0.56
10	0.50
11	0.31
12	0.60

Table 4.19: Hourly Distribution of 2nd 12 hr bell – Downstream Catchment

Time	Hourly Rainfall excess of 1st 12 Hr bell (cm)
1	5.48
2	3.10
3	2.55
4	2.09
5	1.54
6	1.15
7	1.83
8	1.54
9	1.18
10	1.04
11	0.57
12	1.29

Table 4.20: Hourly Rainfall excess of 1st 12 Hr bell – Downstream Catchment

Time	Hourly Rainfall excess of 2nd 12 Hr bell (cm)
1	2.13
2	1.15
3	0.93
4	0.74
5	0.52
6	0.36
7	0.64
8	0.52
9	0.37
10	0.31
11	0.12
12	0.41

Table 4.21: Hourly Rainfall excess of 2nd 12 Hr bell – Downstream Catchment

Time	Hourly rainfall after critical sequencing (cm)
1	1.04
2	1.15
3	1.18
4	1.29
5	1.54
6	1.83
7	2.09
8	3.10
9	5.48
10	2.55
11	1.54
12	0.57
13	0.31
14	0.36
15	0.37
16	0.41
17	0.52
18	0.64
19	0.74
20	1.15
21	2.13
22	0.93
23	0.52
24	0.12

Table 4.22: Hourly Rainfall after critical sequencing – Downstream Catchment

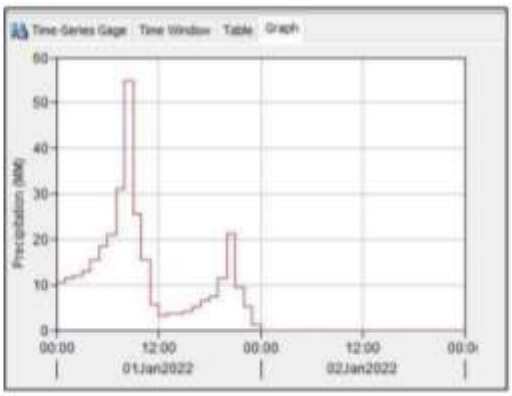

Figure 4.5: Hourly Rainfall after critical sequencing – Downstream Catchment

5. Catchment response

Catchment parameters of sub catchments are estimated using Arc hydro tool in GIS. Longest flow path and slope is determined and is shown in Table 5.1. 1 hr unit hydrograph for the sub catchments is derived using synthetic unit hydro graph parameters provided in the Flood Estimation Report published by Central Water Commission.

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Sl No.	Sub Catchments	Length of Longest Flow Path (Km)	Equivalent Steam Slope in m/Km
1	Pamba	36.9	34.54
2	Kakki	50.1	24.45
3	Azhutha	42.34	16.36
4	Downstream Catchment	35.2	7.93

Table 5.1: Catchment parameters

5.1 Unit Hydrograph

Unit Hydrograph of the Sub catchments are shown in Table 5.2.

Time (Hrs)	SUH ordinates (m3/s)			
	Pamba	Kakki	Azhutha	D/s Catchment
0	0	0	0	0
1	45	35	25	10
2	133	89	60	24
3	86	188	117	46
4	57	130	83	67
5	40	90	58	56
6	26	66	40	44
7	16	53	32	32
8	8	41	28	24
9	3	31	24	19
10	0	22	21	15
11		14	17	12
12		9	13	10
13		5	9	8
14		2	5	6
15		0	0	4
16				3
17				2
18				1
19				0

Table 5.1 – UHG of sub catchments

6. HMS Model

The project is modelled in HEC HMS. The input is rain fall excess of the of the sub catchments (as specified hyetograph) and User specified Unit Hydrograph of sub catchments. The rainfall excess is determined after calculating the spatial average of 100 Yr RP rainfall over the sub catchments and

hourly time distribution as per the FER and then subtracting the losses as specified in FER. Direct runoff hydro graph is generated with the above details. Base flow is considered as 0.15 m3/s per Sq. Km. In the model, it is assumed that the critical scenario occurs when rainfall with 1 in 100 return period falls over the basin when the upstream reservoirs are at Full Reservoir Level. As the inflow to the reservoir will not be subjected to significant moderation to the inflow hydrograph, the sub catchment is not delineated at dam points. The outlet of Pamba and Kakki streams is considered at their confluence at Thriveni. Besides, the DBA is to be carried out for the extreme hydro meteorological condition occurs over the basin.

For reach routing, Muskingum method is considered as the roughness values, cross sectional details etc. of the river to define the river hydraulics is not readily available. For Muskingum method also, estimated parameters for the river is not readily available. Hence K & x parameters are assumed on theoretical basis considering the length of river reach, interval of flood hydrograph ordinates and assumed time of travel between the cross sections under consideration. An average flood velocity of 6 km/hr is assumed as the river downstream of Thriveni is of more or less flat gradient and the flood scenario corresponds to the storm with return period of 100 years. The flow situation in the river may not be extreme like the one caused due to PMP or breach scenario of upstream dams. However, these assumptions are to be validated with the measurements taken at various locations in the river for better precision. The length of sub reaches considered is 6 Km for the reach downstream of Thriveni up to Perumthenaruvi. The K and x value considered for this sub reach is 1 hr & 0.25. K&x of sub reaches considered for routing the outflow Azhutha sub catchment is 0.83 & 0.25.

The HMS model of the Project is shown in the Figure 6.1 below; The elements considered in the model are sub catchment Pamba, sub catchment Kakki, Sub catchment Azhutha, Downstream Sub catchment, Thriveni – Perumthenaruvi reach, Azhutha confluence – Perumthenaruvi reach and sink as Perumthenaruvi pond.

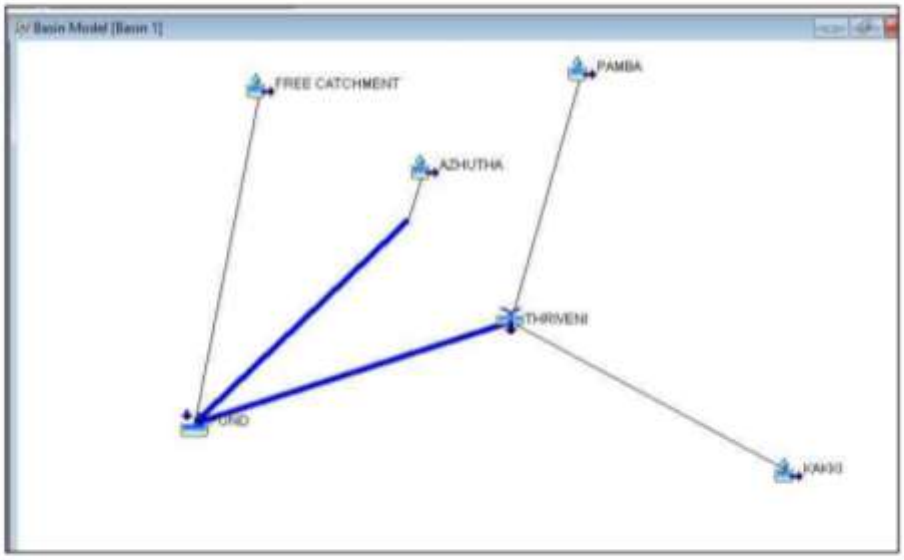

Figure 6.1: HMS Model of Perumthenaruvi Project

7. Results

The design flood is estimated as 4156 m3/s. The results are shown below in tabular and graphical format.

Time	Inflow from Reach Thriveni - Perumthenaruvi (m3/s)	Inflow from Reach Azhutha – Perumthenaruvi (m3/s)	Inflow from Downstream Catchment Perumthenaruvi (m3/s)	Total Inflow (m3/s)
00:00	0	0	0	0
01:00	0	3	31.1	34.1
02:00	0.6	21.5	57.1	79.1
03:00	4.7	66.6	107.8	179.1
04:00	21.9	139	184.3	345.2
05:00	68	242.5	256.4	566.9
06:00	155.5	351.8	324.5	831.8
07:00	286.4	452.9	392.9	1132.1
08:00	452.7	550.8	475.4	1478.8
09:00	637.2	653.6	597	1887.7
10:00	826.6	774.5	737.7	2338.8
11:00	1021	948.9	887.1	2857
12:00	1233.2	1184.9	975.5	3393.7
13:00	1488.9	1409.7	916.3	3814.8
14:00	1812.7	1477	795.4	4085.1
15:00	2180.3	1322.4	653	4155.7
16:00	2478.9	1086.1	536.8	4101.8
17:00	2554.2	875	454.2	3883.4
18:00	2355	738.5	397	3490.5
19:00	1987.5	653.5	360.7	3001.7
20:00	1589	596.5	344.8	2530.4
21:00	1242.7	554.6	353.2	2150.4
22:00	973.4	526.3	375.1	1874.9
23:00	779.3	526.1	406	1711.3
00:00	653.1	558.5	419.1	1630.7
01:00	590	596.7	376.4	1563
02:00	583.4	587.5	312	1482.9
03:00	614.9	507.2	242.1	1364.1
04:00	649	404.5	187.4	1241
05:00	647.6	314.7	148.2	1110.5
06:00	596	252.3	119.8	968.1
07:00	512.2	209.2	98.6	820
08:00	421	175.8	82.1	678.9
09:00	338.8	146.5	68.3	553.6
10:00	270.7	119.1	56.1	445.9
11:00	215.7	93.5	45.7	354.9
12:00	171.8	70.5	37.9	280.2
13:00	137.6	51	31.7	220.3

14:00	111.7	37.7	26.7	176.1
15:00	93	31.4	23	147.4
16:00	80.2	29.3	21.5	130.9
17:00	72.2	28.9	20.8	121.9
18:00	67.8	28.8	20.7	117.4
19:00	65.7	28.8	20.7	115.2
20:00	64.8	28.8	20.7	114.3
21:00	64.4	28.8	20.7	113.9
22:00	64.3	28.8	20.7	113.8
23:00	64.2	28.8	20.7	113.7
00:00	64.2	28.8	20.7	113.7

Table 7.1 – Design flood of Perumthenaruvi Project

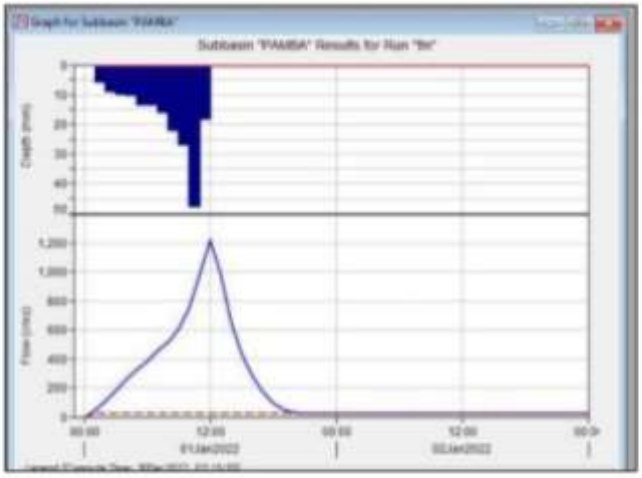

Figure 7.1: Inflow – Sub catchment Pamba

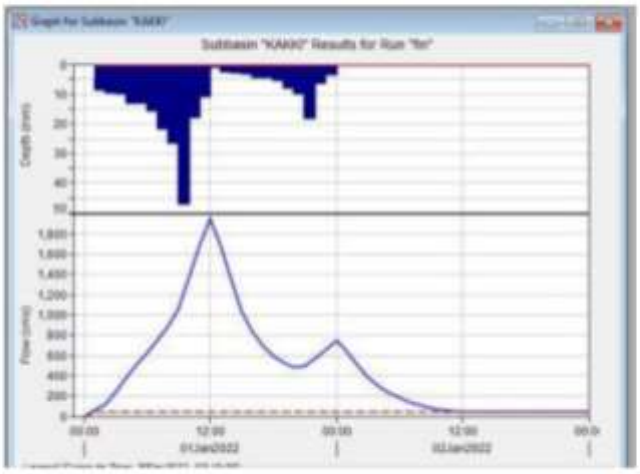

Figure 7.2: Inflow – Sub catchment Kakki

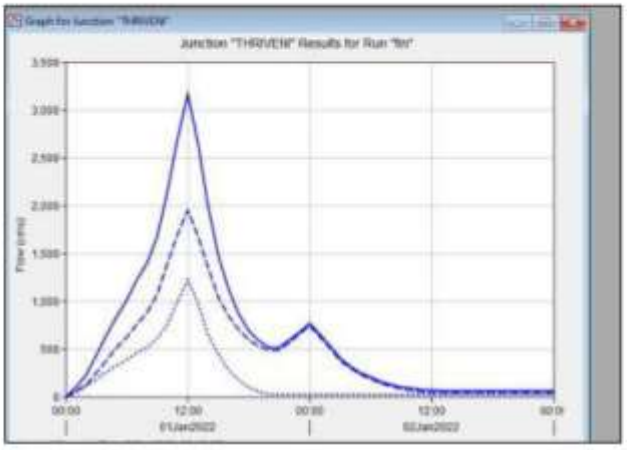

Figure 7.3: Inflow – Thriveni

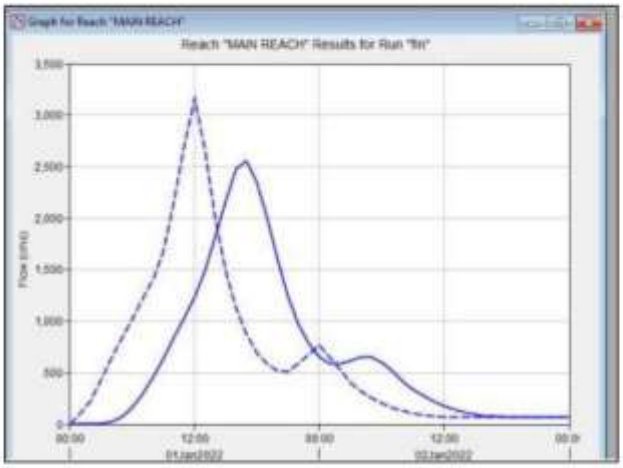

Figure 7.4: Reach Routed Hydrograph – Thriveni - Perumthenaruvi

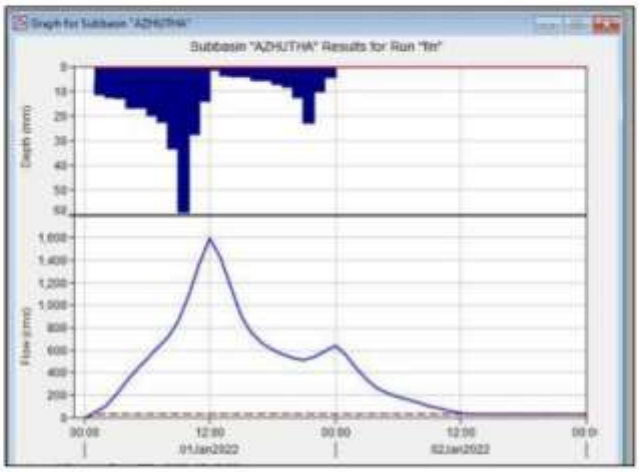

Figure 7.5: Inflow - Sub catchment Azhutha

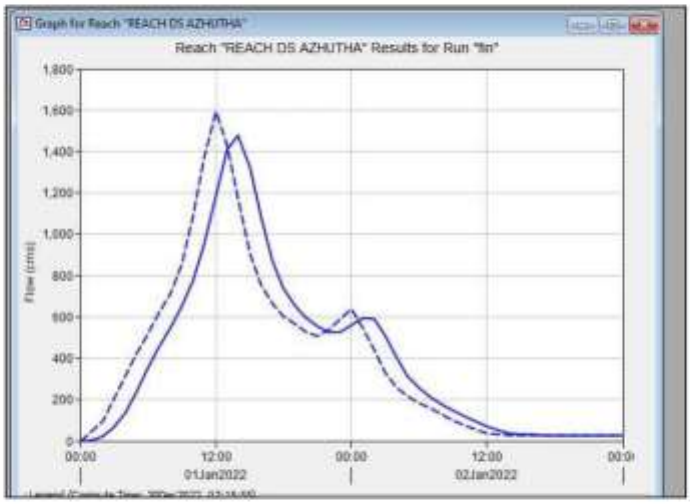

Figure 7.6: Reach Routed Hydrograph – Azhutha Confluence - Perumthenaruvi

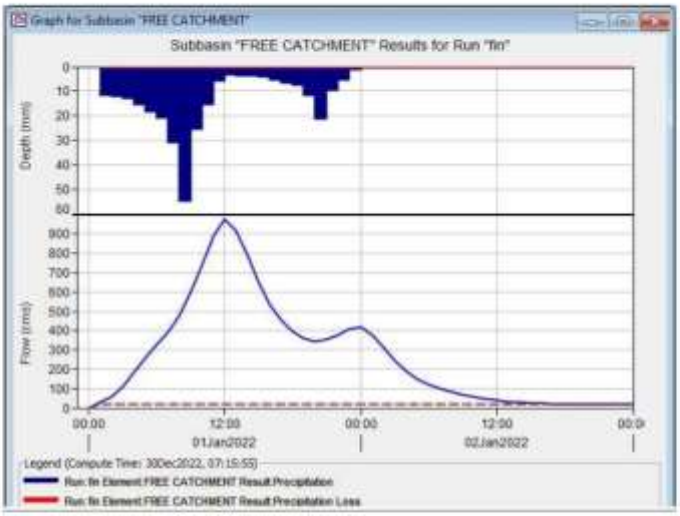

Figure 7.7: Inflow – Downstream Catchment – Perumthenaruvi

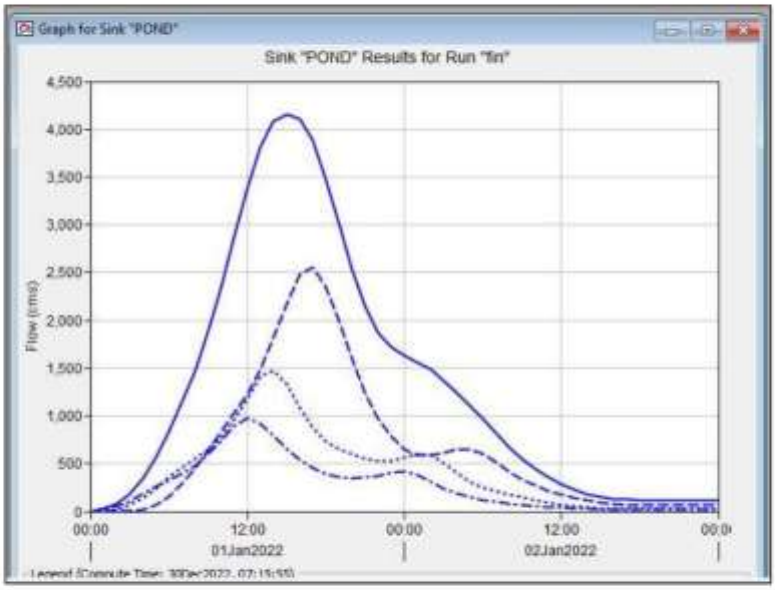

Figure 7.8 - Design Flood Hydrograph – Perumthenaruvi Project

I. Catchment Map – Sub catchments

Unit Hydrograph parameters (FER 5 (a) & 5 (b)) - Pamba sub catchment						
Sl No.	Parameters	Relationships	Value	unit		
1	qp	$0.9178(L/S)^{-0.4313}$	0.892	cumecs/km2		
2	tp	$1.5607(q_p)^{-1.0814}$	1.766	hrs	say	1.5
3	W50	$1.925(q_p)^{-1.0896}$	2.180	hrs		
4	W75	$1.0189(q_p)^{-1.0443}$	1.148	hrs		
5	WR50	$0.5788(q_p)^{-1.1072}$	0.657	hrs		
6	WR75	$0.3469(q_p)^{-1.0538}$	0.391	hrs		
7	T_B	$7.38(t_p)^{0.7343}$	9.939	hrs	say	10.0
8	Tm	$t_p+t_r/2$	2.000	hrs		
	Catchment area	A	149	Km2		
	Qp	q_p X A	132.9	cumecs		

II. Pamba sub catchment

Unit Hydrograph parameters (FER 5 (a) & 5 (b)) Kakki sub catchment					
Sl No.	Parameters	Relationships	Value	unit	
1	qp	$0.9178(L/S)^{-0.4313}$	0.674	cumecs/km2	
2	tp	$1.5607(q_p)^{-1.0814}$	2.393	hrs say	2.5
3	W50	$1.925(q_p)^{-1.0896}$	2.961	hrs	
4	W75	$1.0189(q_p)^{-1.0443}$	1.539	hrs	
5	WR50	$0.5788(q_p)^{-1.1072}$	0.896	hrs	
6	WR75	$0.3469(q_p)^{-1.0538}$	0.526	hrs	
7	T_B	$7.38(t_p)^{0.7343}$	14.463	hrs say	15.0
8	Tm	$t_p+t_r/2$	3.000	hrs	
	Catchment area	A	279	Km2	
	Qp	q_p X A	187.9	cumecs	

III. Kakki Sub Catchment

Unit Hydrograph parameters (FER 5 (a) & 5 (b)) - Azhutha sub catchment					
Sl No.	Parameters	Relationships	Value	unit	
1	qp	$0.9178(L/S)^{-0.4313}$	0.609	cumecs/km2	
2	tp	$1.5607(q_p)^{-1.0814}$	2.668	hrs say	2.5
3	W50	$1.925(q_p)^{-1.0896}$	3.305	hrs	
4	W75	$1.0189(q_p)^{-1.0443}$	1.710	hrs	
5	WR50	$0.5788(q_p)^{-1.1072}$	1.002	hrs	
6	WR75	$0.3469(q_p)^{-1.0538}$	0.585	hrs	
7	T_B	$7.38(t_p)^{0.7343}$	14.463	hrs say	15.0
8	Tm	$t_p+t_r/2$	3.000	hrs	
	Catchment area	A	192	Km2	
	Qp	q_p X A	116.9	cumecs	

IV.Azhutha sub catchment

Unit Hydrograph parameters (FER 5 (a) & 5 (b)) - downstream catchment					
Sl No.	Parameters	Relationships	Value	unit	
1	qp	$0.9178(L/S)^{-0.4313}$	0.483	cumecs/km2	
2	tp	$1.5607(q_p)^{-1.0814}$	3.432	hrs say	3.5
3	W50	$1.925(q_p)^{-1.0896}$	4.258	hrs	
4	W75	$1.0189(q_p)^{-1.0443}$	2.181	hrs	
5	WR50	$0.5788(q_p)^{-1.1072}$	1.297	hrs	
6	WR75	$0.3469(q_p)^{-1.0538}$	0.748	hrs	
7	T_B	$7.38(t_p)^{0.7343}$	18.517	hrs say	19.0
8	Tm	$t_p+t_r/2$	4.000	hrs	
	Catchment area	A	138	Km2	
	Qp	q_p X A	66.6	cumecs	

V. Downstream catchment

ANNEXURE III – Discharge through Spillway

Discharge through Spillway of Perumthenaruvi weir	
Discharge Q cumecs	2.2 Le H $^{(3/2)}$
Total length of spillway including 9 piers of 1.2 m width m	131.5
Clear length of spillway m	120.5
abutment contraction coefficient Ka	0.1
Pier contraction coefficient Kp	0.01
No of piers	9
FRL	51 m
MWL	55.2 m
Head over crest H (m)	**Discharge (m3/sec)**
0.25	33.11
0.50	93.58
0.75	171.78
1.00	264.26
1.25	369.03
1.50	484.72
1.75	610.33
2.00	745.09
2.25	888.36
2.50	1,039.64
2.75	1,198.47
3.00	1,364.47
3.25	1,537.31
3.50	1,716.69
3.75	1,902.35
4.00	2,094.05
4.20	2,251.61

ANNEXURE IV – Rainfall Data

Rainfall Data (in mm) for the year 2010-11

Basin - Pamba, Rain Gauge Station - Koruthode

Date	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
1	0	25	0	0	17	6.6	0	0	0	0	0	0
2	0	8	0	0	18	0	5	42.2	0	0	0	11
3	42	9.8	3	0	20	0	7	0	0	0	0	8
4	0.6	49	40.8	4	40	0	0	0	0	0	65.6	0.6
5	105	29	18	5	22.6	47	0	0	0	0	3.6	0
6	52.2	3.6	0	0	43	23	0	0	0	0	0	0
7	21.4	0	6.8	21.8	36.2	0	0	0	0	0	0	0
8	62.6	14	0	0	26.4	0	0	2	2.6	0	0	0
9	34	25.6	0	15.4	29.6	0	3.4	4.8	0	0	0	0
10	24.6	0	7.8	20.8	16.6	20	0	6.6	0	0	0	0
11	44	71	0	20.2	0	12.6	0	0	0	0	17.6	0
12	44.4	5.8	9	0	0	2.6	0	3	0	0	0	0
13	204	17.2	151	0	0	0	0	0	0	0	0	0
14	40	24	52.4	26.2	0	0	0	0	0	0	0	0
15	16.8	6.2	2.4	10	11.2	0	0	0	0	0	0	0
16	2.8	100	124.8	3.6	17	7.4	0	0	0	0	36.8	24
17	0	30	34.6	3	3.6	7	0	0	0	0	15	0
18	35.4	39	0	5	2.4	48.6	0	0	0	0	20	0
19	32	48.6	7.4	14	9.8	5.2	0	0	0	0	40.6	5.8
20	27.8	80	0	0	9	0	0	0	0	0	35	8.2
21	19.6	26.8	0	0	1	99.6	0	0	0	0	33.4	71.6
22	0	46.4	0	45	37	52	0	0	56	0	19	3.8
23	42	1.2	7.6	90.2	2.6	31.6	28.6	0	35	0	12.2	0
24	37.8	18.4	60.4	57.2	8.4	6.4	1.2	0	1.6	0	68.2	29.4
25	14.8	0	47.4	17.4	0	4.4	0	0	0	40	14.6	12.8
26	34.6	0	71.8	0	0	5	0	0	0	0	0	15
27	8	6.2	42	67	22.8	1.2	8.4	0	34.4	15.6	8	22
28	16	21	28.4	13.6	78	0	0	0	0	17.2	0	40
29	47.8	14.6	103	23	2	0	0	0		0	8	6.6
30	15.2	10.2	32.6	0	10	0	0	0		45.8	3.4	0
31		3.6	26.2		27.8		0	0		0		26.4

Rainfall Data (in mm) for the year 2011-12 Basin - Pamba, Rain Gauge Station - Koruthode												
Date	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
1	58.6	8.6	0	79.6	0	1	2.8	0	0	0	23.6	5.8
2	174	3.6	0	11.4	0	16.6	0	0	0	0	6.4	0
3	51.8	0	0	60	0	23.4	32.6	0	0	1	0	5
4	43.6	2	14.6	3.2	0	23.6	0	0	0	0	0	19
5	87	1	8	23	0	1.6	0	0	0	0	9.8	3
6	23.4	48	31	9	0	0	0	0	8.6	0	36.8	0
7	11	5.4	248.8	30	0	17.8	0	0	0	0	0	0
8	0	32	5	0	0	38.4	0	0	0	3	0	0
9	8.6	0	29	14.8	0	2.4	0	0	0	0	0	0
10	10	26.4	8.4	23	0	0	0	0	5	0	13.6	54.6
11	9.2	7.8	21.4	12.4	0	0	0	17.2	0	0	0	0
12	9.8	9.2	9.2	17.2	18.2	0	0	0	0	0	0	38
13	18.2	39.6	34.4	13.4	0	0	0	0	0	0	0	0
14	37.4	51	0	29	0	0	0	0	0	0	0	0
15	25	81	30.2	9.6	11	0	0	0	0	0	15.6	0
16	6.6	30	0	39	73	0	0	0	0	0	3	13.6
17	41	18.2	19.4	2.2	8.2	0	0	0	0	0	0	0
18	8	39	64	0	8.6	0	0	0	0	0	0	0
19	35	51	0	0	66.2	0	0	0	0	0	0	0
20	0	17.6	24	10	6	0	0	0	0	0	0	0
21	9.8	13.2	6	14.8	3	0	0	0	0	0	0	0
22	0	26	0	16.6	8.6	0	0	0	0	0	0	44.6
23	0	3	41.2	0	10.4	0	0	0	0	0	0	0
24	26	35	26	0	25.2	0	0	0	0	0	55.4	0
25	12.6	22.6	2.4	0	6	0	4.6	0	0	0	53.6	0
26	25.2	33.8	54.8	0	0	3.2	0	0	0	0	51.2	0
27	21	55	6.4	0	1	18.6	0	0	0	0	16	0
28	25	2.6	10	0	5.4	4.4	0	0	0	0	1.8	3.4
29	0	3	0	0	1	0	0	0	0	3.2	0	0
30	0	21.6	25.8	0	15.4	102	0	0		34.6	0	5.6
31		4.8	32.2		12		133	0		0		3

Rainfall Data (in mm) for the year 2012-13 Basin - Pamba, Rain Gauge Station - Koruthode												
Date	**Rainfall in mm**											
	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
1	0	5	0	10.2	4	23	0	0	0	0	0	0
2	0	8	0	7.8	0	12.8	0	0	0	0	0	1
3	6	45.4	0	13.2	0	0.4	0	0	0	0	0	24
4	9	35	8.2	42.4	0	0	0	0	0	0	0	2
5	32	0	0.8	23.6	0	0	0	0	0	0	0	1
6	0.6	0	18.8	5.6	0	0	0	0	0	0	0	5.2
7	37	0	24.4	2.4	54.4	3.6	0	0	0	1.4	0	13.8
8	22.6	30.2	0	19	0.4	72.2	0	0	16.8	0	0	5
9	6	5.2	68.4	9.4	6	0.4	0	0	0	0	0	0
10	0	73.6	25.6	4	0	1	0	0	0	16.6	0	0
11	0	24	15.8	3	74.8	0	0	0	0	5	0	0
12	0	0	17.2	2.4	16.2	9.2	0	0	0	1	20.4	0
13	7.6	0	4.2	0	13	0	0	0	0	0	0	0
14	0.4	24	0	19.8	75	0	0	0	0.4	0	0	5
15	2	7.6	35	5.6	5.6	0	0	0	0	0	0	7.6
16	42.8	3.6	16	0	6.2	0	0	0	0	0	1.4	0
17	18.6	0	57	12.6	23.8	0	0	0	0	0	0	0
18	64.6	1.4	101.6	2.6	21.8	0	0	0	3.6	0	0	0
19	12.2	4.6	14.6	0	24.6	0	0	0	1.8	1.8	0	0
20	18.2	0	0	0	1.8	0	0	0	0	0	0	2
21	23.2	15.6	2.4	0	13.8	0	0	0	0	8.2	0	65.2
22	18.2	8.6	6.2	3.8	10.4	0	0	0	0	0	0	0
23	6	46	57.6	0	0	6	0	0	0	0	0	0
24	36	7.8	12.6	0	0	51.6	0	0	0	0	4.2	10.2
25	9.6	10	34.2	0	0	7	0	0	0	0	31.2	3.2
26	0	0	31.4	0	0	0.4	0	0	0	55	48.6	12.6
27	52.6	2.6	3	0	5.8	0	0	0	0	15.6	0	0
28	0	0	11	0	0	0	0	0	0	0	1	1.2
29	15.6	3.4	5.4	0	0	0	0	0		19	8.6	37.2
30	19.2	6.2	18.8	11.4	5.2	0	16.4	0		39.2	0	3.6
31		0	19		0		0	0		5.6		0

Rainfall Data (in mm) for the year 2013-14 Basin - Pamba, Rain Gauge Station - Koruthode												
Date	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
1	71	17	2	12.6	4	7.8	0	0	0	16.8	0	40.6
2	0	14	72.2	0	6	4.8	2.8	0	0	8.6	0	17.8
3	34.2	65.6	33.8	10.8	10.2	6.4	1	0	0	0	0	5.4
4	0	22.2	27.2	46	17.8	0	0	0	0	4.6	5.8	19.4
5	0	35.8	147.2	20.2	0	0	0	0	0	2.8	0	8.2
6	30.4	19.6	68.4	0	0	0	0	0	0	16.8	0	0
7	25.8	60	2.8	9	1.8	0	0	0	0	27	0	52.6
8	36.6	41.4	14.2	11	0	0	0	0	0	0	3	39.4
9	24.6	57.8	25.2	11.4	25.2	0	0	0	0	0	7.2	48.4
10	11	49.2	12.6	27.6	0	0	0	0	0	0	0	3
11	31.2	29	1.6	10.8	1.6	30.8	0	0	0	0	19	0.6
12	44.2	36.4	34	20.2	0	0	0	0	0	0	15.2	4.6
13	19.4	11	15.4	33.4	12	11	39.8	0	0	0	1.8	49.8
14	47.2	6.6	12.4	31	3.8	6	0	0	0	0	0	0
15	37.8	9.8	1.2	22.4	0	35.2	0	0	0	0	15.6	0
16	112.2	38.4	1.2	49	59	24.8	0	0	0	0	0	0
17	42.4	17	14.2	39.2	48.6	10.6	0	0	0	0	22	0
18	33	27	0	65	1.4	14	0	0	0	0	5	0
19	19.8	56	0	31.6	38.4	35.8	0	0	0	0	0	0
20	61.8	36.2	2	51.6	81	0	0	0	0	0	7.2	1.2
21	27.4	32.4	10.8	35.4	8.4	18.6	0	0	16	18.8	0	43.4
22	46	36.4	6.2	2.2	33.8	0	0	0	20.4	0	0	18.8
23	33.8	10.6	1.2	0	6	8.6	0	0	2.8	0	1.8	22
24	37.6	25	0	0	15	103.4	0	0	0	0	1	10
25	79.6	27	10.8	0	6.4	24.4	0	0	0	0	5.6	5
26	95.2	30	0	0	16.4	0	0	0	0	0	3.2	2.4
27	38	18	0	0	0	0	0	0	0	0	0	5
28	4.8	3	0	0	0	2.8	0	0	0	0	0	3.4
29	0	9.2	0	0	0	0	0	0		0	1.8	76.2
30	0	0	11.4	8.2	15.4	0	0	0		0	13.8	17.2
31		4.6	23		0		0	0		0		0

Rainfall Data (in mm) for the year 2014-15 Basin - Pamba, Rain Gauge Station - Koruthode												
Date	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
1	2.8	45	91	85	19.8	42	0	0.4	0	5	0	6
2	1.6	56.6	54.8	26.2	7.6	6.2	0	0	0	0.8	12	0
3	2.2	0	32	57.4	2.2	12.2	0	0	0	0	2	0
4	0	2.8	92.4	0	0	133.6	0	0	0	25.8	15	32.8
5	10.8	0	50	13.8	36.4	1	0	0	0	21	9.6	14.6
6	5.6	46	34.6	16.8	0	0	0	0	0	0.8	0	10.2
7	4	0	12.2	22.8	24.8	12	0	0	0	1	0	9.4
8	40.2	0	8	19.2	28.8	0	0	0	35.6	2.6	24	1
9	22.4	6.8	31.6	19.6	12	0.6	0	0	0	0	0	37
10	14.8	21.2	13.2	0	17.8	0	4.2	0	0	0	39.4	26
11	38	25	2	4.8	4.8	0	54.2	0	0	0	5.4	0.6
12	19.8	0.8	22.6	0	1.8	2.2	2.6	0	0	0	5.2	4.6
13	2.4	36	0	0	18.8	39	3.6	0	0	0	5.4	20
14	10.2	55	8.2	0	18	44	31.4	0	0	0	25.2	4.8
15	2.6	68.2	0	0	19.2	0	2.6	0	5	0	0.6	0
16	2.8	33.4	21.2	30	35.8	0	0	0	0	16	0	0.6
17	5.4	0	29	0	0.8	0	0	0	0	7.6	6.4	4.4
18	37.4	3.8	4.4	1.2	0	0	0	0	0	0	29.4	14.6
19	34.6	37.8	28	2.8	8.8	3.6	0	0	0	0	0	16.6
20	46	13.6	12.8	3.6	9.6	0	0	0	0	0	0	0.6
21	127.2	13.8	20	0	7.6	12.2	0	0	0	0	5.6	0.4
22	31.2	13.6	15.8	5.2	0	1	4.2	0	0	0	29.4	0
23	0	42.6	132	0	27.6	0.8	0	0	0	0	0	0
24	12.6	30	19	5.6	42	0	0	10.6	0	0	0	0
25	45.8	19.2	0	0	5.4	0	0	0	0	0	19.8	0
26	0	31	0	14.8	17.6	0	0	0	0	0	0	0
27	0	7.8	3.8	95	0.8	0.4	0	0	6.8	0	5	0
28	0	54	0	33.2	80	6	0	0	24.6	2.6	44.6	8
29	0	21.6	28.6	6.6	0	0	2.6	0		0	0	0
30	36.8	14.8	39	28.8	87.4	1	3	0		0	0	2.8
31		14.6	100		1.2		52.4	0		13.6		0

Rainfall Data (in mm) for the year 2015-16 Basin - Pamba, Rain Gauge Station - Koruthode												
Date	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
1	0.6	7.6	0	0	16.4	9.6	1.2	0	0	0	0	15.8
2	0	0	0	0	0	10.2	21.6	0	0	0	0	0
3	3.4	0	6.4	0	6	3.6	0	0	0	0	0	0
4	30.6	1.6	27	12.4	13	4.6	2.8	0	0	0	0	0
5	23.6	12.6	22.6	44.4	38	23.6	0	0	0	0	0	7.6
6	1.6	40	43	5.6	31.8	0	6	0	0	0	0	1.8
7	0	0	10	32.6	0	2	0	0	0	0	11.8	24.8
8	15.4	10.6	14	14.8	0	10.2	6	0	0	0	0	6.8
9	7.2	27.4	6.6	28.8	37.2	0	1.6	0	0	0	0.8	50.6
10	6.2	5	2.6	13.4	12	2.8	0	0	2.8	2.2	2.2	17.2
11	12.4	24.2	27.4	0.6	2	0	0.6	0	30.4	0	1.2	11.8
12	15.8	15.8	64	1.2	2.4	0	0	0	0	13	0	32.6
13	29.6	4.8	35.2	0	1.8	24.6	1.8	0	0	41.6	0	0.6
14	0.6	1	12	0	19.2	19	35	0	0	3	0	0.8
15	20.6	24.2	1.6	1.2	0	0.8	51	0	0	0	2.2	3
16	16.6	11.6	6.8	15	0	1.6	36.8	0	1.2	9.2	0	3
17	5.6	10.8	4.8	35	0	1.2	0	0	0	0	0	8.2
18	17.8	53	20	9	0	2.2	0	0	1.6	0	0	125.6
19	59	30.4	9.8	16.6	2.6	11.2	0	0	0	0	0	8.6
20	13.6	6.8	4	13	7.8	2.8	0	0	0	0	11.6	12.6
21	28.8	32	1	0	0	1.2	0.8	0	0	0	0	0
22	21	10.2	17.4	0	8	0	0	0	0	0	0	0
23	20	10.8	1	0	5.6	1.4	0	0	0	0	0	6.8
24	18.8	26.4	11.4	3.6	0	1	0	0	0	0	0	2.6
25	43.2	1.8	1.8	27.4	5.2	0	0	2.6	0	0	2.8	72
26	54	1	0.8	23.4	0	0	0	0	9.4	0	0	65.6
27	23.4	12	2	63.6	0	0	0	0	0	0	1.2	3.8
28	44	0	0	4.8	0	1	0	0	0	0	0	19.2
29	5.4	0	0	12.4	15.4	7.6	0	0	0	0	0	17.2
30	0	0	0	31.6	8.4	6.8	0	0		0	0	15.2
31		0	0		2.6		0	0		2.6		19

Rainfall Data (in mm) for the year 2016-17 Basin - Pamba, Rain Gauge Station - Koruthode												
Date	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
1	32	12	29.8	0	5.6	37.6	24.2	0	0	0	0	22
2	45.8	32	0	41	14	13.6	7	0	0	0	7.6	0
3	43	9.8	0	18.2	0	45	0	0	0	0	0	0
4	7.4	12	29.8	0	0	27.6	0	0	0	0	6.2	0
5	20	0	43.2	0	0	24	0	0	0	0	0	3
6	33	11.4	61.4	65.4	17.6	0	0	0	0	0	0	18
7	13	20.2	17.8	18.8	0	15.8	0	0	0	0	0	0
8	9	39.8	21	0	15.8	32.8	0	3	53.6	0	0	41.4
9	13.8	25	17	60.4	0	9	16.2	0	62	0	11.4	23.8
10	23.8	2.4	54.6	48	5.2	0	0	0	60.6	0	4	27
11	13	12	40	3	0	0	0	0	0	0	3.8	2
12	10.6	3.6	11.8	11.8	11	26.2	0	0	0	0	15.8	0
13	8	0	0	30.2	126.6	0	138	0	0	0	11	20.8
14	10.4	12	0	130.8	8	0	0	0	0	13	59	14
15	2.6	8.2	0	32	6	0	0	0	0	0	10.6	24.6
16	0	4.4	56.4	9	4	0	0	0	0	3.2	2	34.8
17	0	0	11.4	89	9	0	0	0	0	0	0	43.6
18	0	6	18	68.2	16.4	0	0	0	0	12.8	0	0
19	0	3	15.8	4.6	9.4	0	0	0	0	11.6	0	0
20	2.4	54.6	46.8	16	0	0	0	0	0	0	0	0
21	6.4	6.6	38.2	2	42	0	0	0	0	0	0	0
22	39.4	15.2	47.6	3	0	2.6	0	0	0	37.2	0	2
23	22.2	2.2	3.8	0	0	0	0	0	0	0	0	27.8
24	50.2	2.8	27	0	0	0	0	0	0	0	0	6.2
25	13.4	0	0	0	0	0	0	0	0	0	0	8.8
26	45	0	0	9.8	3.4	0	0	0	0	0	7	3.2
27	74.2	0	15	18.6	4	11.6	0	0	0	0	15.4	12
28	55.4	29.2	55.8	38	26	0	0	0	0	0	16	16
29	0	12	40	46.8	26	0	0	0		0	0	50.2
30	2.6	0	11	17.2	0	0	0	0		0	4	17.8
31		0	14.4		20.8		0	0		0		10

Rainfall Data (in mm) for the year 2017-18 Basin - Pamba, Rain Gauge Station - Koruthode												
Date	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
1	4.2	12	29.8	0	5.6	37.6	24.2	0	0	0	0	22
2	7.2	32	0	41	14	13.6	7	0	0	0	7.6	0
3	51.4	9.8	0	18.2	0	45	0	0	0	0	0	0
4	14.4	12	29.8	0	0	27.6	0	0	0	0	6.2	0
5	0	0	43.2	0	0	24	0	0	0	0	0	3
6	6.4	11.4	61.4	65.4	17.6	0	0	0	0	0	0	18
7	42	20.2	17.8	18.8	0	15.8	0	0	0	0	0	0
8	25.4	39.8	21	0	15.8	32.8	0	3	53.6	0	0	41.4
9	29	25	17	60.4	0	9	16.2	0	62	0	11.4	23.8
10	47.2	2.4	54.6	48	5.2	0	0	0	60.6	0	4	27
11	128	12	40	3	0	0	0	0	0	0	3.8	2
12	77	3.6	11.8	11.8	11	26.2	0	0	0	0	15.8	0
13	47.2	0	0	30.2	126.6	0	138	0	0	0	11	20.8
14	52.8	12	0	130.8	8	0	0	0	0	13	59	14
15	21	8.2	0	32	6	0	0	0	0	0	10.6	24.6
16	0	4.4	56.4	9	4	0	0	0	0	3.2	2	34.8
17	22	0	11.4	89	9	0	0	0	0	0	0	43.6
18	0	6	18	68.2	16.4	0	0	0	0	12.8	0	0
19	52.2	3	15.8	4.6	9.4	0	0	0	0	11.6	0	0
20	30.4	54.6	46.8	16	0	0	0	0	0	0	0	0
21	35.2	6.6	38.2	2	42	0	0	0	0	0	0	0
22	13	15.2	47.6	3	0	2.6	0	0	0	37.2	0	2
23	6	2.2	3.8	0	0	0	0	0	0	0	0	27.8
24	2.4	2.8	27	0	0	0	0	0	0	0	0	6.2
25	0	0	0	0	0	0	0	0	0	0	0	8.8
26	23.2	0	0	9.8	3.4	0	0	0	0	0	7	3.2
27	36.2	0	15	18.6	4	11.6	0	0	0	0	15.4	12
28	28	29.2	55.8	38	26	0	0	0	0	0	16	16
29	7.4	12	40	46.8	26	0	0	0		0	0	50.2
30	9.8	0	11	17.2	0	0	0	0		0	4	17.8
31		0	14.4		20.8		0	0		0		10

Rainfall Data (in mm) for the year 2018-19 Basin - Pamba, Rain Gauge Station - Koruthode												
Date	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
1	4.2	0	4	7	4.2	25.4	0	0	0	0	0	0
2	7.2	8	0	0	0	0	0	0	0	0	0	0
3	51.4	2.6	0	0	73.2	0	0	0	0	0	0	0
4	14.4	0	3.8	0	48.2	0	0	0	0	0	3.4	0
5	0	0	2.6	0	28.4	0	0	0	0	0	5	0
6	6.4	0	2.8	0	3	0	0	0	0	0	0	0
7	42	4	4	0	0	0	0	0	0	0	0	0
8	25.4	60	50.4	0	0	0	0	0	0	4.6	0	0
9	29	34.8	73.2	0	2.6	0	0	0	0	0	28.6	0
10	47.2	104.2	76	0	13.8	0	0	0	12	26	4.8	0
11	128	53.4	73	0	22	0	0	0	9.4	0	0	34.4
12	77	29.2	4.8	0	35.2	3	0	0	0	0	0	37
13	47.2	23	49.8	0	8	0	0	0	0	0	0	35.6
14	52.8	29.2	56	0	0	6.8	0	0	0	0	0	0
15	21	46	125.2	0	24	0	0	0	0	2	0	0
16	0	135.6	144.6	0	0	4.2	0	0	6.8	0	0	0
17	22	49.2	96.2	4.2	0	42	0	0	0	0	16.8	9.6
18	0	54.6	96	0	12	0	0	0	0	0	0	8.8
19	52.2	16.2	35.2	0	53	17.4	0	0	0	0	19	0
20	30.4	43.2	32.6	40	0	0	0	0	0	0	21.6	0
21	35.2	12.4	13.6	0	16.8	2	0	0	0	12.8	2.6	0
22	13	9.2	9.6	12	7.4	0	0	0	0	0	0	22.8
23	6	33.8	0	0	32.8	0	0	0	0	0	22.2	0
24	2.4	41	0	29.4	0	7	0	0	0	0	1.4	20
25	0	42	0	15.4	0	0	0	0	0	0	5.2	11
26	23.2	97	0	6.4	0	0	0	0	0	0	0	0
27	36.2	14.8	0	0	0	0	0	0	0	0	0	5.6
28	28	6.6	15.2	12.8	0	0	0	0	0	0	0	4
29	7.4	76.4	16.4	31.8	0	0	23	0		0	0	0
30	9.8	17.6	0	40.2	0	0	0	9.8		0	5.8	0
31		83	1.2		0		0	5.6		0		0

Rainfall Data (in mm) for the year 2019-20 Basin - Pamba, Rain Gauge Station - Koruthode												
Date	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
1	12.6	0	0	20.4	5.6	6	2.6	0	0	0	0	5.8
2	2.2	9.4	0	16.4	0	0	0	0	0	0	0	0
3	14	23.4	0	49.4	10.4	2.2	0	0	0	0	0	0
4	0	16.8	2.4	21	0	19.6	0	8	0	0	0	0
5	118	7.4	8.8	37.8	0	1	0	56.2	0	3.8	0	0
6	47.8	11	28	55.8	7	10.4	0	1.8	0	0	5	0
7	0	9.6	65.6	32	2	0	0	0	0	0	10.2	23
8	6	4.6	141	8.4	0	77.8	0	0	0	0	0	7.8
9	2	6	142.8	1.2	29.8	24.2	0	0	0	0	3.6	1.4
10	51	5.8	55.6	3.8	0	12	0	0	0	13.6	0	1
11	18.8	5	37	2	4.2	0	0	0	0	4	11	0
12	9	0	30.6	27.6	40	3.8	0	0	0	12.2	0	0
13	13	7.2	17.4	0	6.8	0	0	0	0	11.2	0	26.4
14	8.8	4	102.2	0	34.6	0	0	0	0	0	0	0
15	10	16	21.8	10.8	2.8	0	0	0	0	18.4	0	55.2
16	2.6	5.6	0	30.8	3	4.6	0	0	0	0	27.6	12.8
17	0	2	24.4	7.8	12.6	0	0	0	0	0	0	0
18	0	7.6	0	13	7.8	1	0	0	0	0	0	10.4
19	0	132	14.4	31.2	11.8	0	0	0	0	0	0	50.6
20	39	95.8	4.8	7.8	11	0	0	0	0	3.6	14.2	7
21	4.8	32.2	12.2	0	50.4	0	0	0	0	9	0	11.2
22	27.6	68.6	46	12.6	19.2	0	0	0	0	37.4	0	6.2
23	16.6	20.8	20.6	4.8	0	0	0	0	0	0	9	0
24	40.8	18.8	19.4	80.2	21.6	0	0	0	0	0	10.2	0
25	13.8	2.8	15.4	16.2	4.2	2	0	0	0	0	4	0
26	0	6	35.6	9.2	13.4	0	0	0	0	17.8	0	16
27	0	2.6	41.6	0	1	0	13	0	0	0	4.2	1
28	0	0	3.6	0	0	0	0	0	0	0	10	0
29	0	0	40	1.8	4.8	0	0	0	0	0	12.4	70.4
30	0	2	46.8	49.4	7.2	3.6	0	0		12.4	0	0
31		0	12.2		36.2		1.2	0		0		14

Rainfall Data (in mm) for the year 2020-21 Basin - Pamba, Rain Gauge Station - Koruthode												
Date	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
1	6.8	0	19.2	20	6.8	0	0	0	0	0	2.4	0
2	22.6	4.6	27.8	0	0	13.8	0	0	0	0	1.4	8.4
3	21.4	18.6	30	37.4	0	0	3	0	0	0	0	0
4	13.4	21.6	53	0	0	0	0	0	0	0	0	2.4
5	14.6	32	24	0	0	7.8	63.6	0	0	0	0	6.2
6	43.8	68.8	24.8	27.6	0	24.8	6.2	6	0	0	0	0
7	16.6	59.6	86.8	61.8	27.6	0	12	41.4	3.6	0	0	6.6
8	19.6	1.6	186.6	5.8	10	0	0	0	0	0	0	25
9	0	0	83.4	42.4	65.4	9	0	3	0	0	0	23.2
10	18.2	11.8	35.4	18.2	0	0	0	0	0	0	0	0
11	5	2.6	18.8	5	15.4	0	0	2.2	0	45	0	45.2
12	20.8	47.2	8.8	20.8	18	0	0	0	0	0	0	4.4
13	6	0	1.6	6	57	0	0	0	0	0	0	15.8
14	14.8	0	1	20.8	20.8	19.6	19.2	7.6	0	0	0	48.4
15	5.2	0	0	20.8	44.2	0	0	0	0	0	26.2	124
16	14	12.2	0	24.2	49.4	2.6	6	0	0	0	2.2	62.6
17	13.6	43.6	0	27	2.8	10.2	0	0	0	0	9.4	28.4
18	25.8	10.8	6.8	19.2	35	20.2	0	0	0	0	0	5.4
19	3	5.8	0	24.2	0	10	0	0	10.2	0	5.2	0
20	7	3.8	3	60	14.8	0	0	0	0	0	0	38
21	0	58.2	0	21.2	8.8	0	0	0	0	2	0	5
22	29.6	16.6	0	50	9	0	0	0	0	7.4	11	5.4
23	3	6	0	25.2	0	0	0	0	0	0	19.2	30.4
24	0	1	0	3.6	0	0	0	0	0	0	0	1.2
25	8.4	15.4	37.2	19	0	0	4	0	22	0	0	7.8
26	21.6	1.4	1	8	0	8	0	0	0	0	0	149
27	48.6	0	1.4	0	0	0	0	0	1	0	30.8	41.4
28	3.6	0	0	1.8	16.2	8.4	0	0	0	3.6	15.2	1.8
29	5.8	81.4	0	4	5.8	29.8	0	0		28.6	5.2	4.2
30	64.4	72	32	23	0	0	0	0		0	0	0
31		6	0		0		0	0		0		0

Rainfall Data (in mm) for the year 2021-22 Basin - Pamba, Rain Gauge Station - Koruthode												
Date	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
1	28.8	5.8	6.6	1.2	7.2	2	0	0	0	0	0	6
2	4	55.8	0	26.6	2.2	34.8	0	0	0	0	0	21
3	43	0	7.8	32.4	19.2	50.8	17	0	0	0	0	0
4	131.4	0	2	0	39.2	28.2	1.4	0	0	0	0	0
5	50	7.6	7.4	26.4	24.6	20.4	7.4	0	0	0	0	21.2
6	36.4	0	60.2	14.4	19	9.4	79.4	0	0	0	0	0
7	0	14.6	81.2	22	7	47.4	2.2	0	0	0	52	0
8	0.8	24	37.2	0	11.2	37.2	24.6	0	0	11	0	14.2
9	10.8	5.2	108.8	9.2	64.2	34.8	0	0	0	28.4	38	0
10	10.6	97.6	25.2	0	5	2	0	2.4	0	0	20.2	44.2
11	2.6	16.2	0	0	2.4	34.6	0	0	0	0	9	80
12	8.2	3.2	17.6	25.8	69.2	47	0	0	0	0	7.8	24.6
13	38.4	21.4	0	49.4	20.8	13.4	0	0	0	0	8.8	15.2
14	75.6	50.8	49.8	22.2	12.2	87	0	0	0	0	8.6	12.6
15	17.6	28	23	4.2	2.2	29	0	0	0	0	0	75.2
16	32.2	75.8	2	29.2	25.2	33.4	0	0	0	0	0	3.4
17	60.8	29	0	3.6	254.8	2	0	0	11.6	16.2	0	3.2
18	12.8	24.2	1.8	0	30.4	12.2	0	0	2	0	86.4	30.2
19	0	4.8	43	6.2	19.6	21.6	0	0	0	16	3	31.6
20	7.4	8.2	0	0	41	70.2	0	0	0	0	0	24
21	1	0	0	0	15	0	0	0	0	0	0	69
22	0	19.2	30	0	9	0	0	0	0	0	3	13.4
23	2.4	47.2	7.4	0	3	8	0	12	0	0	0	7.8
24	13	58.4	0	3.4	29	10.6	0	0	0	0	35.4	20.2
25	0	29.6	0	84.2	2.2	0	0	0	0	25.2	5.2	3
26	7	5.8	96.2	2.2	92	31	0	12.4	0	0	0	33.2
27	14.2	1.4	60.2	77.8	71.8	0	0	1.6	0	0	3.6	6.2
28	0	7.8	28.6	20.2	51.6	0	0	0	0	3.6	0	2
29	0	7.6	34.8	16.4	56	9	0	0		15.6	0	44.2
30	61.4	0	38.2	0	13.2	5.8	0	0		0	0	0
31		9.8	0		2		0	0		5.8		0

Rainfall Data (in mm) for the year 2022-23 Basin - Pamba, Rain Gauge Station - Koruthode												
Date	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
1	14.6	31.2	109.8	8.6	12	2.6	0	0	0	0	0	10
2	0	17.4	100	11	0	0	0	0	0	0	0	1
3	7.2	59.4	66.8	6.2	34.2	3.8	3.4	0	0	0	7.6	14
4	61	51.4	83	0	20.4	0	0	0	2.2	0	0	0
5	43.2	37.4	47.4	5.8	43.6	10.6	3.2	0	0	0	4.8	0
6	45.4	42.2	8	116.2	144.2	0	0	0	0	0	9.8	0
7	25.4	33.2	8.8	25.2	0	26	0	0	0	0	0	48
8	3.2	27.6	23.2	8.6	0	0	0	0	0	0	0	0
9	2	36.8	26.2	19.8	0	0	0	0	0	0	0	4
10	0	15.2	10.6	35.6	0	0	3	0	0	0	13.6	66
11	43.6	29.6	0	22	0	0	9	0	0	0	0	32
12	2	12	0	1.2	13.4	6.2	19.6	0	0	4	0	8
13	18.4	31.6	0	2.4	14.2	3.6	7.8	0	0	0	0	6
14	1.4	37.6	0	0	65.2	0	0	0	0	0	0	0
15	0	13.2	0	0	4.8	17.2	14.4	0	0	0	0	0
16	29.2	37.2	0	0	4.4	0	0	0	0	11	0	0
17	3.4	50.4	0	0	49.2	0	0	0	0	6.4	0	0
18	76.4	10.2	0	0	78	115	0	0	0	16.4	0	0
19	2.4	28.2	10	0	4.2	0	0	0	0	11.8	0	0
20	9	3.2	3.6	0	29	0	0	0	0	0	0	0
21	10.8	13.2	0	0	8	0	0	0	0	0	0	11
22	12.2	4.4	29.8	0	4.6	0	0	0	0	0	11.2	0
23	6	15.4	45.2	0	26.8	0	0	0	0	0	0	9
24	19.4	30.2	47.8	0	45	0	0	0	0	0	0	0
25	21	0	3.4	0	0	0	0	4.2	0	95.2	0	5
26	5.6	0	48.2	0	0	0	1.4	0	0	0	11	17
27	0	0	2.4	0	0	0	0	0	0	8.2	20.6	18
28	10	41.4	51.8	0	46.6	45	0	0	0	0	0	15
29	25.2	74.6	19.2	0	0	58	0	0		0	6.6	0
30	16.6	2.4	36.2	13.2	0	15.4	0	0		0	0	0
31		78.8	20.6		0		0	1.4		0		5

ANNEXURE V – GEOLOGICAL INVESTIGATION REPORT

CONSTRUCTION STAGE GEOTECHNICAL INVESTIGATION OF

PERUNTHENARUVI SMALL HYDRO ELECTRIC PROJECT,

PATHANAMTHITTA DISTRICT, KERALA.

PRAVEEN K.R Senior Geologist
VISHNU C.S Senior Geologist

INTRODUCTION

The Perunthenaruvi Small Hydro Electric Project is envisaged to generate 6 MW of power by constructing a 236 m long and 6.5 m concrete weir across River Pamba. The water conductor system includes a460m long rectangular left bank channel, a fore bay of 22m dia and two 9.2m long penstocks of 3.2m dia each. The surface Powerhouse is on the left bank with 32.20m, 23.70m and 13.04m of length, width and height respectively.

Construction stage geotechnical investigation has continued and carried out on 21.10.2016 in response to the request from the Executive Engineer & the Project Manager, Perunthenaruvi Small Hydro Electric Project, Perunad, Pathanamthitta.

The studies carried out include foundation geological mapping and assessment of the non-overflow blocks no. 1 to 4 of the weir on 1:100 scale for an area of ~340sq.m. Mapping and assessment has been carried out for the weir area from Ch-17m to Ch-24m and 1m upstream and 7m downstream of the weir alignment.

SITE GEOLOGY

The foundation has been excavated the levels varying from +45.8m to 52.8m as on date of the investigation. Foliated charnockite will from the foundation media for the proposed structure in the mapped reaches. A one-meter-vide foliation parallel shear zone is present within the mapped reaches from Ch.20.5m,0.5m upstream to Ch. 11.2m, 7.2m downstream.

DISCONTINUITIES

Foliation three sets of prominent joints, a shear zone and one set random joint are the discontinuities deciphered in the foundation rock mass.

FOLIATION

The foliation is well developed in the mapped reaches with strike N $5^0$to 20^0W-S 5^0 to 20^0 E drip 30^0 to 50^0 towards N 70^0 to 85^0 E.

JOINTS

1. Strike N5^0 to 20^0 W-S 5^{0}to 20^{0}Eto 50^0 towards N 70^0 to 85^0 E. foliationjoint : Very closely to closely spaced, persistent, weathered and stained in general. These joint planes are rich in biotite and hence often show surficial staining. Some of these joints are weathered and a 10-15cm wide weathered seam is noted in a joint exposed from Ch.(-) 16.8m, 3.1m downstream to and Ch.(-) 16, 1mdownstream.
2. Strike N5^0 to 15^0 E – S 5^0 to 15^{0}W, drip 50^0 to 60^0 towards N 75^0 to 85^{0}W-Moderately spaced, rough undulating, tight fresh and persistent.
3. Strike N65^0 to 80^{0}W– S 65^0 to 80^{0}E, drip sub – vertical;Moderately spaced smooth undulating, fresh and tight in general
4. Strike N-S, drip- 70^0 to 80^{0}towards E – Random joint.

SHEAR ZONE

A foliation parallel shear zone with an average width of about 1m is present from Ch. 20.5m,0.5m upstream to Ch.11.2m, 7.2m downstream. The shear zone strikes in N 10^0 W-S 10^{0}E direction, drip 35^{0}towards N 80^{0}E to i.e., towards the right abutment.

RECOMMENDATION

The foundation is cleared for concreting subjected to the execution of following foundation treatment measures.

- Provision of dental treatment for the shear zone present from Ch. 20.5m, 0.5m upstreamto Ch.11.2m, 7.2m downstream by excavating twice the width of the zone and back fill with rich concrete
- Provision of additional grout holes or adjusting the designed grout holes so as to be located at Ch. 16m in the axis, Ch.14m, 2m downstream, Ch.12m, 4m downstream and Ch.10m, 6 m downstream.
- Chiseling of weathered and stained joint surfaces and deteriorated biotite rich bands up to fresh levels.
- Removal of loosenedand detached rock blocks exhibiting blast induced cracks by wedging and barring.
- Provision of dowel roads in view of closely spaced foliation parallel joints.
- Only weathered rock and debris are observed in the right abutment area along the present alignment. Partly weathered to fresh bed rock is anticipated to be available at MWL in the middle of the ridge on the downstream. Hence it is suggested to provide a kink on the alignment towards downstream from the middle of the block no. 2 so that the weir can be abutted on the partly weathered to fresh bed rock up to MWL.

Sd/- 26.10.2015 **Sd/- 26.10.2015**

(VISHNU C.S) **(PRAVEEN K.R)**

Senior Geologist **Senior Geologist**

Approved

Sd/- 26.10.2016

(C. Thanavelu)

Director

ANNEXURE VI – GLOSSARY

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.

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.

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 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.

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

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

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

and includes investigation of the non-overflow portion, spillways, abutments, stilling basin, piers, bridge, down-stream toe, drainage galleries, operation of mechanical systems (including gates and its components, drive units, cranes), interior of outlet conduits, instrumentation records, and record-keeping arrangements.

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

Dam safety - the practice of ensuring the integrity and viability of dams such that they do not present unacceptable risks to the public, property, and the environment. It requires the collective application of engineering principles and experience, and aphilosophy 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, - 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.

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.

Fixed wheel gate (fixed-roller gate, fixedaxle 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.

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 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.

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.

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.

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.)
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.
Low-level outlet (bottom outlet) - an opening
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.

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

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

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.

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

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.

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.

, damaged, or failed dam or its component to an acceptable by meeting functional condition.

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.
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.

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.

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.

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.

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.

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.