DESIGN OF CIVIL WORKS FOR A SMALL HYDROPOWER PLANT

A PROJECT REPORT

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BONAFIDE CERTIFICATE

Certified that this project report **"DESIGN OF CIVIL WORKS FOR SMALL HYDROPOWER PLANT"** is the bonafide work of **"PRACHI GUPTA, P. CHAITRICA, RUCHI ASWAL, SHUBHAM TOMAR AND TANSHAY BHATIA"** who carried out the project work under my supervision.

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ABSTRACT

Hydropower is a renewable, non-polluting and environmentally benign source of energy. It is perhaps the oldest renewable energy technique known to the mankind for mechanical energy conversion as well as electricity generation.

Major project on "**Design of civil structures for small hydropower plant**" is based on the study of existing hydropower plant Bhilangana 2A and then with the help of which the hydraulic design of the civil works will be done. Civil works includes the main structures like Dam/Weir, Intake, water conductor system, desilting tank, turbines and power house.

The existing project is located at Sakri in district tehri on river Bhilangana. The catchment area of which is 457 square km, which includes 130.9 square km snow fed areas. The installation capacity is 25 MW, Maximum flood discharge is 1062 cummec and the designed head of 146 m. The civil works in this project includes Raised weir with spillway, it is a runoff river type of project, a D shaped tunnel, a penstock of length 2 km which is further bifurcated of 50 m each it also have a surge tank and a desilting tank which is of rectangular in shape and have hoppers. Turbines used are Pelton turbines and the estimated cost of the project is 18,727 lakhs.

All the processes that are taken while constructing the plant will be taken care under this project which includes site selection, planning, designing. Site selection means selecting a site where all the purpose of basic requirement of plant like narrow valley, required slope and enough space for the construction process to be carried out. Planning normally consist of the plans of time period of what to do in which period of time. Hydraulic design is to be taken into consideration which means to design the structure on the basis of the discharge and velocity of the flowing water.

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CHAPTER 1

INTRODUCTION

Hydropower, hydraulic power or water power is power that is derived from the force or energy of moving water, which may be harnessed for useful purposes. Prior to the development of electric power, hydropower was used for irrigation, and operation of various machines, such as watermills, textile machines, sawmills, dock cranes, and domestic lifts.

The human endeavour to harness water for the generation of electricity is time old. Electricity generated with water is usually referred to as Hydropower. The term "hydro" is derived from the Greek word "HUDOR" meaning Water. Hydropower is the motive energy contained in water which can be converted into electricity through hydropower plants.

Water is needed to run a hydroelectric plant. The level of water in the reservoir created behind the dam is higher than the power plant. When water is released from the reservoir into the penstocks it rushes down into the power house to strike the blades of turbines with such force that they begin to spin. The spinning turbine is connected by a shaft to the generator. Inside the generator is a large electromagnet which spins inside a coil of wire producing electricity. The electricity from the generator is carried to the switchyard where the voltage is boosted for transmission over long distance power lines. Water is released through the base of the turbine and joins the river downstream of the dam.

Hydropower generation has assumed all the more importance in recognition of its distinct and clear economic and environmental advantages over thermal being inexhaustible, perpetual and renewal energy source, more reliable because of its non-dependence on costly and at time unreliable and low quality supply of coal, imported oil etc., non-polluting, high conversion efficiency, flexibility in operation, lower cost of generation as well as operation and maintenance, immune to inflation and threat of shortage of coal due to long distance transportation and strikes etc. It has inherent ability for instantaneous starting and stopping, almost instantaneous load acceptance and rejection. It is ideal for peak load demand. The fuel cost being zero, the cost of generation declines over time unlike thermal power and in the long run it turns out to be economical. Irrigation, flood control, drinking and industrial water supply, development of pisciculture, recreation etc., are the additional benefits in the context of multipurpose river valley project.

1.1 HYDROPOWER DEVELOPMENT

A fast growing power sector is crucial to sustain India's economic growth. India has an assessed hydropower potential to the tune of 84,000 MW at 60% load factor; out of this only about 20% has been developed so far. Spurred by sustained economic growth, rise in income levels, and increased availability of goods and services, India's incremental energy demand for the next decade is projected to be among the highest in the world. This increasing energy demand also translates into higher demand for electricity. It has been estimated that in order to support a growth rate of the gross domestic product (GDP) of around 8% per annum, the rate of growth of power supply needs to be over 10% annually. This calls for rapid development of the country's power sector, taking into account, inter alia, considerations of long-term sustainability, environmental aspects and social concerns.

1.2 RESOURCE POTENTIAL

India is endowed with rich hydropower potential; it ranks fifth in the world in terms of usable potential. This is distributed across six major river systems (49 basins), namely, the Indus, Brahmaputra, Ganga, the central Indian river systems, and the east and west flowing river systems of south India. The Indus, Brahmaputra and Ganga together account for nearly 80% of the total potential. In the case of Indus the utilization is, however, governed by the Indus Water Treaty with Pakistan. The economically exploitable potential from these river systems through medium and major schemes has been assessed at 84,044 MW at 60% load factor corresponding to an installed capacity of around 150,000 MW. As mentioned earlier, so far only 32,325 MW has been established. In addition, pumped storage sites with an aggregate capacity to the tune of 94,000 MW have also been identified, but only about 5,000 MW have so far been developed. The assessment of small hydro (up to 25 MW) potential has indicated nearly 10,000 MW distributed over 4,000 sites. It is estimated there is still an unidentified small hydro potential of almost 5,000 MW.

Hydropower development commenced over a century ago in India with the installation of a 130 kW power station in the Darjeeling district of West Bengal, almost in pace with the world's first hydro-electric station in the United States. However, to date only about 20% of the country's vast hydro potential has been harnessed. The share of hydropower in the total installed capacity has also decreased over the years; from over 50% in 1960-61 to nearly 26% now.

- India is world's 6th largest energy consumer, accounting for 3.4% of global energy consumption.
- Total installed power generation capacity – 174361.40MW as on 31.04.2011.
- The total demand for electricity expected to cross 950,000 MW by 2030.
- Target to add approximately 78,000 MW of installed generation capacity, out of which 62,000 MW will be achieved by 2012.
- Growth in electricity consumption slower than the GDP growth. (The ratio of energy generation and GDP growth should be 1:1)

Table1 :- Distribution of Hydropower potential (MW)

Basin/River	Potential at 60% L.F.(MW)	Number of Schemes	Potential already developed upto 31.3.99	Potential development from ongoing projects(MW)	Total (MW)	% potential developed & under development
Indus	19,988	190	2,936	1,373	4309	22
Ganga	10,715	142	1,760	1,138	2.998	28
Central Indian rivers	2,740	53	634	1,528	2,162	79
West flowing rivers	6,149	94	3,518	684	4,202	68
East flowing rivers	9,532	140	3,663	699	4,362	46
Brahmaputra	34,920	226	453	367	820	2
All India	84,044	845	13,064	5,749	18,853	22,25% upto 2002

1.3 DIFFERENT SIZES HYDROPOWER INSTALLATIONS

Hydropower installations can be classified as follows:

Name	Description
Large	All installations with an installed capacity of more than 1000 kW (according to some definitions more than 10,000 kW)
Small	General term for installations smaller than 1000 kW (or < 10,000 kW). Also used for installations in the range between 500 and 1000 kW.
Mini	Capacity between 100 and 500 kW
Micro	Hydropower installations with a power output less than 100 kW (or less then 1000 kW)

1.4 CONSTRAINTS IN HYDROPOWER DEVELOPMENT

Longer gestation, Poor planning, Financial Constraint, Environmental and Forest Clearance, Higher Initial Investment, Delays in clearance and implementation, Central government guarantee, Rehabilitation and Resettlement, Interstate disputes, International dimensions, Uneven Distribution of potential, Socio-economic impediments, Inadequate Investigation, Geological Surprise, Project Sharing, Attitudinal impediments, Land acquisition, Time and cost over-runs, law and order, Small Vs large dam, Dependence on nature, Contractual Problems, Reservoir induced seismicity, Resevoir siltation, Loss of Forest cover, Natural Calamities

1.5 ASSESSMENT OF AVAILABLE HYDROPOWER

To know the power potential of water in a river it is necessary to know the flow in the river and the available head. The flow of the river is the amount of water (in m^3 or litres) which passes in a certain amount of time a cross section of the river. Flows are normally given in cubic meters per second (m^3/s) or in litres per second (l/s). Head is the vertical difference in level (in meters) of the water falls down.

The theoretical power (P) available from a given head of water is in exact proportion to the head H and the flow Q.

$$P = Q \times H \times c \qquad c = \text{constant} \tag{1.1}$$

The constant c is the product of the density of water and the acceleration due to gravity (g). If P is measured in Watts, Q in m^3/s and H in meters, the gross power of the flow of water is:

$$P=1000 \times 9.8 \times Q \times H \text{ (if taken as a 80\%efficiency multiply by 8)} \tag{1.2}$$

This available power will be converted by the hydro turbine in mechanical power. As a turbine has an efficiency lower than 1, the generated power will be a fraction of the available gross power.

CHAPTER 2

DESIGN CRITERIA OF MAJOR COMPONENTS OF SCHEME

2.1 MAJOR CIVIL ENGINEERING STRUCTURES

The major civil engineering structures of a high head and low discharge hydel scheme in a mountainous terrain can be classified as under:

1. Diversion weir
2. Intake structure
3. Shingle excluder
4. Power duct
5. Desilting tank
6. Power channel
7. Tunnel
8. Forebay
9. Penstock
10. Power House
11. Tail Race channel.

2.2 DIVERSION WEIR

2.2.1 General

In run of the river schemes, a diversion structure across the stream is required to divert the stream water to the water conductor system and ultimately to the power house for power generation. In most of these schemes, this structure is a weir.

In hilly regions, it has been experienced that the conventional types of weir obstructing the stream flow are not ideally suited since hilly streams carry boulders and bed loads. If a conventional over ground weir is constructed across the stream, the structure is vulnerable to damages by the rolling boulders in the stream. Further, the conventional storage type diversion structure is not feasible across such stream firstly because the storage space gets filled up fast by the bed load that get trapped and secondly because there are recurring problems of intake choking. Further, the over ground structure has to be founded on good rock foundation which is not available at reasonable depths. The removal of deep bouldery overburden proves uneconomical. In view of the above, "trench type" or 'drop type' weir is the most feasible solution. This simple and ingenious type of structure does not interfere with the natural regime of the bouldery stream.

A trench weir is a trapezoidal trench (trough) built across the stream below the stream bed level. The trench is given a bed slope of not less than 1 in 25 towards the intake so that sufficient velocity is generated to carry away the silt / shingle that fall into it. The bed slope also gradually increases the cross sectional area of the trench to cater to more and more water entering into it from the stream through the trash rack. The top of the weir is covered with trash rack to ensure that boulders and bigger stones do not fall into the trench and clog it. The rack itself is designed to withstand the load of the rolling boulders. The rack is made removable so that it can be removed periodically after rains or flash floods to clear the trench of any deposits if required. The crest level of the diversion weir is kept slightly below the stream bed to facilitate maximum withdrawal of stream flow during lean periods and to take care of variations in bed level.

The upstream and downstream river beds are joined with the crest in a slope matching the slope of the river bed, so that even at the diversion site the regime of stream is not disturbed. It also prevents the stones / pebbles from resting over the trash rack and makes them roll down. The stream water flowing over it passes through the trash rack and falls into the trench. This water is then conveyed to the R.C.C. intake well located at one end of trench.

The R.C.C. trench is extended to the side abutments so that the stream flow during the heavy floods will pass over the weir without damaging the structure. At the intake structure, flushing arrangement is proposed to clear away the shingle passing through the trash rack. For this purpose, the trench weir is designed to carry 50% extra discharge. The silt is flushed out at the desilting tank for which the trench weir is designed for another 15% extra discharge. The water (conductor system is designed to 10% extra discharge. In other words, the discharging capacity of trench weir is 130% of the design discharge for power generation purposes. In rainy season the water in the river is available more than sufficient. In lean season the water is clear and no desilting etc. is required. Thus the whole water is available for generation.

2.2.2 Hydraulic Design

The flow in such a diversion structure is a spatially varied flow like a side channel spillway. It is assumed that the total energy line is parallel to the crest and that flow profile along the crest is linear. Further, it is assumed that the effect of air entrainment is negligible. The hydraulic design of various features of trench weir is discussed below.

2.2.2.1 Waterways/Length of weir between abutments

The length of weir is the width of flow in a stream. The water way is so fixed that the diversion weir is capable of passing the peak flood discharge corresponding to 100 year return period without causing any significant influx on the highest observed flood level (H.F.L.) at that site. The flood discharging capacity of the weir is determined by the Manning's formula.

$$Q = A \times 1/n \times R^{2/3} \times S^{1/2} \qquad (2.1)$$

where,

Q = Flood discharging capacity in cumecs.

A = Cross-sectional area of flow in the weir / stream in m^2

n = Coefficient of rugosity = 0.018 for bouldery bed of the stream.

R = Hydraulic radius, in meters

P = Wetted perimeter of the stream in meters

S = Longitudinal bed slope of the stream in the reach of the weir.

Normally the length of the weir / waterway is kept equal to the width of the stream so that neither the weir structure interferes with the regime of the stream nor is unnecessary excavation involved to widen the stream. This water-way 'L' is checked for its suitability to pass the peak flood discharge.

With the determination of length of weir, the other two dimensions of weir i.e. width and depth of trench are calculated with hydraulic characteristics of spatially varied flow. As the trash rack for such structure consists of parallel bars. The flow through trash rack is nearly vertical and energy loss is negligible. The width of trench is determined by the following relation:

$$B = \frac{Q}{E_1 E_2 C L \sqrt{2gE}} \qquad (2.2)$$

where,

B = Width of trench / trash rack

Q = Design discharge for power generation + 5% for flushing shingles at the intake + 15% for silt flushing at the desilting tank and 10% extra for excess power generation.

E_1 = Ratio of opening area to total area of the rack surface : (Assume 50% reduction for frame work) = 0.5

E_2 = Ratio of clogged to opening area of trash rack. It is generally Assumed as 0.5.

C = Coefficient of discharge through the openings (say, 0.465 for a slope of 1 in 14).

L = Length of trash rack (water way)

g = Acceleration due to gravity (9.81 m/sec^2)

E = Specific energy at any section of the stream over the trash rack

$$= \frac{(Q)^{2/3}}{CL}$$

and C = Coefficient of discharge for broad crested weir (1.53 average value).

Keeping in view the non-uniform intensity of discharge in the entire length and width of area, the width of the trench is generally kept more than the calculated value for practical reasons like reduction in the length of weir or silting / filling of the trench with bigger size particles. This practice is followed to ensure complete withdrawal of stream flow during lean flow season. Attempt is made to adopt one of the standard trench sections recommended by CBI&P Publication No. 175 dealing with standardization of Small Hydro – Station. Such a standard trench section is checked for discharging capacity based on Manning's formula, in ref. of flood discharge.

2.2.2.2 Depth of Trench

The depth of trench along the length of the trench is determined according to theory of flow in a side channel spillway. It is based principally on the law of conservation of momentum assuming that the only forces producing motion in channel result from fall in the water surface in the direction of its axis. The average depth of the adopted standard trench section is checked for its suitability to divert the design discharge of the trench weir by the Manning's formula.

2.2.2.3 Longitudinal slope of the trench

The longitudinal slope of the trench is checked for pebble movement by the following relation by U.S. Corps of Engineers:

$D = 2.9\ q^{2/3}\ S^{7/9}$ (changed into metric units). (2.3)

where, D is particle size in meters (-0.025 m, generally) that can pass through the openings between the trash rack bars and is to be moved to the intake.

S = Longitudinal slope of the trench

q = Discharge intensity in m^3/s per meter width of trench.

The trench is generally given bed slope of not less than 1 in 25.

2.3 INTAKE STRUCTURE

2.3.1 General

The water collected in the trench channel is led to a rectangular intake structure. This intake structure is on one end of the trench weir. The location of the intake structure is such that the regime of the stream is not disturbed. The intake structure has the following functions:

(i) It regulates the discharge for power generation irrespective of water level in river.

(ii) It traps the sediments to an extent.

(iii) It acts as an abutment on one side of the trench weir.

(iv) Through shingle excluder, it controls the water level in the intake and is also used for flushing the shingle back to the river.

The intake is a R.C.C., rectangular shaped structure which has its top sufficiently above the H.F.L. of stream. The opening of the trench to the intake is restricted by construction of a wall above the crest level so that the flow is an open channel flow and when the discharge is more, the opening acts as an orifice. The end wall of the intake well accommodates two pipes i.e. shingle excluder and power conduit. The shingle excluder is designed to pass the surplus water to the river as well as to flush the shingle load. The power duct is required to convey the water required for power generation to desilting tank. The power duct and shingle excluder are controlled by two separate gates provided at the intake well. These gates are operated manually from a platform constructed at the top of the intake well. The shingle excluder is operated periodically to flush out the shingles collected in the intake well. This is generally done when water is either surplus or is not being used for power generation. The frequency of shingle flushing will be more in rainy season when both the discharge in the stream and the shingle movement increases.

A rung ladder is provided for access to the bottom of the intake for repair and maintenance purposes. The bottom of intake well has tow levels. The lower level is the invert level of shingle excluder pipe and the other is just below the invert level of power conduit. The power duct is designed to carry the design discharge for power generation + 15% extra for silt flushing at the desilting tank + 10% extra for additional power generation. It can be designed as a free flow channel or as a pressure flow conduit and its slope is so selected that the velocity is self cleaning and the sediment load is carried to the desilting tank.

2.3.2 Hydraulic Design

The inside width of intake is generally kept more than the top width of trench and the length of intake is so chosen that it accommodates the two openings and a minimum distance of 1.5 mm is available between two openings to construct a pier to accommodate the embedded parts of both the gates.

The discharge capacity of both the ducts under free flow principle is determined as explained in hydraulic design of trench weir. As an orifice flow, the area of orifice (silt excluder pipe and power conduit) is computed by the equation:

$$Q = A\,C_d\,\sqrt{2gh} \qquad (2.4)$$

where, A = Opening area in sq.m [= $(\pi/4)D^2$), where D is required dia of pipe].

Q = Design discharge of the conduit in m^3/sec.

C_d= Coefficient of discharge, 0.64

h = Net head causing flow (separately for power duct , and for shingle excluder).

g = Acceleration due to gravity.

The shingle excluder has to flush out shingle which settle at the lower level of the intake, its invert level is kept lower than invert level of power conduit which can pass relatively decanted water to the desilting tank. The size and slope of the shingle excluder is so designed that adequate velocity is generated which can flush out the shingle of size equal to the clear distance between trash rack bars.

2.4 DESILTING TANK

2.4.1 General

Generally the water in hilly stream is silt free except during monsoons when it carries lot of silt. The particles smaller than the trash rack opening size enter the trench weir. Of these, heavier particles settle in the intake well and are flushed out through the shingle excluder at the intake. The silt particles, however, flow through the power duct and hence a desilting tank is provided at the end of power duct to trap the silt load of particle size more than the desirable particle size from turbine point of view. Just before the desilting tank a surplussing weir is provided to spill back to the river the flow in excess design discharge. An open channel power duct starts after the desilting tank. The power channel carriers relatively silt free water as the desilting chamber is designed to settle all silt particles bigger than permissible particle size.

The desilting tank is located at a relatively flatter ground keeping in view the structural safety, economy in design and operation, easy accessibility and availability of natural drainage for escape of flushing discharge and for location of surplussing weir.

The sediment particles of size more than 0.2 mm are removed by the desilting tank by gravitational settling.

2.4.2 Hydraulic Design

The basic features of design of desilting tank are:

1. Detention period required and provided.
2. Average linear velocity of flow at top and bottom.
3. Depth, width and length of tank
4. Inlet and outlet transition
5. Cleaning / flushing arrangement.

The settling time for a definite size of particle is estimated by calculation the settling velocity using stokes law.

$$V = \frac{1}{8}\frac{(S - S')}{v}.gd^2 \qquad (2.5)$$

where, V = settling velocity in cm/sec.

g = acceleration due to gravity in cm/sec^2 (=981)

S = specific gravity of the silt particle = 2.65

S'= specific gravity of water (=1)

d = the particle size in cm (0.02)

v = absolute viscosity of water at the normal ambient temperature (= 1.5 x 10^3)

So, V = 2.75 cm / sec.

= 0.0275 m/sec.

The shape and size of the desilting tank is so decided that the tank width is kept more than the depth.

Silt flushing pipes are provided at the bottom of the desilting tank near exist end on the river side of the desilting tank and a manually operated sluice gate / valve is provided for its periodic operation. Another slide gate is provided at the exit end of desilting tank to check flow into the power channel for maintenance of the power channel.

2.5 POWER CHANNEL / TUNNEL

2.5.1 General

In view of economy and maintenance problems, it is proposed to carry the water from desilting tank to forebay in D-shaped trench and in partly open and partly covered channel made of RCC. To safeguard against seepage, it is proposed to use adequate quality of water proofing compound.

The discharging capacity of channel is so fixed that it draws water equal to 110% of the required design discharge for power generation through its travel length. The evaporation losses have been neglected. The cross-section areas of flow and slope for both channel and tunnel are same.

2.5.2 Cross Drainage Work

As the line of flow of surface drainage is across the ground contours, the power duct may have to cross some natural drainage traversed by it. Since the duct is mostly in cutting for whole of its length, the cross drainage work, if any, would be designed as a channel passing over the power channel. The sides of the drain would be stone pitched upto 5 m upstream and 5 m downstream of the channel crossing to ensure stability of the section and the RCC top slab of the power duct would be suitably strengthened to ensure protection against scouring and retrogression. In case of tunnel, there is no cross drainage work.

2.5.3 Seepage Loss

The seepage loss depends on the wetted perimeter, nature of strata, depth of water in channel, position of subsoil water and may vary from one place to another. The seepage loss shall be adopted as 0.6 m^3/s/million sq.m. of wetted perimeter as per IS: 4745. This value for the present case would be negligible.

2.5.4 Free Board

The free board of a channel is the vertical distance between full supply level to the top of channel. The distance should be sufficient to cater to waves or fluctuations in water surface. A free board of 0.3 m is generally provided.

2.5.5 Curves

Curves in power channel alignment shall be as gentle as possible as they cause disturbance of flow and tendency to silt on inside and to scour on out-side of curve. The curves should generally be simple circular curves.

As per IS : 5968, minimum radius of curve should be 5 times the bed width of the channel.

2.5.6 Inspection Manholes

It is proposed to provide inspection manholes along the length of covered power channel for a spacing not more than 100 m. These manholes shall facilitate periodic inspection and repairs. Though the manholes shall be covered at the top, a side opening will also provide ventilation and air expulsion in case of any surge waves. These openings will be provided with grilled doors.

2.5.7 Hydraulic Design

The free flowing water in the power channel, tunnel is subjected to frictional resistance. To over come this resistance, the bed is given a longitudinal slope in the direction flow.

Lined channel is designed by Manning's formula:

$$V = \frac{1}{n} \times R^{2/3} S^{1/2} \qquad (2.6)$$

where, V = velocity of flow on the channel / duct in m/s.

n = coefficient of rugosity = .018, for plastered surfaces.

$$R = \text{Hydraulic radius} = \frac{A}{P} = \frac{\text{Cross sectional area}}{\text{Wetted perimeter}}$$

S = longitudinal bed slope of duct.

So, $Q = A \times V.$ (2.7)

2.5.8 Velocity

The velocity of lined channel should not be less than 1 m / sec and should not exceed 2 m / sec as per IS : 5331 so that it is neither scouring nor silting. The proposed channel shall be designed to have a velocity which is sufficient to carry away silt particles of size below 0.2 mm as per IS : 7916. The silt particles of bigger size are retained in the desilting tank.

2.6 TUNNEL

A free flow tunnel is proposed to be constructed for the power channel. The dimensions of the tunnel to be excavated is 2.1 m wide x 3.0 m height to facilitate construction of the tunnel. On the tunnel floor the channel to carry the water to the forebay shall be constructed which shall have same hydraulic design criteria and dimensions as for the power channel discussed in the foregoing section.

2.7 FOREBAY

2.7.1 General

Looking to the site conditions and availability of building materials, a reinforced cement concrete forebay is proposed. The layout does not involve significant excavation as the storage required is not much. The floor being R.C.C. raft the bearing capacity problem is not anticipated as the geology is favourable. Since the forebay is the nearest structure to the power intake, it is required to meet the immediate water demand when the generating units are switched on. The forebay should, therefore, have some live storage between the full reservoir level (FRL) and the minimum draw-down level (MDDL). This storage for small projects should be at least equivalent to 2 minutes storage.

A surplussing arrangement / escape is proposed to the down stream of the forebay to safely pass the excess inflows during sudden load rejection or for any other reason. The discharging capacity is kept equal to the maximum discharge which the power channel can carry encroaching its free board.

The slope of forebay is adjusted to suit the topography. The downstream wall is shaped to accommodate the bell mouth transition for intake and embedment of penstock. An apron with transition is proposed the vertical transition being in slope of 1:1 for smooth hydraulic entry of water from channel to the forebay.

The opening where gate is proposed is kept rectangular and transition to circular is provided in R.C.C. for ease in construction. The circular concrete length is kept as equal to half the penstock diameter and then penstock is embedded in concrete. An air vent is provided just downstream of the intake gate. A trash rack is provided upstream of bell mouth intake to check entry of any floating debris into the penstock and hence the turbines.

2.7.2 Hydraulic Design

2.7.2.1 Live storage

Since the forebay is required to cater to the immediate water demand for starting the generating units, it should have a minimum live storage equivalent to 2 minutes requirement between full supply level and the minimum draw down level. The minimum draw down level is so fixed that it can provide a minimum water cushion as stipulated in the para below to prevent entry of air into the penstock because this air could damage the turbines.

2.7.2.2 Bellmouth entry for penstock

The transition provided for flow from power channel to the forebay is linear. The length of transition is such that a vertical transition in 1:1 slope is available.

The entrance for penstock is designed to produce an acceleration similar to that found in a jet issuing from a sharp edged orifice. The surfaces are formed to the natural contraction curve of the jet and the penstock is assumed to be the size of the orifice jet at its maximum contraction.

The basic curve for contractions are taken from U.S.BR. manual. The profile of contraction is approximately elliptical and further details are also taken from the manual.

2.7.2.3 Water cushion below minimum draw-down level

The minimum water cushion above the top of opening is kept as 0.6 times the total height of opening and from centre line of mass flow, the minimum water cushion is kept 0.8 time the total height of opening. The height of opening is kept equal to '2 x diameter' of the penstock.

2.7.3 Trash Rack at the Intake

In spite of the fact that power channel is covered throughout its length, it is proposed to provide inclined trash in the forebay to prevent any floating debris from entering into the penstock and damaging the turbines. This is necessary because the forebay itself is open and anything can fall into it.

The trash rack is placed between the side grooves in the walls in the protruding part of the forebay and can be removed easily from the operating platform provided at the top.

2.8 PENSTOCK

2.8.1 General

Steel penstock is proposed to be provided to convey water from forebay to turbines in the power house. It is proposed to provide steel penstock in view of high strength and flexibility.

Spiral welded mild steel pipes are proposed for main penstock and branches with circumferential joints at the end of each ferrule. The reasons for the choice are ready availability for desired water pressure, economy and ease of fabrication and erection.

The penstock installation can be surface, embedded, or buried looking to the site, climate, topographical and geological conditions, it is proposed to provide a buried penstock where steel conduit is laid either on the ground with fill or is placed in the trenches and back filled. This will eliminate the installation and maintenance of expansion joints. The alignment of the penstock is so adjusted as to have minimum excavation and anchor blocks.

The bellmouth entry from rectangular shape to circular is proposed to be accommodated in concrete structure itself and then the single penstock will be embedded in concrete with suitable percolation rings.

The radius of curvature in penstock profile is kept 3 times the diameter of penstock for efficient hydraulic flow.

The bends are proposed to have successive segments of curved portion with optimum deflection angles to avoid sharp change in direction of flow.

Air vent is proposed to be provided just down stream of the control gate of penstock at the forebay. This is provided to avoid development of negative pressure. This also accelerates draining. Similarly while filling it lets the air out. No surge shaft is required where the length of penstock is less than 5 times the maximum head on turbine.

2.8.2 Hydraulic Design Criteria

The hydraulic design of penstock involves determination of hydraulic losses, pressure rise or drop due to turbine operation and fixing an economical diameter.

2.8.2.1 Hydraulic losses

The losses in penstocks can be classified broadly into three categories:

(i) Entrance loss and exit loss.

(ii) Friction loss and

(iii) Other losses such as bend loss, transition loss, valve loss, loss in branches, wye etc.

Out of above, friction loss is dominant and it can be estimated using Manning's equation.

$h_f = fLV^2/2gD$ (2.8)

where,

h_f = friction loss in m.

L = length of pipe in m

V = velocity through pipe m/s

D = diameter of pipe, in m

f = friction loss coefficient which depends upon type and condition of pipe and Reynold's number. The values are taken from Moody's diagram as 0.014.

Thus, $h_f = 0.0011\ (LQ^2/D^5)$

It is proposed to use butterfly valves. The valve loss because of area restriction even in fully opened position is estimated using general trend curve given in CWC Manual on Penstocks.

A sluice valve is provided in each branch pipe in the inlet reach before butterfly valve controlling flow to individual turbine to facilitate maintenance of butterfly seal. Since area of flow is not restricted, head loss due to this valve is neglected.

At bifurcation, the equivalent diameter of the two penstocks are calculated by equating the discharge.

Total Head Loss in Penstock by Scoby's Formula

Based on experience with a large number of penstock, Scoby has given the following relation for determining the total head loss in penstocks:

$h_L = 0.34 \times (V^{1.9} / D^{1.1}) \times (L / 1000)$ (2.9)

where,

h_L = Total head loss in feet,

V = velocity in feet/sec in the penstock

D = diameter of penstock in feet

L = total length of penstock in feet.

2.8.3 Hydraulic and Structural Design

The detailed hydraulic and structural design criteria are dealt in detail in "Manual on Design fabrication, erection and maintenance of steel penstocks brought out by Hydel Design Directorate-I of Central Water Commission, which can be referred. Criteria for hydraulic design of penstocks and structural design of penstocks have also been indicated in IS : 11625 and IS 11639 respectively. Criteria for hydraulic design of hydropower intakes is dealt in IS : 9761.

The bends of the penstock steel liners are designed on consideration of causing minimum hydraulic loss due to change in direction of flow. Accordingly the successor sequent in the curved section shall be designed with optimum deflection angles to avoid sharp changes in direction of flow and the bead is provided with large radius. The general practice is to provide the radius of bend three to fire times the penstock diameter of the pipe. The deflection angle between each successor segments are to be limited between 5^0 to 10^0. Sometimes the penstock alignment is deflected both in horizontal plane as well as in the vertical plane. In such case, it is preferable to combine both the deflections and design a single bend as a compound bend. In the case of ERW pipes ready made beads are available as fabricated pieces which can be conveniently used by adjusting the angle of bend suitably to suit the availability.

Anchor blocks are to provided at the location of bends in penstocks. The same care to be designer for the unbalanced forces acting at the bend junction. The following are the major loads and forces to be considered in the design of anchor block.

(a) Hydrostatic pressure
(b) Dead weight of pipe acting on the anchor blocks
(c) Sliding frictional forces.

2.8.3 Structural Design of Penstock

In Structural design of Penstock the various factors like forces, Stresses etc are taken into consideration.

2.8.4.1 Forces and Stresses in the Penstock

The penstock, where buried completely, shall have a thickness enough to counter the external forces when the pipe remains empty. For normal condition of working the penstock shall be designed to take care of the hoop strains caused by internal pressure which is equal to the static water and dynamic pressure, caused by water hammer for different operating conditions. The water hammer pressure can be calculated by using Allevi's Chart and generally varies from 10% to 20% of the static head.

The thickness of the penstock liner is calculated from the following formulae:

$$t = \frac{P \times D}{2S} \tag{2.10}$$

where,

	t	= thickness in cms
	P	= the pressure in the penstock in kg/cm^2
	D	= diameter of penstock in cms
and	S	= allowable stress in steel in kg/cm^2
		= 1050 kg/cm^2.

The shell thickness of penstock at a location is designed for the pressure head of water at that section plus the water hammer pressure. Since the length of penstock is sufficiently large we can use many thicknesses of penstock pipe say 8 mm to 18 mm in the present case. However, the minimum thickness of penstock liner shall not be less than 5 mm corrosion allowance of 2 mm is to be added to thickness arrived at from the foregoing formulae. The penstock should preferably be ERW pipes.

2.9 POWER HOUSE

2.9.1 General

A surface power house is located at a terrace which is large enough and geologically suitable. The power house will be of indoor type where all erection and maintenance of machines are done in the power house itself. The size of power house is fixed after making a detailed layout plan of the units, control panels, service space etc. Though the size of power house increases by adopting the indoor type yet it is considered necessary looking to the meteorological conditions obtaining at the site.

Due consideration to the surface drainage, ventilation, lighting etc. is given while fixing the size and location of gantry columns is decided considering the economy and the location of expansion joints etc.

The location of power house and fixing of machine hall floor level and setting level of turbines depends also on the HFL and minimum tail water level in the stream. The machine floor is always kept above HFL to prevent flooding of the power house. The protection wall is provided around the power house to protect it from flooding. Setting level of turbines (particularly reaction type) has lot of bearing on the minimum tail water level. Attempt is also made to utilize locally available construction materials to economize the cost.

2.9.2 Structural Design of Power House

The power house design is divided into two units (a) super-structure and (b) sub-structure. The major components of super – structure are:

- **(i)** Roof
- **(ii)** Roof supports
- **(iii)** Gantry girder
- **(iv)** Gantry columns
- **(v)** Cross beams or braces
- **(vi)** Panel walls
- **(vii)** Floor.

The sub-structure can be classified as the portion of the power house which is below the machine hall floor.

2.9.2.1 Super structure

Forces acting on the super-structure:

The super-structure is designed to take care of the following loads.

(a) Dead loads : consisting of self load of the structure and the permanent superimposed loads.

(b) Live loads : for roofs and floors are and taken in accordance with IS : 4247.

(c) Wind loads : taken in accordance with IS 875.

(d) Crane loads : consisting of the weight of fully loaded crane and longitudinal and lateral impact forces.

(e) Earthquake force in accordance with IS : 1893.

(f) Water pressure and earth pressures wherever applicable.

Permissible Stresses

The permissible stresses for design of super – structure are taken as per IS : 456 for R.C.C. and IS : 800 for structural steel. The same are increased for various combination of loads in accordance with IS : 4247.

Table 2. LOADS ACCORDING TO IS: 4247

Sl. No.	Load combination	Permissible increase in stresses
1.	Dead load + live load + moving cranes loaded to half its capacity + normal T.W.L.	8%
2.	D.L. + L.L. + moving crane loaded to half its capacity temperature + normal T.W.L. and wind load	25%
3.	D.L. + L.L. + moving crane loaded to full capacity + temperature + normal T.W.L.	25%
4.	D.L. + L.L. + unloaded standing crane + temperature + earthquake + maximum T.W.L. (Annual)	33.3%

5.	D.L. + L.L. + moving crane loaded to half its capacity + temperature + T.W.L. (maximum possible)	33.3%
6.	D.L. + temporary construction load	25%

The permissible stresses for rivets, bolts etc. are increased by 25% only in all the cases from serial no. (2) to (6).

(i) Roof

Looking to the site conditions, location, size of power house and economy, roof having tubular trusses covered with galvanized corrugated sheets is the best suited. The sheets are fixed on purlins supported on tubular trusses. The thickness of sheet is calculated based on the spacing of trusses, purlins and the loads it has to cater for subject to a minimum thickness of 18 gauge CGI sheets. These corrugated galvanized sheet shall conform to IS : 277. It is laid directly on purlins and secured by hook bolts of 8 to 10 mm diameter spaced at about 400 mm c/c. At joints along the length an overlap of 150 mm. Is provided or alternatively the pitch of hook bolts is reduced to 150 mm. The joints along the sides of the sheet shall over-lap two corrugations and rivets or screw are provided at 300 mm spacing. All holes are made through ridge and curved washers are provided to prevent leakage. To prevent lifting of sheets, the hook bolts spacing at eaves is reduced from 400 mm to 250 mm.

(ii) Roof supports:

Considering the site location, construction equipment facility and construction, time needed, the roof is supported by purline resting on tubular steel trusses. The spacing of trusses is governed by the spacing of columns which are fixed as per layout of the power house. The truss is analysed for loads and permissible stresses.

(iii) Gantry Girders:

The gantry girders can basically be of reinforced cement concrete or of steel. Keeping in view the difficulty in transportation of heavy steel girder to site, R.C.C. gantry girders may be more economical and speedier in construction.

The gantry girders are supported on columns provided with brackets to accommodate the girders. Suitable base plates are also provided for the rails to be fixed.

The gantry girders are designed for moments, shear forces and thrust transmitted to it by the long longitudinal frame when crane is positioned to give the worst effect.

(iv) Columns

The columns can also be of steel or reinforced cement concrete. Keeping in view the transportation difficulties, construction equipment facility, availability of constructions materials and aesthetics, R.C. columns are most ideally suited.

The columns are subjected to moments in transverse and longitudinal directions and direct thrusts. Therefore, these are designed as members subjected to biaxial bending and direct thrust. The design procedures shall be based on IS : 4247 – part – II reinforcement shall be provided in accordance with IS : 456.

The columns are supported on concrete raft floor to limit the pressure below the bases to safe bearing capacity or sub – grade.

(v) Cross Member or Braces:

The cross member in the form of ring beams are provided to stiffen the column in longitudinal direction. These beams shall also be made of reinforced cement concrete and shall support the panel walls. Thus ring beam shall be provided below the gantry girder level. The ring beam is treated as a part of longitudinal frame and is designed for the moment and thrusts obtained from frame analysis, as well as for loads of walls coming over it.

(v) Panel Walls:

Panel walls are proposed to be of stone masonry, looking to the availability of material at site and economy. These panel walls span between the columns and beams and thickness provided is 45 cm upto the crane level and 30 cm above it.

(vii) Floor:

It is designed to carry load of machines, live load and any other thrust transferred through turbines, generators or any other machine. Structurally, it is designed as an RCC raft with openings / pits as required for equipment and cable trenches etc.

2.9.2.2 Substructure

The sub-structure of power house is basically a gravity structure and is assumed to be rigid. The stability analysis is, therefore, done considering-

- **(a)** over-turning and bearing pressure
- **(b)** shear friction factor
- **(c)** floatation.

The analysis is done in two directions, longitudinal and transverse. The loads considered for its design are:

- **(a)** Dead load of structure including embedded parts.
- **(b)** Main equipment loads such as turbines, generators, transformers etc.
- **(c)** Crane loads including horizontal thrust.
- **(d)** Live loads.
- **(e)** Wind loads as per IS : 875
- **(f)** Penstock thrust including water hammer
- **(g)** Weight of water acting on the sub-structure i.e. in scroll case, draft tube etc.
- **(h)** Back-fill pressure
- **(i)** Water pressure due to water level
- **(j)** Up-lift pressure
- **(k)** Pull of conductor if fixed on building
- **(l)** Seismic force in accordance with IS : 1893.

Structurally the foundation for columns are analyses for its behaviour as continuous beam. The recommendations of IS : 456 for minimum reinforcements spacing size etc. are kept in view while providing the reinforcement.

2.10 TAIL RACE CHANNEL

The tail-waters from the power house are led to the stream again through a tail race channel. The channel can be RCC structure, rock cut section or a masonry or random rubble structure. The channel is designed to have a discharging capacity of 25% of one unit discharge under minimum tail water level condition and 110% of full design discharged of all the turbines under normal and maximum tail water level condition.

The channel is generally designed as a rectangular RCC structure upto the bank of stream and thereafter a random rubble / stone crate structure in the stream bed so that it is flexible and can be easily required after the flood seasons. A bridge is also provided across the tail race channel for communication purposes and a sharp crested V-notch or a broad crested weir is provided across the tail race channel for measurement of flow though the tail race.

In its initial reach made of R.C.C. the side walls are designed as retaining walls subjected to saturated earth pressure from behind in tail race empty case or to withstand the water pressure with tail water at maximum level. Bottom slab is designed as a raft fixed to both end walls to withstand bearing pressure and uplift pressure in tail race empty condition. The permissible concrete stresses are adopted as per IS : 456 with permissible stresses for concrete for concrete and reinforcement reduced by 25% for water retaining structure.

CHAPTER 3

HYDROLOGICAL DATA

3.1 DISCHARGE AT TEHRI

Observed ten daily discharge (cumecs) of Bhilangana river at Tehri

The observed Ten Daily Discharge of river Bhilangana at Tehri is given below:-

For reference this data was used. For details – Appendix 1

3.2 ANNUAL MAXIMUM FLOOD DATA IN BHILANGANA RIVER AT TEHRI

The annual maximum flood data in Bhilangana river at Tehri is given below:-

Table 4: ANNUAL MAXIMUM FLOOD AT TEHRI

S.No.	Year	Peak flood (Cummes)
1	1978	640
2	1979	270
3	1980	428
4	1981	402
5	1982	310
6	1983	384
7	1984	349
8	1985	397
9	1986	695
10	1987	380
11	1988	466
12	1989	286
13	1990	380
14	1991	338
15	1992	367
16	1993	733
17	1994	515

3.3 DERIVED TEN DAILY DISCHARGES (M^3/S) AT BHILANGNA III WEIR SITE

Table 5. TEN DAILY DISCHARGES (M^3/S) AT BHILANGNA III WEIR SITE

Month	June			July			August		
Year	I	II	III	I	II	III	I	II	III
1975-76	10.13	15.46	29.39	22.97	75.34	46.89	52.9	67.95	58.35
1976-77	25.11	29.69	15.82	23.51	80.57	96.64	71.25	79.92	56.18
1977-78	9.31	6.31	30.66	105.2	93.49	110.13	82.76	75.63	63.85
1978-79	17.5	25.93	61.66	110.81	77.51	89.24	133.19	99.19	115.24
1979-80	10.36	12.53	45.04	45.96	57	51.85	56.18	84.7	65.36
1970-81	11.68	15.76	38.79	83.2	97.13	98.41	119.32	73.7	72.18
1981-82	29.6	21.6	37.41	26.71	79.12	83.1	81.74	74.38	53.77
1982-83	8.86	8.95	9.2	20.1	27.77	79.28	91.65	101.78	86.67
1983-84	19.78	16.13	20.15	37.27	26.02	52.48	54.1	88.6	77.1
1984-85	24.31	27.77	40.13	72.09	49.83	85	54.5	66.13	71.44
1985-86	13.3	15.88	27.47	38.94	77.17	98.2	88.68	98	92.55
1986-87	23.23	28.81	51.29	48.83	101.97	115.61	106.91	123.63	80.65
1987-88	17.87	16.04	15.66	25.88	28.76	78.5	54.21	54.55	71.92
1988-89	14.46	17.01	28.51	40.21	59.55	71.94	102.49	97.92	65.27
1989-90	17.82	15.69	18.74	20.04	33.55	45.54	37.15	56.05	77.95
1990-91	22.26	19.82	44.67	66.52	84.71	59.87	91.45	79.38	50.61
1991-92	22.41	23.21	22	30.23	57.51	77.39	81.93	51.68	76.34
1992-93	13.21	22.08	29.49	21.5	54.99	70.78	89.8	87.76	83.23
1993-94	20.27	26.68	28.97	36.81	99.28	56.6	45.28	36.68	50.09
1994-95	13.97	15.13	50.68	93.49	73.41	105.71	115.08	58.71	81.03
1995-96	40.98	22.64	21.88	59.73	77.64	72.37	106.44	77.92	91.71
1996-97	11.28	25.35	50.15	47.89	50.57	61.6	79.59	103	87.92
1997-98	13.19	14.72	27.72	64.65	60.77	87.92	96.12	97.22	57.56
1998-99	13.39	23.24	32.01	61.95	68.31	56.1	85.53	75.76	83.74
1999-00	8.34	19.39	21.02	24.17	32.32	36.44	38.87	31.5	33.91
2000-01	20.91	22.21	35.75	32.9	50.34	48.31	41.63	46.36	45.41
2001-02	17.44	19.54	32.09	48.52	64.41	74.46	79.18	76.47	71.16
2002-03	18.87	24.53	26.31	42.04	46.14	55.83	66.79	46.78	41.48
2003-04	26.39	33.13	36.86	52	56.36	57.85	70.36	57.19	62.76
2004-05	11.34	15.94	15.75	32.08	35.92	53.81	63.22	42.34	29.99

Total (Mm^3)	**462.15**	**526.62**	**828.06**	**1258.11**	**1644.65**	**1907.80**	**2048.35**	**1936.73**	**1800.55**

September			October			November		
I	II	III	I	II	III	I	II	III
72.68	46.37	25.35	16.41	17.78	11.66	9.17	8.58	7.64
87.31	44.99	26.87	22.2	17.35	10.12	9.57	10.4	10.63
55.97	51.31	27.1	21.73	19.4	15.09	12.69	10.23	8.04
78.29	50.72	35.42	27.91	19.87	28.84	23.25	24.02	14.95
27.71	21.29	18.2	19.15	16	8.07	7.44	7.48	7.5
39.93	34.84	28.3	21.29	15.84	11.64	9.36	8	8.18
47.58	45.11	48.97	19	7.84	6.1	10.43	9.92	16.12
59.15	33.84	28.15	26.62	17.48	12.14	8.72	7.73	8.28
79.31	44.43	30.89	29.66	22.2	20.42	18.2	14.33	12.36
80.76	40.65	24.14	20.46	17.15	14.55	10.88	9.06	7.93
70.29	67.72	46.39	42.48	52.58	25.2	16.55	13.11	9.97
37.04	28.57	26.04	25.72	22	19.14	14.6	12.43	11.92
66.39	47.81	31.55	18.88	14.12	11.37	10.62	9.82	9.57
33.81	27.31	43.56	27.94	19.48	16.31	13.26	11.61	10.39
66.18	30.79	22.88	21.98	16.91	14.02	12.75	10.93	9.94
43.77	36.6	33.47	28.04	19.12	13.44	11.71	11.06	10.14
59.3	44.56	27.93	22.27	18.72	17.82	15.66	14.92	12.46
76.61	51.88	31.1	30.88	18.89	13.51	10.99	10.94	10.79
80.42	63.78	33.48	24.08	19.85	13.89	11.01	11.13	9.26
89.88	41.89	24.08	27.57	19.4	11.76	10.76	9.06	8.3
109.54	41.28	29.67	27.55	19.99	13.72	11	9.41	9.3
85.48	43.85	25.54	21.24	14.06	11.94	10.23	8.11	9.17
58.1	61.22	31.02	26.23	18.15	15.62	12.82	12.29	8.43
40.78	34.7	31.94	78.45	116.65	79.68	59.64	46.81	38.25
29.62	33.61	25.91	24.52	16.87	13.69	12.5	8.47	7.98
42.64	27.34	20.39	18.31	13.62	11.69	12.28	9.16	6.47
62.25	42.17	29.94	24.83	20.16	15.22	12.76	11.23	10.08
48.69	48.89	20	12.21	8.88	6.83	5.16	5	4.6
59.48	37.69	32.52	21.26	15.9	9.63	9.31	6.97	6.69
13.75	16.44	14.62	17.39	14.62	12.25	10.2	9.59	9.15
1579.17	**1087.69**	**766.87**	**671.24**	**570.17**	**425.18**	**353.48**	**308.18**	**275.49**

December			January			February		
I	II	III	I	II	III	I	II	III
5.99	6.03	6.8	6.93	7.45	7.63	8.55	6.79	6.8
6.87	6.1	5.24	4.3	4.43	4.59	2.74	4.92	4.08
5.59	4.36	4.19	4.67	4.63	3.98	3.51	4.28	3.49
13.72	11.81	6.26	6.6	7.01	7.36	7.64	9.66	11.46
7.13	5.87	5.58	5.74	5.34	4.15	4.01	4.13	4.42
6.63	5.98	6.26	5.59	5.36	5.83	5.66	5.27	5.45
9.15	7.61	5.75	3.83	4.39	5.04	5.52	5.82	6.01
7.59	7.53	7.64	8.07	5.72	6.97	7.06	6.49	6.93
9.71	7.82	6.69	6.01	6.44	6.39	6.23	6.64	7.99
7.18	6.72	5.3	6.08	4.6	4.78	4.61	4.35	4.39
7.42	6.49	6.39	5.14	4.89	5.26	5.19	6.17	5.41
9.33	9.88	7.9	7.45	6.63	6.39	6.15	9.18	9.07
8.34	6.92	6.03	5.89	6.07	5.45	4.27	3.56	4.77
10	8.41	9.38	11.14	11.53	9.49	8.18	7.08	6.61
7.36	7.02	7.19	6.6	6.28	5.97	5.73	6.32	6.72
7.86	7.59	7.21	8.46	6.5	6.17	5.98	6.18	6.09
8.25	7.25	7.74	6.83	5.33	6.37	7.84	8.04	6.17
8.84	6.31	5.88	6.37	6.37	5.82	5.72	6.16	6.79
8.56	6.33	5.63	5.4	5.4	5.33	5.36	5.37	5.41
6.26	4.26	4.05	4.02	4.36	4.33	4.33	5.99	5.16
7.92	8.15	8.1	7.07	7.34	6.54	6.44	6.29	8.76
10	9.16	8.75	8.65	8.16	8.59	7.75	7.45	8.64
8.75	9.86	8.64	8.19	7.53	5.93	5.19	4.72	7.59
11.32	8.32	7.75	6.99	6.63	6.35	6.52	5.67	4.99
7.53	6.94	6.53	6.26	6.21	5.98	6.67	6.82	6.09
5.49	4.73	4.59	4.92	4.28	4.37	4.07	3.88	3.82
8.18	7.21	6.6	6.43	6.11	5.96	5.8	6.05	6.27
4.38	5.09	5.43	5.24	4.91	4.94	5.22	5.77	6.35
6.62	6.81	4.83	4.52	4.54	4.3	4.05	4.3	5.01
8.58	7.79	7.1	6.57	6.18	5.53	5.16	5.41	5.62

210.72	**187.77**	**171.20**	**166.40**	**158.22**	**153.99**	**149.93**	**156.59**	**163.25**

March			April			May		
I	II	III	I	II	III	I	II	III
7.84	8.56	9.23	6.99	12.23	13.78	10.6	19.33	18.5
3.97	3.75	3.53	4.09	4.53	4.76	5.02	5.56	4.89
9.35	9.89	8.75	8.44	16.44	13.16	21.86	30.56	23.74
10.39	10.76	11.2	12.06	10.6	12.08	11.62	10.45	12.95
4.42	3.68	5.59	5.75	6.17	10.64	10.15	10.08	9.18
5.54	7.12	11.46	15.93	20.93	21.58	26.27	29.21	32.88
7.75	5.22	5.31	7.83	6.39	7.83	11.18	7.56	7.39
8.98	10.18	11.95	14.52	21.31	27.61	27.1	26.43	26.14
7.15	6.81	7.78	7.5	7.22	9.07	13.71	16.28	20.07
4.28	4	4.86	5.5	8.14	8.03	7.61	8.75	19.89
5.15	6.99	7.39	7.95	13.33	17.5	17.94	25.7	25.58
9.69	9.57	10.81	11.33	10.65	13.03	15.92	16.47	17.06
5.74	11.48	11.97	12.75	14.13	13.24	13.56	15.39	17.62
7.65	7.41	9.49	12.88	11.94	11.57	12.68	17.01	18.12
9.27	9.33	18.45	14.27	21.91	22.43	19.97	28.68	29.69
7.92	9.03	10.11	13.53	15.87	15.82	20.1	20.25	22.89
6.32	6.33	9.28	10.99	13.06	14.88	15.48	19.77	15.17
7.5	10.34	19.88	11.52	18.1	24.44	27.52	17.98	24
5.28	5.34	5.42	7.14	5.87	5.79	14.37	12.89	18.92
4.83	4.59	13.34	10.03	11.8	14.23	13.46	23.11	12.86
7.16	9.78	10.57	9.52	12.57	12.42	13.56	11.47	12.68
8.55	7.14	7.13	7.72	8.68	11.13	11.18	11.57	12.63
11.46	13.89	13.12	16.65	15.95	19.63	19.52	20.2	22.97
5.13	5.14	5.41	6.12	6.29	8.37	9.38	9.91	14.17
6.22	6.19	7.76	9.28	9.65	11.6	12.68	15.94	19.1
3.77	3.67	4.02	4.22	4.71	6.56	8.69	12.49	11.86
6.97	7.55	9.38	10.3	11.58	11.27	10.25	12.56	13.97
7.56	6.46	10.17	10	11.97	14.11	12.58	13.9	16.32
4.95	6.98	7.7	5.81	7.14	9.14	8.68	12.91	21.23
8.23	8.67	8.93	13.27	11.69	13.3	14.57	16.64	18.02

183.10	**197.84**	**245.27**	**257.45**	**307.34**	**349.52**	**383.00**	**437.17**	**473.47**

3.4 DERIVED TEN DAILY DISCHARGES (M^3/S) AT BHILANGNA II A WEIR SITE W.R.T. BHILANGA III A.

Table 6: TEN DAILY DISCHARGES AT BHILANGNA II A W.R.T. III A.

Month	June			July			August		
Year	I	II	III	I	II	III	I	II	III
1975-76	11.37	17.35	32.98	25.77	84.53	52.61	59.35	76.24	65.47
1976-77	28.17	33.31	17.75	26.38	90.40	108.43	79.94	89.67	63.03
1977-78	10.45	7.08	34.40	118.03	104.90	123.57	92.86	84.86	71.64
1978-79	19.64	29.09	69.18	124.33	86.97	100.13	149.44	111.29	129.30
1979-80	11.62	14.06	50.53	51.57	63.95	58.18	63.03	95.03	73.33
1970-81	13.10	17.68	43.52	93.35	108.98	110.42	133.88	82.69	80.99
1981-82	33.21	24.24	41.97	29.97	88.77	93.24	91.71	83.45	60.33
1982-83	9.94	10.04	10.32	22.55	31.16	88.95	102.83	114.20	97.24
1983-84	22.19	18.10	22.61	41.82	29.19	58.88	60.70	99.41	86.51
1984-85	27.28	31.16	45.03	80.88	55.91	95.37	61.15	74.20	80.16
1985-86	14.92	17.82	30.82	43.69	86.58	110.18	99.50	109.96	103.84
1986-87	26.06	32.32	57.55	54.79	114.41	129.71	119.95	138.71	90.49
1987-88	20.05	18.00	17.57	29.04	32.27	88.08	60.82	61.21	80.69
1988-89	16.22	19.09	31.99	45.12	66.82	80.72	114.99	109.87	73.23
1989-90	19.99	17.60	21.03	22.48	37.64	51.10	41.68	62.89	87.46
1990-91	24.98	22.24	50.12	74.64	95.04	67.17	102.61	89.06	56.78
1991-92	25.14	26.04	24.68	33.92	64.53	86.83	91.93	57.98	85.65
1992-93	14.82	24.77	33.09	24.12	61.70	79.42	100.76	98.47	93.38
1993-94	22.74	29.93	32.50	41.30	111.39	63.51	50.80	41.15	56.20
1994-95	15.67	16.98	56.86	104.90	82.37	118.61	129.12	65.87	90.92
1995-96	45.98	25.40	24.55	67.02	87.11	81.20	119.43	87.43	102.90
1996-97	12.66	28.44	56.27	53.73	56.74	69.12	89.30	115.57	98.65
1997-98	14.80	16.52	31.10	72.54	68.18	98.65	107.85	109.08	64.58
1998-99	15.02	26.08	35.92	69.51	76.64	62.94	95.96	85.00	93.96
1999-00	9.36	21.76	23.58	27.12	36.26	40.89	43.61	35.34	38.05
2000-01	23.46	24.92	40.11	36.91	56.48	54.20	46.71	52.02	50.95
2001-02	19.57	21.92	36.00	54.44	72.27	83.54	88.84	85.80	79.84
2002-03	21.17	27.52	29.52	47.17	51.77	62.64	74.94	52.49	46.54
2003-04	29.61	37.17	41.36	58.34	63.24	64.91	78.94	64.17	70.42
2004-05	12.72	17.88	17.67	35.99	40.30	60.37	70.93	47.51	33.65
Total (Mm^3)	518.53	590.87	929.08	1411.60	1845.30	2140.55	2298.25	2173.01	2020.21

September			October			November		
I	II	III	I	II	III	I	II	III
81.55	52.03	28.44	18.41	19.95	13.08	10.29	9.63	8.57
97.96	50.48	30.15	24.91	19.47	11.35	10.74	11.67	11.93
62.80	57.57	30.41	24.38	21.77	16.93	14.24	11.48	9.02
87.84	56.91	39.74	31.32	22.29	32.36	26.09	26.95	16.77
31.09	23.89	20.42	21.49	17.95	9.05	8.35	8.39	10.30
44.80	39.09	31.75	23.89	17.77	13.06	10.50	8.98	9.18
53.38	50.61	54.94	21.32	8.80	6.84	11.70	11.13	18.09
66.37	37.97	31.58	29.87	19.61	13.62	9.78	8.67	9.29
88.99	49.85	34.66	33.28	24.91	22.91	20.42	16.08	13.87
90.61	45.61	27.09	22.96	19.24	16.33	12.21	10.17	8.90
78.87	75.98	52.05	47.66	58.99	28.27	18.57	14.71	11.19
41.56	32.06	29.22	28.86	24.68	21.48	16.38	13.95	13.37
74.49	53.64	35.40	21.18	15.84	12.76	11.92	11.02	10.74
37.93	30.64	48.87	31.35	21.86	18.30	14.88	13.03	11.66
74.25	34.55	25.67	24.66	18.97	15.73	14.31	12.26	11.15
49.11	41.07	37.55	31.46	21.45	15.08	13.14	12.41	11.38
66.53	50.00	31.34	24.99	21.00	19.99	17.57	16.74	13.98
85.96	58.21	34.89	34.65	21.19	15.16	12.33	12.27	12.11
90.23	71.56	37.56	27.02	22.27	15.58	12.35	12.49	10.39
100.85	47.00	27.02	30.93	21.77	13.19	12.07	10.17	9.31
122.90	46.32	33.29	30.91	22.43	15.39	12.34	10.56	10.43
95.91	49.20	28.66	23.83	15.78	13.40	11.48	9.10	10.29
65.19	68.69	34.80	29.43	20.36	17.53	14.38	13.79	9.46
45.76	38.93	35.84	37.41	55.62	37.99	28.44	22.32	18.24
33.23	37.71	29.07	27.51	18.93	15.36	14.03	9.50	8.95
47.84	30.68	22.88	20.54	15.28	13.12	13.78	10.28	7.26
69.84	47.31	33.59	27.86	22.62	17.08	14.32	12.60	11.31
54.63	54.85	22.44	13.70	9.96	7.66	5.79	5.61	5.16
66.74	42.29	36.49	23.85	17.84	10.80	10.45	7.82	7.51
15.43	18.45	16.40	19.51	16.40	13.74	2.24	10.76	10.27
1771.83	**1220.38**	**860.43**	**708.80**	**573.80**	**432.01**	**354.85**	**319.32**	**289.14**

December			January			February		
I	II	III	I	II	III	I	II	III
6.72	6.77	7.63	7.78	8.36	8.56	7.62	7.63	8.80
7.71	6.84	5.88	4.82	4.97	5.15	5.52	4.58	4.45
6.27	4.89	4.70	5.24	5.19	4.47	4.80	3.92	10.49
15.39	13.25	7.02	7.41	7.87	8.26	10.84	12.86	11.66
8.00	6.59	6.26	6.44	5.99	4.66	4.63	4.96	4.96
7.44	6.71	7.02	6.27	6.01	6.54	5.91	6.11	6.22
10.27	8.54	6.45	4.30	4.93	5.65	6.53	6.74	8.70
8.52	8.45	8.57	9.05	6.42	7.82	7.28	7.78	10.08
10.89	8.77	7.51	6.74	7.23	7.17	7.45	8.96	8.02
8.06	7.54	5.95	6.82	5.16	5.36	4.88	4.93	4.80
8.33	7.28	7.17	5.77	5.49	5.90	6.92	6.07	5.78
10.47	11.09	8.86	8.36	7.44	7.17	10.30	10.18	10.87
9.36	7.76	6.77	6.61	6.81	6.11	3.99	5.35	6.44
11.22	9.44	10.52	12.50	12.94	10.65	7.94	7.42	8.58
8.26	7.88	8.07	7.41	7.05	6.70	7.09	7.54	10.40
8.82	8.52	8.09	9.49	7.29	6.92	6.93	6.83	8.89
9.26	8.13	8.68	7.66	5.98	7.15	9.02	6.92	7.09
9.92	7.08	6.60	7.15	7.15	6.53	6.91	7.62	8.42
9.60	7.10	6.32	6.06	6.06	5.98	6.03	6.07	5.92
7.02	4.78	4.54	4.51	4.89	4.86	6.72	5.79	5.42
8.89	9.14	9.09	7.93	8.24	7.34	7.06	9.83	8.03
11.22	10.28	9.82	9.71	9.16	9.64	8.36	9.69	9.59
9.82	11.06	9.69	9.19	8.45	6.65	5.30	8.52	12.86
12.70	9.34	8.70	7.84	7.44	7.12	6.36	5.60	5.76
8.45	7.79	7.33	7.02	6.97	6.71	7.65	6.83	6.98
6.16	5.31	5.15	5.52	4.80	4.90	4.35	4.29	4.23
9.18	8.09	7.41	7.21	6.86	6.69	6.79	7.03	7.82
4.91	5.71	6.09	5.88	5.51	5.54	6.47	7.12	8.48
7.43	7.64	5.42	5.07	5.09	4.82	4.82	5.61	5.55
9.63	8.74	7.97	7.37	6.93	6.20	6.07	6.31	9.23

236.43	**210.68**	**192.08**	**186.71**	**177.53**	**172.78**	**175.70**	**183.16**	**205.44**

March			April			May		
I	II	III	I	II	III	I	II	III
9.60	10.36	7.84	12.23	15.46	11.89	21.69	20.76	18.5
4.21	3.96	4.59	4.53	5.34	5.63	6.24	5.49	4.89
11.10	9.82	9.47	16.44	14.77	24.53	34.29	26.60	23.74
12.07	12.57	13.53	10.60	13.55	13.04	11.72	14.53	12.95
4.13	6.27	6.45	6.17	11.94	11.39	11.31	10.30	9.18
7.99	12.86	17.87	20.93	24.21	29.47	32.77	36.89	32.88
5.86	5.96	8.79	6.39	8.79	12.54	8.48	8.29	7.39
11.42	13.41	16.29	21.31	30.98	30.41	29.65	29.33	26.14
7.64	8.73	8.42	7.22	10.18	15.38	18.27	22.52	20.07
4.49	5.45	6.17	8.14	9.01	8.54	9.82	22.32	19.89
7.84	8.29	8.92	13.33	19.64	20.13	28.84	28.70	25.58
10.74	12.13	12.71	10.65	14.62	17.86	18.48	19.14	17.06
12.88	13.43	14.31	14.13	14.86	15.21	17.27	19.77	17.62
8.31	10.65	14.45	11.94	12.98	14.23	19.09	20.33	18.12
10.47	20.70	16.01	21.91	25.17	22.41	32.18	33.31	29.69
10.13	11.34	15.18	15.87	17.75	22.55	22.72	25.68	22.89
7.10	10.41	12.33	13.06	16.70	17.37	22.18	17.02	15.17
11.60	22.31	12.93	18.10	27.42	30.88	20.17	26.93	24
5.99	6.08	8.01	5.87	6.50	16.12	14.46	21.23	18.92
5.15	14.97	11.25	11.80	15.97	15.10	25.93	14.43	12.86
10.97	11.86	10.68	12.57	13.94	15.21	12.87	14.23	12.68
8.01	8.00	14.07	8.68	12.49	12.54	12.98	14.17	12.63
15.58	14.72	18.68	15.95	22.02	21.90	22.66	25.77	22.97
5.77	6.07	6.87	6.29	9.39	10.52	11.12	15.90	14.17
6.95	8.71	10.41	9.65	13.02	14.23	17.88	21.43	19.1
4.12	4.51	4.73	4.71	7.36	9.75	14.01	13.31	11.86
8.47	10.52	11.56	11.58	12.64	11.50	14.09	15.67	13.97
7.25	11.41	10.00	5.61	15.83	14.11	15.60	18.31	16.32
7.83	8.64	5.81	8.01	10.26	9.74	14.49	23.82	21.23
9.73	10.02	13.27	11.69	13.30	16.35	18.67	20.22	18.02

221.98	**275.19**	**290.49**	**302.54**	**390.74**	**429.72**	**490.50**	**531.20**	**473.47**

3.5 TEN DAILY DISCHARGE (CUMECS) OF BHILANGANA II A W.R.T. TEHRI

TABLE 7: TEN DAILY DISCHARGE OF BHILANGANA II A W.R.T. TEHRI

Month	June			July			August		
Year	I	II	III	I	II	III	I	II	III
1975-76	9.34	14.26	27.11	21.18	69.5	43.26	48.8	62.68	53.83
1976-77	23.17	27.39	14.59	21.68	74.33	89.15	65.7	73.72	51.82
1977-78	8.59	5.81	28.28	97.05	86.24	101.6	76.35	69.77	58.9
1978-79	16.14	23.91	56.88	102.22	71.5	82.32	122.87	91.5	106.31
1979-80	9.56	11.55	41.55	42.39	52.58	47.83	51.82	78.14	60.29
1970-81	10.77	14.53	35.78	76.75	89.6	90.78	110.08	67.99	66.58
1981-82	27.31	19.92	34.5	24.64	72.98	76.66	75.4	68.62	49.6
1982-83	8.17	8.26	8.48	18.54	25.61	73.14	84.55	93.89	79.95
1983-84	18.24	14.87	18.58	34.38	24	48.41	49.9	81.73	71.12
1984-85	22.43	25.61	37.01	66.5	45.97	78.41	50.27	61	65.9
1985-86	12.27	14.65	25.33	35.91	71.19	90.58	81.81	90.4	85.37
1986-87	21.43	26.58	47.31	45.05	94.06	106.65	98.62	114.04	74.39
1987-88	16.48	14.8	14.44	23.87	26.53	72.42	50.01	50.32	66.35
1988-89	13.34	15.68	26.29	37.09	54.94	66.36	94.54	90.33	60.21
1989-90	16.44	14.47	17.28	18.48	30.95	42.01	34.27	51.71	71.9
1990-91	20.53	18.28	41.21	61.36	78.14	55.23	84.36	73.22	46.69
1991-92	20.67	21.4	20.29	27.89	53.05	71.39	75.58	47.68	70.42
1992-93	12.18	20.37	27.2	19.83	50.73	65.3	82.83	80.96	76.78
1993-94	18.7	24.6	26.72	33.95	91.58	52.21	41.77	33.84	46.21
1994-95	12.88	13.95	46.74	86.24	67.72	97.52	106.16	54.16	74.75
1995-96	37.8	20.88	20.18	55.1	71.62	66.76	98.19	71.88	84.6
1996-97	10.4	23.38	46.26	44.17	46.64	56.82	73.41	95.01	81.11
1997-98	12.16	13.58	25.56	59.63	56.06	81.1	88.67	89.68	53.1
1998-99	12.35	21.43	29.53	57.15	63.01	51.74	78.9	69.88	77.25
1999-00	7.69	17.89	19.39	22.3	29.81	33.61	35.86	29.05	31.28
2000-01	19.29	20.49	32.97	30.35	46.43	44.56	38.4	42.76	41.89

September			October			November		
I	II	III	I	II	III	I	II	III
67.04	42.77	23.38	3.05	4.66	8.85	6.92	22.70	14.13
80.54	41.5	24.78	7.57	8.95	4.77	7.08	24.28	29.12
51.63	47.33	25	2.81	1.90	9.24	31.70	28.17	33.18
72.22	46.79	32.67	5.27	7.81	18.58	33.39	23.35	26.89
25.56	19.64	16.79	3.12	3.77	13.57	13.84	17.17	15.62
36.83	32.14	26.1	3.52	4.75	11.69	25.07	29.26	29.65
43.89	41.61	45.17	8.90	6.51	11.27	8.05	23.84	25.04
54.56	31.22	25.96	2.63	2.70	2.77	6.06	8.36	23.89
73.16	40.98	28.49	5.93	2.70	6.07	11.23	7.84	15.81
74.5	37.49	22.26	7.33	8.38	12.09	21.72	15.01	25.61
64.84	62.47	42.79	4.01	4.78	8.27	11.73	23.25	29.58
34.17	26.35	24.01	7.00	8.68	15.45	14.71	30.72	34.83
61.24	44.1	29.1	5.38	4.83	4.72	7.80	8.66	23.65
31.19	25.19	40.18	4.38	5.12	8.59	12.11	17.94	21.67
61.05	28.4	21.1	5.37	4.73	5.64	6.04	10.11	13.72
40.37	33.76	30.88	6.71	5.97	13.46	20.04	25.52	18.04
54.7	41.1	25.76	6.75	6.99	6.63	9.11	17.33	23.32
70.67	47.86	28.69	3.98	6.65	8.88	6.48	16.57	21.33
74.19	58.84	30.88	6.11	8.03	8.73	11.09	29.91	17.05
82.91	38.64	22.21	4.21	4.56	15.27	28.17	22.12	31.85
101.05	38.08	27.37	12.35	6.68	6.59	18.00	23.39	21.80
78.85	40.45	23.56	3.40	7.64	15.11	14.43	15.23	18.56
53.59	56.47	28.61	3.97	4.44	8.35	19.48	18.31	26.49
37.62	32.01	29.46	4.03	7.00	9.64	18.67	20.58	16.90
27.32	31	23.9	2.51	5.84	6.33	7.28	9.74	10.98
39.33	25.22	18.81	6.30	6.69	10.77	9.91	15.16	14.55

December			January			February		
I	II	III	I	II	III	I	II	III
15.94	20.47	17.58	21.90	13.97	7.64	6.57	5.22	16.01
21.46	24.08	16.92	26.30	13.55	8.09	2.10	3.78	9.61
24.94	22.79	19.24	16.86	15.46	8.17	2.70	3.29	2.68
40.13	29.88	34.72	23.59	15.28	10.67	5.87	7.43	8.81
16.92	25.52	19.69	8.35	6.41	5.48	3.08	3.17	3.39
35.95	22.21	21.75	12.03	10.50	8.52	4.35	4.05	4.19
24.63	22.41	16.20	14.33	13.59	14.75	4.24	4.47	4.62
27.61	30.66	26.11	17.82	10.20	8.48	5.42	4.98	5.32
16.30	26.69	23.23	23.89	13.38	9.30	4.79	5.10	6.14
16.42	19.92	21.52	24.33	12.24	7.27	3.54	3.34	3.37
26.72	29.52	27.88	21.18	20.40	13.98	3.99	4.74	4.15
32.21	37.25	24.30	11.16	8.61	7.84	4.72	7.05	6.97
16.33	16.43	21.67	20.00	14.40	9.50	3.28	1.20	3.66
30.88	29.50	19.66	10.19	8.23	13.12	6.28	5.44	5.08
11.19	16.89	23.48	19.94	9.28	6.89	4.41	4.86	5.16
27.55	23.91	15.25	13.18	11.03	10.09	4.60	4.75	4.68
24.68	15.57	23.00	17.87	13.42	8.41	1.50	6.18	4.75
27.05	26.44	25.08	23.08	15.63	9.37	4.40	4.73	5.22
13.64	11.05	15.09	24.23	19.22	10.09	4.12		4.16
34.67	17.69	24.41	27.08	12.62	7.25	3.33	4.60	3.97
32.07	23.48	27.63	33.00	12.44	8.94	4.95	4.83	6.73
23.98	31.03	26.49	25.75	13.21	7.69	5.95	5.73	6.64
28.96	29.29	17.34	17.50	18.44	9.34	3.99	3.63	5.83
25.77	22.82	25.23	12.29	10.45	9.62	5.01	4.36	3.83
11.71	9.49	10.22	8.92	10.12	7.81	5.13	5.24	4.68
12.54	13.97	13.68	12.85	8.24	6.14	3.13	2.98	2.94

March			April			May			
I	II	III	I	II	III	I	II	III	
6.03	6.58	7.10	5.37	1.14	10.59	8.15	14.86	14.22	20.63228
3.05	2.88	2.71	3.15	3.48	3.66	3.86	4.27	3.76	22.96825
7.19	7.60	6.72	6.49	12.63	10.11	16.80	23.49	18.25	27.47087
7.98	8.27	8.61	9.27	8.15	9.28	8.93	8.03	9.95	33.20691
3.40	2.83	4.30	4.42	4.75	8.18	7.80	7.75	7.05	18.53604
4.26	5.47	8.81	12.24	16.08	16.58	20.19	22.45	25.27	28.24352
5.95	4.01	0.00	6.02	4.91	6.02	8.59	5.81	5.68	23.05942
6.90	7.83	9.18	11.16	16.38	16.38	20.83	20.31	20.09	22.9003
5.49	5.24	5.98	5.77	5.55	6.97	10.54	12.51	15.42	20.99278
3.29	3.07	3.74	4.23	6.25	6.17	5.85	6.73	15.28	23.44658
3.96	5.38	5.68	6.11	10.24	13.45	13.79	19.75	19.66	28.05016
7.19	7.36	8.31	8.71	8.18	10.02	12.24	12.66	13.11	29.22015
4.41	8.82	9.20	9.80	10.86	10.18	10.42	11.83	13.54	20.00692
5.88	5.70	7.30	9.90	9.17	8.89	9.74	13.07	13.93	23.25324
7.13	7.17	14.18	10.96	16.84	17.24	15.35	22.04	22.82	19.15249
6.09	6.94	7.77	10.40	3.28	12.16	15.44	15.56	17.59	24.55668
4.86	4.87	7.13	8.44	10.03	11.43	11.89	15.19	11.66	22.24857
5.76	7.95	15.28	8.85	13.91	18.79	21.15	13.82	18.45	25.33999
4.06	4.10	4.16	5.49	4.51	4.45	11.05	9.90	14.54	21.61848
3.71	3.53	10.26	7.71	9.07	10.94	10.35	17.76	9.89	28.57992
5.50	7.52	8.12	7.31	9.66	9.54	10.42	8.81	9.74	28.13977
6.57	5.49	5.48	5.93	6.67	8.55	8.59	8.89	9.70	25.18851
8.81	10.68	10.08	12.80	12.26	15.09	15.00	15.53	17.65	26.42916
3.94	3.95	4.16	4.70	4.83	6.43	7.21	7.62	10.89	22.50753
4.78	4.76	5.96	7.13	7.41	8.92	9.74	12.25	14.68	13.90921
2.89	2.82	3.09	3.24	3.62	5.04	6.68	9.60	9.11	16.29003

3.6 DOUBLE MASS CURVE:

The double- mass curve is used to check the consistency of hydrologic data by comparing the data's. The double-mass curve is use for the inconsistent precipitation data's. The graph of the cumulative data of one variable versus the cumulative data of a related variable is a straight line so long as the relation between the variables is a fixed ratio. Breaks in the double-mass curve of such variables are caused by changes in the relation between the variables. These changes may be due to changes in the method of data collection or to physical changes that affect the relation.

Table 8: CUMULATIVE VALUES FOR DOUBLE MASS CURVE

Annual	Cummilative
2047.3	2047.3
2186.73	4234.03
2641.25	6875.28
3285.96	10161.24
1819.66	11980.9
2714.17	14695.07
2221.68	16916.75
2319.89	19236.64
2193.98	21430.62
2267.09	23697.71
2874.5	26572.21
2868.92	29441.13
2006.62	31447.75
2381.89	33829.64
2001.94	35831.58
2473.29	38304.87
2274.45	40579.32
2528.94	43108.26
2158.43	45266.69
2715.1	47981.79
2729.06	50710.85
2457.9	53168.75
2630.31	55799.06
2451.7	58250.76
1514.74	59765.5
1630.36	61395.86

Annual	Cummilative
765.05	765.05
801.5	1566.55
979.79	2546.34
1217.17	3763.51
673.85	4437.36
1010.5	5447.86
818.08	6265.94
874.59	7140.53
822.94	7963.47
835.85	8799.32
1074.37	9873.69
1064.9	10938.59
750.7	11689.29
891.6	12580.89
762.1	13342.99
924.2	14267.19
851.44	15118.63
947.97	16066.6
801.37	16867.97
1000.92	17868.89
1009.11	18878
909.85	19787.85
983.54	20771.39
1161.39	21932.78
576.58	22509.36
605.86	23115.22

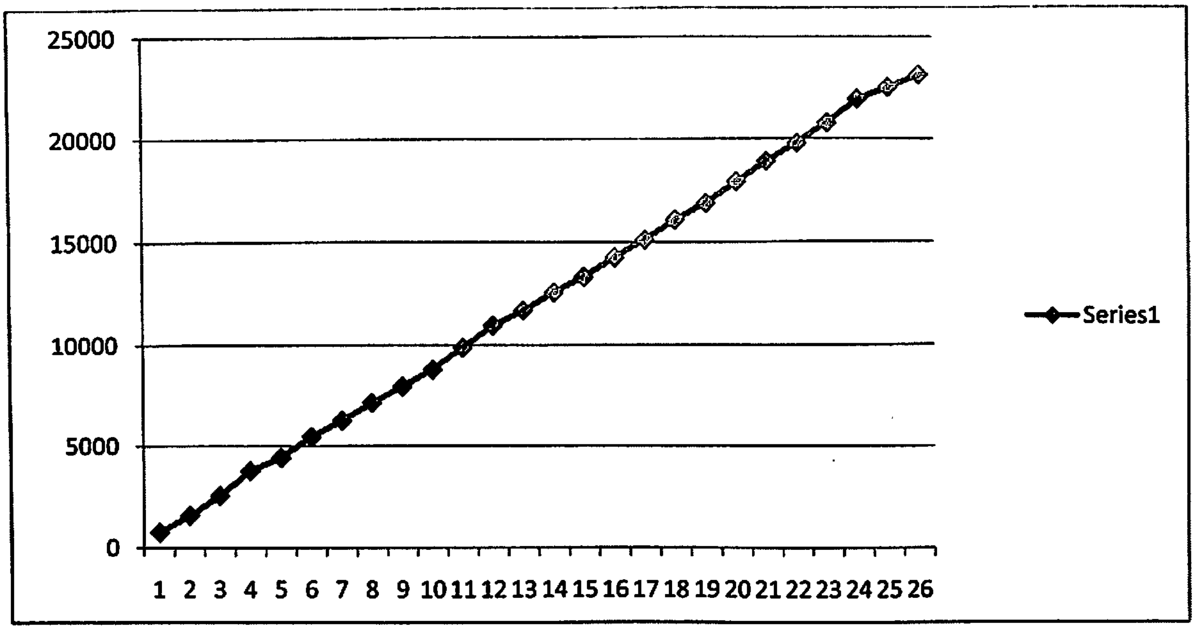

Fig 1 : Double mass Curve

3.7 SEASON REGRESSION

3.7.1 Post Monsoon

Table 9: DISCHARGE FOR POST MONSOON IN 2A W.R.T. TEHRI

Tehri		2A w.r.t. Tehri	
167.65	167.65	60.31	60.31
188.91	356.56	81.75	142.06
205.12	561.68	106.98	249.04
326.7	888.38	115.28	364.32
154.45	1042.83	67.10	431.42
174.85	1217.68	103.93	535.35
163.33	1381.01	83.61	618.96
190.53	1571.54	46.44	665.40
275.69	1847.23	49.60	715.00
188.32	2035.55	90.12	805.12
376.28	2411.83	81.63	886.75
248.98	2660.81	111.40	998.15

175.04	2835.85	55.05	1053.20
232.95	3068.8	69.79	1122.99
203.63	3272.43	45.60	1168.59
220.04	3492.47	89.73	1258.32
239.69	3732.16	70.12	1328.44
225.92	3958.08	63.89	1392.33
209.91	4167.99	80.92	1473.25
204.36	4372.35	106.16	1579.41
214.08	4586.43	88.95	1668.36
175.91	4762.34	74.36	1742.72
220.08	4982.42	81.03	1823.75
419.48	5401.9	76.82	1900.57
197.7	5599.6	42.68	1943.25
168.33	5767.93	63.39	2006.64

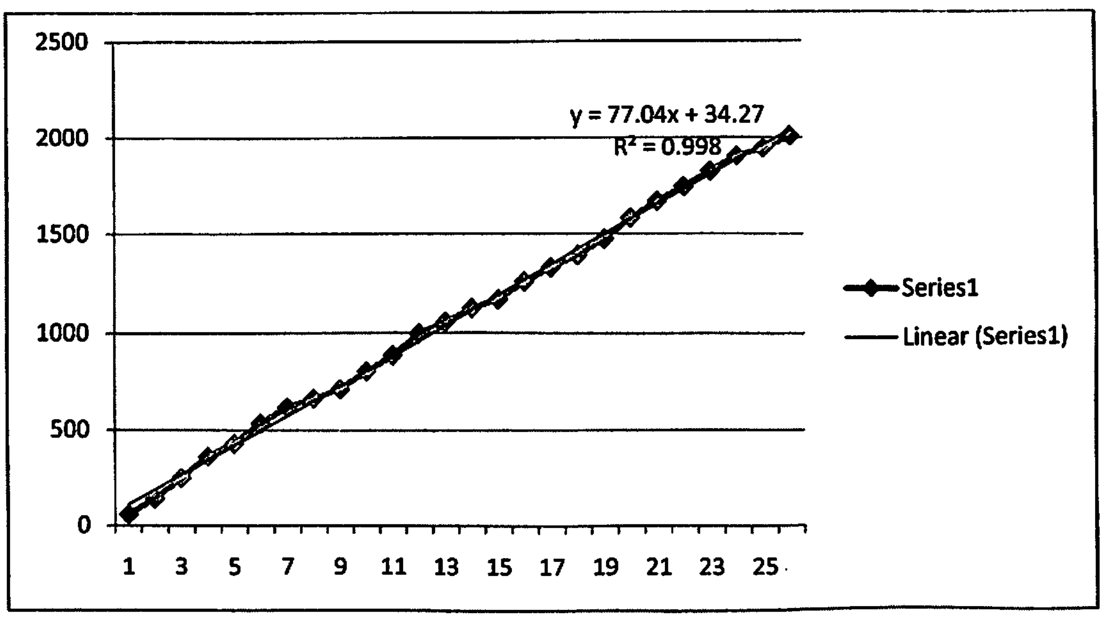

Fig 2 : Post Monsoon

3.7.2 Monsoon:

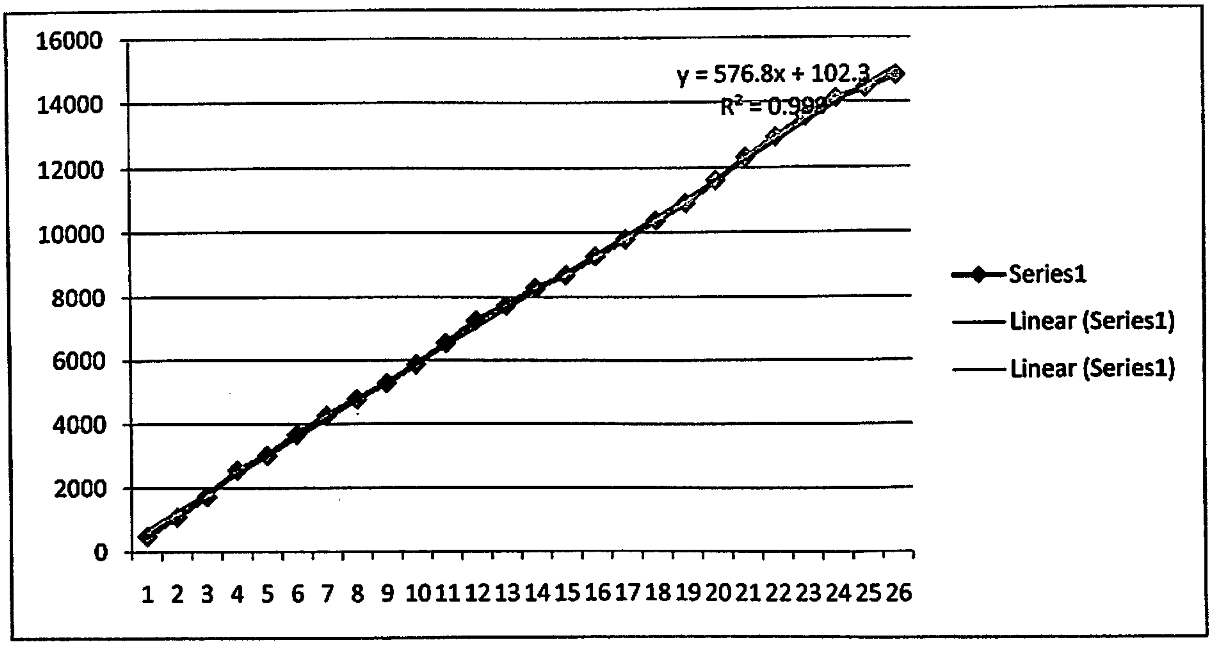

Fig 3 : Monsoon

Table-10: DISCHARGE FOR MONSOON SEASON FOR 2A W.R.T. TEHRI

Tehri		2A w.r.t. tehri	
1479.52	1479.52	483.15	483.15
1801.63	3281.15	588.37	1071.52
2010.43	5291.58	656.55	1728.07
2527.21	7818.79	825.33	2553.4
1401.56	9220.35	457.7	3011.1
2014.68	11235.03	657.93	3669.03
1776.95	13011.98	580.3	4249.33
1568.82	14580.8	512.33	4761.66
1542.92	16123.72	503.86	5265.52
1798.57	17922.29	587.35	5852.87
2074.96	19997.25	677.61	6530.48
2182.23	22179.48	712.66	7243.14

1438.19	23617.67	469.66	7712.8
1700.52	25318.19	555.34	8268.14
1249.58	26567.77	408.06	8676.2
1788.36	28356.13	584.03	9260.23
1622.75	29978.88	529.93	9790.16
1786.44	31765.32	583.4	10373.56
1633.66	33398.98	533.49	10907.05
2155.34	35554.32	703.88	11610.93
2123.58	37677.9	693.51	12304.44
1898.72	39576.62	620.06	12924.5
1893.05	41469.67	618.21	13542.71
1715.82	43185.49	560.33	14103.04
946.55	44132.04	309.1	14412.14
1226.41	45358.45	400.5	14812.64

3.7.3 Snow Melting

Table 11: DISCHARGE FOR SNOW MELTING IN 2A W.R.T. TEHRI

Tehri		2A w.r.t. Tehri	
251.94	251.94	74.02	74.02
94.37	346.31	30.82	104.84
334.62	680.93	109.29	214.13
240.24	921.17	78.46	292.59
154.53	1075.7	50.47	343.06
402.2	1477.9	131.36	474.42
156.38	1634.28	46.99	521.41
409.97	2044.25	133.90	655.31
224.95	2269.2	73.47	728.78
167.23	2436.43	54.62	783.40

300.09	2736.52	98.01	881.41
268.72	3005.24	87.76	969.17
272.7	3277.94	89.06	1058.23
255.9	3533.84	83.58	1141.81
409.45	3943.29	133.73	1275.54
318.89	4262.18	95.23	1370.77
261.83	4524.01	85.51	1456.28
379.53	4903.54	123.95	1580.23
190.62	5094.16	62.26	1642.49
254.76	5348.92	83.20	1725.69
234.66	5583.58	76.64	1802.33
201.72	5785.3	65.88	1868.21
360.94	6146.24	117.88	1986.09
164.54	6310.78	53.74	2039.83
231.58	6542.36	75.63	2115.46
141.15	6683.51	46.10	2161.56

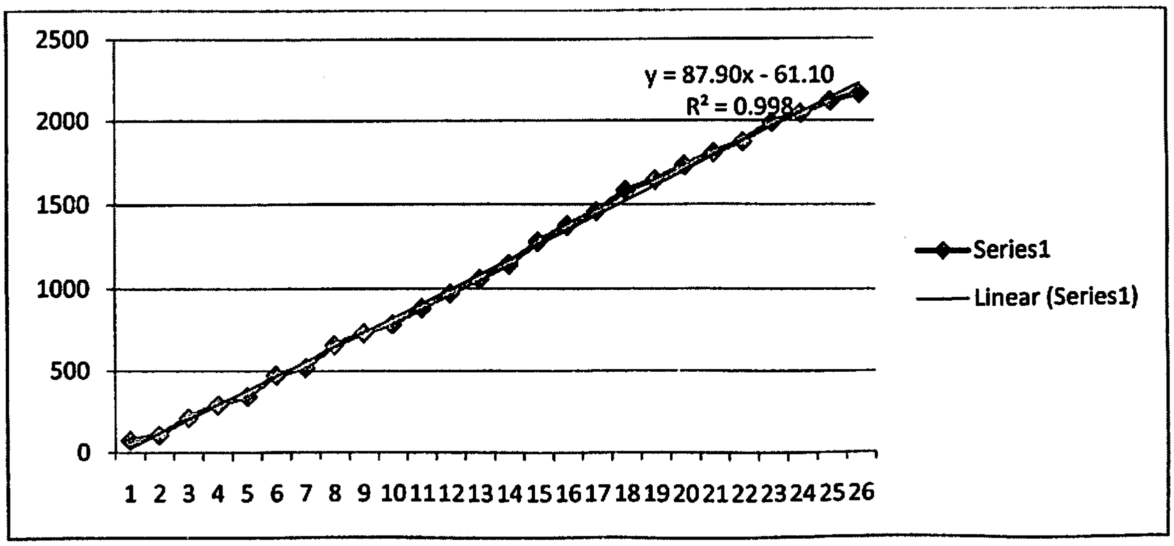

Fig 4 : Snow Melting

3.7.4 Snow Accumulation

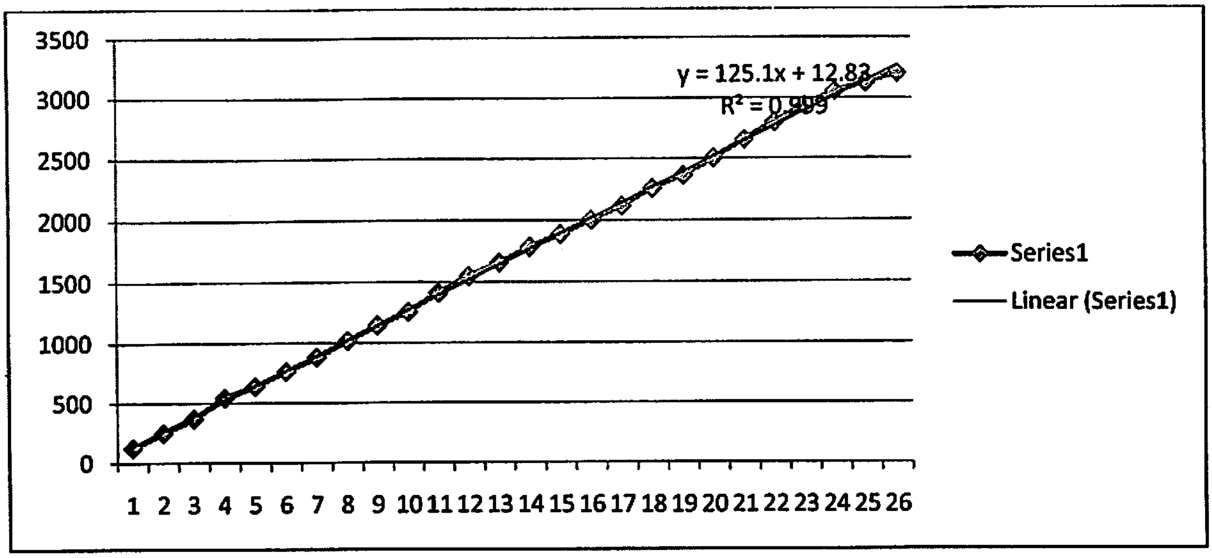

Fig 5 : Snow Accumulation

Table 12: DISCHAREGE FOR SNOW ACCUMULATION IN 2A W.R.T. 3A

Tehri		2A w.r.t. Tehri	
148.19	148.19	125.29	125.29
101.82	250.01	125.90	251.19
91.08	341.09	116.12	367.31
191.81	532.9	176.37	543.68
109.12	642.02	92.03	635.71
122.44	764.46	123.54	759.25
125.02	889.48	119.25	878.50
150.57	1040.05	136.62	1015.12
150.42	1190.47	128.83	1143.95
112.97	1303.44	111.97	1255.92
123.17	1426.61	152.56	1408.48
168.99	1595.6	140.10	1548.58
120.69	1716.29	106.49	1655.07
192.52	1908.81	128.38	1783.45
139.28	2048.09	102.10	1885.55

146	2194.09	115.04	2000.59
150.18	2344.27	115.39	2115.98
137.05	2481.32	141.00	2256.98
124.24	2605.56	105.73	2362.71
100.64	2706.2	135.62	2498.33
156.74	2862.94	154.07	2652.40
181.55	3044.49	146.48	2798.88
156.24	3200.73	134.33	2933.21
151.86	3352.59	119.39	3052.60
138.91	3491.5	73.32	3125.92
94.47	3585.97	76.45	3202.37

3.8 RANKING

Table 13: RANKING FOR THE DISCHARGE

Acsending to decending	Rank	Probability
33.20683844	1	3.7037037
29.0431695	2	7.40740741
28.67704978	3	11.1111111
28.24321172	4	14.8148148
28.14351344	5	18.5185185
28.05022011	6	22.2222222
27.47057272	7	25.9259259
26.42906978	8	29.6296296
25.34001322	9	33.3333333
25.18830206	10	37.037037
24.52227355	11	40.7407407
23.44595372	12	44.4444444
23.2526265	13	48.1481481
23.05978517	14	51.8518519
22.96791528	15	55.5555556

22.50760317	16	59.2592593
22.44628611	17	62.962963
22.25607223	18	66.6666667
21.61852506	19	70.3703704
21.1416655	20	74.0740741
20.69926305	21	77.7777778
19.59358578	22	81.4814815
19.15235244	23	85.1851852
18.53616894	24	88.8888889
16.29008828	25	92.5925926
13.90932822	26	96.2962963

3.9 50% 90% DEPENDABILITY

Table 14: DISCHARGE FOR CALCULATING 50% 90% DEPENDABILITY

1981-82	27.31	19.92	34.5	24.64	72.98	76.66	75.4	68.62	49.6	43.89
2000-01	19.29	20.49	32.97	30.35	46.43	44.56	38.4	42.76	41.89	39.33

41.61	45.17	8.92	6.51	11.27	8.05	23.84	25.04	24.63	22.41	16.20
25.22	18.81	6.30	6.69	10.77	9.91	15.16	14.55	12.54	13.97	13.68

14.33	13.59	14.75	4.24	4.47	4.62	5.95	4.01	0.00	6.02
12.85	8.24	6.14	3.13	2.98	2.94	2.89	2.82	3.09	3.24

4.91	6.02	8.59	5.81	5.68
3.62	5.04	6.68	9.60	9.11

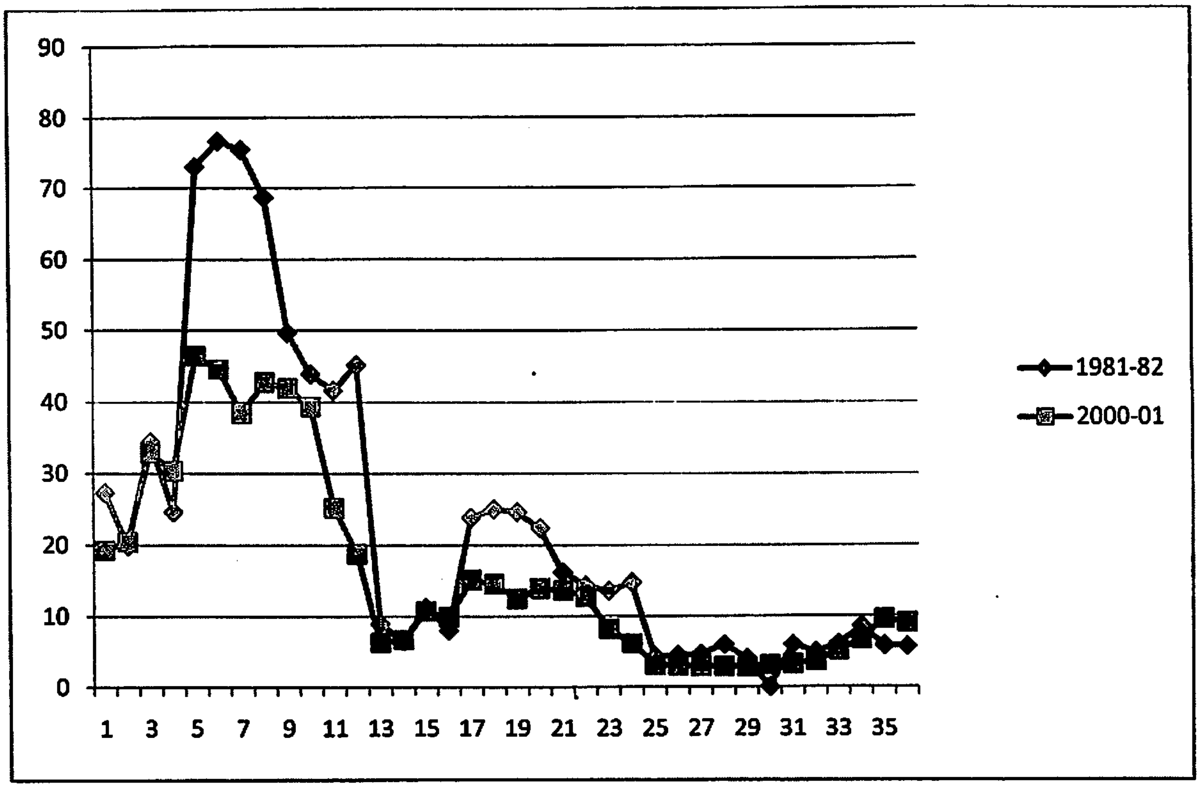

Fig 6 : 50 and 90 Dependibility

3.10 GUMBLE METHOD

Gumble distribution method is used to model the distribution of the maximum (or the minimum) of a number of samples of various distributions. For example we would use it to represent the distribution of the maximum level of a river in a particular year if we had the list of maximum values for the past ten years . It is useful in predicting the chance that an extreme flood or other natural disaster will occur.

Table 15: CALCULATION FOR GUMBLE METHOD

S.No.	Year	Flood Discharge	Q`	m	T	Q-Q`	Square
1	1993	733	431.7647059	1	18.0	301.2353	90742.7
2	1986	695	431.7647059	2	9.0	263.2353	69292.82
3	1978	640	431.7647059	3	6.0	208.2353	43361.94
4	1994	515	431.7647059	4	4.5	83.23529	6928.114
5	1988	466	431.7647059	5	3.6	34.23529	1172.055
6	1980	428	431.7647059	6	3.0	-3.76471	14.17301
7	1981	402	431.7647059	7	2.6	-29.7647	885.9377
8	1985	397	431.7647059	8	2.3	-34.7647	1208.585
9	1983	384	431.7647059	9	2.0	-47.7647	2281.467
10	1990	380	431.7647059	10	1.8	-51.7647	2679.585
11	1987	380	431.7647059	11	1.6	-51.7647	2679.585
12	1992	367	431.7647059	12	1.5	-64.7647	4194.467
13	1984	349	431.7647059	13	1.4	-82.7647	6849.997
14	1991	338	431.7647059	14	1.3	-93.7647	8791.82
15	1982	310	431.7647059	15	1.2	-121.765	14826.64
16	1989	286	431.7647059	16	1.1	-145.765	21247.35
17	1979	270	431.7647059	17	1.1	-161.765	26167.82
		431.7647059					303325.1
							18957.82
						S.D=	137.6874

Table 16: CALCULATIONS FOR GUMBLE METHOD:

T			yt	yn	sn	kt	Qt
2	2	0.693147	0.366513	0.5181	1.0411	-0.1456	411.717
5	1.25	0.223144	1.49994	0.5181	1.0411	0.943079	561.6149
10	1.111111	0.105361	2.250367	0.5181	1.0411	1.663882	660.8603
25	1.041667	0.040822	3.198534	0.5181	1.0411	2.574617	786.2571
50	1.020408	0.020203	3.901939	0.5181	1.0411	3.250253	879.2836
100	1.010101	0.01005	4.600149	0.5181	1.0411	3.9209	971.6233
200	1.005025	0.005013	5.295812	0.5181	1.0411	4.5891	1063.626
500	1.002004	0.002002	6.213607	0.5181	1.0411	5.470663	1185.006
1000	1.001001	0.001001	6.907255	0.5181	1.0411	6.136927	1276.742

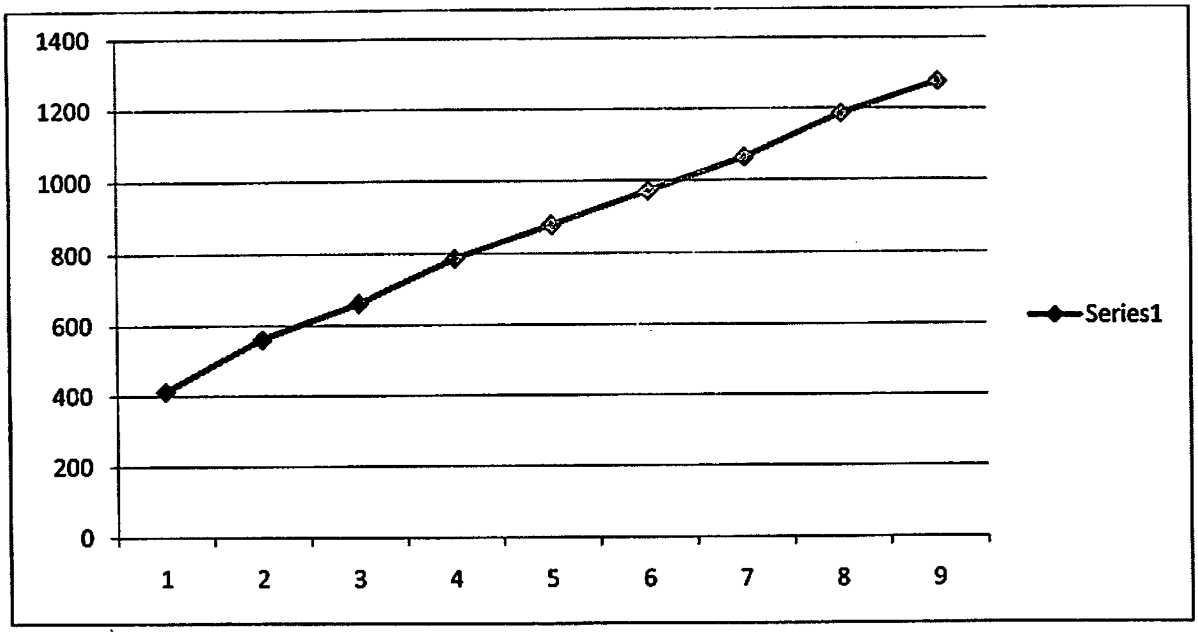

Fig 7 : Gumbel Curve

3.11 FLOW DURATION CURVE

Flow duration curve represents the data in a condensed form and is extremely useful in estimation of power. Flow duration curve will be different from the curve drawn on daily basis and weekly basis. Variation of daily flow will be more than that of weekly flow. The error in the use of the monthly flow rates is more from 5 to 15% depending upon the characteristics of the stream ant the monthly flow duration curve and extent of utilization of flow. However the difference between the daily flow duration curve and monthly flow duration is negligible

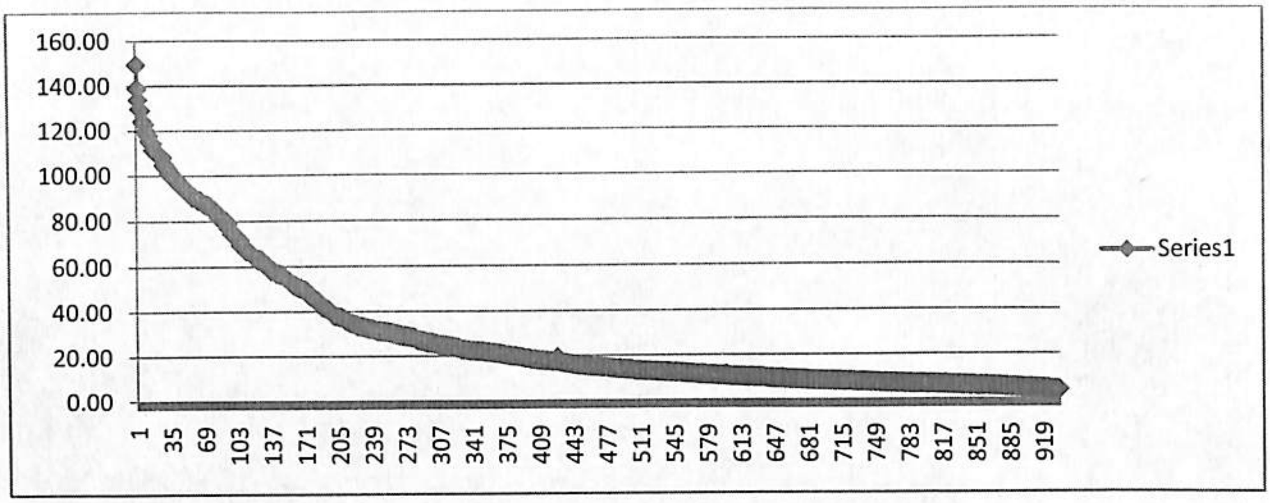

Fig 8 : Flow Duration Curve

3.12 DICKEN

This formula is used to calculate the peak discharge at a particular site.It is based on the calculation of discharge for different return period

$Q= CA^{3/4}$ (3.1)

A= Catchment area excluding snow bound area

C= Constant (depends on proportion of snow area and avg slope of the main stream of basin)

Q= Peak Discharge

C=2.342log (0.6*T)*log(1185/P)+4

Percentage of snow fed area

P=((a+6)/(A+a))*100

a= snow area = 130.9 km^2

A= total catchment area = 457 km^2

Table 17:

S.no.	T				C	Q
1	2	0.079181246	1.706618	0.316479	4.316479	426.6451
2	5	0.477121255	1.706618	1.907006	5.907006	583.8543
3	10	0.77815125	1.706618	3.110192	7.110192	702.7785
4	25	1.176091259	1.706618	4.700718	8.700718	859.9877
5	50	1.477121255	1.706618	5.903905	9.903905	978.9119
6	100	1.77815125	1.706618	7.107092	11.10709	1097.836
7	200	2.079181246	1.706618	8.310278	12.31028	1216.76
8	500	2.477121255	1.706618	9.900804	13.9008	1373.969
9	1000	2.77815125	1.706618	11.10399	15.10399	1492.894

P=((a+6)/(A+a))*100 =	23.28627
a=130.9 square km	
A=457 square km	
C=2.342log (0.6*T)*log(1185/P)+4	

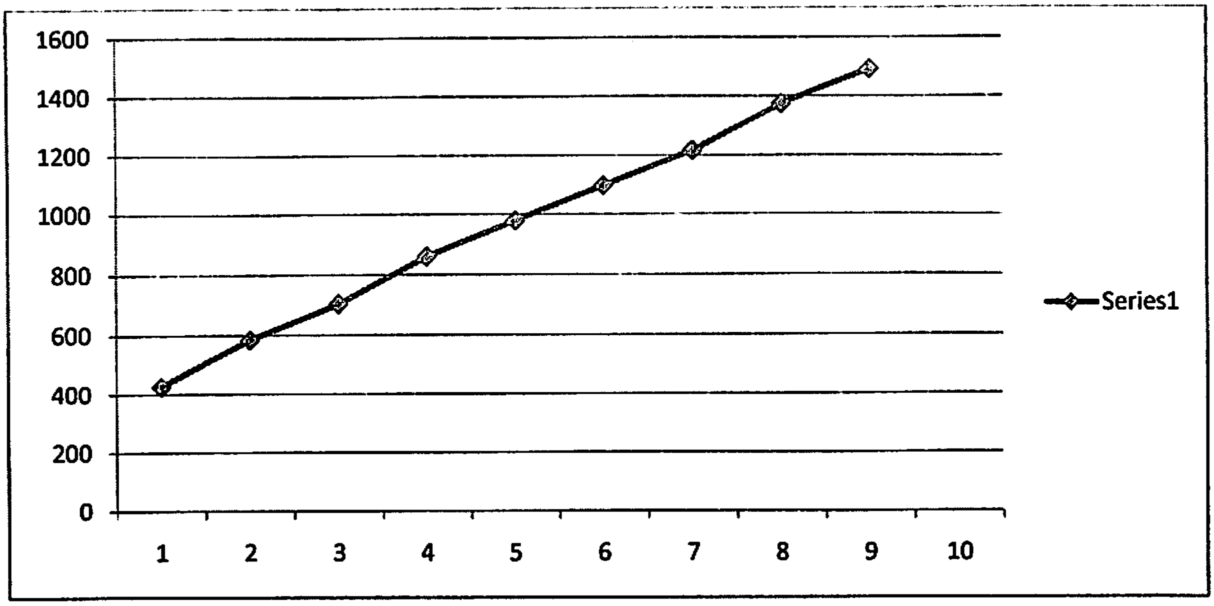

Fig 9: Modified Dickens Curve

CHAPTER 4

HYDRAULIC DESIGN OF CIVIL STRUCTURES

4.1 SITE DATA AND CALCULATIONS:

1	Slope of gad (river) at proposed diversion weir site	1V : in 15 H
2	HFL at weir site (determined)	1415.0 m
3	Proposed top of Diversion Weir	1415.0 m
4.	HFL at power house site	1342.0 m
6.	Design discharge	50.6 cumecs(for2 – units)
7.	Total drop of head in the scheme (assumed)	13m

Slope 1 in 345

Total Length of water conductor system = 4.6 km

Drop = 4600/345

= 13.33 m

8. Water surface level at Fore bay Tank= (1415.0 – 13) = 1402.0 m

9. Gross Head available at forebay

= (1401.7 – 1342.0) m = 59.7 m

10. Net Head available for Power Generation

= 59.7m

= Say 59 m

11.Proposed Capacity of the Plant (presently only two units would be installed)

Power = P = 8.39 x Q x H (Q = 59.7, H = 59 m)

P = 8.39 x 50 x 59 = 25044 KW = 25 MW

It is proposed to install two (2) units of 25000 KW each. If found techno-economical, the third unit would be installed after observation of available discharge in gad for atleast two lean seasons.

4.2 PROPOSED DIMENSIONS OF IMPORTANT UNITS :

4.2.1 Shingle excluder B = 1.0 m Diversion Trench weir: Trench 80 m. wide and 23 m. long;

4.2.2 , FSD = 0.45 m, L = 150.0 m

4.2.3 Power duct 4.6 km. long, 23 m wide, full supply depth = 0.95 m, vortex tubes – 2 nos.; dia = 0.45 m. each at an angel of 60^0 from direction of flow

4.2.4 De silting Tank – 30.9 m long. U/S transition 12.1 m, d/s transition 1.0 m, width 7.5 m, Water depth = 2.0 m above hoppers; size of hopper 37 m x 37 m; depth of hopper = 4.3 m

4.2.5. Fore bay Tank for Two minutes storage. L = 100.0, B = 20.0
Total depth = 8 m

4.2.6. Main Penstock pipe - approx. 2 km. long; dia = 4 m

4.3 DESIGN DISCHARGES FOR VARIOUS CIVIL STRUCTURES:

The following design discharges has been adopted for various civil structures. The civil structures have been designed for the discharge equal to two units, while initially only two units would be installed, and the cost of scheme is based on civil structures described above and two units only.

Table 18: DISCHARGE OF CIVIL STRUCTURES FOR 2 UNITS

Sl. No.	Name of civil structure for which design discharge is being adopted	Discharge for 2units(cumecs)
1.	Design discharge of turbine	50
2.	Discharge for tail race channel, penstock etc.	50
3.	Discharge for forebay (including flushing) and power channel, outgoing discharge from 'D' Tank	50
4.	Discharge for flushing forebay	50
5.	Incoming discharge to D'Tank	58.6
6.	Discharge for flushing D'tank	58.6
7.	Discharge of power duct including vortex tubes	58.6
8.	Discharge for vortex tubes	58.6
9.	Discharge for shingle excluder from intake	3.0

4.4 DESIGN OF DIVERSION TRENCH WEIR AND INTAKE CHAMBER:

4.4.1 Maximum Flood Discharge= Qmax. = C x A^3/4 (4.1)

Where Qmax = Maximum flood discharge of 100 year frequency in cumecs.

C = a constant = 14, for Hills

A = Catchment Area in Sq. Kms. = 457 Sq. Kms.

Therefore Qmax = 14 x (457)^3/4 = 1383.74 cumecs

4.4.2 Width of the stream at the Diversion Site = 90 m.

4.4.3 Top RL of Diversion Weir = 1415 m

4.4.4 Depth of flow 'H' at Maxm. Flood Discharge, "H" can be ascertained from the formula Q_{max} = 1.71 x L x H^3/2 (4.2)

Where L = Crest Length of flow = 90.0 m.

Therefore 1385 = 1.71 x 90.0 x H^ 3/2

Or, H^3/2 = 1385 / (1.71 x 90)

Or, H = 4.32 m

4.4.5 Calculate Pond Level = 1415.0 – 4.32 = 1410.68 m (Say 1788.0) .

4.4.6 Maximum Scour Depth "Ds":

Maximum Flood discharge = 1383 cumecs.

Discharge /rm =1383 / 90 .= 15.36 cumecs. = q

Average depth of Scour "ds " = 1.35 (q^2/f)^1/3 (4.3)

Where f = silt factor which varies for Hill streams from 1 to 20.

A value of 20 is being adopted in the absence of related data.

therefore ds =1.35 x 2.276 = 3.07 m.

Maximum Scour Depth Ds = 2.0 x ds = 2.0 x 3.07 =6.14 m.

4.4.7 Deepest Foundation level of U/S cut off wall shall be taken to a depth such that the cut off wall has at least 0.5 m of Ds as grip length i.e.,6.14 + 0.5 = 6.64 m. As such the foundation of U/S cut off wall shall be taken to a RL of 1415 – 6.64 = 1408.36m. But keep at RL 1408.0 m for practical purpose.

4.4.8 Deepest Foundation level of D/S cut off wall shall be taken to a depth such that the cut off wall has at least 1.5 m of Ds as grip length i.e., 6.14 + 1.5 = 7.54 m. As such the foundation of D/S cut off wall shall be taken to a RL of 1415 – 7.54 = 1407.46 m. But keep at RL 1407 m for practical purpose.

4.5 DESIGN OF TRENCH WEIR

4.5.1 Design Discharge = 1097 cumecs.

4.5.2 Length of Weir = 90 m. (The trench is proposed to be provided in part length of 23 m. The top of the trench weir shall be kept at 1415.0 m. and the following dimensions has been proposed for the trench weir in reference to CBIP manual on the subject.)

4.5.3 B = Q/(E1xE2xCdxLx2gE^1/2) (4.4)

Where B = Width of trash rack (width of opening of trench weir at top),

Q = Diverted discharge = 7.5 cumecs.

E1 = Ratio of area of opening in the trash rack surface over the trench weir = 0.5

E2 = Ratio of area of opening in the trash rack likely to be clogged = 0.5

Cd = Coefficient of discharge through the opening of the trash rack = 0.46

L = Width of the stream = 90 m (in which trench is provided).

E = Specific energy at any section of the stream in the trench weir =(Q/CL)^2/3, where C is the coefficient of discharge for broad crested weir and is taken as 1.53; Therefore E = (1097/1.53x80)^2/3 =4.315; $\sqrt{2gE}$ = 9.195. Therefore B = 1097 / [(0.5 x 0.5 x 0.46) x 80 x 9.195] = 22.57 m.

However, from practical considerations provide 23 m. wide trench weir (trash rack) in a length of 90 m of river.

Check for discharge capacity of trench:

Length of the trench in the weir = 80 m

Design discharge = 1097 cumec

Top width of opening of the trench = 23 m

Let water depth along a d/s section of trench is d = 8.05 m with a longitudinal slope of 1 in 20, n = 0.018.

Therefore area of flow A = 184 sq.m., $R = \frac{A}{P}$, $R^{2/3} = 4.71$

$$S = \frac{0.75}{15} = \frac{1}{20}, \quad S^{1/2} = 0.2236$$

Using Mannings formula discharge through trench

$$Q = \frac{A}{n}.R^{2/3} \times S^{1/2} = \frac{184}{0.018} x4.71 \times 0.2236 = 1531.41 \text{ cumec} > 1097. \quad \text{O.K.}$$

Provide depth of trench 8 m. at start increasing it to 184 m. at the entry to the Intake chamber.

4.5.4 Calculation for various levels of Intake and for Water conductor System:

Pond (Weir Top) level = 1410.68 m.

HFL at weir site = 1415 m

RL of top of wing wall and intake chamber = 1415 + 1.5 = 1416.5 m

by providing free board of 1.5 m.

RL of bottom of trench at junction with intake = 1410 – 8

= 1402 m

RL of bottom of intake at junction with trench = 1402-0.5 = 1401.05 m

4.6 HYDRAULIC DESIGN OF WATER CONDUCTOR SYSTEM:

4.6.1 Design of Power duct: Length = 4.6 km,

$$\text{Total drop} = \frac{4600}{345} \text{ m.} = 13.3 \text{ m}$$

Design discharge = 978 cumecs.

Rugosity coefficient = N = 0.018

Let bed width , B = 23 m

Let full supply depth D = 0.95 m

Cross sectional area provided A = 23 x 0.95 = 21.83 sqm.

Wetted Perimeter P = 23 + 2 x 0.95 = 25.85 m

$$R = \frac{A}{P} = 0.87 \qquad R^{2/3} = (A/P)^{1/3} = 0.87$$

Let S = Bed slope of power duct $= \frac{1}{345}; S^{1/2} = 0..053$

Using Manning's formula; velocity $V = \frac{1}{N}..R^{2/3}.S^{1/2}$

$$V = \frac{0.053 \ \ x\, 0.910}{0.018}$$

$= 2.67$ m/sec

Q $= 2.66 \times 2.67$

$= 58.2$ cumecs   O.K.

$$\sqrt{gD} = \sqrt{9.81 \times 0.95} = \sqrt{9.3195} = 3.0528$$

$$\text{Froude No.} = \frac{V}{\sqrt{gD}} = x\,\frac{2.672}{3.0528} \le 0.795 \le 0.8 \quad \text{O.K.}$$

4.7 DESIGN OF POWER CHANNEL:

4.7.1 Open channel

Design discharge = 58.2 cumecs.

Rugosity coefficient = N = 0.018

Let bed width B = 20 m and Full supply depth D = 1.32 m (Say 1.35 m) for practical purpose)

Cross sectional area provided A = 20 x 1.32 = 27.0 sqm.

Wetted Perimeter P = 20 + 2 x 1.32 = 22.7 m.

$R = 1.89$; $R^{2/3} = 0.122$,

Let S = Bed slope of power channel = $\frac{1}{500}$, $S^{1/2} = 0.0447213$

Using Manning's formula, Q = A/N x R^2/3 x S^1/2

Thus Q = 20 / 0.018 x (0.0447213) x 0.122

Q = 49.10 cumec OK.

Provide free board = 0.3 m,

Hence adopted section of channel B = 20 m; Total depth = 1.35 + 0.3 = 1.65 m

4.7.2 Rectangular box section

Take width, FSD and slope same as for open channel. Here because of closed box, a man can go inside so its internal height is being kept 1.8 m.

Hence the free board = 1.8 – 1.35 = 0.45 m i.e. more safe.

4.7.3 Design of pipe (MS Pipe)

Design discharge = 4.8 cumecs.

Rugosity coefficient = N = 0.010, friction factor for pipe = 0.012

$$\text{Head loss} = \frac{fL}{D}.\frac{V^2}{2g} \qquad (4.5)$$

where,

f = friction factor

L = length of pipe in m

D = dia of steel pipe in m

V = velocity in pipe in m/sec.

Provide a MS pipe of dia = 1.7 m with thickness = 6 mm and to be used at suitable locations.

4.7.2 Head race tunnel, D – shaped (Free flow),

Taking B = 2.1, FSD = 1.35, Free board = 0.3,

Depth including free board = 1.35 + 0.3 = 1.65; above this there is semi circular arch of radius R = 1.275,

Total height at centre of tunnel = 2.925 m.

4.8 DESIGN OF SHINGLE EXCLUDER (RECTANGULAR SECTION OF RCC M_{20})

Q = 1.0 cumec,

Let S = Bed slope of shingle excluder

Bed width= $\frac{1}{80}$, $S^{1/2}$ = 0.1118033

Let B = 1.0 m, Full supply depth = D = 0.45 m

Provide length of shingle excluder = 150.0 m, so as to discharge in river above HFL

HFL at 150 m d/s of weir = 1788.0 - $\frac{150}{15}$ = 1778.0 m

RL of bed of shingle excluder at RD 0.0 = 1780.60

RL of Bed at RD 150.0 m = 1780.6 - $\frac{150}{80}$ = 1778.725 which is 0.785 m higher than HFL Hence O.K.

Cross sectional area provided A = 1.0 x 0.45 = 0.45 sqm.

Wetted Perimeter P = 1.0 + 2 x 0.4 = 1.9 m

$R = \frac{A}{P} = 0.237$; $R^{2/3} = 0.382$.

Using Manning's formulae, $Q = \frac{A}{N}.R^{2/3}.S^{1/2}$

Thus Q = 0.45 / 0.018 x (0.382) x 0.1118033

Q = 1.07 cumec > 1.0 cumec, OK.;

Finally adopted B = 1.0, FSD = 0.45, Free board = 0.55, total depth 1.0 m

length of shingle excluder = 150.0 m

4.9 DESIGN OF DE SILTING TANK:

Average Design Discharge Q = 58.6 cumecs

Particle size to be removed = 0.2 mm and above

Let flow through velocity = Vf = 0.35 m. / sec

Settling velocity = Vs = 2.75 cms / sec = 0.0275 m/sec

Let, Width of De silting Tank = W = 7.5 m.

Water depth required above hopper D = Q / (W x Vf) = 58.6 / (7.5 x 0.35) =

4.71 m, (Say 2.0 m)

. = 4.71^0.5 = 2.17

Moderated settling velocity = Vm= Vs – (0.132/2.17) x Vs

= 0.0108cms /sec

Therefore settling length = (0.35 / 0.0108) x4.71 = 152.63 m, But provide 153 m for practical purpose as under.

Length = 4x37.14 + 3 x 1.48 = 153 m

Provide depth of water above hoppers = 4.5 m.

Length of Intake side (u/s) fluming= $5.17 \times \left(\frac{7.5-2.8}{2}\right) = 12.15m$, Say 12.1 m

Length of off take side (d/s) transition = 1.0 m

Total length of De silting Tank including transitions =12.1 + 153 + 1.0 = 164.1 m

Dimensions of the Hopper portion of Desilting Tank: L = 153 m., W = 37m.,

Water depth above hopper = 4.5 m

Depth of hopper = 4.3 m, side slope IV : 0.79 H

Free board = 0.5 m

Total depth = 6.8 m

No. of hoppers = 4

Size of hopper 37 m x 37 M

4.10 DESIGN OF FORE BAY TANK:

Design discharge = 50 cumecs.

Let Draw down depth = 3.0 m.

Storage capacity = 2 minutes volume

By way of providing 2 minutes storage capacity the volume of Fore bay Tank shall be = 2 x 60 x 50 = 6000 cum.

Plan area required for Fore bay Tank = 6000 /3.0 .= 2000 sq.m., Let L=100;

Let Length L = 100 m and width B = 20 m.

Cross-sectional area provided = = 2000 sq.m O.K.

RL of Central line of Penstock in forebay

Full Supply Level in forebay = 1401.7 m.

Minimum Draw Down Level = 1401.7 – 3.0 = 1398.7 m

Penstock Diameter = 1.5 m.

Opening height of penstock including bell mouth h_e = 2 x 1.5 = 3.0 m.

Allowance for water cushion above belt mouth opening = 0.6 x 3 = 1.80 m,

Central line of Penstock Opening = MDDL at fore bay – water cushion–half of the penstock opening =1398.7 –(1.8+3) = 1393.9 m

Let depth of floor below bell mouth = 0.5 m

RL of bottom of tank near bell mouth = 1393.9 – (1.5 + 0.5) = 1391.9 m

Head over crest of spillway = 0.7 m

Free board above water surface at spillway = 1.0 m

∴ top RL of forebay tank = 1401.7 + 1.7 = 1403.4 m

Depth of tank near bell mouth = 1403.4 – 1391.9 = 11.5 m

Provide Fore bay Tank of size: L = 100.0 m., B = 20.0 m., Free board = 0.7 + 1.0 = 1.7 m

Total water depth = 3.0 + 1.5 + 3 + 0.5 = 8.0 m

Volume provided = 100 x 20 x 3.0 = 6000 cum Hence, O.K.

4.11 DESIGN OF BYEPASS SPILLWAY

Design discharge Q = 58.6 cumecs, Let L = length of crest of spillway,

Full Supply Level at Fore bay = 1401.7 = RL of Crest of over flow section

Assume depth of flow = head over spillway crest = H = 0.7 m

$\therefore H^{3/2} = 0.583$

Q = 1.71 x L x H^3/2

Or, L = 58.6/(1.71 x H^3/2) = (1.71 x 0.583 ^3/2) = 4.8 ./ (1.71 x 0.583)

= 58.78 m., Say 60.0 m.

Therefore provide a spillway-crest 60 m. long and head over crest 0.7 m.

4.12 HYDRAULIC DESIGN OF ESCAPE CHANNEL:

Design discharge = 50 cumecs.

Velocity limited 2.0 to 2.5 m. per second.

Rugosity coefficient N = 0.018

lArea of flow required = 50 / 2.5 = 20 sqm.

Provide bed width B = 18 m. and depth of flow D = 0.98 m.

Cross sectional area provided A = 17.64 sqm

Wetted Perimeter P = 19,96 m.

$R = \frac{A}{P} = \frac{2.2}{5.1} = R = 0.883; \quad R^{2/3} = 0.92,$

Let S = Bed slope of escape channel = $\frac{1}{345}$, $S^{1/2} = 0.053$

Using Manning's formula, Q = A/N x R^2/3 x S^1/2

Thus Q = 17.64 / 0.018 x (0.92) x 0.053

Q = 50.785 cumec > 50 cumec, OK.

Velocity V = Q/A = 50.785 / 18 = 2.75 m/sec O.K.

If required at site, this channel can be a box section of RCC

4.13 (A) DESIGN OF STEEL PENSTOCK:

Design discharge Q = 50 cumecs.

Full Supply Level at Fore bay = 1401.7 m

RL of Max. water level in tail race channel d/s of power house = 1342.0 m

Length of penstock = 2 km . (from contour map, layout of scheme).

Time Constant = 10 secs.

Diameter of penstock: Let velocity of flow be 5.0 m / sec.

Area of penstock = 50 / 5.0 = 10 sqm

Provide 4 m internal diameter of penstock

Area of penstock provided = 22/(7 x 4) x (4)^2 = 12.56 sqm

Hence, O.K.

Y-junction (Manifold) is required to be provided at the end of the penstock for more than one unit; in the present case for two units.

Therefore dia of pipe for each unit $D_2 = \frac{D_1}{2^{0.4}} = \frac{D_1}{1.32} = \frac{4}{1.32} = 3.03$ m

So, provide 3 m.ID pipe of 14 mm thick.

Area of flow provided = $\frac{\pi}{4}$ x 4 ^2 = 7.06 sqm

Velocity through unit penstock = $\frac{50}{2} \times \frac{1}{7.065}$ = 3.53 m/sec O.K.

* Water Hammer:

Maximum water level at Fore bay = 1777.56 m

RL of max. tail race level d/s of power house = 1506.0 m.

Internal steady Head = hi = 1777.56 – 1506.0 = 271.56 m = 891 ft.

(Referring to Allevi's chart)

Pipe line constant K = av/2ghi

Where a = velocity of travel pressure

v = velocity = 4.6 / 0.95 = 4.84 m./sec = 15.88 ft / sec.

hi = internal steady head

Ratio of diameter of penstock pipe to thickness of steel liner (for thickness t = 10 mm thick) = 1.1 / 0.01 = 110

Read from graph a = 3250

Therefore pipeline constant = K = $\frac{av.}{2\,gh_i}$ (in ft units)

= (3250 x 4.89 x 3.28)/(2 x 32.2 x 271.56 x3.28) = 0.8994 = K

and Time constant N = QT/2L = (3250 x 10)/2 x560x 3.28) = 8.845

From graph; for N = 8.845and K = 0.8994, P = 0.06

Therefore ratio of pressure rise to initial steady head = 2KP

=2 x 0.8994 x 0.06 = 0.108, say 108% i.e. 8% above.

Therefore ultimate pressure including that of water hammer = 271.56 + (8% of 271.56) = 21.73 = 293.3 m of water = 29.33 kg/sq.cm.

* Thicknesses of steel liner of penstocks.

Thickness of steel liner at lowest end t = (P x D)/2S (4.6)

Where,

P = ultimate preserve at that elevation

D = dia of penstock

S = Allowable stress in steel (= 1050 kg/cm^2)

= (29.33 x 1.1)/(2 x 1050) = 0.0154 x 100 = 1.54 cm i.e. 15.4 mm + 1.5 = 16.9 mm

But provide thickness as 18 mm and for other elevations or other length of penstock thicknesses of steel liner are as follows:

Table 19:

Thickness of main penstock	Length From forebay towards power house
8 mm	00 to 200 m = 200 m
10 mm	200 to 280 = 80 m
12 mm	280 to 360 = 80 m
14 mm	360 to 440 m = 80 m
16 mm	440 to 520 = 80 m
18 mm	520 to 560 = 40 m
Total length 560 m	

$$\text{Thickness of unit penstock} = \frac{29.33\text{x}0.8\text{x}100}{2 \text{ x } 1050} cm = 1.12 cm = 11.2\text{mm} + 1.5 = 12.67 \text{ mm} \quad \text{say } 14 \text{ mm}$$

Total length of unit penstock approximate 2 x 25 = 50 m.

4.14 HYDRAULIC DESIGN OF TAIL RACE CHANNEL

Design discharge = 50 cumecs

Let the channel section be rectangular with bed width

B = 20 m and full supply depth d = 0.8 m

Let bed slope $S = \frac{1}{350}, S^{1/2} = 0.0534518$

A = 20 x 0.8 = 16 sqm; P = 20 + 2 x 0.8 = 21.6 m

$R = \frac{A}{P} = \frac{2.4}{4.6} = 0.68, \ R^{2/3} = 0.779$

N = 0.018, Using Mannings formula

$$Q = \frac{AR^{2/3} \text{ x } S^{1/2}}{N} = \frac{20 \text{ x } 0.779 \text{ x } 0.0534518}{0.018} = 45.68 \text{ cumec} \qquad \text{O.K.}$$

Hence adopted section is safe and adequate.

Provide free board 0.5 m.

$\therefore$ total depth = 0.8 + 0.5 = 1.3 m.

CHAPTER 5

POWER PLANT EQUIPMENT AND POWER EVACUATION

5.1 INTRODUCTION

The installed capacity of the power plant of Kaldigad SHP has been fixed at 2 units of 4500 KW_e totaling to 9000 KW_e. The net head available for power generation is 264 metres.

5.2 TURBINE

For an operating head of 59 metres and turbine output of 25044 KW (with generator efficiency = 96%), Pelton turbines are appropriate and hence proposed.

For low outputs, turbine – generators with horizontal shaft configuration are preferred from economic and technical reasons and hence the same layout has been adopted for the Kaldigad SHP.

Assuming a rotational speed of 500 rpm (=N)

$$\text{Specificspeed}, N_S = \frac{500(25044)^{0.5}}{(59)^{1.25}} = 485.45 \text{ in m-kw units}$$

The main characteristics of the turbine are summarized as follows:

Type of turbine : Horizontal Pelton – 2 jet

Nos. of units : 2 (two)

Design head : 59 meters

Rated discharge : 50 cumec

Turbine output: 25044 kw

Turbine rated speed : 500 rpm

Runner diameter : 1300 mm

The runner shall be fabricated of 13% Cr, 4% Ni stainless steel secured to the shaft with self centering device for ease of assembly and dismantling. The water distributor shall be of fabricated steel plates. The nozzle - assembly shall be fabricated of 13% Cr, 4% Ni stainless steel.

The turbine shall be provided with adequate capacity to delivery 10% continuous over load capacity of the generator.

Speed rise and Runaway Speed:

The moment of inertia of the unit and the normal nozzle closing time shall be so adjusted that the maximum momentary speed rise of the turbine shall not exceed 20%, and the maximum pressure rise in the penstock shall not exceed 15% of the rated head under any condition of operation. The turbine shall be capable of running safely at maximum runaway speed without any damage to its parts for a period of not less than 15 minutes for every such occurrence.

The turbine shall be provided with deflector device and reverse jet for control of speed rise and pressure rise.

Factor of Safety:

All parts of turbine shall be designed and constructed to safely withstand the maximum stresses during normal running and runaway and short circuit conditions, out of phase synchronizing and brake application. The maximum unit stresses of the rotating parts shall not exceed two third of the yield point of the material. For other parts, the factor of safety based on yield point shall not be les than 3 at normal conditions. For overload and short circuit conditions, a factor of safety of 1.5 on yield point shall be permitted.

Noise Level:

Maximum noise level resulting from any of the operating conditions shall not exceed 90 db (A) at any place 1.0 m away from operating equipment in the machine hall.

5.3 MAIN INLET VALVE

Each of the turbine inlets shall be provided with individual shutoff rotary type valves. The valves should be so designed as to cause minimum head loss. The valve body should be designed to withstand 150% of the static head on the valve including the pressure rise in the event of sudden gate closure with full rated load throw-off by the turbine.

The valve shall be capable of sealing the water flow through it with full penstock pressure (static head) on the upstream side and atmospheric on the turbine side. The valve shall be also be capable of closing against the maximum flow at the design head. While opening the inlet valve, a bye-pars valve may be provided if considered necessary by the manufacturer to equalize the pressure between the upstream and the downstream sides of this valve.

The valve shall be opened automatically by a single acting hydraulic servomotor and closed by means of counterweight.

5.4 GENERATOR

Generator shall be synchronous type with horizontal shaft. The generator shall be rated at 5625 KVA, 3.3 KV, 500 rpm and 0.8 power factor. The generator shall be provided with natural air cooling with shaft mounted fans within the enclosure. The insulation shall be of class F with class B temperature rise. The generator should be designed for operation at an elevation of 1700 m above mean sea level.

The voltage variation permissible shall be ± 5%. The stator winding shall be star connected with neutral point earthed through suitable resistor. The short circuit ratio shall not be less than 0.8 and inertia constant shall not be less than 1. The generator shall be capable of delivering maximum continuous output of 110 percent of rated output at rated power factor. The generator will be connected to the turbine directly. Each generator shall be star connected and the three main neutral leads shall be brought out of the stator frame for insertion of current transformers for protection, metering and surge protection apparatus. The generator neutral shall be grounded through resistor. The generators shall be designed to safely withstand any mechanical / magnetic stresses resulting from either a three phase or a single phase fault. Each generator shall comply in all respects with the requirement of the latest edition of Bureau of Indian Standards IS : 4722 except where specified otherwise.

Speed Rise and runaway Speed:

The moment of inertia of the generator together with the moment of inertia of the turbine and flywheel (if any) shall be such that the maximum momentary speed rise shall not exceed 40% of the rated speed. Each generator shall be designed and constructed so as to be capable of running for a period of 15 minutes at the maximum runaway speed.

Noise Level:

The noise level shall not exceed 90 db (A) when measured at a radial distance of 1 m from any component of the generator.

Temperature Rise :

The generator shall be capable of delivering rated output continuously at any voltage and frequency in the operating range at rated power factor without exceeding the following values of temperature rise at ambient temperature of 40^0C.

(a) Stator winding 80^0C

(b) Rotor winding

(i) Single layer 90^0C

(ii) Multi-layer 80^0C.

Maximum temperature rise when the generator is delivering maximum output corresponding to continuous overload capacity for conditions stated above shall not exceed 100^0, 110^0, and 100^0C for both stator and rotor winding respectively.

Rotor:

The design and construction of rotor shall be in accordance with the best modern practice. The factor of safety at maximum runaway speed based on yield point of material shall not be less than 1.5.

Necessary flywheel effect shall be incorporated into the rotating parts of the generator. In case requisite moment of inertia is not available from the rotor, a separate flywheel shall be provided, to furnish the additional flywheel effect required.

Field Winding:

Field winding shall consist of fabricated field coils or any other type with adequate provision for cooling purpose. The insulation between turns shall be of special epoxy impregnated asbestos paper.

Damper Winding:

The field poles shall be provided with adequate damper windings to ensure stability under fault conditions.

Shaft:

The generator shaft shall be made of the best quality carbon steel properly heat-treated. The shaft shall be of adequate size of operate at all speeds including maximum runaway speed and shall be able to withstand short circuit stresses with excessive vibration or distortion.

Bearings:

The generator bearings can be:

(i) Pad type or sleeve type or babbit lined oil/grease lubricated either self lubrication or forced lubrication type.

(ii) Antifriction ball/roller bearings oil or grease lubricated.

These bearings shall be guaranteed for minimum continuous working for 100,000 (One Hundred Thousand) hours.

Ventilation :

The generator shall be provided with screen protected enclosures for open ventilated type machines.

Heaters:

Space heaters of adequate rating shall be provided for maintaining the stator temperature 5^0C above the ambient temperature during the shutdown of the machine. The temperature shall be maintained through thermostatic control. The space heater shall automatically switch-off when the machine is run.

Flywheels and Brakes:

A separate flywheel of suitable dimensions shall be supplied in case the required moment of inertia for limiting the speed rise / runaway speed is not available from the generator rotor exciter, etc. The flywheel shall be mounted on the generator- turbine shaft directly. Necessary provision for application of brakes, if required, shall be provided on the flywheel surface.

The generator shall be provided with Brushless Excitation System with 'High Initial Response' as described by IEE Std 421 (standard criteria and definitions for excitation system) with a response ratio of 1.5, capable of continuously carrying the required excitation current at 40^0C ambient temperature when the generator is delivering 100% rated KVA at rated power factor, rated frequency and 10% rated voltage. It shall also be capable of carrying short circuit current for 30 seconds after reaching rated temperature when the generator is delivering 100% rated KVA at rated power factor and 100% rated voltage. AC exciter and generator shall be electrically connected to one another. The exciter shall be of rotating armature and stationary field type to be coupled with a salient pole, rotating field type stationary armature generator. A diode wheel consisting of six diodes and selenium surge suppressor shall be mounted on the shaft.

An electronic voltage regulator shall sense the armature voltage and control the DC supply to exciter field, under varying load conditions to maintain the voltage very near to preset value.

Automatic Voltage Regulator:

Each automatic voltage regulator (AVR) shall be provided with two channels for working i.e. one in operation and one as standby for automatically coming into operation in case of failure of the first channel in operation. The voltage regulator shall be sensitive to change of $\pm 0.25\%$ of normal voltage of the generator when operating under steady load conditions for any load or excitation within operating range and shall initiate corrective action without hunting. After full rated load rejection the AVR should limit the maximum-rise of voltage not to exceed 20% of normal rated voltage and shall control the excitation at such a high speed so that the generator voltage settles down within 10 seconds to restore the terminal voltage to a value not more than 5% above or below the voltage being held before load rejection and shall maintain the voltage within these limits throughout the period of generator over-speed. The voltage regulator shall be provided with cross current compensating devices for parallel of generators. The range of the voltage control shall extend from 80% to 110% of rated voltage of the generator.

There shall exist the facility for transferring from manual to auto-control and vice-versa without the risk of sudden change of excitation level at the instant of change over.

<u>Line Terminal and Neutral Grounding Cubicles</u>

One number terminal cubicle for each machine housing surge capacitor, potential transformers, current transformers, lightning arrestors shall be provided.

5.6 EARTHING AND EARTHMAT

Suitable earthing system based on earth resistivity tests shall be designed and installed for the power station and switchyard as per IS 3043-1987 and Indian Electricity Rules (1956). While designing following important features shall be achieved.

- (i) Stabilization of the circuit potentials
- (ii) Protection life and property from over voltage.
- (iii) Limiting the over all potential rise.
- (iv) Providing a low impedance path to fault current resulting in prompt and consistent operation of protection device during earth faults.
- (v) Prevention of danger to persons walking or touching metallic object near the power station and switchyard.
- (vi) Keeping the maximum voltage gradient along the surface inside and around the power station and switchyard within safe limits during the fault conditions.
- (vii) Protection of buried and underground cables in trenches etc. from overall ground potential and voltage gradients due to system ground faults.

In power house and switchyard there shall be provisions for earthing the following:

(a) The neutral points of each separate voltage system have to be earthed at the station.

(b) All apparatus, metal framework and other non-current carrying metal work either enclosing or in close proximity of power carrying systems.

(c) Boundary fence of metal work, steel structures, sheaths of communication cables etc.

(d) Earth point of lightening arrestors, CVT, CT, PT, etc. and the lightening down conductors in the sub-stations through their permanent independent earth electrode.

Neutral points of systems of different voltages, all apparatus and framework and other non-current-carrying metal work shall be connected to the earthmat (MS flats) and grounding rods of adequate dimensions.

Ground Wires and Ground Rods

The net/mesh consisting of M.S. conductors / strips clamped or welded at each intersection and fastened to anchored steel ground rods shall be installed.

5.7 STANDARDS

The design, manufacture and testing of the various equipments shall comply with the latest editions of the following and other relevant BIS Standards.

1.	Alternating current circuit-breakers requirements	: IS 2516 (PART-I & II)
2.	Metal enclosed switchgear control gear	: IS 3427
3.	Degree of protection provided by enclosures for switchgear	: IS 2147
4.	Arrangement for switchgear bus bar, main connections and auxiliary wiring	: IS 375
5.	HRC cartridge fuses	: IS 2208
6.	Current transformers	: IS 2705
7.	Potential transformers	: IS 3516
8.	Lightning arrestors	: IS 3070
9.	Switch fuse units and switches	: IS 4047

10.	Code of installation and maintenance of switchgear	: IS 3072
11.	Indicating instruments	: IS 1248
12.	Push buttons	: IS 1336
13.	Protective relays	:IS 3842, IS 3231, IS 8714, & IS 8686
14.	Thermal relays	: IS 3842
15.	AC electricity meters	: IS 722
16.	Porcelain post insulators	: IS 2544
17.	PVC insulated and PVC sheathed cables	: IS 1554 (Part-I)

The installation shall conform to latest National Electrical code of Bureau of Indian Standards.

5.13 CONTROL PANELS

Switchboards and control panels shall be of unit type of construction, compact in size and shall be capable of being easily extended at site on either side. The arrangement of equipment and the design of switchboard/control panels shall be such that, adequate space is provided for inspection and maintenance of wiring, terminals and switchboard equipment.

Terminal blocks shall be mounted on the switchboard/control panels to terminate all cables to the switchboard and control panels and to provide atleast 10 percent spare terminals.

Each door shall be provided with a locking latch with a chromium plated handle and locking mechanism with keys removable in both locked and unlocked positions. Suitable electrical interlock shall be provided to prevent opening of any cubicle with power supply to that panel being "ON".

The switchboards and control panels shall be provided with strip heater of adequate rating with thermostat control to maintain the temperature within the enclosures at about 5^0C above the rated ambient temperature to prevent condensation of moisture. The switchgears and control panels shall be designed to have cable entry from bottom.

CHAPTER 6

CONCLUSION:

Data collection was done from different govt./pvt. Organization for study of Small Hydro Electric Project and different Civil Components Scheme of SHP are studied in literature review. By organizing the data, we calculated the dependability of the given data and verified the calculations through Regression Curve value (i.e,R<1). The next step was to calculate the Hydrological Data i.e. Design discharge which we obtain through various methods viz. Gumble Distribution Method, Modified Dicken method which came out to be 978.91 cumecs.

Forth coming step was the hydraulic designing of various Civil Structures of Small Hydro Power Project, in this the dimensions were calculated and checked. The design values are mentioned below :-

1. Diversion Trench weir:- Trench 80 m wide and 23 m long
2. Shingle excluder B = 1.0 m, FSD = 0.45 m, L = 150.0 m
3. Power duct of length 4.6 km with a width of 23 m and ful supply depth of 0.9 m. it has 2 vortex tube of diameter 0.45 m each at an angle of 60° from the direction of flow.
4. De-silting Tank Length= 30.9 m U/S transition =12.1 m D/s transition =1.0 Width = 7.5 m Water depth = 2.0 m above hoppers Size of hopper =37 m x 37 m, Depth of hopper = 4.3 m .
5. Fore bay Tank for Two minutes storage Length = 100.0m, Breadth= 20.0m , Total depth = 8 m .
6. Main Penstock pipe Approx. length= 2 km, Dia = 4 m.
7. Tail Raise Channel Bed Width = 20 m Full supply depth = 0.8m
8. The main characteristics of the turbine are summarized as follows:

Type of turbine	: Horizontal Pelton – 2 jet
Nos. of units	: 2 (two)
Design head	: 59 meters
Rated discharge	: 50 cu m
Turbine output	: 25044 kw
Turbine rated speed	: 500 rpm

CHAPTER 7

REFERENCES

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4. Available, www.smallhydropower.com/manual3.htm , dated 4th March, 2012.

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Table 1: TEN DAILY DISCHARGE OF BHILANGANA AT TEHRI APPENDIX 1

December			January			February		
I	II	III	I	II	III	I	II	III
14.1	14.19	16.01	16.31	17.53	17.95	20.11	15.98	16.01
16.17	14.36	12.34	10.11	10.42	10.8	6.44	11.57	9.61
13.16	10.25	9.87	10.98	10.9	9.36	8.27	10.07	8.22
32.29	27.79	14.74	15.52	16.49	17.31	17.97	22.74	26.96
16.78	13.82	13.13	13.51	12.57	9.77	9.43	9.72	10.39
15.6	14.08	14.72	13.16	12.62	13.72	13.32	12.39	12.83
21.53	17.91	13.54	9.02	10.34	11.85	12.99	13.69	14.15
17.87	17.71	17.98	18.99	13.45	16.4	16.61	15.26	16.3
22.84	18.41	15.74	14.14	15.16	15.04	14.66	15.62	18.81
16.89	15.82	12.47	14.3	10.83	11.25	10.85	10.23	10.33
17.46	15.27	15.03	12.09	11.51	12.37	12.21	14.51	12.72
21.6	23.25	18.58	17.54	15.59	15.03	14.46	21.6	21.34
19.62	16.29	14.18	13.86	14.28	12.83	10.04	8.37	11.22
23.54	19.78	22.07	26.22	27.13	22.33	19.24	16.65	15.56
17.32	16.52	16.91	15.53	14.78	14.05	13.49	14.87	15.81
18.49	17.86	16.97	19.9	15.3	14.52	14.08	14.55	14.33
19.41	17.05	18.21	16.08	12.54	14.99	18.44	18.93	14.53
20.79	14.84	13.84	14.98	14.98	13.69	13.47	14.49	15.97
20.14	14.9	13.25	12.7	12.7	12.55	12.62	12.64	12.74
14.74	10.03	9.54	9.47	10.25	10.18	10.19	14.09	12.15
18.64	19.17	19.05	16.63	17.28	15.4	15.15	14.8	20.62
23.54	21.56	20.58	20.35	19.2	20.21	18.23	17.54	20.34
20.59	23.2	20.34	19.27	17.72	13.95	12.21	11.1	17.86
26.63	19.57	18.23	16.45	15.61	14.95	15.34	13.34	11.74
17.71	16.34	15.37	14.72	14.61	14.08	15.7	16.05	14.33
12.93	11.14	10.8	11.57	10.07	10.28	9.57	9.12	8.99

March			April			May			
I	II	III	I	II	III	I	II	III	
18.45	20.14	21.73	16.45	28.78	32.42	24.94	45.49	43.54	56.86944
9.34	8.83	8.3	9.63	10.65	11.21	11.82	13.08	11.51	60.7425
22.01	23.28	20.59	19.86	38.68	30.96	51.45	71.92	55.87	73.36806
24.44	25.31	26.35	28.38	24.94	28.42	27.35	24.58	30.47	91.27667
10.41	8.66	13.16	13.53	14.53	25.04	23.88	23.73	21.59	50.54611
13.04	16.76	26.97	37.49	49.24	50.77	61.81	68.74	77.38	75.39361
18.23	12.28	12.5	18.43	15.03	18.43	26.3	17.78	17.4	61.71333
21.12	23.96	28.11	34.16	50.15	64.97	63.78	62.2	61.52	64.44139
16.82	16.03	18.3	17.66	17	21.35	32.26	38.31	47.22	60.94389
10.08	9.41	11.44	12.95	19.15	18.9	17.9	20.6	46.8	62.97472
12.12	16.46	17.38	18.7	31.36	41.18	42.22	60.47	60.2	79.84722
22	22.52	25.43	26.67	25.06	30.67	37.47	38.76	40.14	79.69222
13.51	27.02	28.17	30.01	33.24	31.16	31.91	36.21	41.47	55.73944
18.01	17.44	22.34	30.3	28.09	27.22	29.83	40.02	42.65	66.16361
21.82	21.95	43.42	33.57	51.55	52.79	47	67.49	69.86	55.60944
18.64	21.25	23.8	31.84	37.34	37.22	47.29	47.64	53.87	68.7025
14.88	14.9	21.84	25.85	30.72	35.01	36.42	46.52	35.69	63.17917
17.65	24.34	46.77	27.11	42.58	57.52	64.76	42.32	56.48	70.24833
12.42	12.56	12.75	16.8	13.82	13.62	33.82	30.32	44.51	59.95639
11.36	10.81	31.4	23.6	27.76	33.49	31.68	54.39	30.27	75.41944
16.85	23.01	24.87	22.39	29.59	29.22	31.91	26.99	29.83	75.80722
20.11	16.8	16.78	18.17	20.43	26.19	26.3	27.23	29.71	68.275
26.96	32.69	30.87	39.18	37.53	46.19	45.94	47.54	54.04	73.06417
12.07	12.09	12.74	14.4	14.79	19.7	22.07	23.33	33.35	68.10278
14.64	14.56	18.25	21.84	22.7	27.3	29.83	37.51	44.95	42.07611
8.86	8.64	9.45	9.93	11.08	15.44	20.46	29.39	27.9	45.28778