Online training of SAARC Professionals on Small, Mini and Micro Hydro Power Generation
(Sept 13 - 17, 2021)

# Civil engineering aspects of designing SMMHP plants

**Sept 14, 2021**

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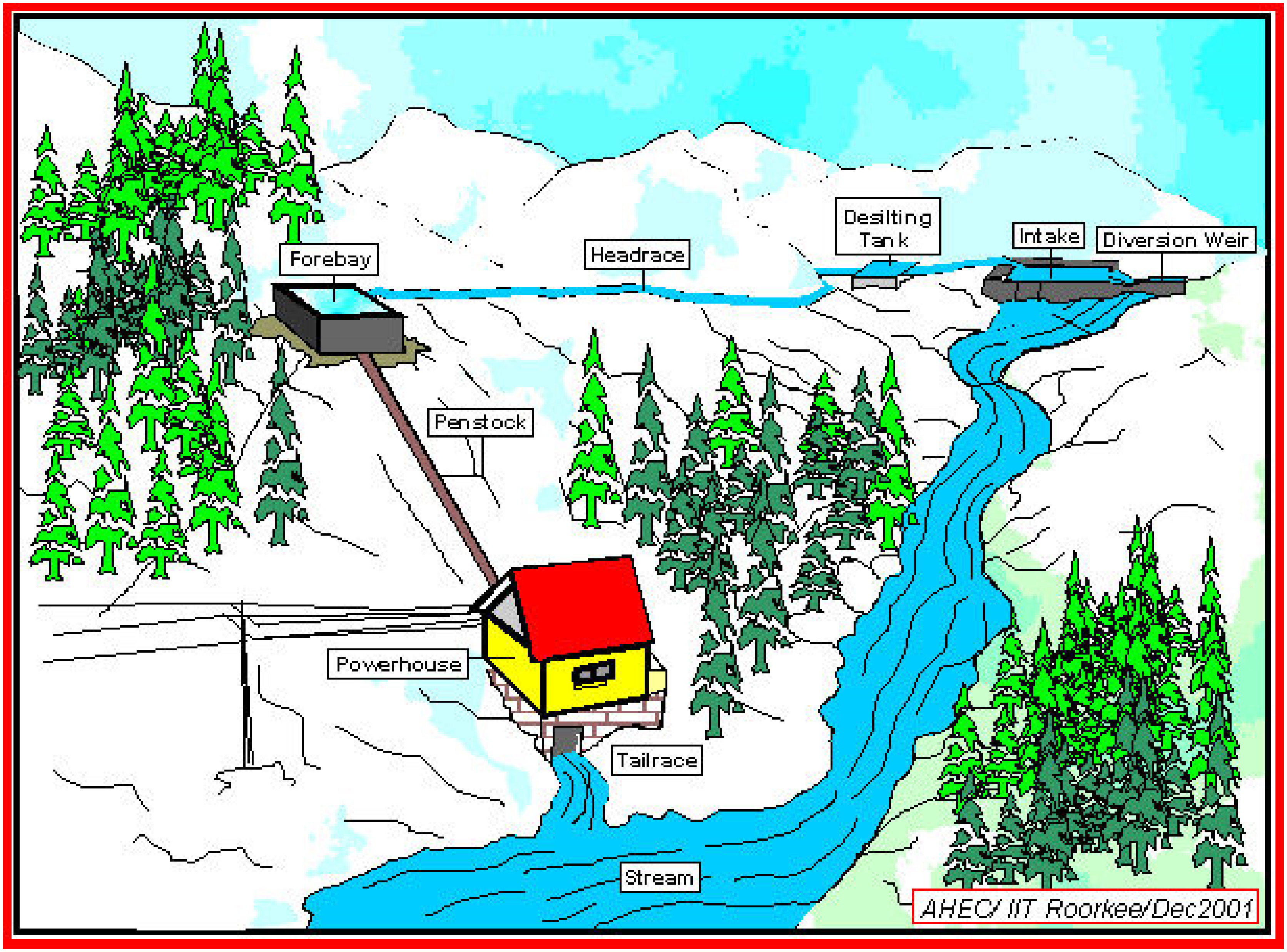
# LIST OF CONTENTS

Planning, Design methodologies and Design Examples of following Civil Components of Small, Mini and Micro Hydro Projects

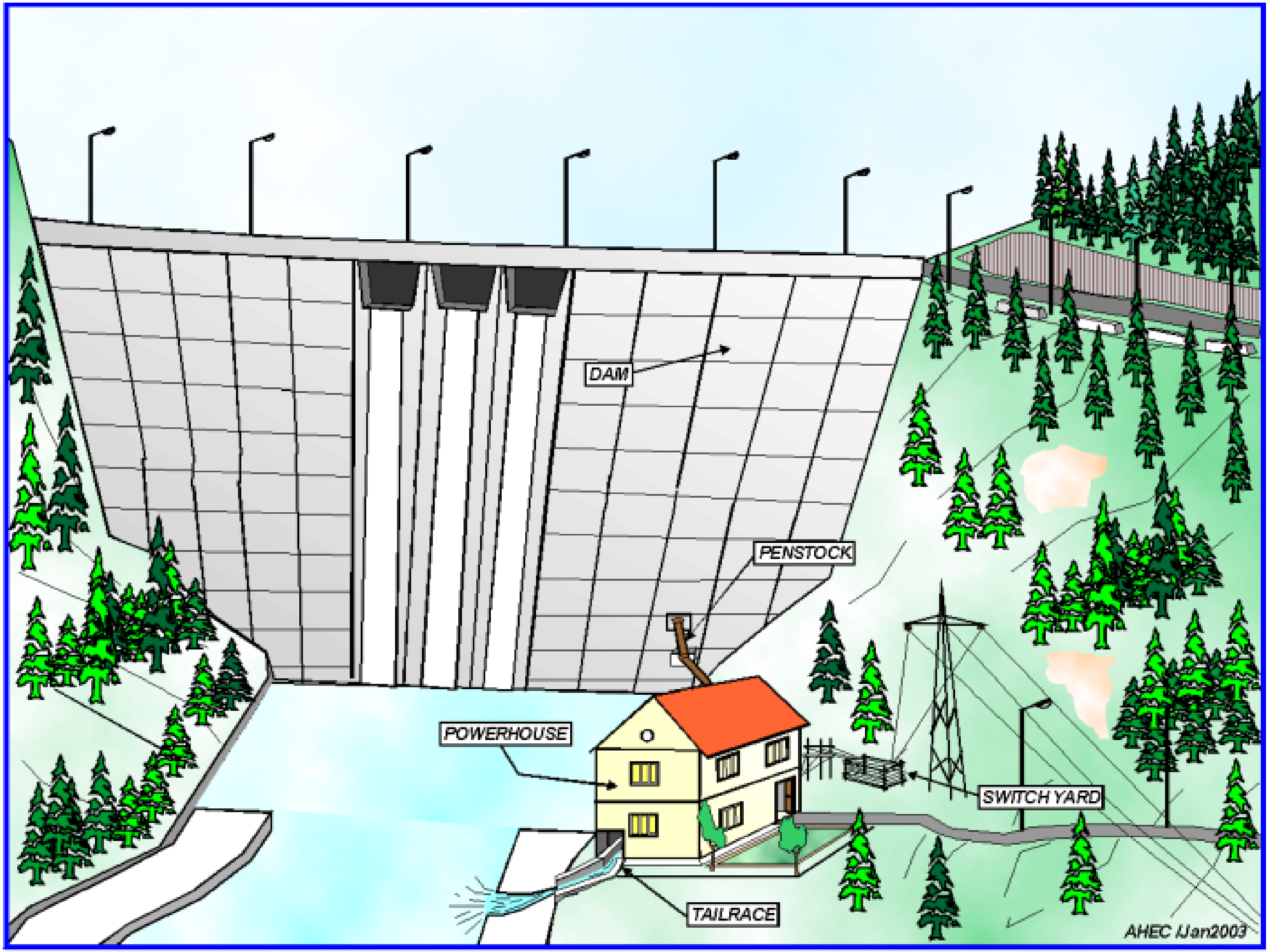
- Diversion
- Feeder Channel
- Desilting Tank
- Forebay cum Spillway
- Penstock
- Power House
- Tail Race Channel

# OBJECTIVES

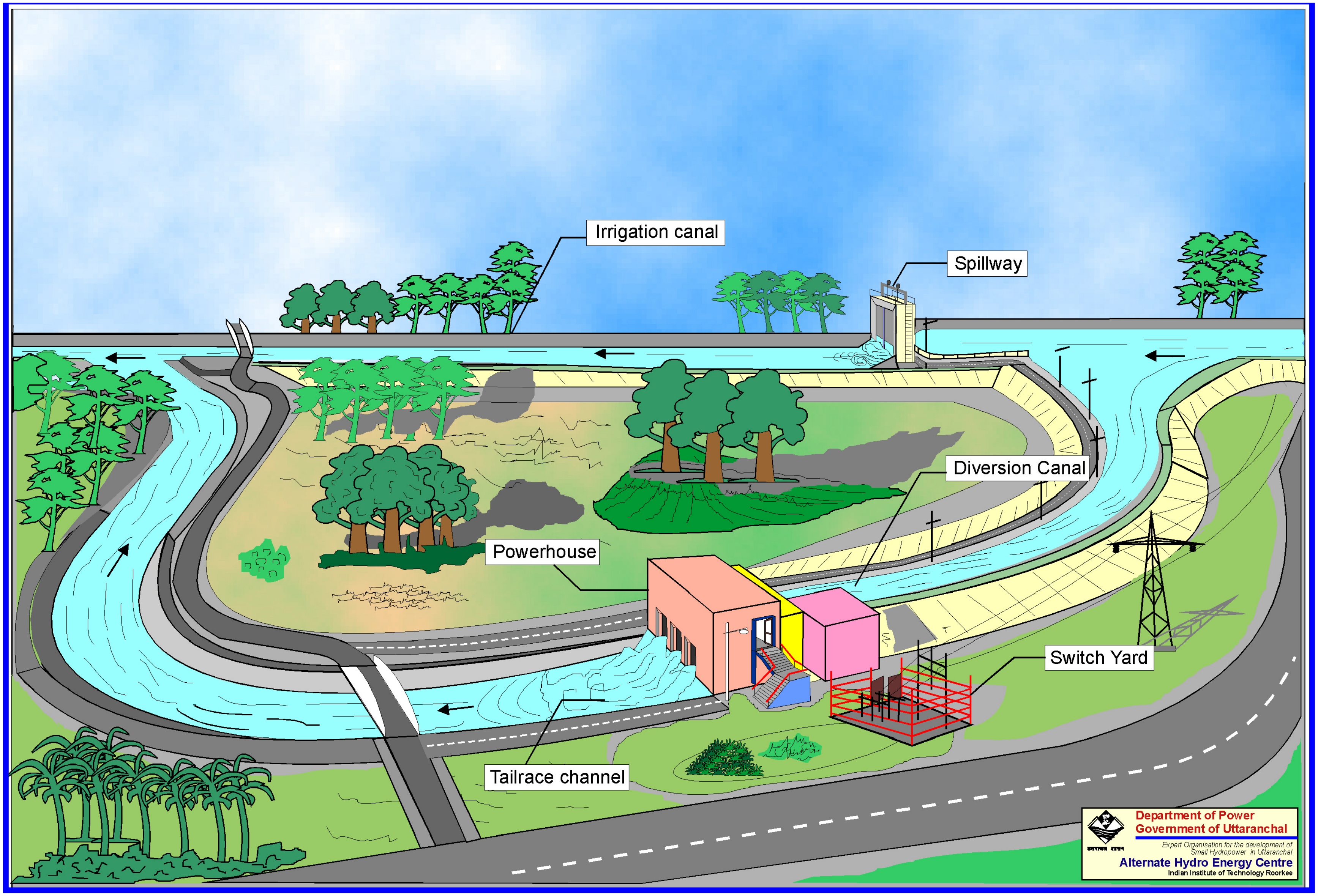
- The participants shall be made aware of planning and designing of Civil components of Small, Mini and Micro Hydro Projects. The site problems shall be discussed to clarify the concepts



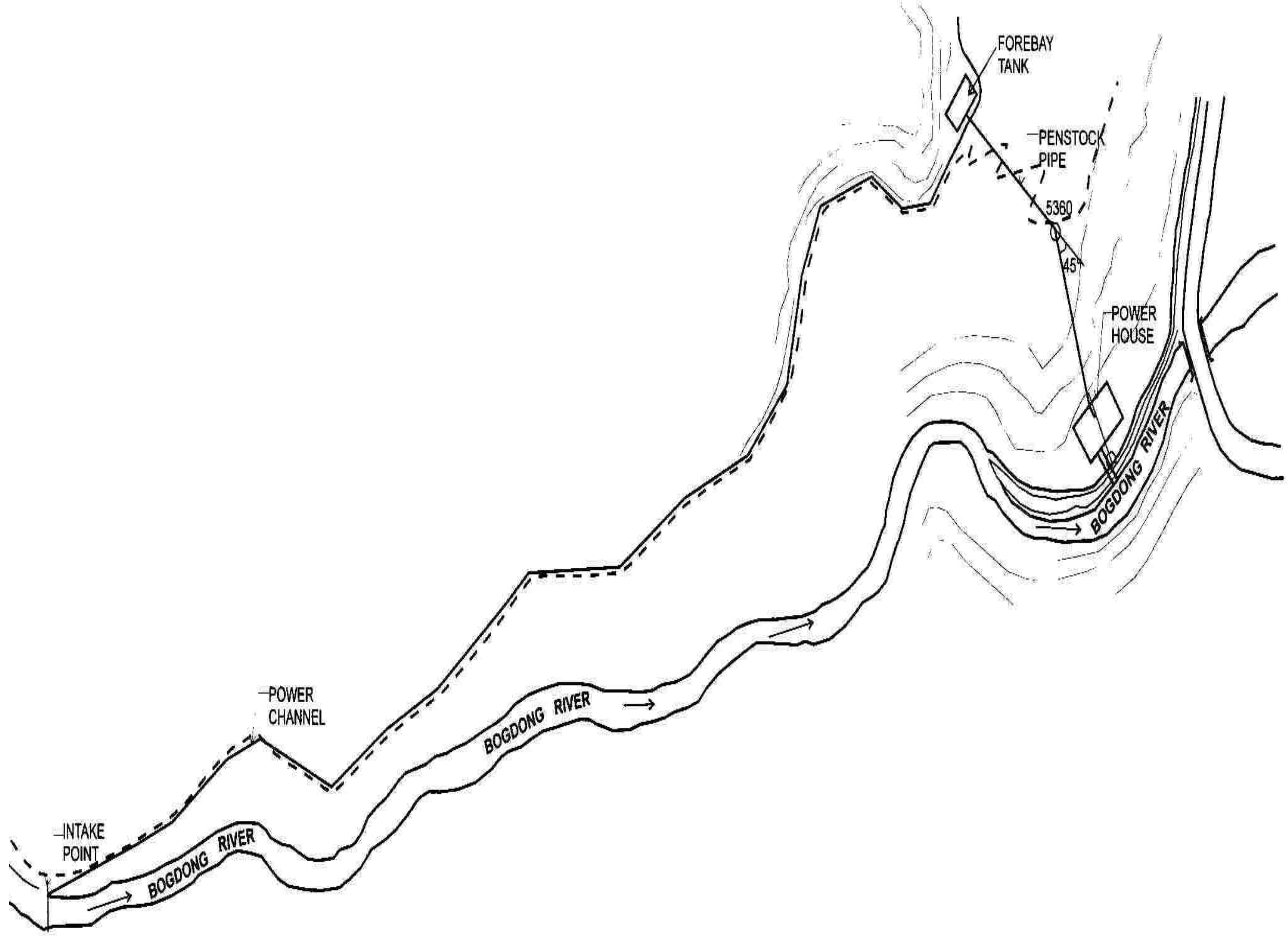

Typical Arrangement of Small Hydro Power Station

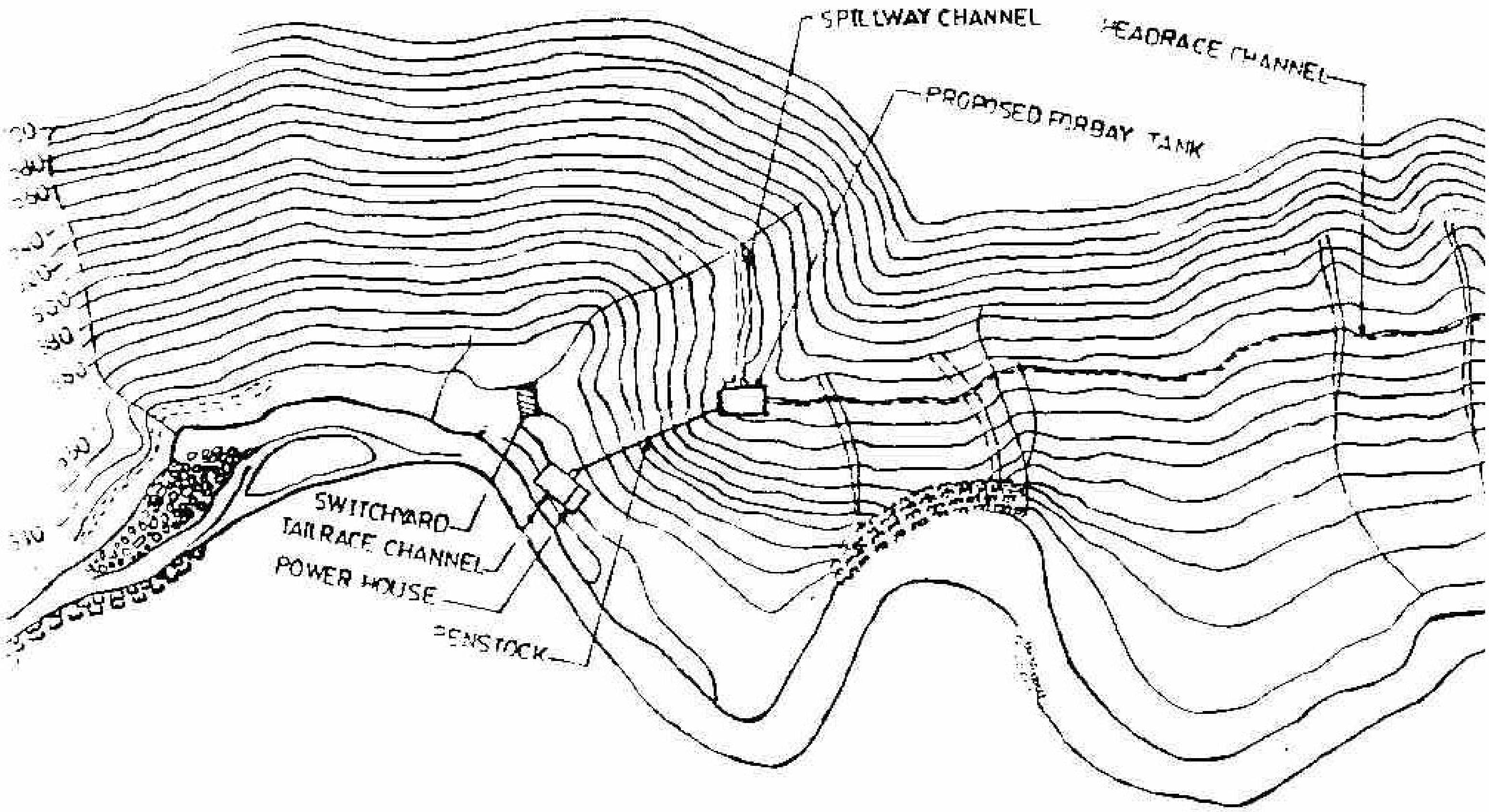



**Typical Arrangement of Dam toe Small Hydro Power Station**




**Typical Arrangement of Canal Fall Small Hydro Power Station**


FOREBAY
TANK
PENSTOCK
PIPE
5360
45°
POWER
HOUSE
BOGDONG RIVER
POWER
CHANNEL
BOGDONG RIVER
INTAKE
POINT
BOGDONG RIVER


SPILLWAY CHANNEL
HEADRACE CHANNEL
PROPOSED FORBAY TANK
SWITCHYARD
TAILRACE CHANNEL
POWER HOUSE
PENSTOCK

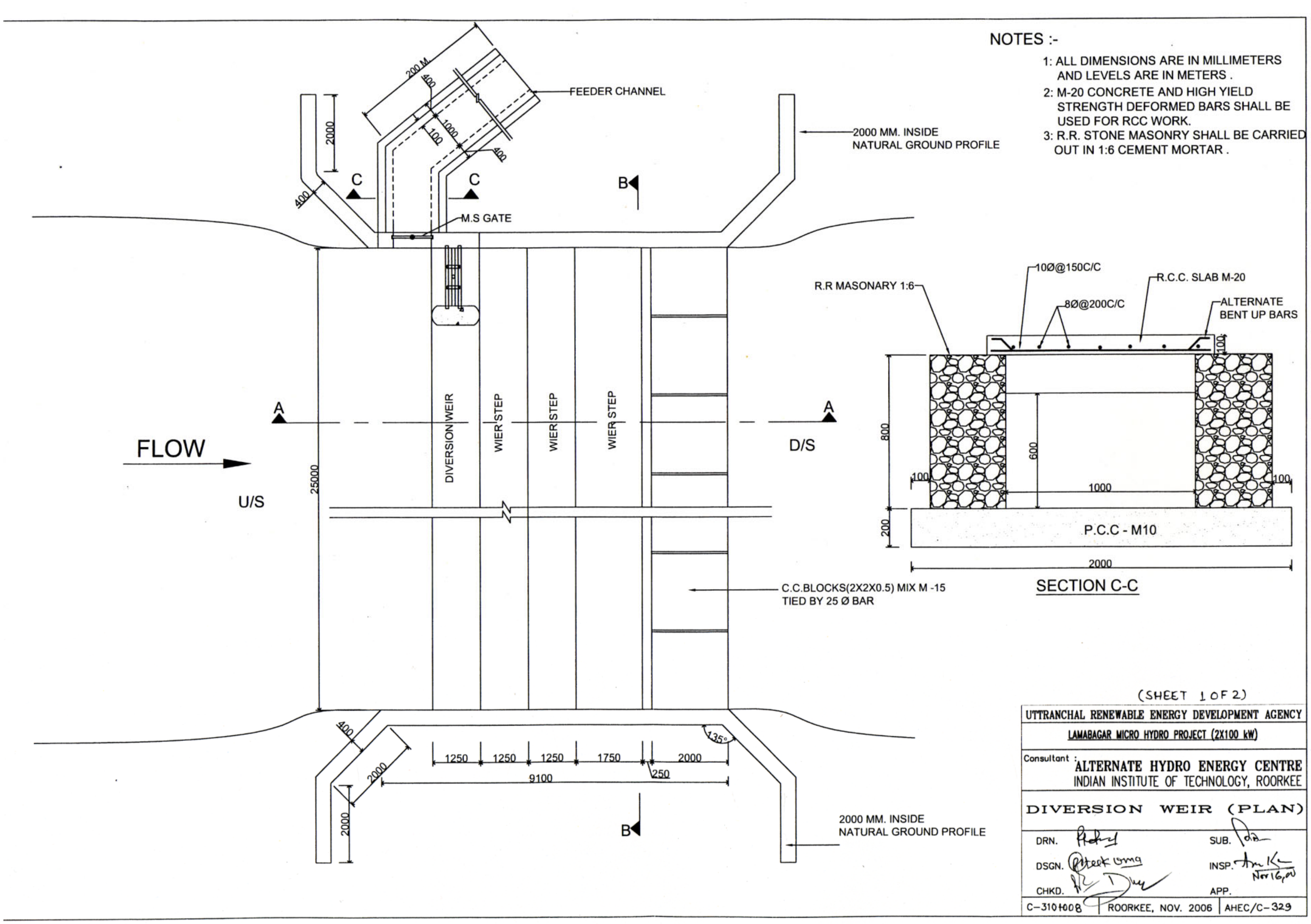
## DESIGN DISCHARGE FOR CIVIL WORKS

| | | |
|---|---|---|
| 1. Discharge required for Power Generation | = | Q |
| 2. Design discharge for head race channel, forebay, Spillway, Penstock, Tail race channel ($Q_f$) | = | Q |
| 3. Design discharge for ($Q_d$) desilting chamber and intake channel (15% extra) | = | $Q_f/0.85$ |
| 4. Design discharge for intake ($Q_I$) (5% extra) | = | $Q_d/0.95$ |

# 1.0 DIVERSION WORKS

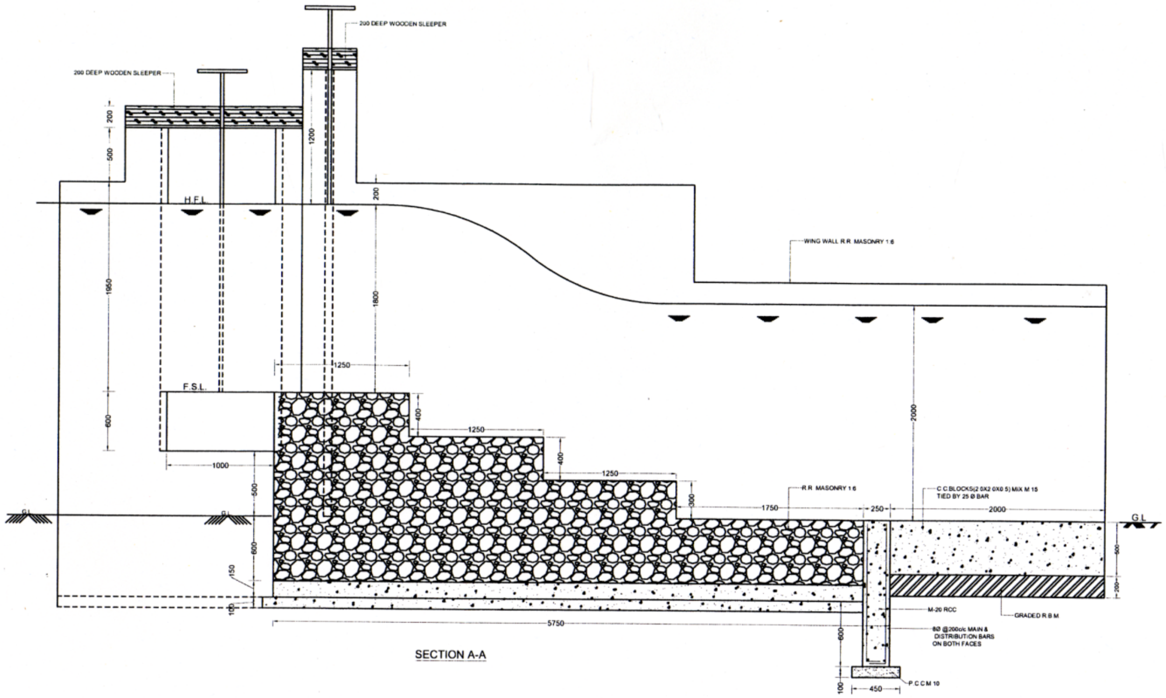
## (a) Raised crested weir

This weir is provided for low discharges

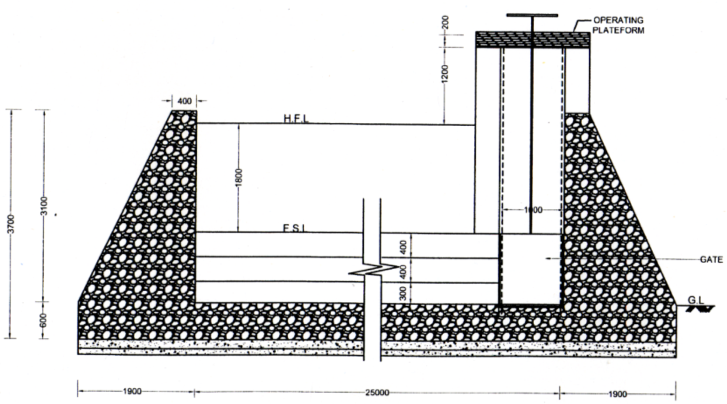


NOTES :-

1: ALL DIMENSIONS ARE IN MILLIMETERS AND LEVELS ARE IN METERS .
2: M-20 CONCRETE AND HIGH YIELD STRENGTH DEFORMED BARS SHALL BE USED FOR RCC WORK.
3: R.R. STONE MASONRY SHALL BE CARRIED OUT IN 1:6 CEMENT MORTAR .




SECTION A-A



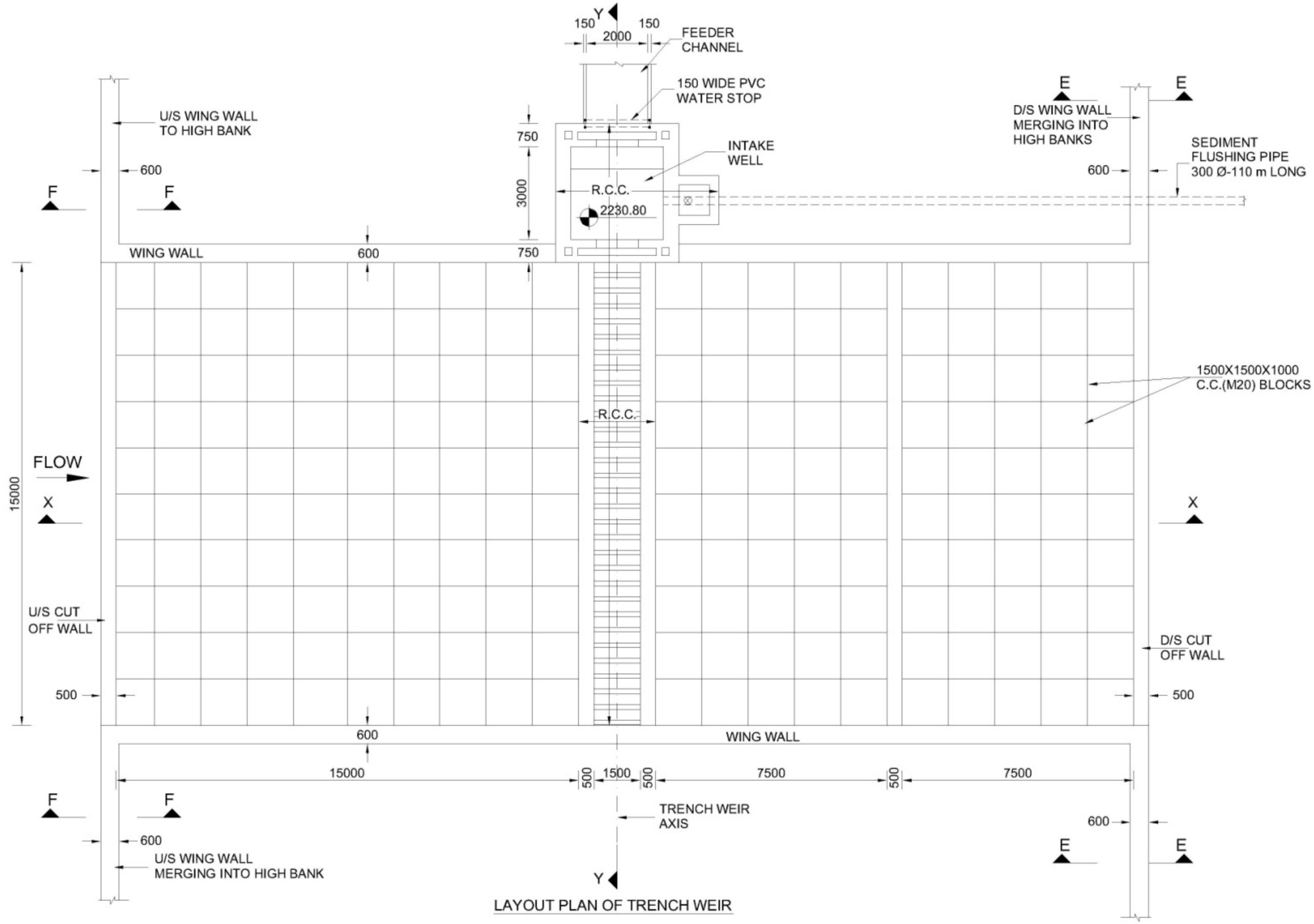

SECTION B-B

(SHEET 2 OF 2)

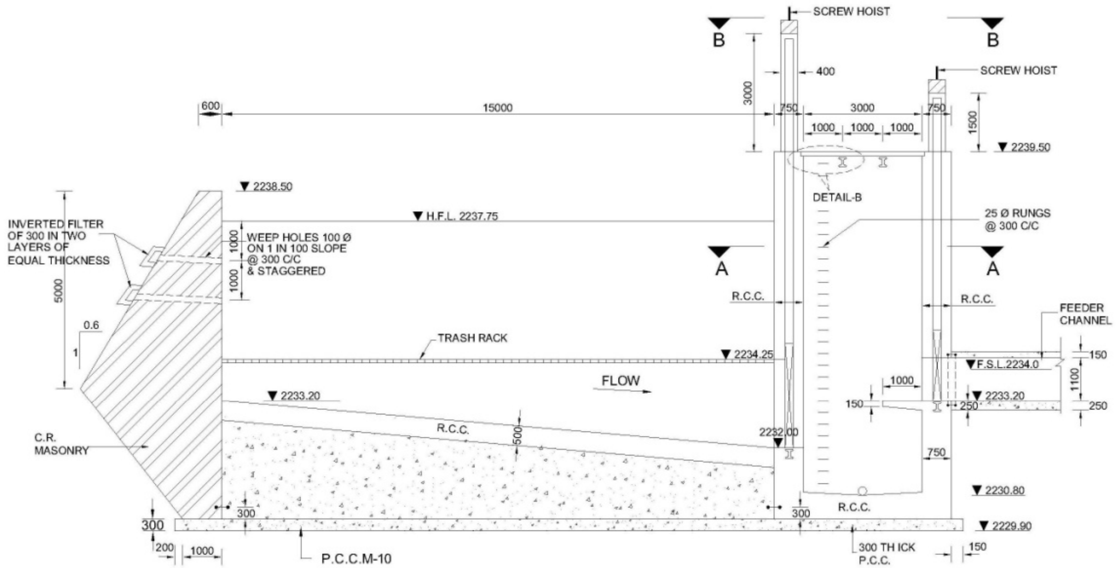
| |
|---|
| UTTRANCHAL RENEWABLE ENERGY DEVELOPMENT AGENCY |
| Consultant : ALTERNATE HYDRO ENERGY CENTRE INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE |
| LAMABAGAR MINI HYDRO PROJECT (2X100kW) |
| DIVERSION WEIR SECTION |
| DRN. SUB. |
| DSGN. INSP. Nov 16, 06 |
| CHKD. APP. |

## (b) **Trench weir**

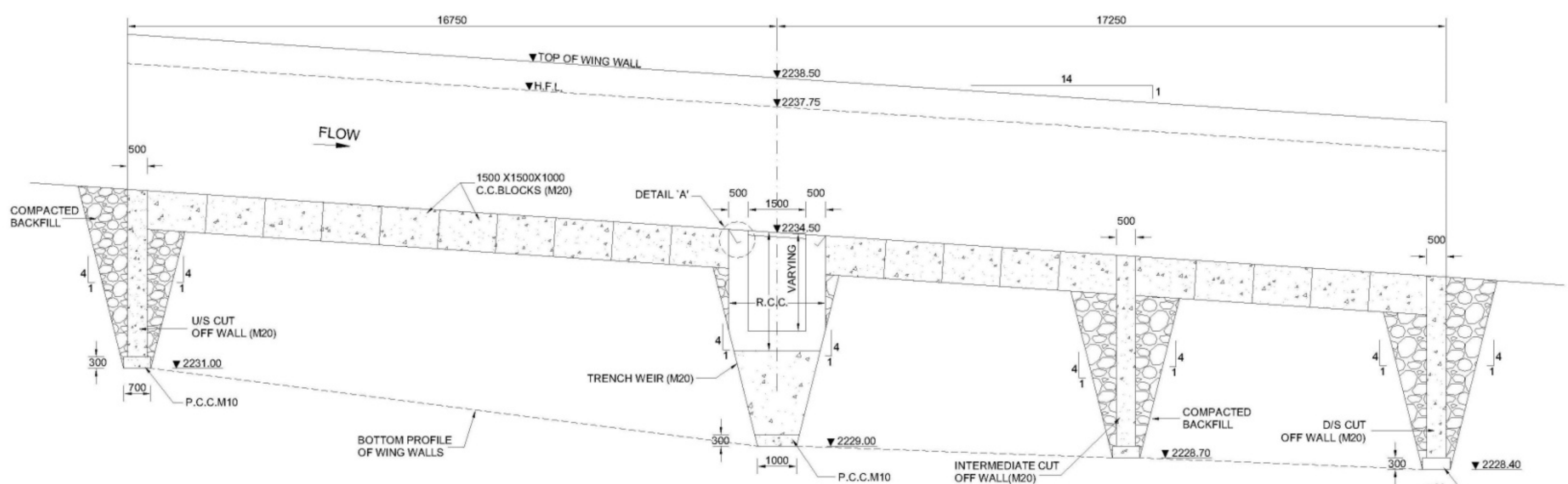
This weir is provided in hilly areas for medium discharges




LAYOUT PLAN OF TRENCH WEIR



SECTION Y-Y



SECTION X-X

## DESIGN OF TRENCH WEIR AND INTAKE

| | | |
|---|---|---|
| Lacey's water way | = | 4.75 x $\sqrt{Q}$ |
| 40% of Lacey's | = | 0.4 x 4.75 x $\sqrt{Q}$ |
| Width of Trench (B) | = | $\dfrac{Q}{E_1 E_2 C d L \sqrt{2gE}}$ |

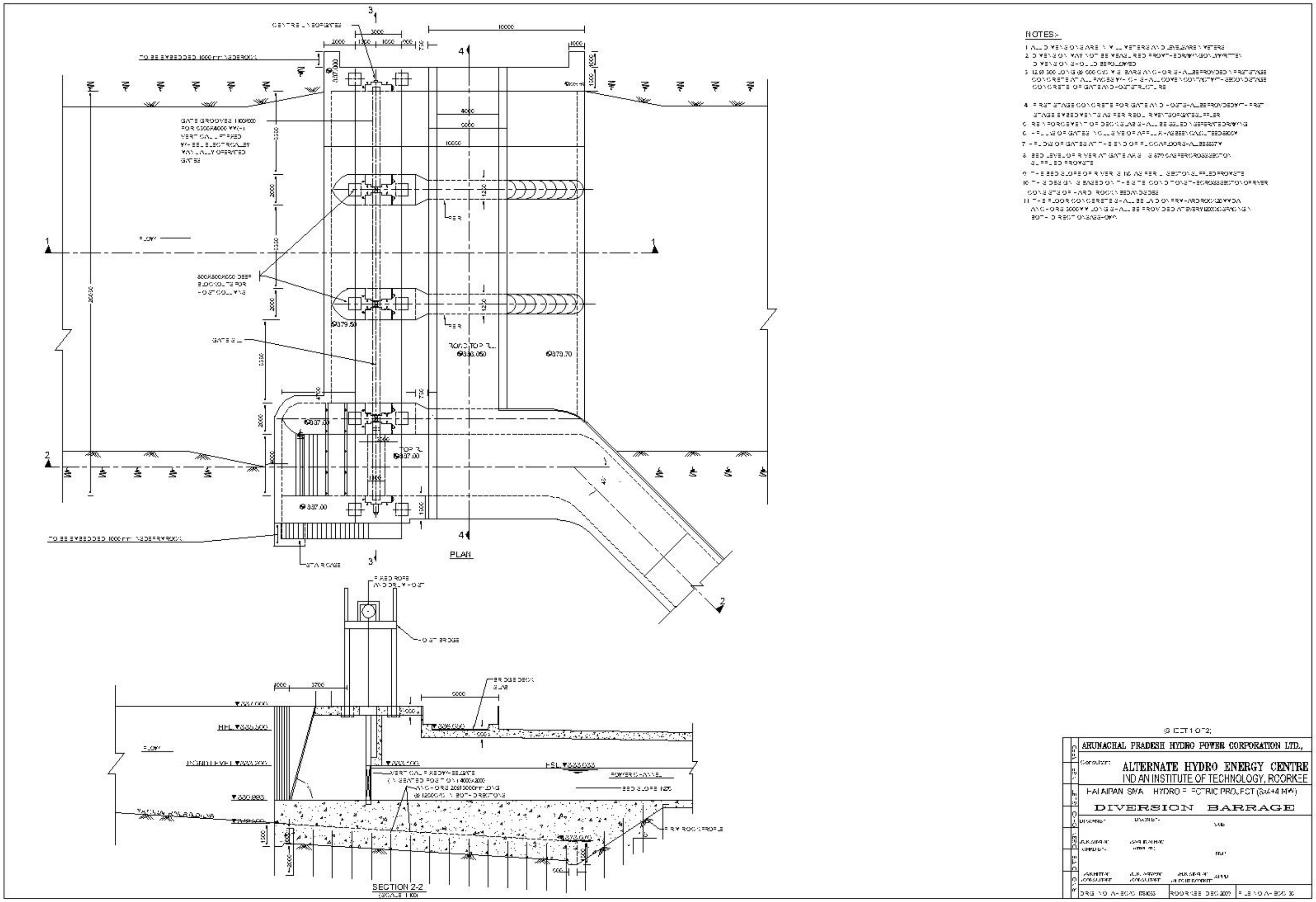
Where

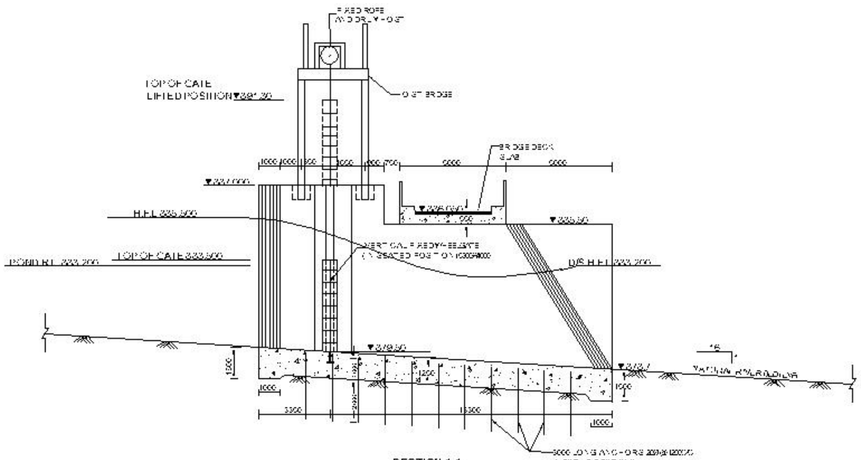
| | | |
|---|---|---|
| E1 (blockage ratio due trash rack) | = | 0.5 |
| E2 (clogging ratio of available opening ) | = | 0.5 |
| Cd (discharge coefficient through bars) | = | 0.4 |
| specific energy of the flow at the trench | | |

| | | |
|---|---|---|
| Specific Energy E | = | (Q/(L*C)^2/3 |
| C | = | Coefficient of discharge of broad crested weir (1.71) |

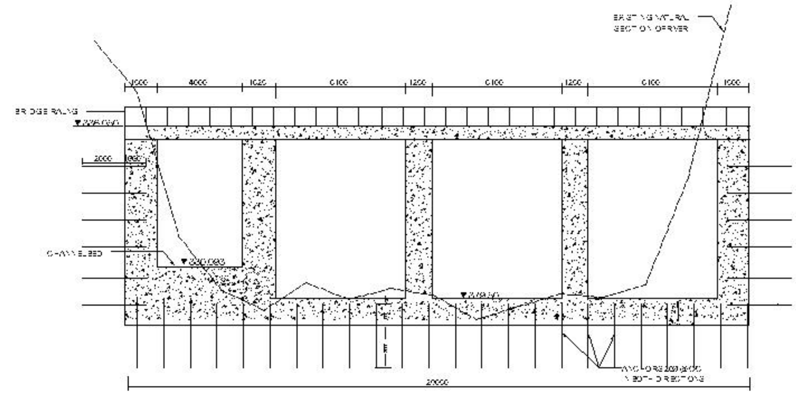
## (c) **Barrage**

This structure is provided in hilly area where slope of the river is mild



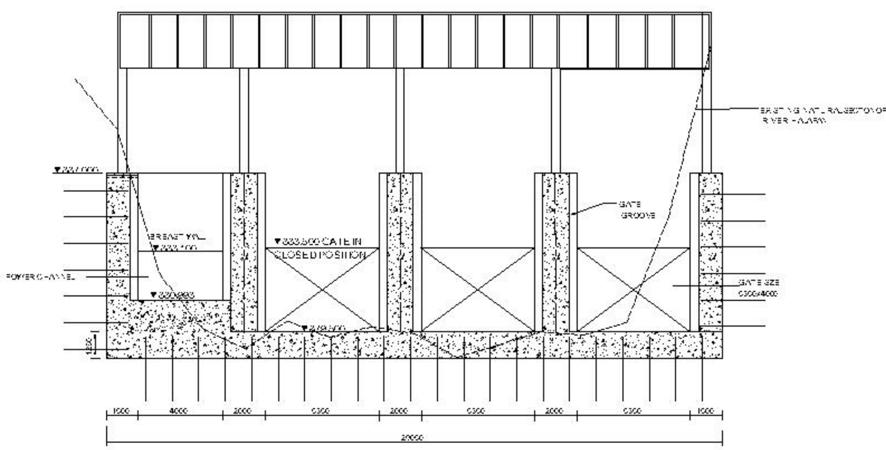



SECTION 1-1




SECTION 4-4

NOTES:-



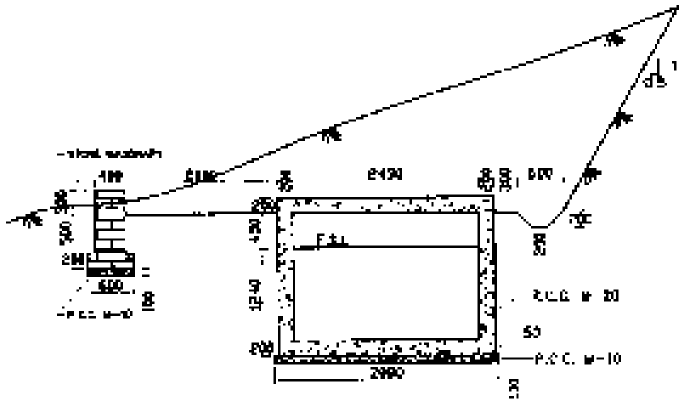

SECTION 4-4

ARUNACHAL PRADESH HYDRO POWER CORPORATION LTD.,

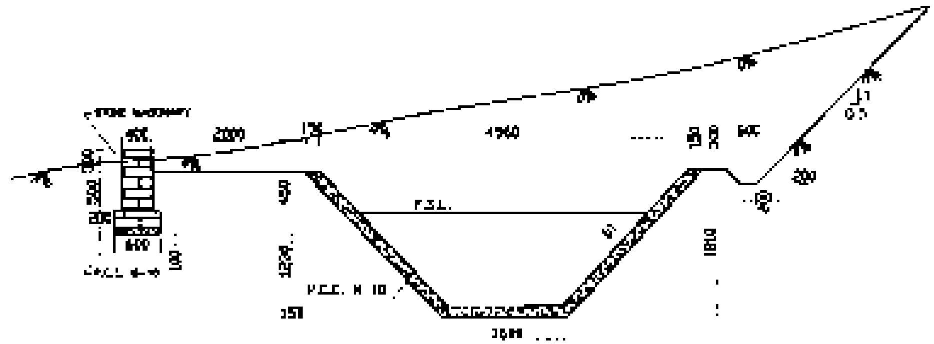
ALTERNATE HYDRO ENERGY CENTRE
INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE

DIVERSION BARRAGE

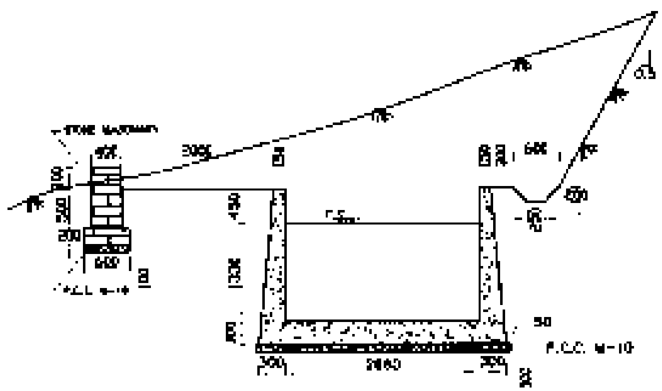
# 2.0 INTAKE AND HEAD RACE CHANNEL



CROSS-SECTION OF INTAKE CHANNEL
(FROM INTAKE TO DESILTING TANK R.D. 0 TO 80)



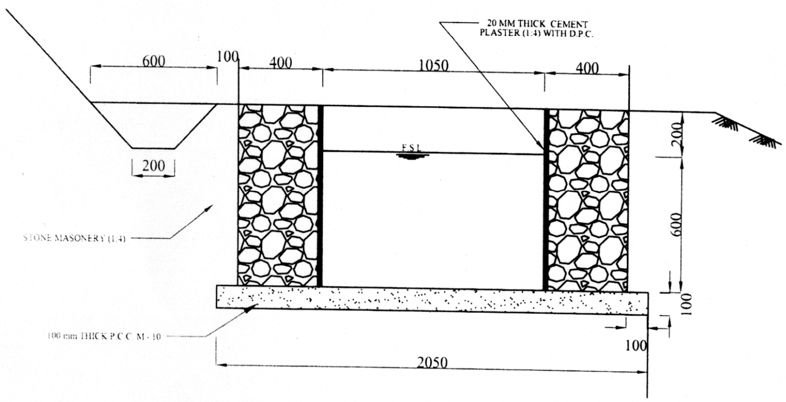
CROSS-SECTION OF HEAD RACE CHANNEL
(FROM DESILTING TANK TO FOREBAY R.D. 138.45 TO 4639.95)



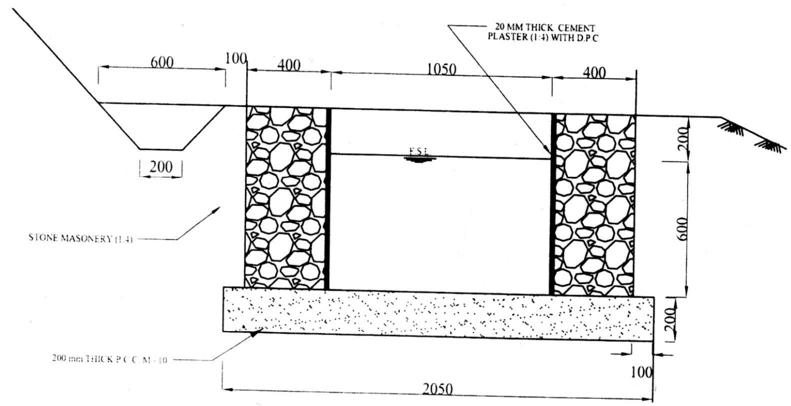
CROSS-SECTION OF HEAD RACE CHANNEL
(FROM DESILTING TANK TO FOREBAY R.D. 138.45 TO 4639.95)
(ALTERNATE)

NOTES:-

1. ALL DIMENSION ARE IN MILLIMETERS AND LEVELS ARE IN METERS.
2. PROVIDE BED SLOPE IN POWER CHANNEL 1 : 300 FROM DESILTING TANK & FOREBAY TANK




ROCK PORTION




NON ROCK PORTION

## TYPICAL CROSS-SECTION OF POWER CHANNEL

| | | |
|---|---|---|
| UTTRANCHAL RENEWABLE ENERGY DEVELOPMENT AGENCY | | |
| Consultant : ALTERNATE HYDRO ENERGY CENTRE INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE | | |
| LAMABAGAR MINI HYDRO PROJECT X– SECTION OF POWER CHANNEL | | |
| DRN. | SUB. | |
| DSGN | INSP. | |
| CHKD. | APP. | |
| DRG NO. AHEC C-318 1003 | ROORKEE, JAN 2006 | FILE NO.AHEC R-201 |

## DESIGN OF INTAKE CHANNEL/ HEAD RACE CHANNEL

Discharging capacity Q = $\frac{AR^{2/3}S^{1/2}}{n}$

Where

A = Cross Section Area of Channel

R = Hydraulic Radius (A/P)

P = Wetted Perimeter

S = Bed Slope

n = Manning' Roughness Coefficient

| | | | For Rectangle Section | Trapezoidal Section (Side slope 1(V):s (H) |
|---|---|---|---|---|
| Area | A | = | Bd | d(B+ sd) |
| Wetted perimeter | P | = | B + 2d | B + 2d x (1+s^2)^0.5 |

# Manning's Coefficient (n)

| Sl. No. | Type of material | Value of n |
|---|---|---|
| 1. | Stone masonry with plaster | 0.014 |
| 2. | R.C.C./PCC Lining | 0.018 |

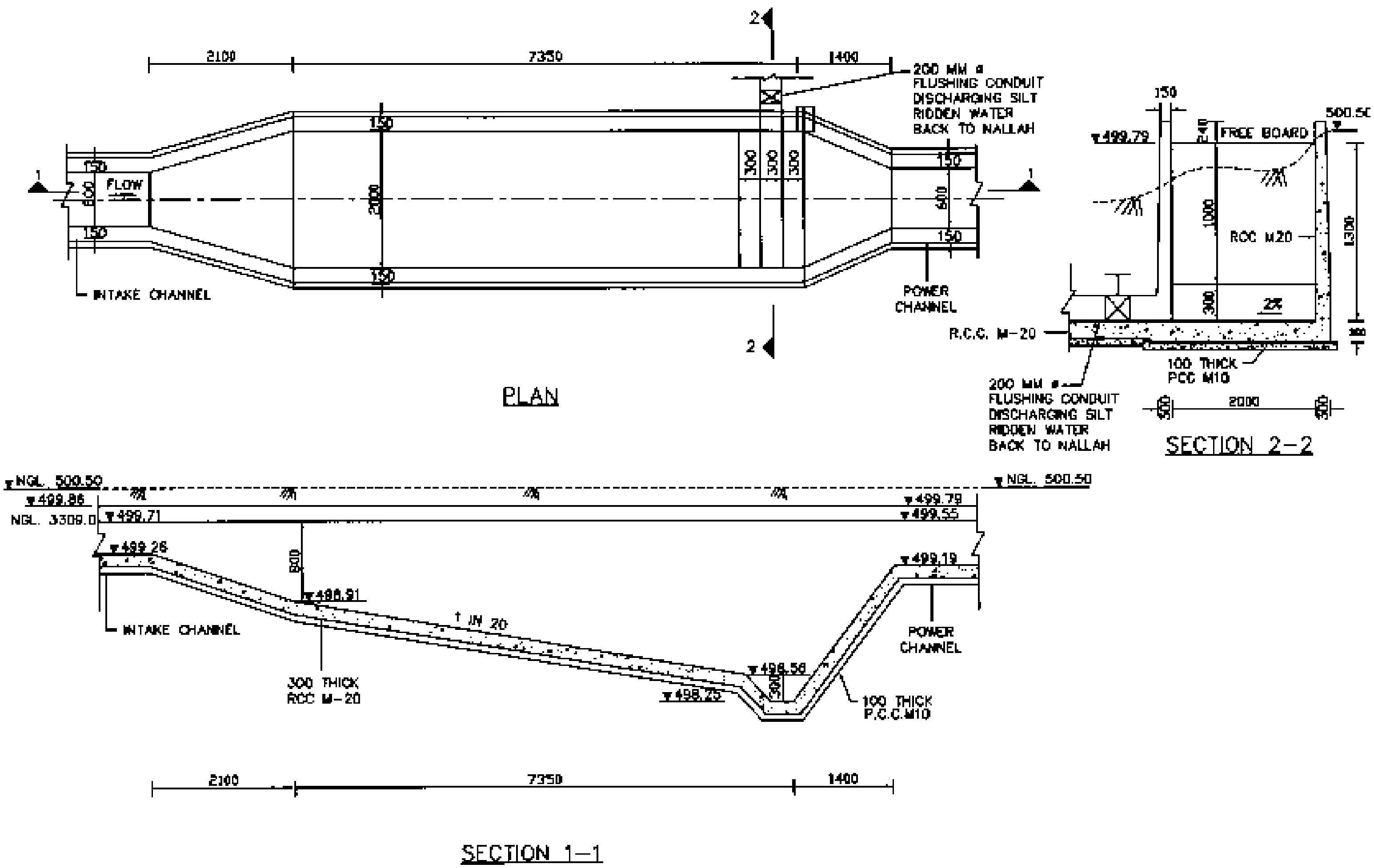
# Permissible Velocity

| Sl. No. | Type of material | Intake Channel | | Head Race channel | |
|---|---|---|---|---|---|
| | | Min. | Max. | Min. | Max. |
| 1. | Stone masonry with plaster | 1.5 m/s | 2.0 m/s | 1.0 | 2.0 |
| 2. | R.C.C./ PCC Lining | 1.5 m/s | 3.0 m/s | 1.0 | 3.0 |

# 3.0 DESILTING TANK

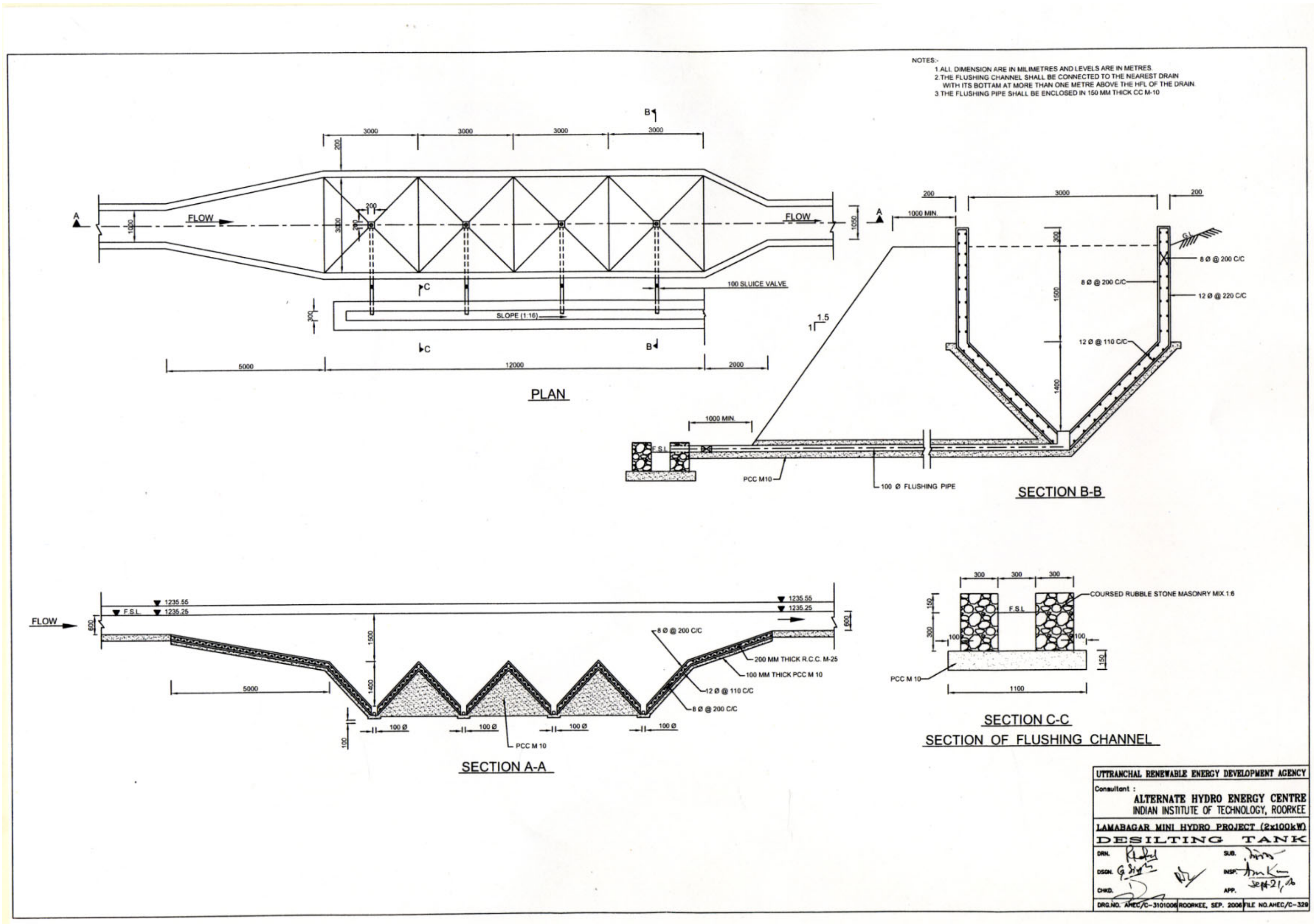
## (a) Manual Cleaning Type

This type of Desilting Tank is provided for small Project



### (b) Automatic Cleaning Type (Hooper type)

This type of Desilting Tank is provided for Medium and Big Project



**DESIGN OF DESILTING TANK**

Following steps to be followed :

(a) The recommend particle size to be removed for power projects is 0.25 mm and above.

(b) Flow Velocity ($V_f$) in tank to be approx. 0.20 m/s.

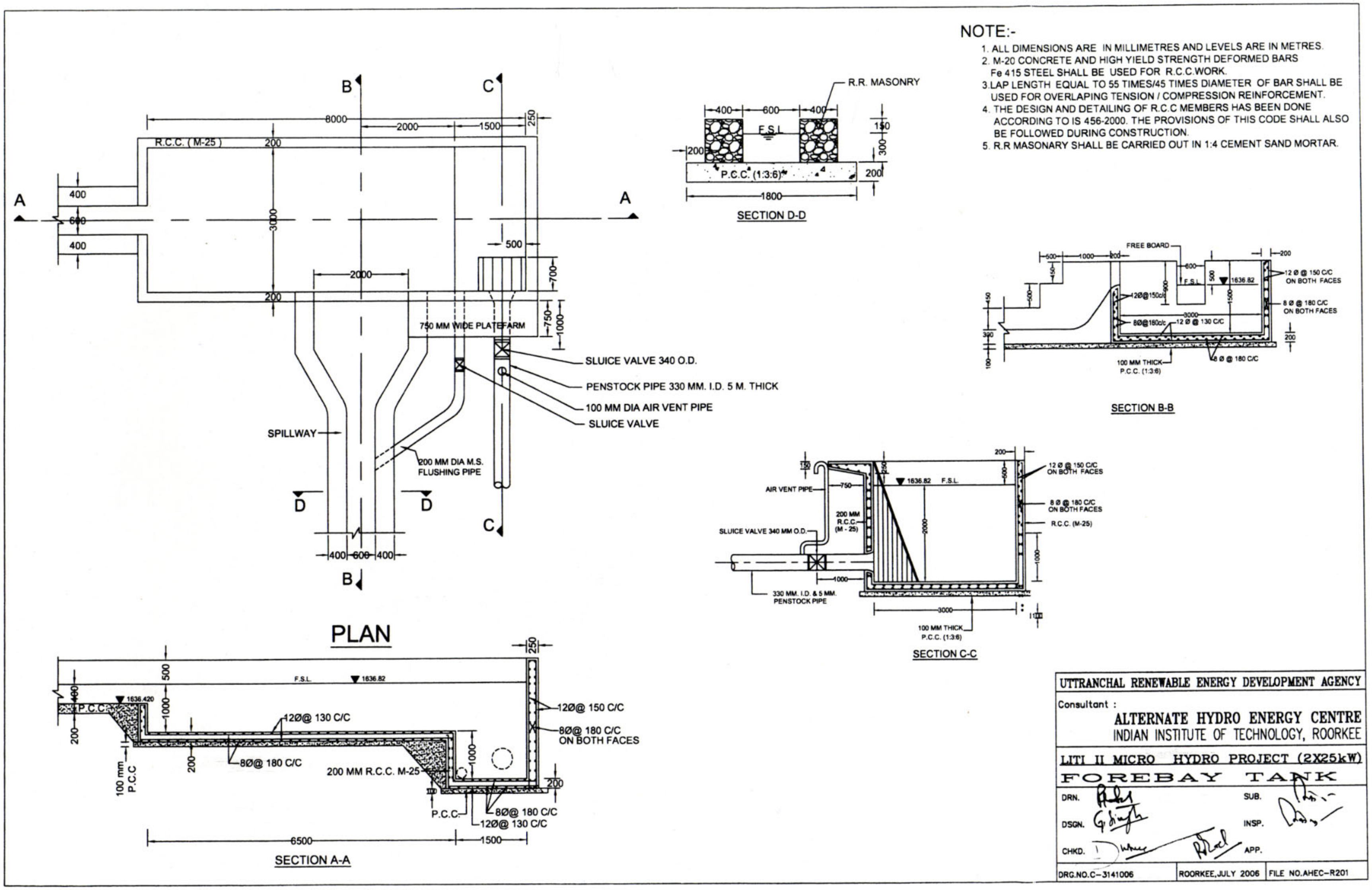
(c) Settling velocity ($V_s$) in tank for Settling of Particle size 0.25 mm and above may be taken as 2.75 cm/sec.

$$D = \frac{Q}{W \times V_f}$$

$$\text{Moderate settling velocity} = V_s - \frac{0.132}{\sqrt{D}} \times V_s$$

$$\text{Length of tank required} = \frac{V_f}{V_s} \times D$$

# 4.0 FOREBAY TANK AND SPILLWAY



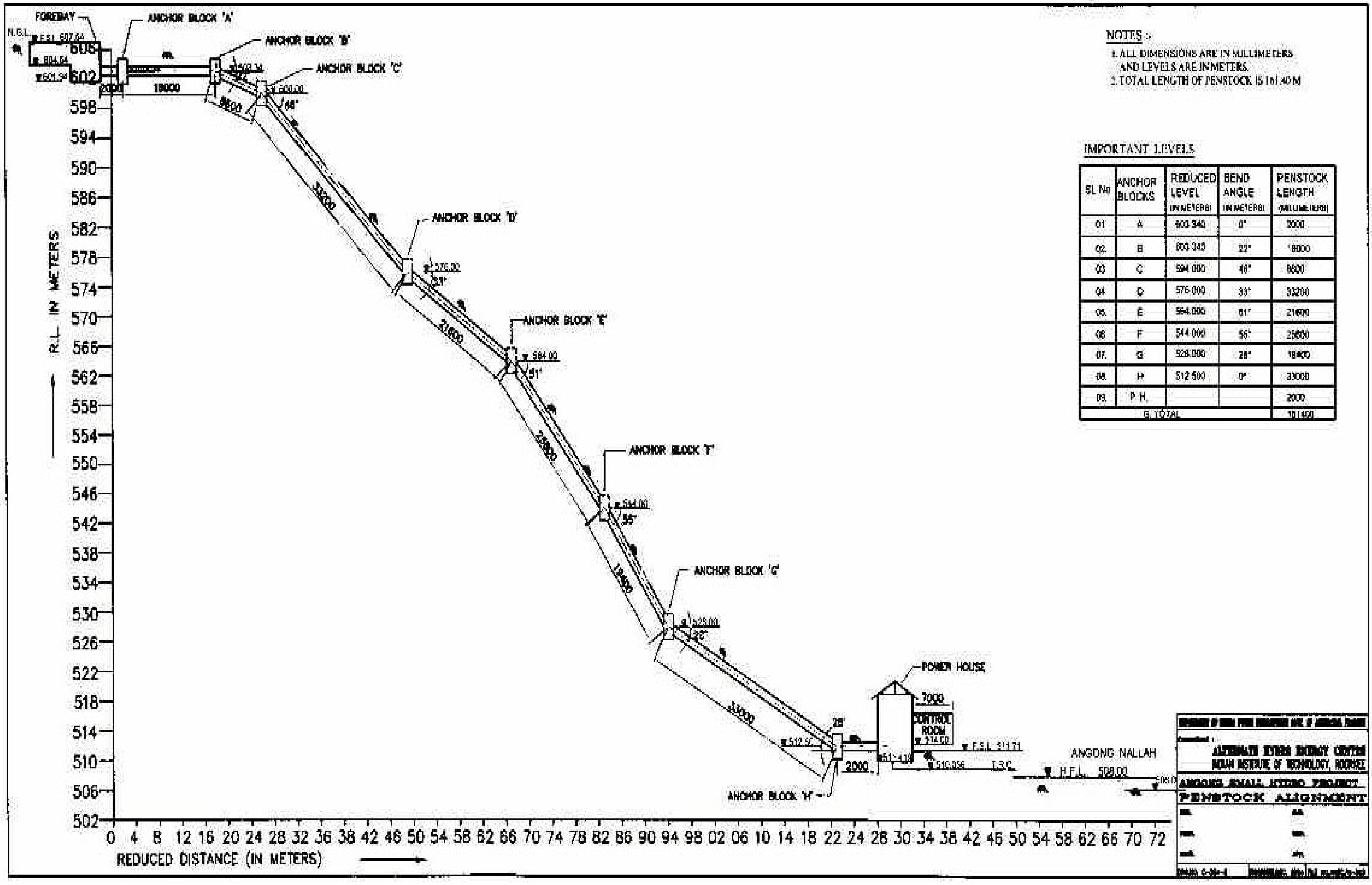
## DESIGN OF FOREBAY TANK

| | | |
|---|---|---|
| Storage required | = | 2 minute |
| Capacity of tank | = | 2 x 60 x Q |
| Taking water depth | = | d |
| Area (A) | = | Capacity/ d |
| Taking length | = | L |
| Width B | = | A/ L |

## DESIGN OF SPILLWAY

| | | |
|---|---|---|
| Q | = | $CLH^{3/2}$ |
| C | = | 2.0 |
| H | = | Head over the crest of spillway |
| | = | 0.40 m (Assume) |
| L | = | Length of spillway |

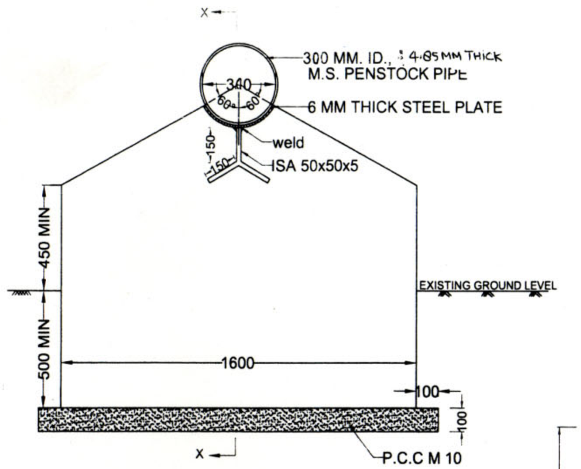
# 5.0 PENSTOCK


FOREBAY
ANCHOR BLOCK 'A'
ANCHOR BLOCK 'B'
ANCHOR BLOCK 'C'
ANCHOR BLOCK 'D'
ANCHOR BLOCK 'E'
ANCHOR BLOCK 'F'
ANCHOR BLOCK 'G'
ANCHOR BLOCK 'H'
POWER HOUSE
CONTROL ROOM
ANGONG NALLAH
R.L. IN METERS
REDUCED DISTANCE (IN METERS)
NOTES :-
1. ALL DIMENSIONS ARE IN MILLIMETERS AND LEVELS ARE IN METERS.
2. TOTAL LENGTH OF PENSTOCK IS 161.40 M
IMPORTANT LEVELS
SL No | ANCHOR BLOCKS | REDUCED LEVEL (IN METERS) | BEND ANGLE (IN METERS) | PENSTOCK LENGTH (MILLIMETERS)
01 | A | 600.340 | 0° | 2000
02 | B | 600.340 | 22° | 18000
03 | C | 594.000 | 46° | 8600
04 | D | 576.000 | 33° | 33200
05 | E | 564.000 | 51° | 21600
06 | F | 544.000 | 55° | 25600
07 | G | 528.000 | 28° | 18400
08 | H | 512.500 | 0° | 33000
09 | P.H. | | | 2000
G. TOTAL | | | | 161400
ALTERNATE HYDRO ENERGY CENTRE
ANGONG SMALL HYDRO PROJECT
PENSTOCK ALIGNMENT

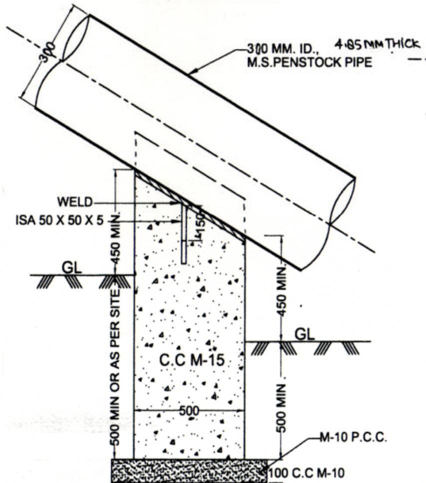
NOTE :

1. ALL DIMENSIONS ARE IN MILLIMETRES.
2. ANCHOR BLOCKS SHALL BE PROVIDED AT HORIZONTAL & VERTICAL BEND AND NOT MORE THAN 150 METRES APART.
3. SADDLE BLOCKS SHALL BE PROVIDED AT A DISTANCE OF 5 METRES CENTER TO CENTER.
4. SUITABLE EXPANSION JOINTS SHALL BE PROVIDED IN THE PENSTOCK JUST DOWN STREAM OF EVERY ANCHOR BLOCK.
5. AT PLACES WHERE THERE HAPPEN TO BE A BEND BOTH IN HORIZONTAL AS WELL AS VERTICAL PLANE SUITABLE COMPOUND BEND SHALL BE PROVIDED.

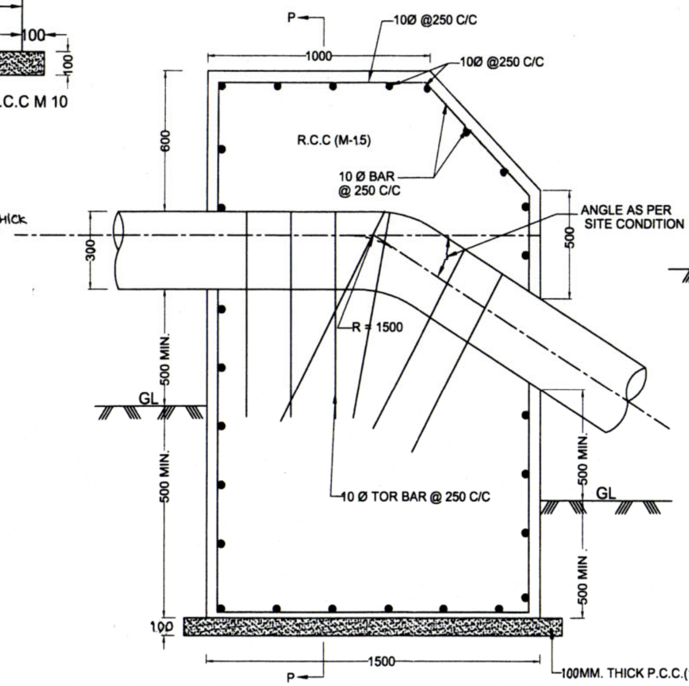
REVISION NOTES-(1)- 1. THE PENSTOCK PIPE THICKNESS MODIFIED TO 4.85 mm. AS 4.00mm THK PIPE NOT AVAILABLE (REFER LETTER NO 625 UREDA B(1-1) 2006 Dt 9.11.06.
2. PENSTOCK PIPE LENGTH IS 140 METER. (REFER ABOVE LETTER)



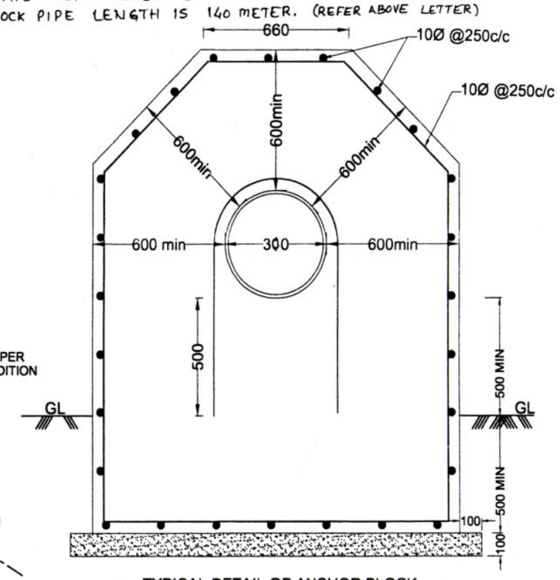

TYPICAL DETAIL OF SADDLE SUPPORT




TYPICAL DETAIL OF SADDLE SUPPORT SECTION X-X




TYPICAL DETAIL OF ANCHOR BLOCK




TYPICAL DETAIL OF ANCHOR BLOCK SECTION P-P

| | |
|---|---|
| UTTRANCHAL RENEWABLE ENERGY DEVELOPMENT AGENCY | |
| UTI-II MICRO HYDRO PROJECT (2X25kW) | |
| Consultant : ALTERNATE HYDRO ENERGY CENTRE INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE | |
| DETAILS OF PENSTOCK PIPE | |
| DRAWN | SUBT. |
| DSGN. | INSP. |
| CHKD. | APPD. |
| DRG. NO. C-3141007 | ROORKEE, AUG. 2006 AHEC/C-201 |

| R.NO | DATE | DSGN | CHKD | SUB | INS | APPD. |
|---|---|---|---|---|---|---|
| 1 | 14-11-06 | | | | | |

## Design of Penstock

## Economical Diameter Of Penstock

$$D = \frac{C_1 C_2 Q^{0.43}}{(H)^{0.12}}$$

Where

| | | |
|---|---|---|
| $D_e$ | = | Economical diameter in m |
| $Q_0$ | = | Design discharge of the penstock in $m^3/s$ |
| $H_0$ | = | Design head in m |
| $C_1$ | = | Coefficient taking into consideration the energy cost in the area, 1.2 to area where energy cost is low. |
| $C_2$ | = | Coefficient taking into account the material of penstock, 1 for steel penstock |
| D | = | Diameter of Pipe |

**Calculation for thickness of penstock**

Thickness of steel liner $= \dfrac{P \times D}{2 \times \sigma}$

where

P is the Pressure (kg/cm^2) in pipe including water hammer

i.e. 1.5 x 0.1 x H

σ = Permissible Stress which 1050 kg/cm^2

The thickness increased is to be obtained by 1.5mm to account abrasion

**Calculation for handling point of view**

Thickness from handling criteria

$t = \dfrac{D + 50}{400}$

D = Diameter in cm

## Calculations of Penstock Losses

Friction factor ( f) from Moody's diagram = 0.011

1. Length of Penstock = L
2. No. of Anchor block = n
3. Friction Loss in penstock = $\frac{f \times L \times v^2}{2 \times g \times d}$
4. Trash Rack Loss = $Kt\frac{V^2}{2g}$

   where kt = 0.35
5. Intake entrance loss = $\frac{0.25 \times V^2}{2g}$
6. Exit loss = $Ke\frac{V^2}{2g}$

   where Ke = 1.0

7. Bend losses $= n\,Kb\dfrac{V^2}{2g}$

where kb $= 0.2$

8. Valve losses

(a) Near forebay for gate value (hvg) $= \dfrac{0.5V^2}{2g}$

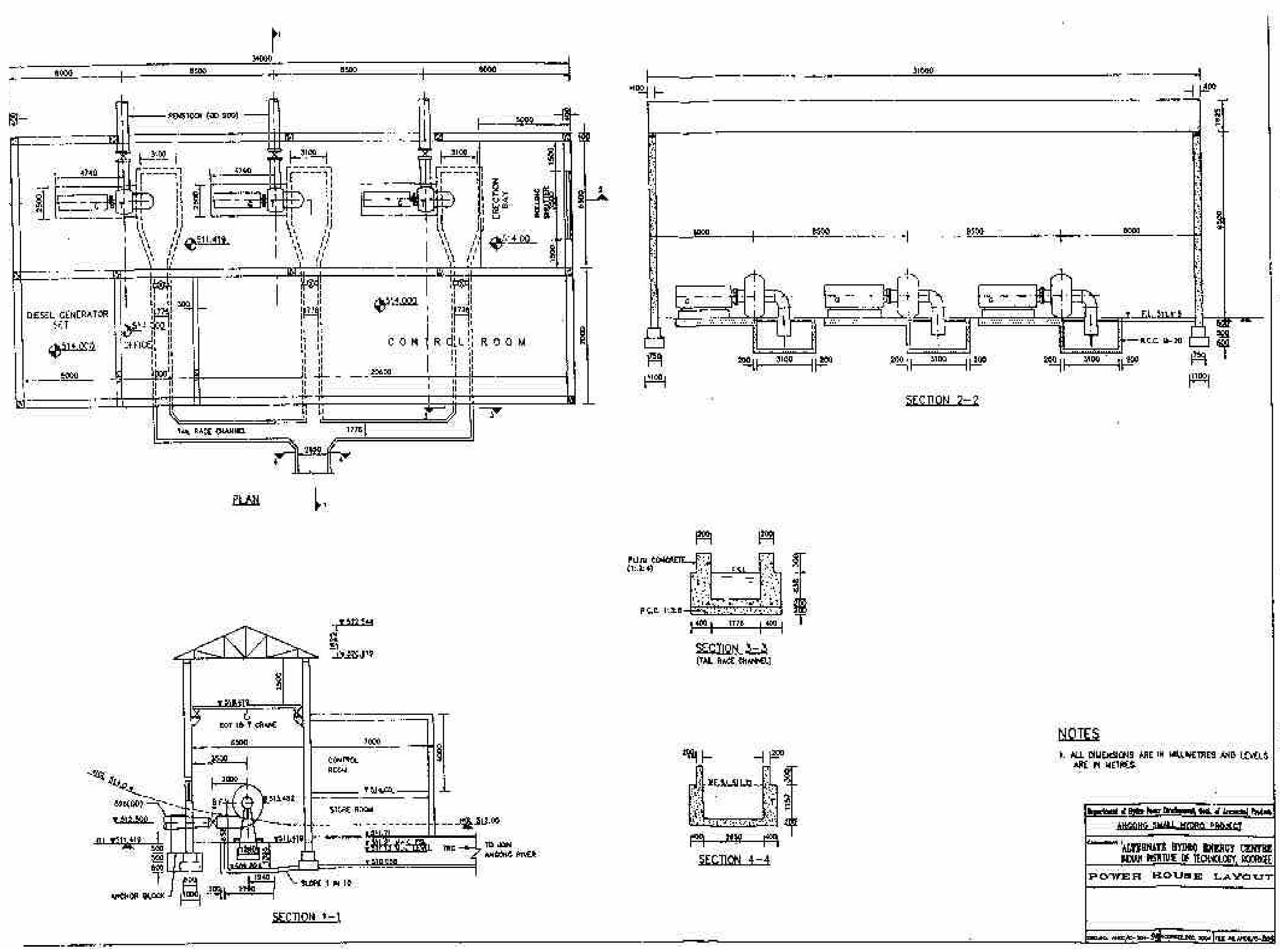
(b) Inside power house (hvb) $= \dfrac{0.5V^2}{2g}$

9. For butterfly valve (hvg) $= 0.60\dfrac{V^2}{2g}$

10. Transition losses $= 0.65\dfrac{V^2}{2g}$

Total Loss = Sum of all above losses

# 6.0 POWER HOUSE



NOTES-

1. ALL DIMENSIONS ARE IN MILIMETRES EXCEPT LEVELS WHICH ARE IN METRES.
2. THIS DRAWING DOES NOT INDICATE DETAILS OF MACHINE & B.F. VALVE FOUNDATIONS. THESE DETAILS SHALL BE SUPPLIED AFTER RECEIPT FROM TURBINE & GENERATOR MANUFACTURERS.
3. DETAIL OF DRAFT TUBE AND TAIL RACE CHANNEL WILL BE SENT SEPARATELY.
4. THE SIZES OF DOORS & WINDOWS SHALL BE AS BELOW.

D1 = 1500 X 2100

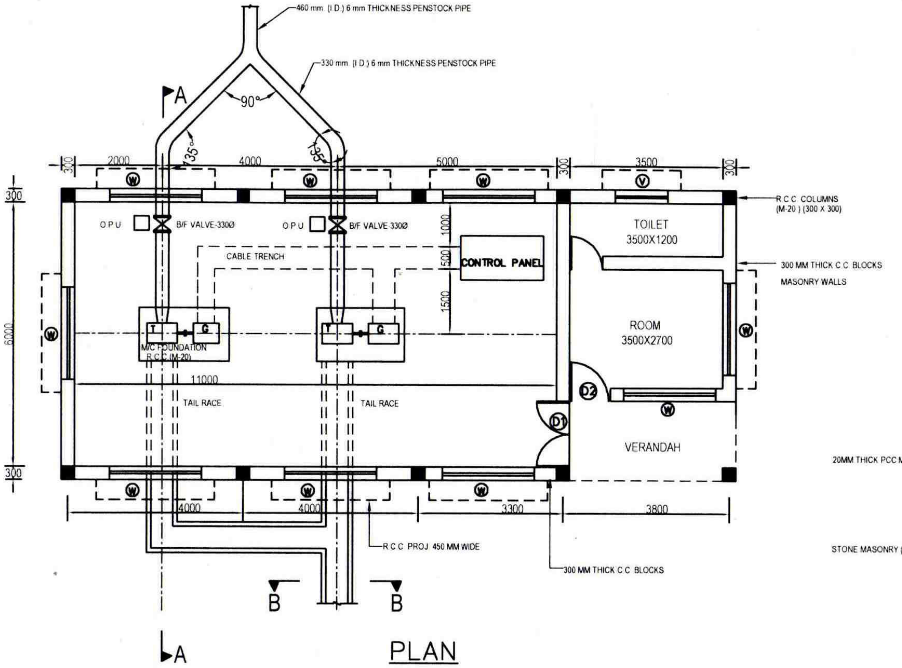
D2 = 1200 X 2100

D3 = 900 X 2100

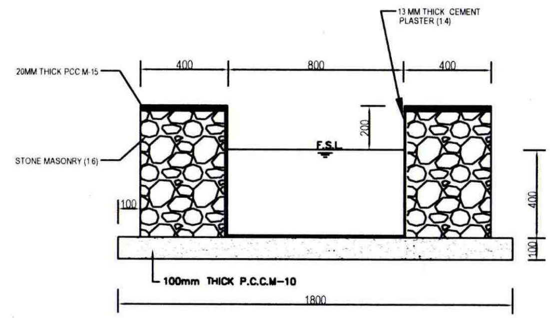
W = 2100 X 1200

V = 450 X 1200

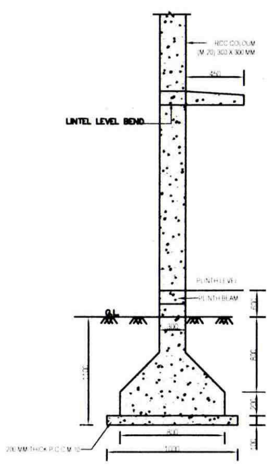
5. DETAILS OF PENSTOCK Y - PIECE SHALL BE SUPPLIED SEPARATELY.



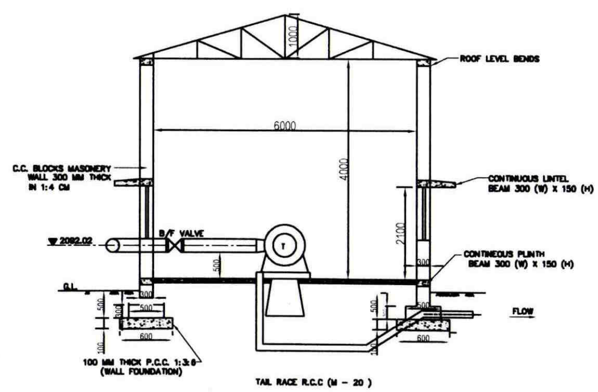

PLAN




SECTION B–B




COLUMN - SECTION




SECTION A - A

| | |
|---|---|
| **UTTRANCHAL RENEWABLE ENERGY DEVELOPMENT AGENCY** | |
| Consultant : **ALTERNATE HYDRO ENERGY CENTRE** INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE | |
| **OBRAGAD MICRO HYDRO PROJECT (2X50 kW)** **POWER HOUSE** | |
| DRN. | SUB. |
| DSGN. | INSP. |
| CHKD. | APP. |
| DRG.NO. AHEC/C-321-8 ROORKEE, MAR.2007. | FILE NO.AHEC/372 |

# SOLVED EXAMPLE

## 1.0 DESIGN DATA

| | | |
|---|---|---|
| F.S.L. at Forebay | = | 607.54 |
| Water level in tail race channel | = | 511.21 |
| Gross head | = | 607.54 – 511.21 |
| | = | 96.33 m |
| Head loss | = | 4.33 m |
| Net head | = | 96.33 – 4.33 |
| | = | 92.0 m |
| 50% dependable discharge | = | 8.38 cumecs |
| 75% dependable discharge | = | 6.96 cumecs |
| 90% dependable discharge | = | 5.65 cumecs |
| 100% dependable discharge | = | 5.10 cumecs |

## 2.0 POWER POTENTIAL AVAILABLE

Taking efficiency of turbine and generator as 0.88 & 0.94 respectively. The power potential (P) available at site.

(i) At 50 % dependable discharge

$$P = 9.81 \times 92.0 \times 8.38 \times 0.88 \times 0.94$$

$$= 6256.21 \text{ kW}$$

(ii) At 75 % dependable discharge

$$P = 9.81 \times 0.88 \times 92.0 \times 0.94 \times 6.96$$

$$= 5196.08 \text{ kW}$$

(iii) At 90 % dependable discharge

$$P = 9.81 \times 5.65 \times 92.0 \times 0.88 \times 0.94$$

$$= 4225.55 \text{ kW}$$

Discharge required for 4500 kW generation

$$= \frac{4500}{9.81 \times 0.88 \times 92.0 \times 0.94} = 6.0 \text{ cumecs}$$

Rated Discharge = 6.0 cumecs

It is proposed to provide 3 machines of 1500 kW each for the generation.

## 3.0 FIXING OF DISCHARGING CAPACITY FOR VARIOUS CIVIL STRUCTURES

(i) Design discharge for Head Race Channel, Forebay, Penstock, Spillway Channel and Tail race Channel = 6.0 cumec

(ii) Design discharge of intake channel upto desilting tank (Add 15% discharge for silt flushing ) = 6.0 x100/85 = 7.05 cumec

(iii) Design discharge for Trench Weir (Add 5% of item ii) = 7.05x100/95 = 7.43cumec

## 4.0 CALCULATION OF HFL AT WEIR SITE

High flood discharge = 447.0 cumecs

Natural cross section of river upto 622.50m (at 60 m U/s of proposed diversion site)

| | | |
|---|---|---|
| Area | = | 60.34 $m^2$ |
| Wetted perimeter | = | 37.8 m |
| Taking value of N | = | 0.035 |
| River bed slope | = | 1 in 27 |
| Discharge comes out | = | 453.0 m |
| Therefore, H.F.L. at diversion site | = | 622.50 – 60 x 1/27 |
| | = | 620.27 m |
| Bed level at diversion site | = | 617.70 m |
| H.F.L. | = | 620.27 m |

**Calculation For Scour Depth**

Scour depth (Ds) = $1.35 \times \left(\frac{q^2}{f}\right)^{1/3}$

Discharge per unit width = 447/40 $m^3$/sec.

= 11.175 $m^3$/s/m

(Silt factor varies form 1.0 for sandy rivers to 20.0 for rivers having big boulder movement)

Take f = 8.0

Ds = $1.35 \times (11.175^2/8)^{1/3}$

= 3.37 m

U/s cut off wall depth = 1.25 x Scour depth

= 1.25 x 3.37 = 4.21 m

U/s cut off wall level = HFL – U/s cut off wall depth

= 620.27 – 4.21 = 616.06 m

The U/s cut off wall has been provided upto the level of 616.06 m.

HFL 25 m D/s = 620.27-25/27

= 619.344 m

The D/s cut off wall depth = 1.5 (Scour depth)

= 1.5 x 3.37 = 5.055 m

The D/s cut off level = 619.344 – 5.055

= 614.289 m

The D/s cut off wall has been provided upto the level of

= 614.289 m

## 5.0 DESIGN OF TRENCH WEIR AND INTAKE

Lacey's water way = $4.75 \times \sqrt{Q}$

40% of Lacey's = $0.4 \times 4.75 \times \sqrt{Q}$

Width of Trench (B) = $\dfrac{Q}{E_1 E_2 CdL\sqrt{2gE}}$

Where

E1 (blockage ratio due trash rack) = 0.5

E2 (clogging ratio of available opening ) = 0.5

Cd (discharge coefficient through bars) = 0.4

specific energy of the flow at the trench

E = (Q/(L*C)^2/3

C = Coefficient of discharge of broad crested weir

= 1.543

$$E \text{ (specific Energy)} = \left(\frac{8.21}{1.543 \times 40}\right)^{2/3} = 0.260$$

$$B = \left(\frac{8.21}{0.5 \times 0.5 \times 0.46 \times 40\sqrt{2 \times 9.81 \times 0.260}}\right)$$

$$= 0.789 \text{ m}$$

Provide a width of 2.0 m from practical consideration

## 6.0 INTAKE CHANNEL/ FEEDER CHANNEL

Length of channel = 90 m

Q = 7.80 $m^3/s$

S = 1 in 25 0

n = 0.018

Rectangular reinforced cement concrete section has been provided.

Area A = Bd

Wetted perimeter P = B + 2d

R = A/P

Q = $\frac{AR^{2/3}S^{1/2}}{n}$

Provide B = 2.490 m

D = 1.24 m

Free board = 0.45 m

Flow velocity = 2.55 m/s

Area A = 3.08 $m^2$

Wetted perimeter P = 4.97m

Hydraulic Radius = 0.62 m

Design discharge = 7.89 $m^3/s$

## 7.0 DESILTING TANK

**Design Calculation Of Desilting Tank: -**

The recommend particle size to be removed for power projects having gross head of 96.33 m and above is 0.25 mm.

| | | |
|---|---|---|
| Design discharge | = | 7.80 $m^3/s$ |
| Flow Velocity ($V_f$) | = | 0.22 m/s |
| Particle size to be removed | = | 0.25 mm & above |
| Settling velocity ($V_s$) | = | 2.75 cm/sec |
| Width proposed (W) | = | 12.0 m |
| Depth required $\frac{Q}{W \times V_f}$ | = | $\frac{7.80}{12.0 \times 0.22}$ |
| | = | 2.95 m 3.0 m |
| Depth provided | = | 3.0 m |
| Moderate settling velocity | = | $V_s - \frac{0.132}{\sqrt{D}} \times V_s$ |

$$= 2.75 - \frac{0.132}{\sqrt{3.0}} \times 2.75$$

$$= 2.75 – 0.2095$$

$$= 2.54 \text{ cm/s}$$

$$= 0.0254 \text{ m/s}$$

Settling length $= \dfrac{V_f}{V_s} \times Depth$

$$= \frac{0.22}{0.0254} \times 3.0$$

$$= 25.98 \text{ m}$$

Provided length = 26.0 m

Depth = 3.0 m

Width = 12.0 m

Provide U/s transition length $= 3 \times \left(\dfrac{12.0 - 2.490}{2}\right)$

$= 14.26$ m

14.50 m

Provide D/s transition length $= 2 \times \left(\dfrac{12.0 - 1.60}{2}\right)$

$= 10.40$ m Say $= 10.50$ m

Provide Free Board $= 0.40$ m

## 8.0 HEAD RACE CHANNEL

| | | | |
|---|---|---|---|
| Length of channel | | = | 4500 m |

**Trapezoidal Channel**

| | | | |
|---|---|---|---|
| Q | | = | 6.63 $m^3/s$ |
| S | | = | 1 in 500 |
| Side Slope | | = | 1:1 |
| n | | = | 0.018 |

Trapezoidal stone masonry section has been provided

| | | | |
|---|---|---|---|
| Hydraulic Radius | R | = | A/P |
| Discharge | Q | = | $\frac{AR^{2/3}S^{1/2}}{n}$ |
| Provide bottom width | B | = | 1.60 m |

| | | |
|---|---|---|
| Provide Top width | = | 4.06 m |
| Water depth | = | 1.23 m |
| Free board | = | 450 mm |
| Area A | = | 3.48 $m^2$ |
| Wetted perimeter | = | 5.07 m |
| Hydraulic Radius | = | 0.68 m |
| Velocity | = | 1.93 m/s |
| | | |
| Discharge capacity | = | 6.72 $m^3/s$ |
| | | |
| Q | = | 6.63 $m^3/s$ |
| S | = | 1 in 500 |
| n | = | 0.018 |

## Rectangular RCC

| | | | |
|---|---|---|---|
| Area | A | = | B x d |
| Wetted perimeter | (P) | = | B + 2 d |
| | R | = | A/P |
| | Q | = | $\dfrac{AR^{2/3}S^{1/2}}{n}$ |
| Provide | B | = | 2.66m |
| Water depth | D | = | 1.33m |
| Free board | | = | 0.45 m |
| Flow velocity | V | = | 1.89m/s |
| Area | A | = | 3.53 m |
| Wetted perimeter | | = | 5.32 |
| Discharge Capacity | | = | 6.69 $m^3/s$ |

## 9.0 DESIGN CALCULATION OF FOREBAY TANK

| | | |
|---|---|---|
| Design discharge | = | 6.30 $m^3/s$ |
| Storage required | = | 2 minute |
| Capacity of tank | = | 6.30 x 2 x 60 |
| | = | 756.0 $m^3$ |
| Taking water depth | = | 3.0 m |
| Area A | = | $\frac{756}{3.0}$ |
| | = | 252.0 $m^2$ |
| Area | = | L x B |
| Taking length | = | 23.0 m |
| | = | $\frac{224.80}{23}$ |
| Width B | = | 10.95 m |
| Provide Length | = | 23.0 m |
| Provide width | = | 11.0 m |
| Provide Depth | = | 3.0 m |

## 10.0 DESIGN CALCULATION OF SPILLWAY

| | | | |
|---|---|---|---|
| Discharge capacity | $Q$ | = | $6.30\ m^3/s$ |
| | $Q$ | = | $CLH^{3/2}$ |
| | $C$ | = | 2.0 |
| | $H$ | = | Head over the crest of spillway |
| | | = | 0.40 m (Assume) |
| | $L$ | = | Length of spillway |
| | | = | $\dfrac{6.30}{2.0 \times (0.40)^{3/2}}$ |
| | | = | 12.45 m |
| | | = | Say 12.50 m |

## Design Of Spillway Channel

| | | | |
|---|---|---|---|
| Length of channel | | = | 60.0 m |
| Q | | = | 6.30 $m^3/s$ |
| S | | = | 1 in 250 |
| n | | = | 0.018 |

Rectangular stone masonry section has been provided

| | | | |
|---|---|---|---|
| Area | A | = | B x d |
| Wetted perimeter | (P) | = | B + 2 d |
| | R | = | A/P |
| | Q | = | $\frac{AR^{2/3}S^{1/2}}{n}$ |
| Provide | B | = | 2.40 m |
| Water depth | D | = | 1.10 m |
| Free board | | = | 0.30 m |
| Flow velocity | V | = | 2.42 m/s |
| Area | A | = | 2.64 $m^2$ |
| Wetted perimeter | | = | 4.60 m |
| Discharge Capacity | | = | 6.40 $m^3/s$ |

## 11.0 PENSTOCK

### Economical Diameter Of Penstock

$$D = \frac{C_1 C_2 Q^{0.43}}{(H)^{0.12}}$$

$$= \frac{1.20 \times 1.0 \times (2.10)^{0.43}}{(92.0)^{0.14}}$$

Where

$D_e$ = Economical diameter in m

$Q_0$ = Design discharge of the penstock in $m^3/s$

$H_0$ = Design head in m

$C_1$ = Coefficient taking into consideration the energy cost in the area, 1.2 to area where energy cost is low.

$C_2$ = Coefficient taking into account the material of penstock, 1 for steel penstock

D = 0.876 m

= 0.880 m

= 880 m

$$V = \frac{Q}{\frac{\pi}{4} \times D^2}$$

$$= \frac{2.10}{\frac{\pi}{4} \times (0.880)^2}$$

= 3.454 m/s

**Calculation for thickness of penstock**

| | | |
|---|---|---|
| Gross Head | = | 96.33 m |
| Stress in steel | = | 1050 kg/cm$^2$ |
| Diameter of Main penstock | = | 88.0 cm |
| | | |
| Pressure rise due to water hummer | = | 50% (Assured) |
| Total Head | = | 96.33 + 48.165 |
| | = | 144.495 m |
| | = | 14.44 kg/ cm$^2$ |
| | | |
| Thickness of steel liner | = | $\dfrac{P \times D}{2 \times \sigma}$ |
| Penstock | = | $\dfrac{14.44 \times 88}{2 \times 1050}$ |
| | = | 0.605 cm |
| | = | 6.05 mm |

Add 1.5 mm corrosion & 1.5 mm corrosion allowances

| | | |
|---|---|---|
| | = | 6.05 mm |
| Thickness of penstock | = | 6.05 mm + 1.50 + 1.50 |
| | = | 9.05 mm   10.0 mm |
| Penstock   Inner Dia | = | 880 mm |
| Outer Dia | = | 900 mm |

Thickness from handling criteria

$$t = \frac{D+50}{400}$$

D = Diameter in cm

$$t = \frac{88.0+50}{400}$$

$$= 0.345 \text{ or } 3.45 \text{ mm (O.K.)}$$

**Loss in Penstock**

The friction factor depends upon Reynolds number of flow and relative roughness of pipe.

Reynolds number (Re) $= \dfrac{VD}{\gamma}$

Where

$\gamma$ = Kinematic viscosity of water

Re $= \dfrac{3.454}{1 \times 10^{-6}}$

$= 3.45 \times 10^{6}$

Relative Roughness = k/D

$= \dfrac{0.045}{0.880 \times 1000}$

$= 0.000051$

Friction factor ( f) from Moody's diagram = 0.011

1. Length of Penstock = 162.0 m

2. No. of Anchor block = 7.0

3. Friction Loss in penstock = $\frac{0.011 \times 162.0 \times 3.454^2}{2 \times 9.81 \times 0.88}$

= 1.13 m

4. Trash Rack Loss = $Kt\frac{V^2}{2g}$ $kt = 0.35$

= $\frac{0.35 \times 3.454^2}{2 \times 9.81}$

= 0.212m

5. Intake entrance loss $= \dfrac{0.25 \times V^2}{2g}$

$= \dfrac{0.25 \times (3.454)^2}{2 \times 9.81}$

$=$ 0.1520 m

6. Exit loss $= KE\dfrac{V^2}{2g}$ $\quad kE = 1.0$

$= \dfrac{1.0 \times (3.454)^2}{2 \times 9.81} = 0.608$

7. Bend losses (7 bends) $= n\,Kb\dfrac{V^2}{2g}$

$= \dfrac{7 \times 0.20 \times 3.454^2}{2 \times 9.81}$

$=$ 0.85 m

8. Valve losses

(a) Near forebay for gate value (hvg) $= \dfrac{0.5 \times V^2}{2g} = \dfrac{0.5 \times 3.454^2}{2 \times 2.98}$

$= 0.30$ m

(b) Inside power house (hvb) $= \dfrac{0.5 \times V^2}{2g} = \dfrac{0.5 \times 3.454^2}{2 \times 2.98}$

$= 0.30$

9. For butterfly valve (hvg) $= 0.60 \dfrac{V^2}{2g}$

$= \dfrac{0.60 \times 3.454^2}{2 \times 9.81} = 0.360$m

10. Transition losses $= 0.65 \dfrac{V^2}{2g}$

$\dfrac{0.65 \times 3.454^2}{2 \times 2.98} = 0.390$ m

Total Loss = 1.13 + 0.212 +0.152 + 0.608 +0.85 + 0.30 + 0.30 + 0.360 + 0.390

= 4.302 m ~ 4.33 m

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**Online training of SAARC Professionals on Small, Mini and Micro Hydro Power Generation (Sept 13 - 17, 2021)**

*Thank you*