Best Practices Manual on SMALL HYDRO

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IREDA
ENERGY FOR EVER

ARUN KUMAR

Best Practices Manual

on

SMALL HYDRO

FORWARD

Being Environmentally benign and having short gestation period, harnessing of Small Hydro Resources is receiving world wide attention both in developed and developing countries to supplement energy generation. The greater awareness of Small Hydro potential and opportunities for exploitation has led to innovative uses for grid connected power generation as well as to cater to the needs of small isolated communities in far-flung areas without easy connection to grid. On one hand it became an attractive business opportunity for private sector entrepreneurs and on the other hand it has helped in supplementing the energy needs of the rural community, as electricity is considered one of the basic inputs to raise the standard of living of people. It has been identified as one of the appropriate renewable energy resource for development due to mature indigenous technology and expertise.

With aggressive policy support from Ministry of Non-conventional Energy Sources coupled with active participation of State Governments and utilities, the Small Hydro Development programme in India has emerged as a trend setter for small scale power generation from Renewables. The World Bank Line of credit through IREDA for financing private sector projects also played a crucial role in this achievement.

Technology for small Hydro has to be certainly different from that of conventional ones so that installations will be robust, easy to install and maintain by local people besides to be cost effective. Considering the rapid advances in technology for harnessing this resource and the experience gained from the initial projects especially in private sector, it was considered opportune to document the Best Practices available for Small Hydro Power Projects for the benefit of prospective investors. This will help the new entrants in the field to appreciate the technology better and also to take more confident investment decisions to set up state-of-the-art Small Hydro projects.

IREDA take this opportunity to thank the Central Board of Irrigation & Power, other experts and consultants, developers, officials of MNES and IREDA staff for their valuable contribution and efforts in preparation of this manual. I am sure, this manual will be of immense benefit to the prospective developers who will be venturing to install Small Hydro Power Projects.

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Managing Director, IREDA

P R E F A C E

Hydro-Power Schemes having smaller capacities have certain advantages over other hydro-schemes with large capacities. Such schemes upto a certain range have been defined as "SMALL HYDRO PROJECTS" (SHP).

In India total capacity of SHP which includes Micro & Mini Hydro Projects has been restricted to 25,000 KW.

TYPE	TOTAL CAPACITY
Micro	Upto 100 KW
Mini	Upto 2000 KW
Small	Upto 25000 KW

The ***'Best Practices Manual'*** on small hydro is prepared for meeting the *"Need to know requirements of potential investors"*. It is felt that private developers by virtue of their involvement in projects in other sectors of economy are fully conversant with financial and management aspects, but lack adequate knowledge on technology of small hydro. One of the important objectives of this Manual is to fill the gap and enable intending entrepreneurs to take informed investment decisions on small hydro development. The specific aspects linked with the development of small hydro are dealt with in this manual.

Small Hydro Electric Power involves limited investment, simple civil works, short gestation period, minimum operation and maintenance expenses besides being environment friendly and could be viewed as an economical proposition for long term outlook. SHP is site specific which means that features of the project have to be determined to suit the natural characteristics of the site. This feature differs from other modes of electric power generation, since the size of scheme is proportional to the product of head and discharge available at the particular site. The same installed generating capacity could have different size and type of machines depending on head and discharge. For taking up a SHP therefore, it is essential to gather reliable site specific data of topography, geology, discharge etc. At the same time small hydro concept should not be thought of as a miniaturisation of major hydro electric scheme but as an entity having an identity of its own. In India Himalayas and associated mountains, is the main area where many, even small, streams are available for developing high head SHP. Many such streams have some flow all the year round, although the monsoon flow is many times that in the dry period. In the western Himalayas in J&K, H.P. and U.P. many sites can be found where snow melt augments the flow in summer. In Arunachal Pradesh, the rains occur for 6 to 7 months. The other regions of the country where sites available for occasional high head and frequently medium head SHP, are the hills of North-Eastern States and hill regions of Orissa, A.P., M.P. and Bihar. Medium head SHP, are likely to occur at small dams constructed for irrigation or water supply etc. Such works have been widely constructed throughout peninsular India right from the undulating plains in Aravalli and Vindhays in the south of Delhi to Kanya Kumari. Many such sites are being developed with indigenous approaches. Low head SHP, by and large, are associated with irrigation head works or canals. Many of these have been constructed in recent times. Suitable sites exist in the undulating plains of peninsula and the rim of the plains of Indus-Ganga-Brahmaputra.

The private developer would like to maximise returns and minimise risks. The returns could be maximised by reducing the cost and construction period. The formulation of the project thus assume more importance since properly formulated project would not only optimise the cost but also shorten the construction period. An innovative approach would need to be adopted in formulation of feasibility reports which very often have to be based on scanty hydrological data and limited geology. During construction, there could be consideration for use of helicopter transport for appropriate transportation particularly of generating units in inaccessible areas to save time. A multi-disciplinary team consisting of hydrologist, geologist, civil engineer, Electrical/ Mechanical Engineer and an economist having expertise should be associated at the formulation stage of the project. It will be desirable to develop an attitude of greater flexibility in regard to degree of permanence of work. An approach of providing for constructive maintenance rather than attempt to provide permanent risk-free structure at high cost and with no real assurance would be more appropriate. Suitable insurance policies could also be thought of to provide for risk contingencies.

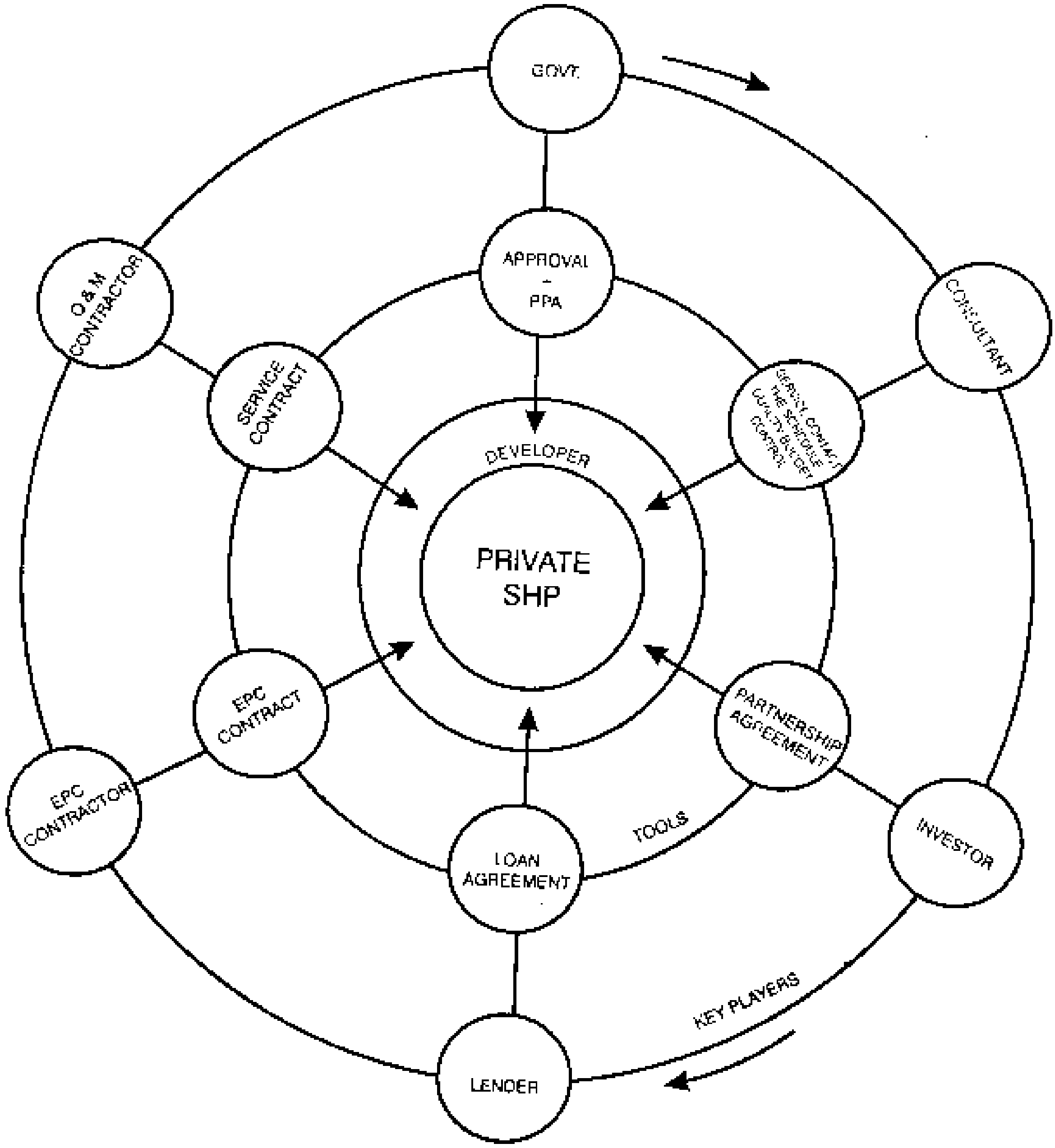
China has made significant strides in development of SHP. It utilised local equipment and labour. The cost had been brought down by utilisation of local pre-fabricated material for civil construction and less efficient generating machines and equipment which were manufactured locally. In addition to the subsidies, labour to some extent, had been made voluntary. This concept has well suited China to make use of the local manpower and material. In India, the private developers are more conscious about their return and risks. They prefer maintenance-free sound structure and efficient machine, if possible remote controlled, to minimise future O&M costs and risks. The choice of more investment now and less O&M cost later or otherwise rests with the developer and could be considered appropriately.

Various related issues pertaining to development of SHP including identification of site, assessment of potential and annual energy generation, machine selection, cost effective designs, cost-estimates, economic and financial analysis etc., are dealt with in this manual to guide the developer in adopting best and appropriate practices.

The SHP require certain approvals for implementation besides assistance from the Government of India and the State Government Departments. They also attract certain concessions and subsidies. These along with other technical and financing requirements are also documented in this manual. This ***"Best Practices Manual"*** may thus be a document to assist intending developers in concept visualisation and planning for development of small hydro. A pictorial view of the involvement of key agencies in development of SHP, is shown at Figure-1. Figures 2 and 3 depict hill stream and canal drop development respectively.

TERMS USED IN SMALL HYDRO PROJECTS

Gross Head	Difference in elevation between the water levels of the forebay and the tailrace.
Net Head	Gross Head less all hydraulic losses that occur due to flow from reservoir/forebay to tailrace except those chargeable to the turbine
Gwh	Gega Watt hour equal to Million Kwh (Unit of Energy)
FRL	Full Reservoir Level
MDDL	Minimum draw down level of the reservoir
Tail water curve	Tail water elevation at the site showing elevations for all flows from Zero to average yearly flood
Plant Factor	Ratio of average generation of the plant (for the period under study) to the plant installed capacity
Forebay	Storage reservoir for meeting diurnal fluctuations in load demand or sudden load rejection/ acceptance
Power Draft	Discharge of the stream utilised for power generation in the Power House expressed as volume of water flowing per unit of time
Banking Charge	Charge for storing energy for subsequent use so that it could be utilised as and when needed during the agreed period. Normally charged by the owner of the Grid (usually the State Electricity Board) from the SHP.
Wheeling Charges	Charges for transportation and delivery of electrical power at the agreed location.
EPC Contract	Engineering, Procurement and Construction Contract
POL	Petroleum, Oil and Lubricants



INVOLVEMENT OF KEY AGENCIES IN DEVELOPMENT OF SHP

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CHAPTER - 1

IDENTIFICATION OF SITE

1.0 INTRODUCTION

Selection of an appropriate Small Hydro-electric Project site is the most important aspect since it has a direct influence on the benefits, costs and time. It requires careful consideration of topography, geology, hydrology, infrastructure facilities and environment. The site identification for hydro power development on river/streams has been done quite widely by State Government organisations, particularly while planning optimal development of the entire river reach. This identification is carried out on the basis of data available. Many such identified sites are offered for development by private developer. The developer has to select site out of the lot offered and then carry out necessary surveys, investigations and studies for accumulating more detailed data and arriving at an optimal development and finalisation of features of the project. These aspects have been dealt with in this Chapter.

Small Hydro projects can be broadly classified in two types:-

(i) Small independent projects in the hills, mostly Himalayan, where small streams can be tapped. These are mostly of medium and high head utilizing small discharges.

(ii) Small installations on Canal Falls/Dam Toe which utilize water regulated for other purposes e.g. irrigation canal, small dams etc. These are usually of low or medium head utilizing larger discharges and located in the foot hills, peninsular or the plain regions.

1.1 IDENTIFICATION

1.1.1 Type-I – Small Schemes on Hill Streams

These schemes are normally run of the river type with a small diversion structure to divert the flows through the head regulator located in the intake portion of the diversion structure. A stretch of the stream is chosen on the basis of desk studies or reconnaisance aimed at utilising a relatively large fall consistent with utilizing a good portion of the catchment flows to tap as much potential as is economically feasible. Other factors are also taken into account like ease of access to site, proximity of consumption centres, socio-economic objectives at particular locations etc. The length of the water conductor needs also to be kept within reasonable limits from considerations of economy; further local topographical and geolological features as also other local water uses may have a bearing on utilisable reaches. The water conductor system would usually comprise of a diversion and Head Regulator, a water conveyance system comprising a power channel, a cut and cover duct or even pipe lines; generally a judicious combination of these dictated by topographical and geological considerations, a desilting basin, forebay, penstock, and tailrace leading from the Power House to the stream (refer Figure 1.1). Depending on site conditions, part of the water conductor could be a tunnel. In exceptional cases the entire water conductor could be a tunnel section. However, tunnels are not generally preferred due to comparative high costs and difficulty of executing in remote areas of the hilly region.

1.1.2 Type-2 – Small Installations on Canal Falls/Dam Toe

(i) Small power houses at location of falls of irrigation canals

(ii) Small power houses located just downstream of a dam, barrage or similar structure to utilize the difference in the water level in the reservoir and in the canal downstream.

Such schemes may be on new canals or structures or may have to be constructed on old existing works. In the case particularly of existing works, the first category would involve a bypass channel to bypass the flows adjacent to the fall structure and a power house provided in the bypass channel. The bypass channel is suitably connected to the main channel to maintain the flow through the power house while it is in operation (refer Figure 1.2). The falls may have to be equipped with automatic gates of a suitable kind.

The second category would involve creation of an approach channel in the reservoir and a water conductor from or through the dam to the power house and tailrace (refer Figure 1.3). Where provision already exists in the dam in the form of penstock or sluices openings only suitable connection structures and power house would be required. In case of new structures, the concepts may differ slightly on the ground of economy and functional advantages.

1.2 HYDROLOGY

1.2.1 Type-I

Realistic estimation of hydrological inputs is an important aspect for the assessment of power potential of small hydro power scheme. If the record of flows at the site or nearby location is available for a few years, it will be very useful, but normally this would not have been done for small streams where such schemes are located. In the absence of discharge measurements in the vicinity of the site of the proposed project, the same should be carried out by an accurate method. The measurements should be taken at least for two lean and one flood season. It may be pointed out that discharges for the lean period are very important for power potential estimates. Long term data of some river basins in the similar hydro-meteorological region would be useful for extending short-term data at the project site through correlation studies.

Availability of discharges for years of different levels of dependability for various percentages of time (50%, 75% & 90%) needs to be established after carrying out relevant hydrological analysis to work out the power potential of the scheme.

It is usually found that for typical flow patterns of streams the capacity of generating units to be installed should be almost equal to that needed to utilise the discharge available for 50% time in a 50% year (long term median discharge). Considering the fact that the discharges above design discharge in 50% year are not available for energy generation, the average energy generation from the project will be close to that available in a 75% year and can be used for studies of economic viability which is as per established convention.

In addition to the normal river discharge data on flood discharge including high flood levels both at the diversion site and at the site of the confluence of the tailrace with the stream needs to be collected. The high flood levels and flood discharge data on the nalahs intercepted by the water conductor would require to be obtained. These aspects have a bearing on design of civil structure for diversion, water conductor and power house.

1.2.2 Type-2

In regard to schemes of this type hydrological data would be available already. The pattern of mean 10 days/months/years canal discharges during the recorded period for irrigation or other purposes would be the basic consideration for assessment of power potential.

The hydrological aspects are discussed in detail in Chapter - 2 "Hydrological Analysis and Potential Estimates using scanty data".

1.3 TOPOGRAPHICAL SURVEYS

Detailed field surveys would be required to fix the location and design of all the civil structure of the project. The area to be surveyed should be based on the preliminary toposheet studies and field reconnaissance assessment by an Expert Team (refer page 57). The surveys should be connected to the Survey of India datum in the vicinity. Care should be taken to include local identifiable spots in the survey.

1.3.1 Type-1

Surveys for the general layout of the scheme should extend along the river valley from about 2 km upstream of the diversion site to 1 km downstream of the confluence of the tailrace with the river or stream, to a scale of 1:10,000. The limits of extension of survey could be reduced depending on the assessment of the Expert Team during field reconnaissance. The survey should cover both banks of the river covering sufficient height to provide an idea of hill slopes on both the banks. Important features like access roads, bridle paths, villages, habitations, structures, forest land, temporary or permanent bridges etc. should be identified in the survey and marked in the survey maps. These details are essential for optimizing the location of the various features of the scheme and in selection of the river bank for alignment of the water conductor system.

Surveys for the various features viz. Diversion structure, water conductor, cross drainage works, forebay, penstock, tailrace etc., should cover an area sufficient to accommodate all possible arrangements. The scale and particulars of survey required for the above two types are indicated in Table-1.1 (refer pages 10 & 11). The cross section of the river at its confluence with the tailrace indicating bed levels and water levels of known HFL should be indicated for selecting the location of the Power House. The power house area should cover the switchyard and alternative layouts of the station. A test check of the level difference between the Diversion weir site and the confluence of the tailrace with the river should be made independently by running a longitudinal section from the head works viz. diversion site to the tailrace confluence of the river. Such a check would ensure that there is no error in the assumption of the gross head and the length of the water conductor which form the basis for calculating the power potential of the scheme.

1.3.2 Type-2

Category - 1

Surveys would be required for locating the Power House and by-pass channel leading to the Power House and back to the source canal.

Category - 2

For schemes with existing small dams or diversion structure where penstocks are already embedded, surveys would be required only for the power House. If penstocks have not been embedded surveys would be required covering the routing of channel or tunnel in addition to the power House site and tailrace.

1.4 GEOLOGICAL INVESTIGATIONS

1.4.1 Type-1

A judicious and careful geological assessment and limited geological exploration is essential. Extensive geological investigations, however, are not considered necessary for small hydro schemes in view of the small size of the civil structures.

For the diversion structure, geological exploration with a trial pit as close to the deepest bed level as possible and two trial pits, one on each bank would meet the requirement. One of these locations of the trial pit should be at the location of the intake structure. In addition a geological assessment of abutment conditions (with a geological section indicating the dip and strike directions) needs to be made.

As regards the water conductor system, a few trial pits along the alignment, say every 200 metres which may include vulnerable locations as revealed by the field survey should be taken for geological assessment of the foundation strata especially as regards permeability and subsidence. The slope stability for the excavated slopes on the hill face is of prime importance. For this purpose geological sections need to be developed by surface observations and limited geological studies. This may be at interval of 200 m along the water conductor and is to include critical locations as revealed by the field survey and geological reconnaissance. Such a study would enable delineation of unstable reaches along the water conductor requiring stabilization measures. In regard to the Forebay site, a trial pit may be taken for geological assessment of the foundation strata including the permeability aspect and the hill slope behind the forebay assessed for slope stability. The penstock slope likewise may be assessed for slope stability. Foundation strata at Anchor Block and Power House locations can be ascertained by trial pits.

1.4.2 Type - 2

Category - 1

In case of these schemes, geological investigations needed would be minimal. Type and permeability of soil characteristic likely to be met at the power house site would be required to be determined by test pits.

Category - 2

In case of these schemes geological condition along the water conductor can be ascertained by trial pits and slope stability assessment as in the case of Type-1. In case the water conductor comprises of a tunnel, the assessment has to be based on bore holes at the entry and exit sections of the tunnel and at locations of suspected low rock cover and a geological section along the tunnel alignment developed. Power house foundation can be ascertained either by trial pit or by a Drill Hole where warranted.

The requirements of geological investigations as outlined above is indicated in Table-1.2 (refer page 13).

1.5 POWER MARKET SURVEY

Power market survey is required to assess the energy absorption from the scheme. It requires collection of data for the number of users, type of load, i.e. domestic/commercial/common community loads, industrial and irrigation loads, like water pump, flour mill, saw mills etc. The demand pattern would require to be worked out and the total energy which would be consumed on account of each load, should be computed. Based on above and considering the generation pattern, the energy absorption from the power station, should be assessed, in an isolated system. The load curve so developed by market survey would also help to finally decide the size of units and number of units etc.

1.6 INFRASTRUCTURE

Availability of necessary infrastructure is of great importance for construction of a project as it cuts down the construction period to a great extent. The infrastructure mainly includes the following:-

1. Roads and bridges upto the project area and Internal roads/ paths in the project area
2. Construction power
3. Drinking water
4. Communication facilities
5. Office Building and Staff Quarters etc.

The above aspects should be clearly documented in the feasibility report as these have direct impact on the cost and construction period.

1.7 ASSESSMENT OF POWER POTENTIAL

Power potential is the product of available Head and quantity of water at any point of time and determined by using the following formula:

$$P = 9.81\ Q \times h \times n$$

where

where	P	=	Power in kW
	Q	=	discharge in cu. m. per sec.
	H	=	Net head in meters
	n	=	overall unit efficiency

Net head is computed by deducting the tail race level from the upstream water level and also the losses in the water conductor system. Generally unit efficiency is considered between 0.85 to 0.9 depending on the size of small hydro generating unit.

Where the water is directly drawn from a reservoir, as in the case of Type 2 schemes, a working table is prepared to determine the drawal of water from the reservoir, resulting level and power generation. The working table considers the inflows, out flows, evaporation losses, reservoir levels at the beginning and at the end of a stipulated period and determine the average level in the reservoir. With the help of tail water rating curve, which indicates the tail water level at various discharges, the gross head is computed by deducting the tail water level from the average water level in the reservoir.

The power potential for a small hydro scheme is determined corresponding to 75% and 50% water availability. The method for computing the water availability has been dealt in Chapter-2. It is relevant to remark that in case of small run-of-river H.E. schemes, the basic stream flow data available is generally meagre and data for studies has to be generated by hydrological approaches.

1.8 OPTIMISATION STUDIES

The features of the project are finalized after carrying out studies of cost and benefits for various alternatives. The cost of civil and electrical/mechanical works are almost of the same proportion. The first step in optimisation is the assessment of power potential with various installed capacity. The incremental values of energy generation with the increase of installed capacity initially provides a basis of determining the installed capacity. The installed capacity, in an isolated system, has to match with the forebay capacity and power requirements. In a system, where the power generation from the project is proposed to be fed into the grid, the scale of incremental energy generation with increase in capacity is the first guide. For determining the optimal installed capacity, a few alternative capacities are considered with cost and benefits. The alternative which shows the least cost of energy generation is adopted. The relative costs may be influenced by a sharp change if some kind of subsidy is available upto certain capacity. In certain cases, higher installed capacity is provided to derive more benefits and the cost of generation is compared with alternative source i.e. thermal or diesel. If the energy generation in certain period is to displace energy being produced at some other power station i.e. thermal or diesel, the incremental cost of energy from the additional capacity may correspond to the fuel cost of energy which is being displaced or saved. Thus, there are no rigid rule for determining the installed capacity, it depends on the economy of generation and the role a particular project is expected to play.

1.8.1 Criteria of Grading of Schemes

Each potential site has specific characteristics. Some are more attractive than others. Without going into specific details, at the initial stage before taking up investigations, the developer could make an approximate judgement from the preliminary report made by authorities about the attraction of a scheme by glancing at certain parameters which are detailed in the table below.

TABLE
Grading of Small H.E. Projects - At a Glance

Sl.No.	Scheme	Grade			
		I	II	III	IV
1.	**Data Availability**				
	(a) Discharge measurements	5 years	3 years	1 year	—
	(b) Topographical Survey	Very Reliable	Reliable	Less Reliable	Poor
	(c) Geological	Very good	Good	Average	Adverse
2.	Access to site	Very good	Good	Poor	Inaccessible
	Habitation	Very near	Near	Far	Very far
3.	Distance from inter-connection	10 Km.	15 Km.	20 Km.	More than 20 k.m.
4.	Need of Power	Full utilization	70% utilization	50% utilization	Less than 50% utilization
5.	Features of Project Simplicity of civil structures	Diversion weir and short W.C.S.	Diversion weir and long W.C.S.	Diversion weir and longer W.C.S.	Diversion weir and very long W.C.S.
	(a) Topographical and geological condition	Very good	Good	Moderate	Poor
	(b) Head (m)	Above 150m	100m - 150m	50m	Less than 50 m
	(c) Ratio of length of WCS/Head	5	10	15	Above 15
	(d) Energy Generation (75% year)/MW installed capacity	6.1 Gwh and above	5.3 Gwh to 6.1 Gwh	4.4 Gwh to 5.3 Gwh	Below 4.4 Gwh.
	(e) Annual Plant L.F.	70% and above	60% to 70%	50% to 60%	Below 50%
	(f) Cost/M.W.	Rs.4.5 crores/MW	Rs.5 crores/ MW	Rs.5.5 crores/ MW	Above Rs.5.5 crores/MW
	(g) Cost of generation	Rs.1.50/Kwh & below	Rs.2.00/ Kwh	Rs.2.0 to Rs.2.5/ Kwh	Above Rs.2.5/Kwh
6.	Stage Govt. Policy				
	(a) Purchase of Power	Yes	Yes	Yes	Yes
	(b) Banking & Wheeling	Yes	Yes	Yes	Yes
	(c) Royalty on water use	Nil	Yes	Yes	Yes
	(d) Provision of leasing of land	Nil	Yes	Yes	Yes
	(e) Subsidies/ concessions	Yes	Yes	Yes	No

Note : 5(b) & (c) not applicable for Type 2 Schemes

TABLE - 1.1

TOPOGRAPHICAL SURVEYS

S. No.	Feature	Survey Requirement	Scale	Contour Interval	Additional Requirement
1.	General Layout	(1) Contour Plan to cover all components of the project extending from 2 km u/s of diversion structure to 1 km d/s of confluence of Tailrace with the river.	1:10,000	5 m.	—
		(2) River Cross Sections at 200 m. interval to cover both banks well above the highest flood marks and include power channel for the reach where it is close to the river.	1:500		The following information be included:- i. Date of Survey ii. Water level on date if survey iii. Max. observed H.F.L. on the basis of flood marks.
2.	Diversion Structure	(1) Contour Plan to cover reach 50 m u/s to 50 m d/s of the proposed structure and extend at least 10 m above anticipated highest flood level.	1:200	2 m.	—
		(2) 3 Cross sections, 1 along the axis and 2 on either side i.e. u/s and d/s of the axis.			The following information to be included: i. Date of survey ii. Water level on the date of survey iii. Max. observed H.F.L. on the basis of flood marks.
3.	Water Conductor Systems	(1) Contour Plan along water conductor alignment extending 20 m. towards the hill side and 10 m. towards the valley side.	1:500	5 m.	—

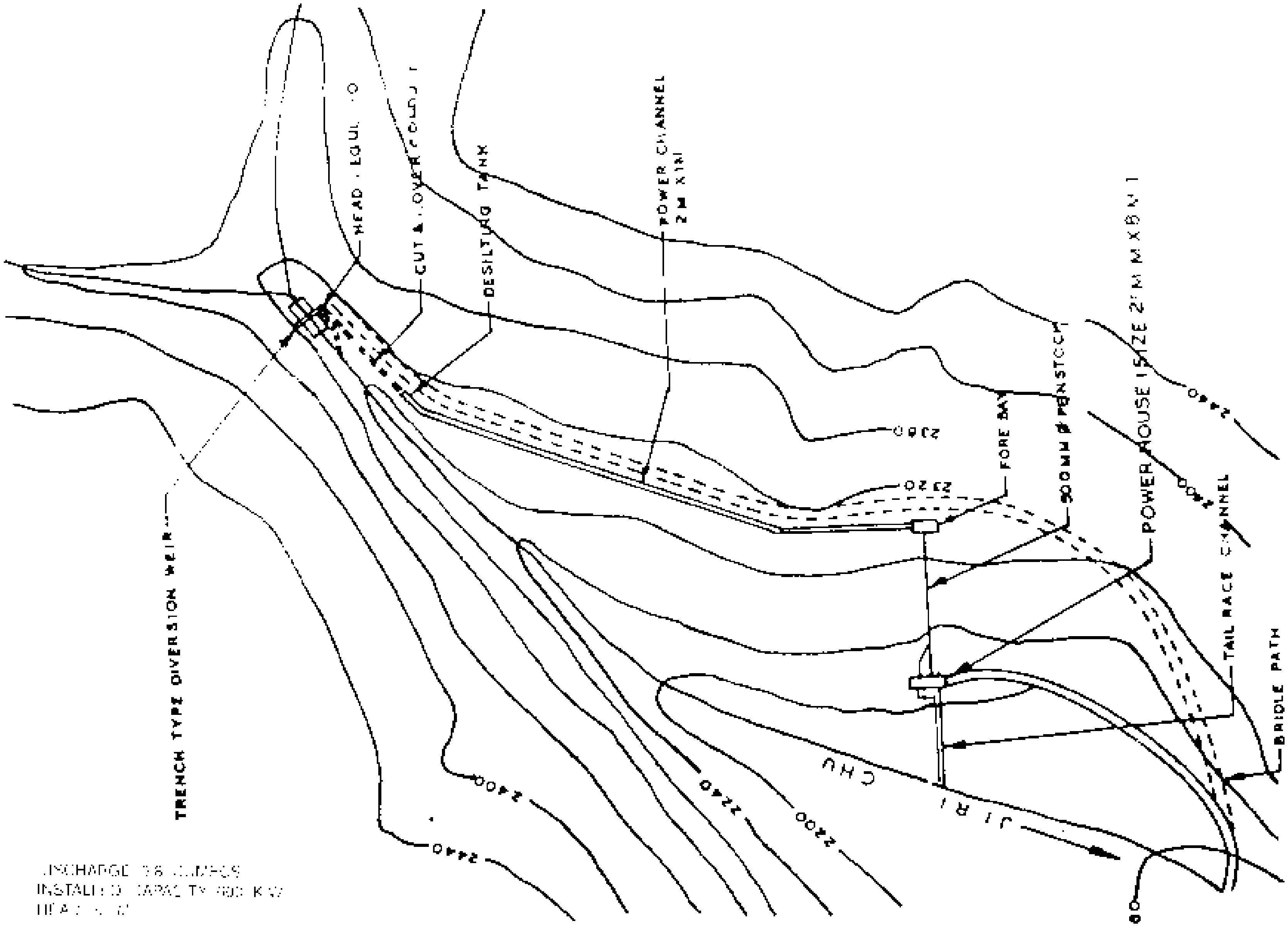
		(2) 'L' Section along the alignment of water conductor	1:500	—	—
		(3) Cross sections along the water conductor at 100 m. intervals and at locations where nalas are intercepted as also at locations where topography changes abruptly.	1:500	-	
		(4) Three cross sections of the Nalahs - one on the alignment and one each on either side of the alignment.	1:500	—	—
		(5) 'L' Section along Nalas, 100 m. on either side of water conductor.			The following information to be included :- i. Date of survey. ii. Water level on date of survey iii. HFL if any based on flood marks to be indicated.
4.	Forebay	(1) Contour plan to cover entire area of forebay including its vicinity.	1:500	2 m.	—
		(2) Longitudinal Section & cross sections	1:500		- -
5.	Penstock	(1) Contour Plan extending 20 m. on either side of the alignment.	1:500	2 m.	—
		(2) 'L Section along penstock alignment.	1:500		--
6.	Power House	(1) Contour Plan to cover sufficient area to include different alternative layouts of power house & switchyard and tailrace channel upto its confluence with the river.	1:200	2 m.	—

(2) 'L' Section along the power house and Tailrace channel upto its confluence with the river.	1:200	—	The following information to be included :- i. Date of Survey ii. Water level at the point of confluence of the tailrace with the river. iii. Max. observed HFL on the basis of flood marks.

TABLE - 1.2

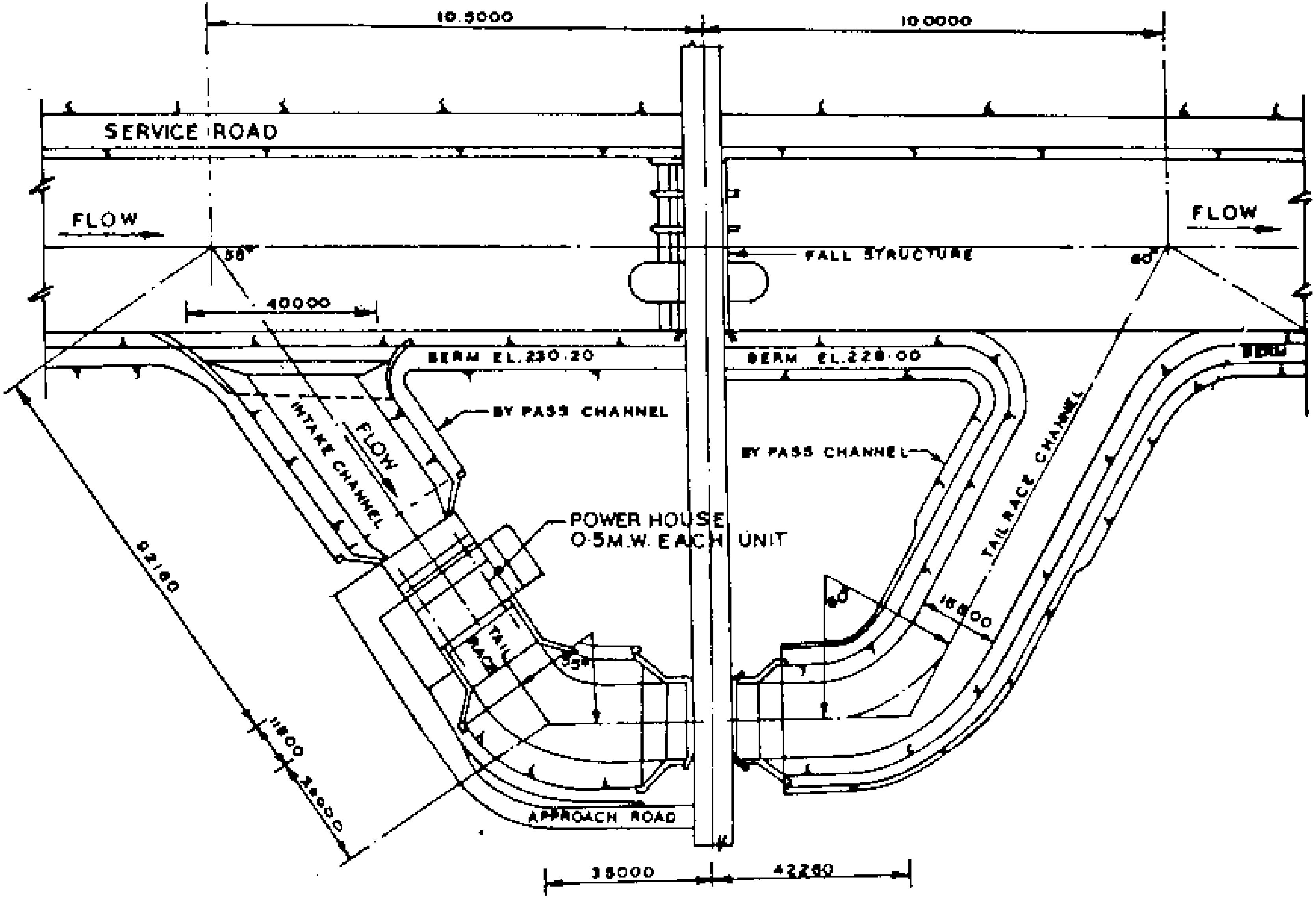
GEOLOGICAL FIELD INVESTIGATION

S. No.	Structure	No. of Trial Pits	Location of trial pits	Depth of trial pits	Additional Requirement
1.	Conventional weir/Trench Weir	3	One trial pit at middle and two trial pits, one each on either abatement end.	1.5m.-2 m.	Geological assessment of stability of rock slope on either abatement.
2.	Water Conductor	3 - 5	Trial pits at every 500 m. c/c and at critical locations.	1.5 m.-2 m.	Geological assessment of stability of rock slopes along the alignment reach-wise.
3.	Forebay	2	One trial pit in forebay area and another trial pit at penstock intake location.	1.5 m-2 m.	Geological assessment of rock slope on hill side of forebay.
4.	Penstock	2	Along the alignment of penstock preferebly at another block locations.	1.5 m.-2 m.	Geological assessment of penstock slope.
5.	Power House	1	Power House area	1.5 m.-2 m.	Geological assessment of excavation slope.
6.	Tailrace	1	Along the alignment	1.5 m.-2 m.	Geological assessment of excavation slope.



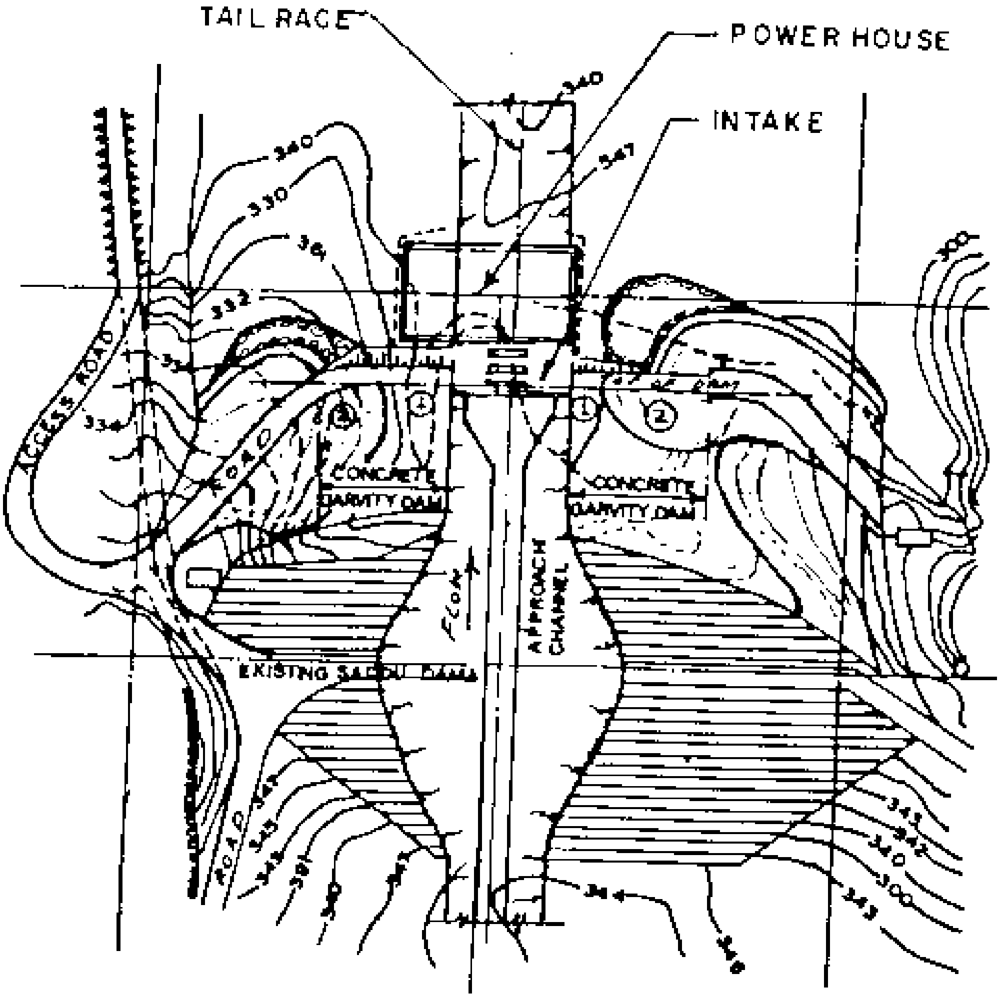
GENERAL LAYOUT

FIGURE 1.1 . MEDIUM/HIGH HEAD SMALL HYDRO ELECTRIC SCHEME



GENERAL LAYOUT

FIGURE 12 : LOW HEAD SMALL HYDRO ELECTRIC SCHEME



GENERAL LAYOUT

FIGURE 1.3 : SMALL HYDRO ELECTRIC SCHEME

① CONCERETE DAM
② CONCERETE DAM WITH EARTH RAPAROUND

CHAPTER 2

HYDROLOGICAL ANALYSIS AND POTENTIAL ESTIMATES USING SCANTY DATA

2.1 TYPE - 1

INTRODUCTION

Assessment of availability of water for power generation is an important aspect as it requires prediction of future water flows. Reliable assessment requires collection of data over a long period of time. Most of the major rivers are being continuously gauged by State Governments and Central Water Commission. However, the small streams on which most of the Small Hydro-electric Projects are located have scanty hydrologic data. The assessment of water availability on such streams is more relevant to the development of small hydro-electric project and this aspect has been dealt with in this chapter. The other aspects relating to such developments are the expected high flood discharges and corresponding water levels and the silt content in the flowing water. These topics have also been dealt with in this chapter.

2.1.1 SCOPE OF HYDROLOGIC STUDIES

Any potential hydro-electric scheme of medium or large size involves hydrologic analysis which would include:

(i) Collection of available hydrological data like rainfall, stream flows, snow-melt and silt in respect of gauging stations in the project area.

(ii) Appraisal of the existing network of rainfall and river gauging stations and need for establishment of additional river/rainfall gauging stations in the catchment

(iii) Assessment of water availability

(iv) Estimation of design floods and the corresponding flood levels at project site

(v) Study of chemical and grain size characteristics of silt content in the river discharges

Keeping in view the above hydrological aspects, collection of hydrological data and study of project hydrology has to be studied to provide a data base for fixing the installed capacity of the powerhouse and assessment of energy generation, design of intake structure, water conductor system, silt chamber etc.

In case of a small hydro electric project however time and cost factors as also some greater allowable tolerance on accuracy of data may permit some simplifications.

2.1.2 DATA COLLECTION:

The first essential in formulating a small hydro-electric scheme is to obtain records of streamflow and rainfall/ snowfall in the project catchment area for as long a period of time as possible.

Most of the streams on which small hydro projects are contemplated may not have any river-flow measurement data; even the catchment may not have any raingauge station. In such a situation, it is necessary to collect hydrological data as accurately as possible by establishing river and rainfall gauging stations at appropriate locations within the project catchment. According to the "Small Hydro Stations-Standardisation", CBIP Publication No.175 (Revised July, 1995), the measurements should be taken for atleast two years. Based on these recommendations, the river gauging may be carried out for a minimum period of two lean seasons and one flood season. The guidelines for stream-flow measurement are given in Annexure 2.1. (refer pages 22 & 23).

2.1.3 PROJECT HYDROLOGY

The hydrological studies of a project comprise the following topics:

2.1.3.1 River System

The river system shall be described upto the project diversion site. The topographical features, land use patterns, broad geology shall be indicated. A catchment area plan upto the project diversion site shall be prepared from the Survey of India toposheets giving the following information:

(i) Contours
(ii) Diversion site
(iii) Rainfall gauging stations
(iv) River gauging and silt observation stations
(v) Permanent snow-line, if any

2.1.3.2 Climate

The parameters for the climate will include temperature, relative humidity, wind speed, sun-shine hours, rainfall and snowfall. The previous records of data of these parameters shall be collected from India Meteorological Department (IMD) or any other organisation which may have collected it and analysed. If the data is not available for the project catchment, similar information may be collected for a similar hydrometeorological region.

2.1.3.3 Data Availability

The data required for hydrological analysis are precipitation (rainfall, snowfall), stream discharge and sediment load. All available information for the project site should be collected. In case these data are not available for the project site, data in the adjoining river basins in the similar hydro-meteorological region are to be collected. In addition, river discharge data shall be collected near the project site by establishing a river gauging station as indicated in para 2.1.2 & Annexure 2.1.

2.1.3.4 Hydrologic Analysis

Precipitation

Precipitation analysis shall cover monthly and annual rainfall distribution over the catchment area. The annual rainfall duration curves for 50% 75% and 90% dependabilities shall be prepared and monthly and annual rainfalls for the three dependabilities shall be estimated.

Water Availability

This is the most critical parameter which needs to be studied in great detail. Depending on the extent and type of data available the analysis shall be different from project to project. The river flows (10 day/ monthly basis) shall be assessed at 50%, 75% and 90% dependabilities. Guidelines on 'Water Availability' are given in Annexure 2.2 (refer pages 47-51).

Design Flood

The design flood is required for the design of the diversion structure and also for general consideration for locating the power house. The criteria for fixing the design flood shall be decided depending on the type of structure and hazard potential downstream of the structures in the event of the failure of the diversion structure. Guidelines on 'Design Flood' are given in Annexure 2.3 (refer pages 42 to 44).

Sedimentation

The information of physical and chemical characteristics of the sediment load is required for the design of silt chamber for exclusion of particles larger than certain sizes to ensure trouble-free operation of turbines. Information is also required by turbine manufacturers.

Samples of the suspended silt in river water shall be collected during the monsoon season at the gauging site. The grain size and chemical analysis of these samples shall be carried out and presented in suitable format (Sample at page 21 enclosed).

2.2 TYPE - II

These schemes utilise canal discharges which are measured by the department operating the canals. Accordingly, no special efforts are required to measure discharges as in the case of a river. The detailed hydrological analyses which are necessary for a Type-I scheme (refer para 2.1.3.3) are also not required for a Type-II scheme. The assessment of water availability is the only hydrological aspect that is to be analysed.

2.2.1 WATER AVAILABILITY

Unlike river discharges, the canal discharges are regulated at canal headworks. The canal discharges do not vary as widely as the river discharges from month to month and year to year. In view of the regulated pattern of flows, the mean 10-day/monthly canal discharges over the period of record would be the basic consideration for assessment of power potential. The water availability at different percentages of dependability (50%, 75% and 90%) for Type-II project would be then evaluated based on this data.

2.3 POWER POTENTIAL

The power potential would be worked out for 10-day discharges available in a 75% and 50% dependable years. The method of assessment has been indicated in Chapter I.

GRAIN SIZE AND CHEMICAL ANALYSIS OF SILT SAMPLES

ITEM	VALUE	UNIT
Quantity of silt		ppm
Grain size analysis		-
> 0.425 mm		%
bet 0.425 mm and 0.200 mm		%
bet 0.200 mm and 0.075 mm		%
< 0.075 mm		%
Weighted mean diameter		mm
Chemical Analysis		-
Electrical Conductivity		mmhos/cm
pH value		-
Dissolved Solids		ppm
Suspended Matter		ppm
Sulphate, SO_4		ppm
Total hardness		-
Bi-carbonates (HCO_3)		ppm
Carbonates (CO_3)		ppm
Chlorides (Cl)		ppm
Iron (Fe)		ppm
Aluminium (Al)		ppm
Calcium (Ca)		ppm
Magnesium (Mg)		ppm

STREAM-FLOW MEASUREMENT

1. CRITERIA FOR GAUGING SITE SELECTION

The general criteria for selecting a suitable site for measurement of discharges of streams are described in the "Stream Gauging Manual" published by Central Water & Power Research Station (CWPRS, Pune). More important ones of these criteria are as follows:

(i) The river banks and bed should be sufficiently straight, both upstream and downstream of the cross-section, for a distance of at least four times the width of the river during floods or 0.8 Km., whichever is less.

(ii) The reach of the river described in (i) should be fairly uniform in cross-section at and below the high flood level and the water surface and bed slopes should not be subject to sudden changes. The river bed should also not have a reverse slope in this reach.

(iii) When a discharge site is located upstream of a confluence, whether on the main or tributary streams, its distance from the confluence should not be less than three times the maximum width of the channel or 0.8 km., whichever is more. In case the site is located downstream of the confluence, the minimum distance should be three times the width, 0.8 Km. or one meander length, whichever is more.

(iv) If gauge sites already exist within the reach where discharge measurements are required, it is advantageous to consider the possibility of establishing a discharge site at the gauge station itself. This would enable the gauge discharge relation to be established and made use of. If however, gauge and discharge sites cannot, for any reason, be at the same location, the alternative is to keep them as close as possible. Care should be taken to see that no inflow or outflow takes place between these two sites.

(v) The site should not be unduly exposed to wind. Direction of the flow should be as divergent as possible from wind direction, specially during the period when stream gauging is required to be most accurate.

(vi) The site chosen should be accessable at all times of the year. It is also desirable that the river reach upstream and downstream be clearly visible from the discharge site. This is essential when floats are used for the measurement of velocity.

(vii) At the selected site, the water should flow in a single channel. If such channel is not available, two or more channels satisfying all conditions should be adopted and individual measurements taken.

2. METHODS OF DISCHARGE MEASUREMENTS

The various methods used for streamflow measurement may be broadly classified into two categories, i.e. (i) direct methods and (ii) indirect methods. The important direct methods are the velocity-area methods using current meters or floats. The indirect methods include those using flow-measuring structures such as weirs, notches, flumes and gated structures, and the slope-area method. Of these, the use of flumes and notches is limited to small streams. Most of these methods are based on the measurement of velocity and area in a cross-section which permit the calculation of discharge at the given stream section.

The continuous measurement of stream discharge is very difficult to obtain. So periodic measurements using above methods are made to determine the relation between stage (water level) and discharge at a stream gauging station. This stage-discharge relation (rating curve) developed is used with the continuous record of stage to develop a continuous record of discharge. Where the flow-measuring devices are used, it is customary to observe the head and use a rating curve to translate this into discharge.

The stage which is the elevation of water surface of the stream is measured relative to a datum which can be the mean-sea level or any arbitrary datum connected to the mean sea level.

2.1 Velocity Area Method (IS:1192-1981)

In velocity-area method, the cross-section is considered to be divided into a number of subsections by verticals. The average velocities in these subsections are determined using a velocity measuring device. The depths of water for cross sectional area are determined using weighted sounding lines, calibrated rods, or ultrasonic devices. The observations of velocity are obtained at one or more points in the verticals. The measured widths, depths, and velocities permit computation of discharge for each segment of the cross-section. The summation of these segment discharges is the total discharge.

2.1.1 Velocity Measurement by Current-Meter Method

In this method, the flow velocity at one or more points in different verticals of the subsections are determined by using a current meter which is held in the desired position by means of a wading rod in the case of shallow channels or by suspending it from a wire or rod from a bridge, cableway, or boat.

2.1.1.1 Type of Current Meter

After experience and improvement, the currentmeters now used extensively in India are either Gurley or Watt's. This is a versatile instrument and combines accuracy with ruggedness. Standard Gurley meter has a normal range of velocity from 0.15 to 4.0 m/sec. The accuracy of these instruments is about 1.5% at threshold value and improves to about 0.30% at speeds in excess of 1.0 m/sec.
Besides the standard currentmeter, another version of Gurley meter is Gurley-Pygmy currentmeter which is used to measure velocities in shallow streams.

2.1.1.2 Determination of Mean Velocity in a Vertical

The mean velocity of the water in each vertical is generally determined by the reduced point methods, depending on the time available and having regard to the width and depth of the water, to the bed conditions and to changing stage, and whether there is ice cover, as well as to the accuracy which is to be obtained. One-point, two-point or three-point methods are normally used.

(i) One-point Method: Velocity observations are made at each vertical by exposing the current meter at 0.6 of the depth below the water surface. The value observed is taken as the mean velocity in the vertical.

(ii) Two-point Method: Velocity observations are made at each vertical at 0.2 and 0.8 of the depth below the surface. The average of the two values is taken as the mean velocity in the vertical.

(iii) Three-point Method: Velocity observations are made by exposing the current meter at each vertical at 0.2, 0.6 and

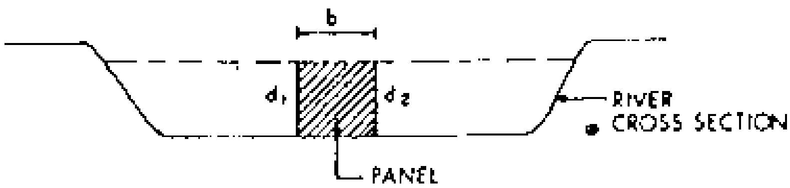
0.8 of the depth below the surface. The average of the three values may be taken as the mean in the vertical.

The two-point method is used where the velocity distribution is normal and depth is greater than about 60 cm; the one-point method is used for shallower depths. The three-point method should be used for measurements under ice or in stream channels overgrown by aquatic vegetation.

The measurement of depth during the lean season on small channel can be made by wading rods, but during floods, the measurement of depth of water at various segments may be made from a single span wooden bridge or a suspension bridge at the site of observation. If the width of river is excessive, a cableway alongwith cradle may be provided.

2.1.1.3 Computation of Discharge

The discharge may be computed arithmetically by mid-section method. In this method, the cross-section is regarded as being made up of a number of panels, each bounded by two adjacent verticals.



If v_1 is the mean velocity at the one vertical and v_2 the mean velocity at the adjacent vertical, and if d_1 and d_2 are the total depths measured at verticals 1 and 2, respectively, and b is the horizontal distance between verticals, the discharge q of the panel is taken to be

$$q = \left[\frac{\overline{v_1} + \overline{v_2}}{2} \right] \left[\frac{d_1 + d_2}{2} \right] b$$

This is repeated for each panel and the total discharge obtained by adding the discharge from each panel.

2.1.1.4 Limitations

Theoretically, the area velocity method using a current meter is capable of giving substantially correct results. There are, however, certain limitations affecting the accuracy of this method in field conditions. Slight inaccuracy in the rating of current meter, small fluctuations in discharge, turbulent flows, wind-effect, personal errors in the measurement of depth and velocity are some of the factors which introduce errors. Discharge and water level rarely remain constant during gauging operations. In order to complete the discharge measurement within a limited period, during which the gauge remains stable, the number of observation points and the verticals have to be restricted.

2.1.2 Velocity Measurement by Float Method

This method is used only when it is impossible to employ a current meter, because of unsuitable velocities or depths, presence of material in suspension, non-availability of adequate funds or when the discharge measurement must be made in a very short time.

2.1.2.1 Type of Floats

Surface floats or rod floats may be used. A surface float is one whose depth of immersion is less than one-quarter the depth of the water. Surface floats are not used when they are likely to be affected by wind. A rod float is one whose depth of immersion exceeds one-quarter the depth of the water. Rod floats must not touch the channel bed. Floating trees or ice cakes may serve as natural floats during periods when it is unsafe to be on the river.

2.1.2.2 Measuring Procedure

Three cross-sections are selected along a reach of straight channel. The cross-section are so spaced that the time the float takes to pass from one cross-section to the next can be measured accurately. A travel time of 20 seconds between two cross-sections has been recommended. However, a shorter time may have to be used on small rivers with high velocities.

Floats are uniformly distributed over the stream width. Each float is released far enough above the cross-section to attain a constant velocity before reaching the first cross-section. The time at which the float crosses each of the three cross-sections are noted by stopwatch. This procedure is repeated with the floats in each panel. Depth of flow at points in the cross-section are determined by means of sounding rods or other means discussed earlier.

2.1.2.3 Computation of Velocity

The velocity of the float is equal to the distance between cross-sections divided by the time of travel. The mean velocity of flow in the panel is equal to the float velocity multiplied by a coefficient which is based on the shape of the vertical velocity profile and relative depth of immersion of the float. A flow velocity adjustment factor F as function of R, the immersed depth of float to depth of water is used for estimating the mean velocity of flow from the surface velocity of the float.

R	0.10	0.25	0.50	0.75	0.95
F	0.86	0.88	0.90	0.94	0.98

2.1.2.4 Computation of Discharge

Discharge in each panel is computed by multiplying the average area of the cross-section of the panel by the mean velocity of flow in the panel. The total discharge is then equal to the sum of the discharge in the panels.

2.1.2.5 Limitation

Float observations are far too inferior to current meter observations and should be resorted to when the latter are not possible for any reason.

2.2 INDIRECT METHODS OF FLOW MEASUREMENT

The methods of flow-measuring structures, and the slope area methods fall under this category. These make use of the relationship between the flow discharge and the depths at specified locations. A brief on these is as under:

2.2.1 Flow-Measuring Structures (S:1193-1959)

The structures like notches, weirs and flumes are used for flow measurement on the principle that these structures produce a unique control section in the flow. The thin metal plate structures like V-notch, rectangular full width and contracted notches; broad-crested concrete or masonry weirs; and concrete, masonry or metal sheet flumes are types of flow measuring structures used for discharge measurement.

The notches of all types are suitable for measuring small discharge in a stream or canal system. The accuracy of this method will largely depend on the following conditions;

(i) A uniform, stable and straight reach of the stream. The length of such a reach shall not be less than 15 times the maximum head over the notch and the cross-section of the stream in this reach shall not be less than six times the head over the crest. The gauge observation shall be made at a minimum distance of four times the depth of flow from the notch.

(ii) Notch plates shall be vertical and have a sharp right angled edge on the upstream side. The downstream edge shall be bevelled at 45°. The crest width shall be about 3 mm.

(iii) The crest shall be perfectly horizontal in case of rectangular and Cipolletti notches, and 45° to the horizontal for 90° notch.

(iv) Distance between top of crest and bed of the stream and between the sides of the notch and sides of stream shall not be less than twice the depth of water above the crest and shall not be in any case less than 30 cms.

(v) A minimum head of 6 cm. over the crest is necessary.

(vi) There shall be no leakage around the structure.

The notches are suitable for measurement of small discharges in the range of 0.03 to 0.30 m^3/sec.

The formulae for the measurement of discharge by notches as per IS: 1193-1959 are :

For Rectangular notches:

(a) Without end contractions:

$Q = 2/3\ Cd\ \sqrt{2g} L H^{3/2}$

(b) With end contractions:

$Q = 2/3\ Cd\ \sqrt{2g}(L-0.1\ nH)H^{3/2}$, where

n = number of end contractions

For Triangular notches:

$Q = 8/15\ Cd\ \sqrt{2g}\ \tan\ \theta/2 X H^{5/2}$, where

θ = Angle of notch

For 90° notch: tan 02 = tan 45° = 1.0

$Q = 8/15\ Cd\ \sqrt{2g} x H^{5/2}$

For Broad - Crested Weir

$$Q = Cd\ LH^{3/2}$$

where,

Q	=	Total discharge in m³/sec.
Cd	=	Co-efficient of discharge to be determined experimentally
g	=	Acceleration due to gravity m/sec²
L	=	Breadth of notch in m
H	=	Head of water over the sill in m

The above equations are applicable so long as the downstream water level is below a certain limiting water level known as the modular limit. Such flows are independent of the downstream water level, and are known as free flows. If the tailwater conditions do affect the flow, then the flow is a drowned, also called a submerged flow. The discharges under drowned condition are obtained by applying a reduction factor to the free flow discharges.

The submerged flow over a weir is estimated by the Villemonte formula,

Where

Q_s	=	Submerged discharge
Q_1	=	Free flow discharge
H_1	=	Upstream water surface elevation above weir crest
H_2	=	Downstream water surface elevation above weir crest
n	=	Exponent

For a rectangular weir, n = 1.5

For V-notch, n = 2.5

2.2.2 Measurement of Discharge by Area Slope Method

In this method, discharge is worked out by multiplying the average cross-sectional area with the average velocity of the channel, which is indirectly found by using one of the open channel formulae, for example the Manning's Formula.

$$v = \frac{R^{2/3} \quad S^{1/2}}{N}$$

where

v	=	Velocity of water in m/sec
R	=	Hydraulic mean radius in m
S	=	Hydraulic gradient
N	=	Rugosity coefficient

The area slope method lacks accuracy, since both area and velocity can be determined only approximately. Very often the area measured during dry weather is used for computations of flood discharges. Evaluation of accurate value of rugosity co-efficient in an open channel is another limitation of this method. Besides rugosity co-efficient, data of river slope may not, many times, be available. This is because high water level may have been determined from flood marks and slope may not be uniform.

Due to these limitations, discharge estimates by area slope method should not be used for computing daily discharges. At best, this method may be adopted for estimating high flood discharges from flood marks.

2.3 ILLUSTRATION

Central Board of Irrigation and Power has brought out a publication titled "Hydrological Observations with Illustrations" for educating and enlightening the field staff engaged in hydrological observations. A few typical illustrations from this publication are appended (refer pages 31 to 35).

2.4 REFERENCES

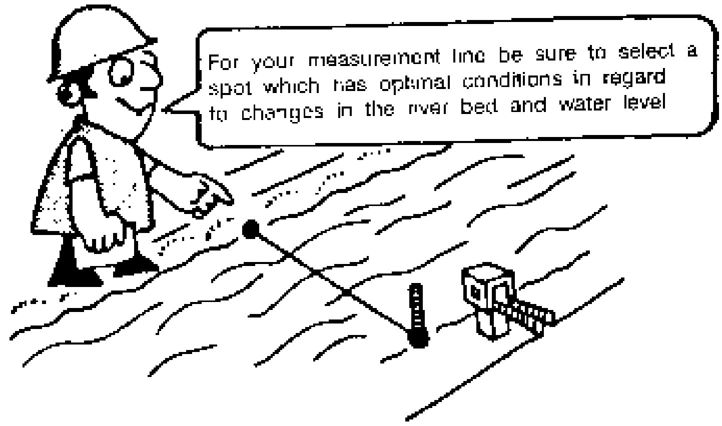
In the foregoing paragraphs, the guidelines for streamflow measurements have been presented in brief. For detailed information, the following documents may be referred to :

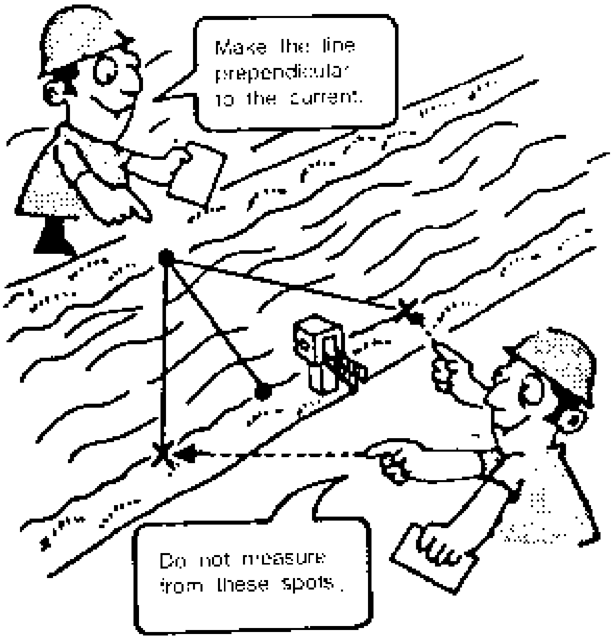
1. Stream Gauging, published by Central Water and Power Research Station (CWPRS), Pune

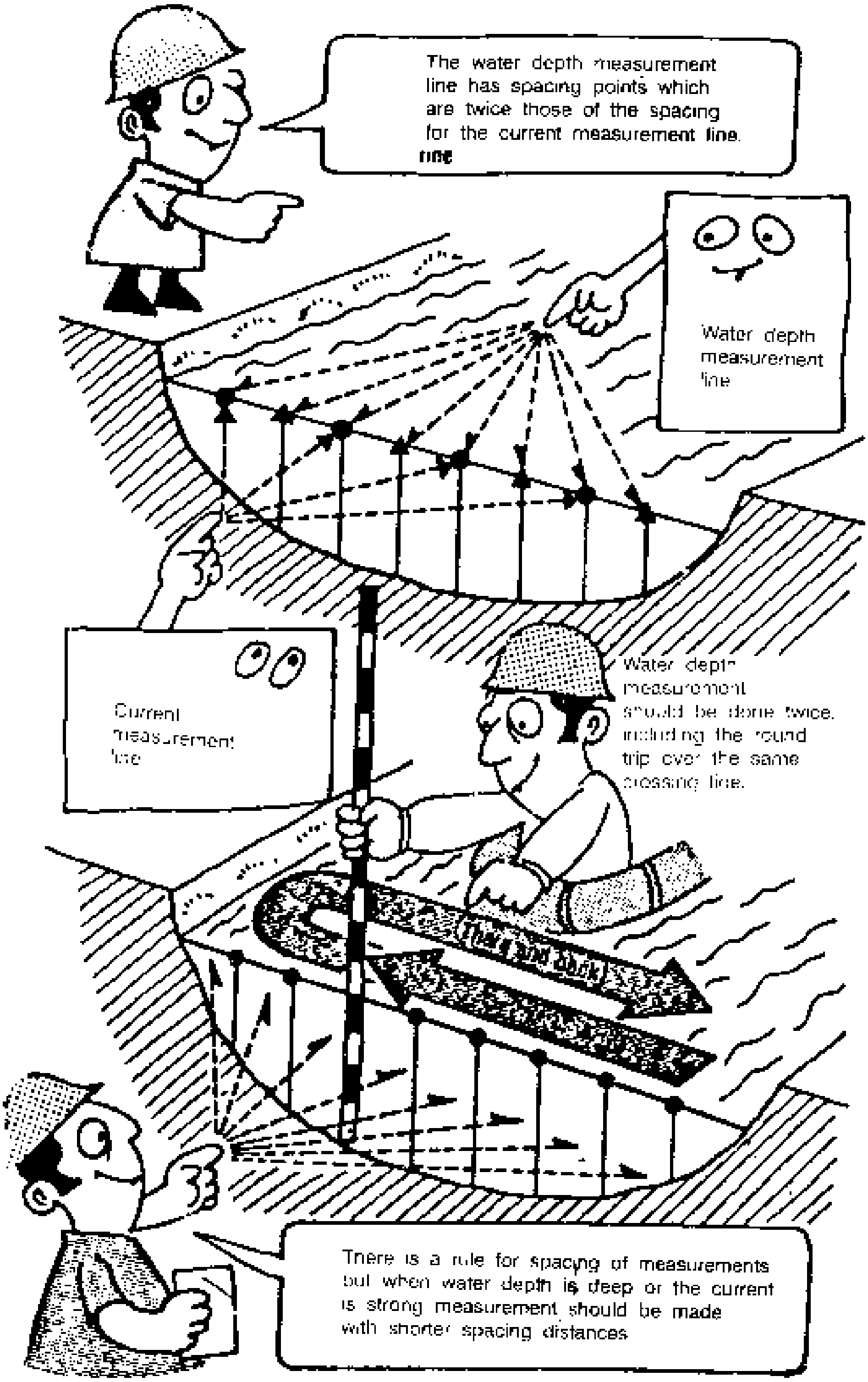
2. Methods for measurement of flow of water in open channels using Notches, Weir and Flumes, IS 1193-1959

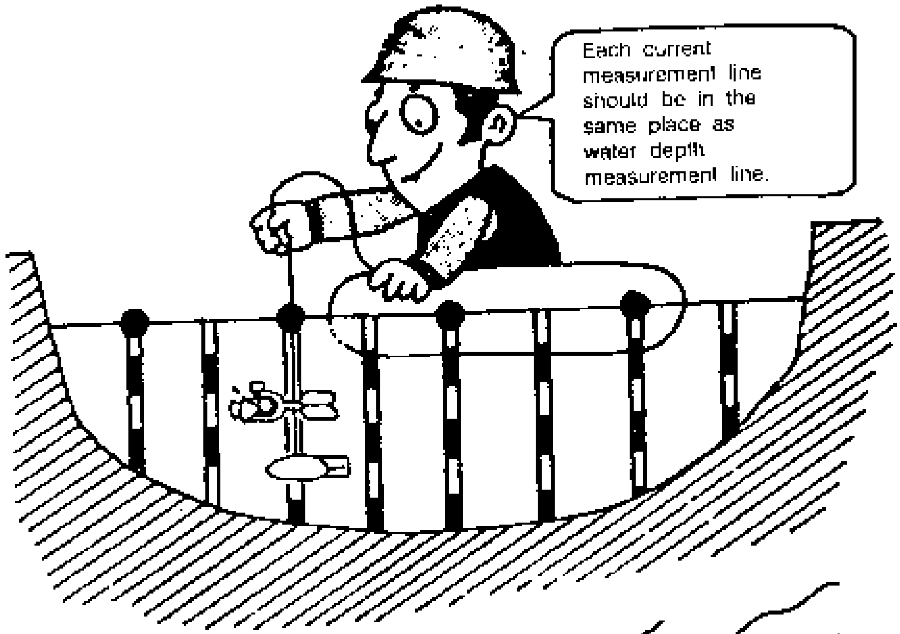
3. Velocity Area Methods for measurement of flow of water in open channels, IS 1192-1981

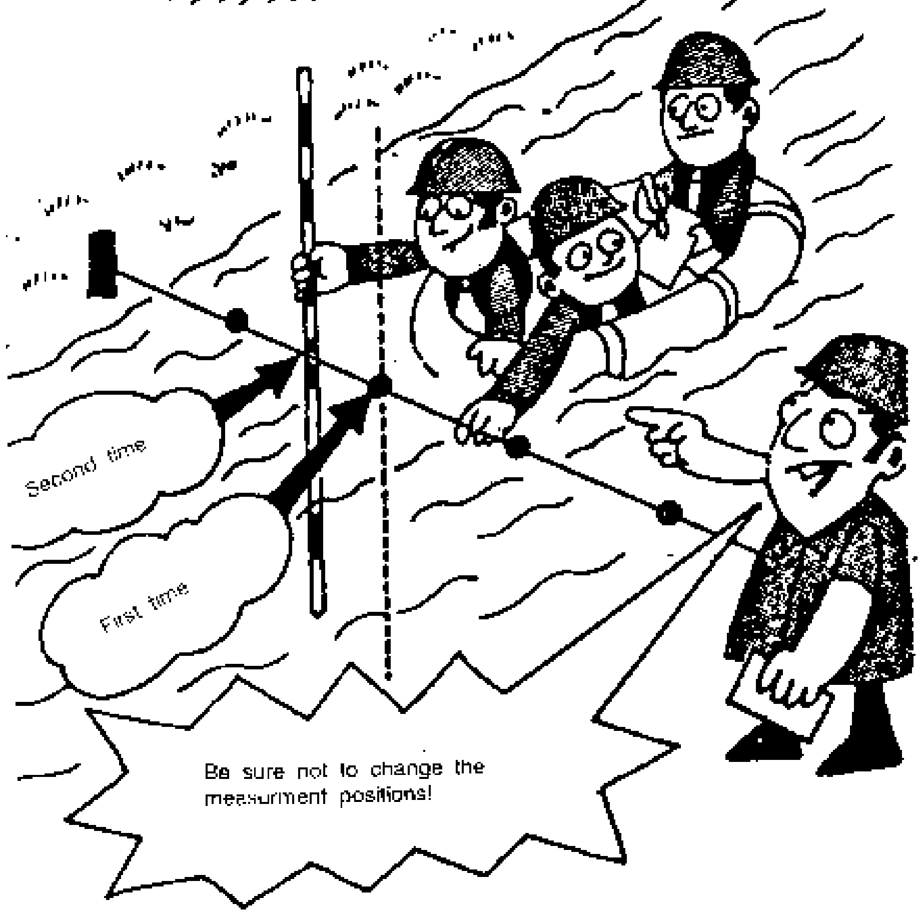
4. Recommendation for liquid flow measurement in open channels by Slope Area Method, IS 2912-1964.

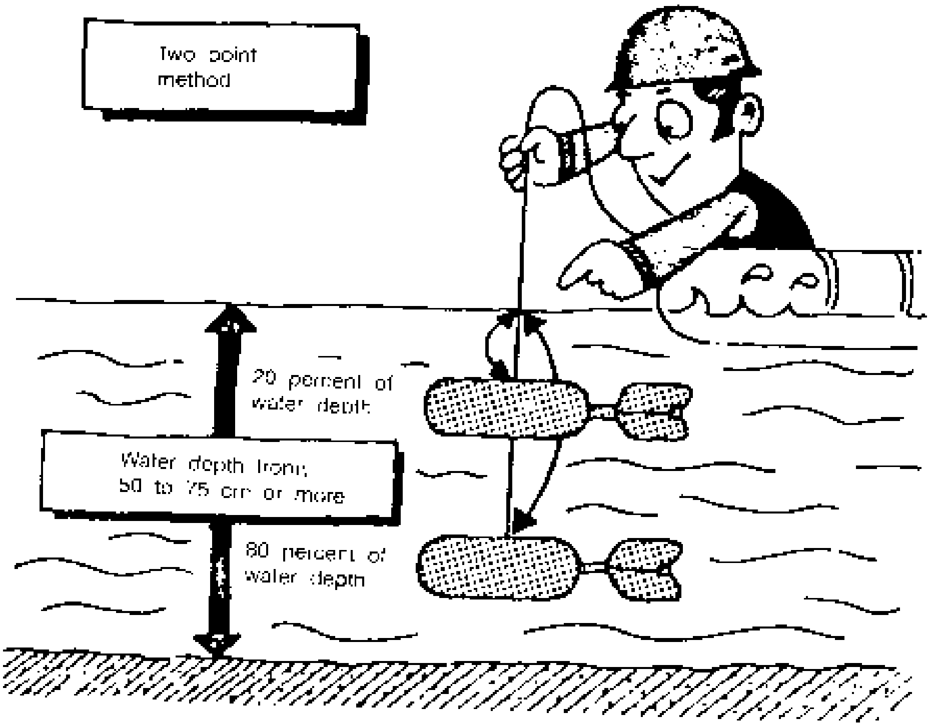

For your measurement line be sure to select a spot which has optimal conditions in regard to changes in the river bed and water level

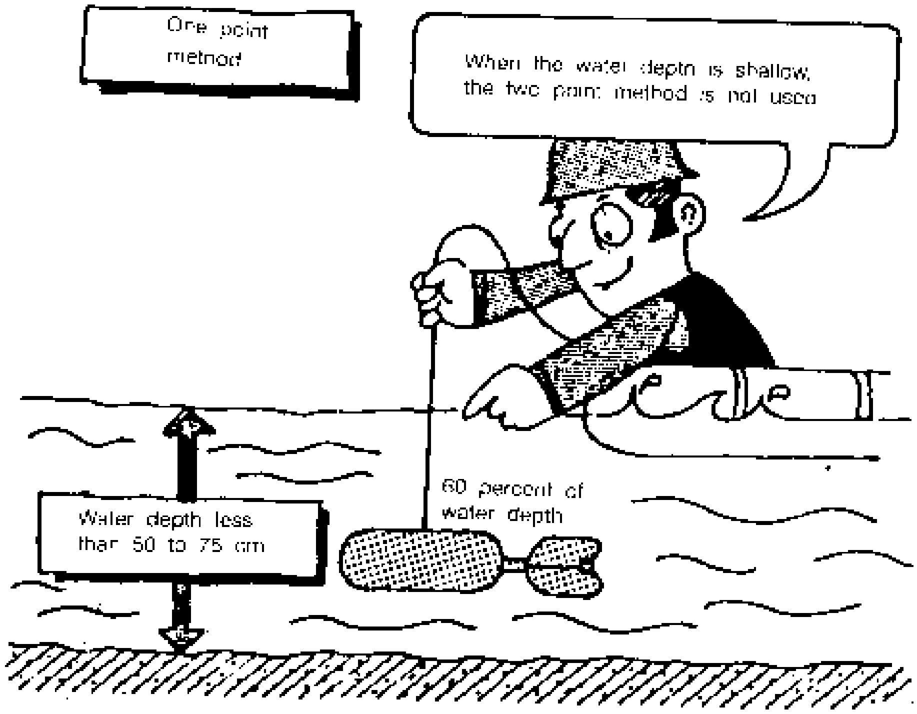

Make the line prependicular to the current.
Do not measure from these spots.

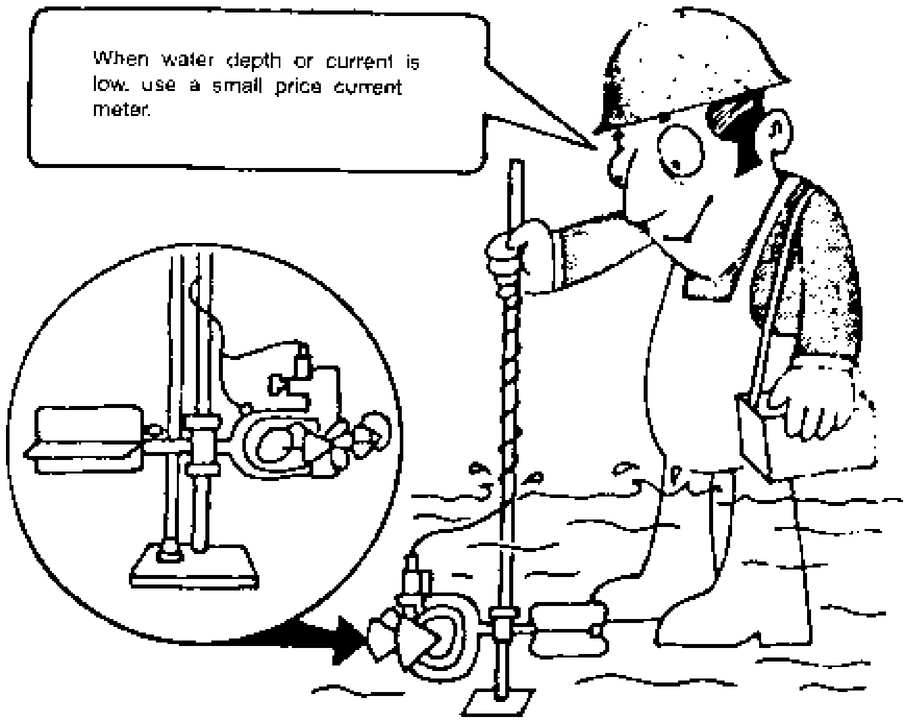

The water depth measurement line has spacing points which are twice those of the spacing for the current measurement line. line
Water depth measurement line
Current measurement line
Water depth measurement should be done twice, including the round trip over the same crossing line.
There is a rule for spacing of measurements but when water depth is deep or the current is strong measurement should be made with shorter spacing distances.

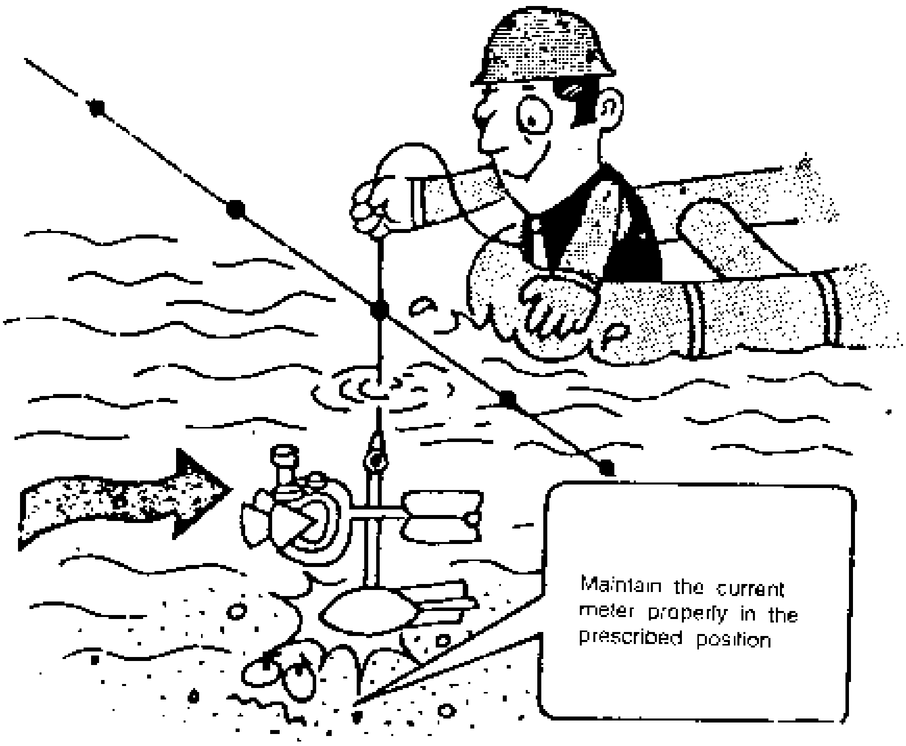

Each current measurement line should be in the same place as water depth measurement line.


Second time
First time
Be sure not to change the measurment positions!


Two point method
20 percent of water depth
Water depth from 50 to 75 cm or more
80 percent of water depth


One point method
When the water depth is shallow, the two point method is not used
60 percent of water depth
Water depth less than 50 to 75 cm


When water depth or current is low, use a small price current meter.


Maintain the current meter properly in the prescribed position

WATER AVAILABILITY

TYPE - I

1. SCOPE OF STUDY

The stream-flow data is analysed for assessing water availability for hydro-power generation. The availability of stream discharges is determined for a time unit, such as daily, 10-day and monthly. For a small run-of-the river hydro-power scheme, a time unit of 10-day period is considered adequate.

In an ideal case where observed river flow data are available on daily basis for a long period, say more than 25 years, the power potential may be assessed considering the entire data series. The installed capacity, number of units and energy generation can be determined based on a comprehensive analysis of the long-term discharge data.

In case of small hydro-electric projects where available discharge data is scanty, such a detailed analysis is not feasible. In such a situation, a simplified approach is adopted. Three typical flow series on monthly/10-day basis are generated, i.e., flow series with 50%, 75% and 90% dependabilities.

2. HYDROLOGIC ANALYSIS

2.1 Approach

Small hydro-power projects are normally located on streams in remote areas which may not have measured discharges. Even the catchment may not have any raingauge. In such a situation, the collection of discharge data should be commenced and continued for a minimum period covering two lean and one monsoon seasons. Simultaneously, the rainfall data should also be collected by establishing a raingauge if no such records are being maintained in the project catchment.

The stream-flow data collected for two lean and one monsoon seasons may be treated as 'scanty data' which is not adequate to make realistic assessment for long-term stream-flow patterns. However in order to take up small hydro-power projects urgently, the short-term streamflow is a valuable information or which indirect methods can be superimposed to estimate design discharges for assessing power potential.

The following hydrologic techniques are found very useful for computing water availability at a project site with scanty data

i) Runoff-Runoff correlation
ii) Regional specific discharges

It may be pointed out that with scanty data of two lean and one monsoon seasons no realistic rainfall-runoff correlation can be developed and hence this method can not be used.

2.2 Runoff-Runoff Correlation

In this approach, the long-term observed discharge data in an adjoining catchment is utilised. A correlation is developed between short-term discharges collected at project site and the concurrent discharges of the nearby site where long-term records are available. The correlation equation may be either linear or non-linear as follows:

i) $Y = AX + B$ (Straight-line equation)
ii) $Y = AX^n$ (Parabolic equation)

where, Y is the discharge at project site
X is the discharge at a site with a long-term record of discharges
A, B and n are constants determined statistically.

The correlation studies may be carried out separately for lean and monsoon months.The correlation equation developed can be used to generate long-term discharge series at the project site corresponding to the observed long-term discharge series of the nearby station.

2.3 Regional Specific Discharge

If long-term observed discharges in an adjoining catchment are not available, the regional specific discharges may be computed and adopted. The specific discharge is defined as discharge per unit area. In this method, the discharge data of a few gauging stations located in the similar hydrometeorological region are collected from the concerned state government departments or other agencies maintaining the gauging sites. The mean monthly discharges for 50%, 75% and 90% dependabilities are computed based on the available data of each gauging station and are converted into mean monthly specific discharges. The hydrographs of mean monthly specific discharges for a particular dependability at the gauging stations are plotted on a common X and Y axes as shown in the Figure 2.1. A mean hydrograph may be considered as the hydrograph of regional monthly specific discharges which may be adopted for computing mean monthly discharges at the proposed diversion site.

2.4 MeanMonthly Discharges

The regional specific discharges when multiplied by the catchment area of the project site will give the mean monthly discharges at that site.

2.5 Mean 10-Day Discharges

Mean 10-day to monthly discharge ratios based on the short-term observed discharges at the project site or at the nearest gauging station are computed.

The mean 10-day discharges in a month are computed by multiplying with that months' 10-day to monthly ratios. For example, let m_1, m_2 and m_3 represents mean 10-day to monthly discharge ratios of January based on observed data. Let M be the mean monthly discharge in January corresponding to 50% dependability. Then mean 10-day flows in January would be as follows:

DAYS	MEAN FLOW
1-10	m1 M
11-20	m2 M
20-31	m3 M

2.6 Percentage Dependability of Observed Discharges

The mean monthly specific discharges at the project site are computed based on the short-term data collected and these are compared with regional mean monthly specific dishcarges corresponding to 50%, 75% and 90% dependabilities. Such a comparison would give an idea of the percentage dependability of the observed discharges.

2.7 Flow Duration Curve

When the values of a hydrologic event are arranged in a descending order of their magnitude, the percentage of time for each magnitude to be equalled or exceeded can be computed. If the magnitudes are plotted as Y-axis against the corresponding percentage of time as X-zxis and a curve is drawn through the plotted points, such a curve is called 'Flow the duration curve'. Similarly, if the even is rainfall, the duration curve is called 'Rainfall-duration curve'. A flow-duration curve may be considered to represent the hydrograph of the average year with the flows arranged in order magnitude.

A typical monthly flow duration curve is shown in Figure 2.2. This curve has been computed condiering the observed discharges of a river at a guaging site which is availble for 22 years. The computations are shown in Table 2.1. In this table, the discharges have been arranged in descending order of magnitude. The percent of time a flow magnitude is equalled or exceeded is given by the expression mX100/(N+1), where m is the rank of the magnitude in the descending order and N is the total number of items. The figure 2.2 has been derived by plotting the flow magnitudes on Y-axis and percent time the magnitude equalled or exceeded on X-axis. The monthly discharge for 50% dependability, for example, as read from Figure 2.2 is 7.80 cumecs.

Table 2.1
Computation of Flow Duration Curve

Monthly Flow in Descending Order (Cumecs)	Rank (m)	Percent of Time m x 100/(N+1)
14.90	1	4.35
11.90	2	8.70
9.98	3	13.04
9.70	4	17.39
9.14	5	21.74
8.79	6	26.09
8.67	7	30.43
8.56	8	34.78
8.43	9	39.13
8.14	10	43.48
7.94	11	47.83
7.76	12	52.17
7.27	13	56.52
7.18	14	60.87
7.14	15	65.22
6.79	16	69.56
6.21	17	73.91
5.83	18	78.26
5.37	19	82.61
4.77	20	86.96
4.76	21	91.30
1.52	22	95.65

TYPE-2

- Unlike Type-I Scheme, no detailed water availability studies are required for this type of schemes. The pattern of mean 10-day/ monthly observed canal discharges over the period of record would be the basic consideration for assessment of power potential.

FIGURE 2.1

TYPICAL REGIONAL SPECIFIC DISCHARGE HYDROGRAPHS

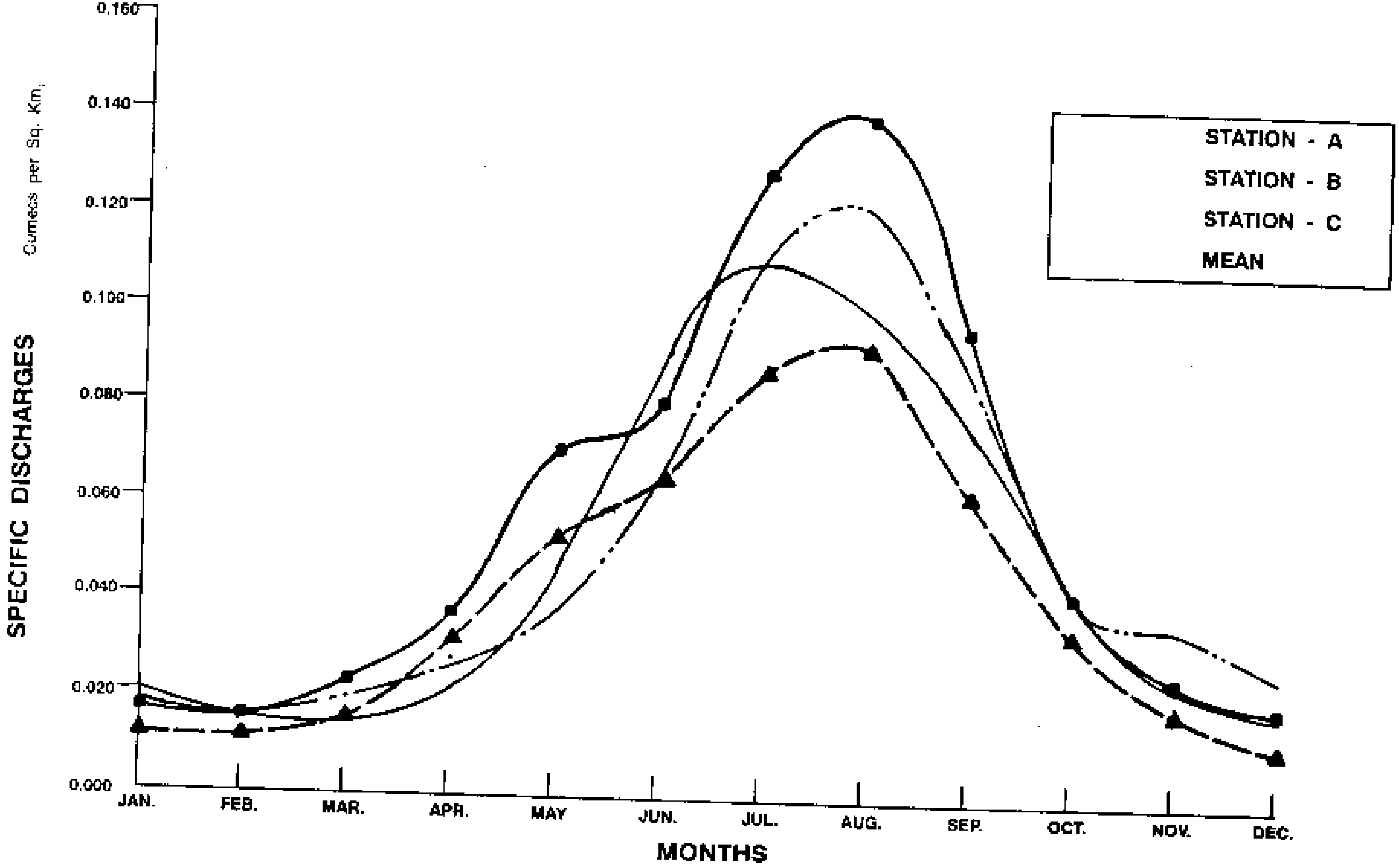
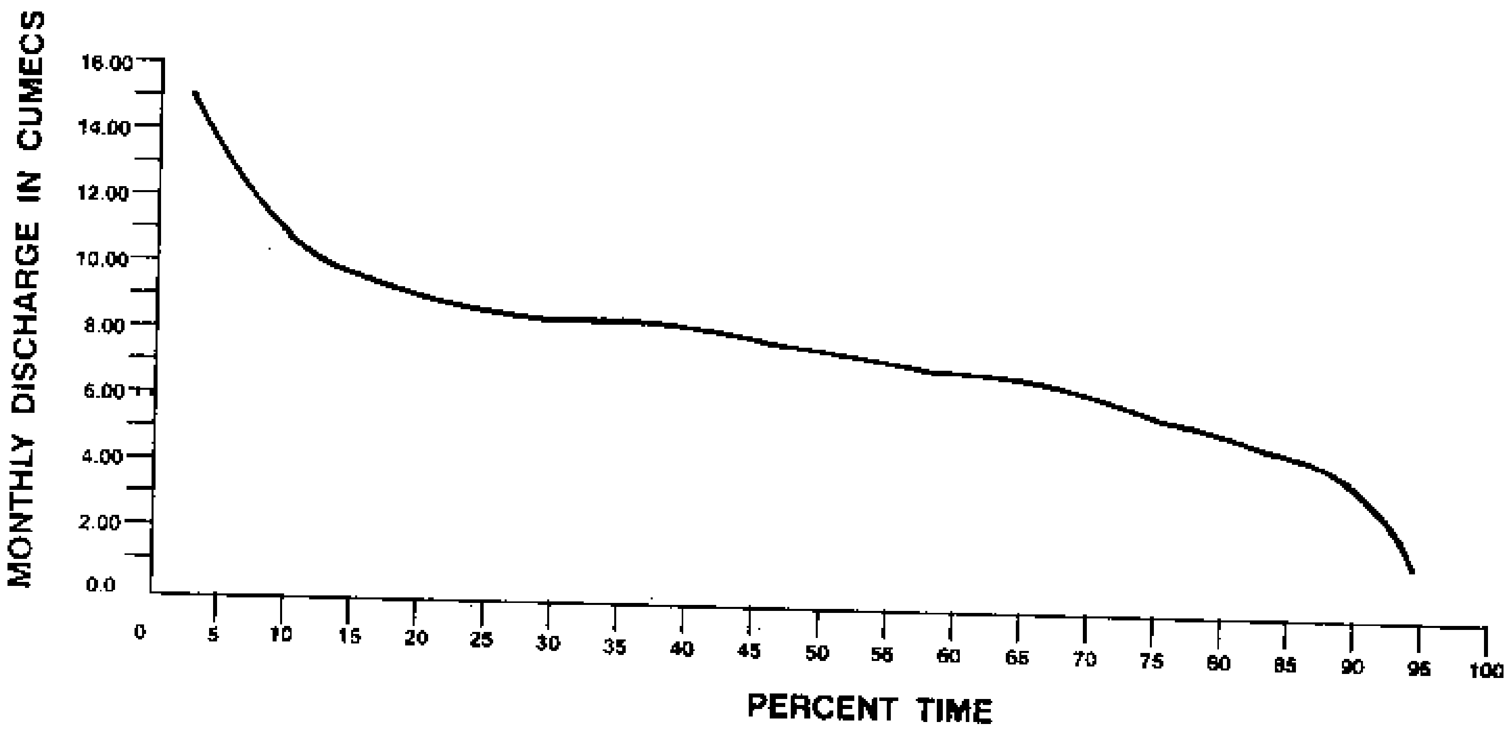


FIGURE 2.2

MONTHLY FLOW DURATION CURVE



DESIGN FLOOD DISCHARGE

TYPE - 1

1. DESIGN CRITERIA

A diversion structure across a stream must be capable of passing the maximum flood discharge without causing damages to itself, properties down below and any loss of life. The peak flood discharge adopted for the design of a hydraulic structure is called 'design flood'.

A run-of-the-river small hydro-electric project does not require any major diversion structure. It is usually of a trench weir type where no storage is involved. In the event of failure of such a structure, it is unlikely to cause any loss of life or damages to the properties downstream of the diversion structure. A 50-year return period design flood is considered adequate on economic consideration.

Where a storage dam is proposed as the diversion structure, the hazard involved in the eventuality of dam failure would be high. The design flood discharge for the spillway of dam as per I.S. code 11223-1985 (Guidelines for fixing spillway capacity) is a 100-year return period flood for small dams upto a height of 12.0 m and gross storage upto 10.0 million m^3. For dam with a height between 12 m and 30 m and gross storage between 10.0 and 60.0 million m^3 the design flood would be a standard project flood.

As regards the waterways of the cross-drainage works across the water conductor the design flood would be 25-year return period for small/medium size structures and 50-year return period for major structures.

2. ESTIMATION OF DESIGN FLOOD

Depending upon the type and extent of data availability, the most commonly methods of estimating a design flood are:

i) Flood Frequency Analysis
ii) Unit Hydrograph Method
iii) Empirical Formulae

2.1 Flood Frequency Analysis

This is a statistical approach which requires long-period annual peak discharges. The statistical method commonly used is the Gumbel's extreme value type I distribution.

As long-period record of peak flood discharges are usually not available for project sites of small hydro-electric projects the flood frequency analysis is not possible. An alternative to this method is to estimate a storm rainfall of suitable duration with the desired return period, say 50-year. The storm rainfall is then transformed into a flood hydrograph using unit hydrograph method.

2.2 Unit Hydrograph

A unit hydrograph (UH) is a hydrograph of surface run-off resulting from 1.0 mm (or 1.0 cm) of rainfall-excess distributed uniformly over the basin area at a uniform rate during a unit period (for example 1-hour, 3-hour, 6-hour etc.)

In the unit hydrograph method, a suitable unit hydrograph is developed based on observed river-flow data and short-duration rainfall data. Hydrometeorological studies are carried out to estimate a design storm rainfall profile of a suitable duration. This storm rainfall is then convoluted with the ordinates of the unit hydrograph to compute the design flood. For flood computation by unit hydrograph method a reference may made to 'Estimation of Design Flood Recommended Practices, CWC Sept. 1977'.

In case observed hydrological data are not available or inadequate, the unit hydrograph is developed by a synthetic approach. The following two methods are recommended:

(i) Regional unit hydrograph parameters developed by C.W.C., Small Catchment Directorate, (Refer Basin Wise Flood Estimation Reports)

(ii) Triangular unit hydrograph developed by Soil Conservation Services (SCS), USA (Refer Design of Small Dam, USBR)

2.3 Empirical Formulae

A common empirical flood formula expresses the peak flow discharge (Q) as a function of catchment area (A)

$$Q = CA^n$$

The coefficient C and exponent n depend on catchment characteristics and storm rainfall intensities.

Some of the regional empirical formulae in vogue are as under:

(i) Dicken's Formula, $Q = CA^{3/4}$
(ii) Ryve's Formula $Q = CA^{2/3}$
(iii) Inglis Formula,

The Dicken's formula has been widely used in Central and Northern India.

The Ryve's formula has been generally used in Tamil Nadu, Andhra Pradesh and parts of Karnataka.

The Inglis formula was developed in Maharashtra and its use has been confined to that State only.

The above empirical formulae are not recommended. These may be used only when the unit hydrograph method cannot be adopted due to data constraints. In case an empirical formula is adopted, care has to be taken to use a reasonable value of the coefficient C.

Type-2

The hydrological studies for design flood are not normally necessary for this type of scheme.

CHAPTER - 3

COST EFFECTIVE DESIGNS, MACHINE SELECTION, ENVIRONMENT ASPECTS

3.1 INTRODUCTION

SHP could be a competitive option if cost effective designs, by utilising local material, manpower and indigenous equipment with simple layouts, are adopted. The design of civil structures and selection of machines assume more importance in cutting down the cost and affording greater reliability for trouble free operation. The civil designs of H.E. Projects, even small HEPs, have to be site specific and suit the requirements of machines to be installed. In designs a consideration has to be given to meet the hydraulic and operating requirements of the plant. This chapter deals with appropriate techniques of designs and machine selection commensurate with the type of development. Also, although SHP is considered environment friendly, the related aspects in this regard have also been documented.

One of the **most important decisions that the Developer has to take is to select consultants of established competence.** In case of small hydro projects, sites/locations already identified by government agencies are offered to Developers. The Developer then has the task of making of optimal plan and location of the various structures of the Project, work out benefits at the chosen location, prepare Project Report and process the same for approval and agreements. In the first instance an Expert team of specialists in the field comprising of Civil Engineer (Planning & Design-Hydro), Electrical/Mechanical Engineer (Planning & Design-Hydro), Hydrologist, Geologist (Engineering Geology) & Costing Engineer should be formed who would evolve, the best approach suited to the site and give the guidelines and terms of reference for appointment of consultant. The expert team shall remain during reconnarssance stage, feasibility study stage and detailed project preparation stage for tendering necessary advice and guidance. For carrying out detailed engineering studies at the construction stage involving preparation of specifications and construction design and drawings, a firm having competent engineers both civil as well as Electrical/Mechanical should be entrusted with proven ability for design of Small Hydro projects with a background of experience in the field. Implementation of cost effective design successfully would require a construction agency of proven competence in construction of similar Small Hydro Projects.

3.2 DESIGNS OF CIVIL WORKS

Small HEPs are broadly categorized in 2 main categories (i) Medium/high head type and (ii) Low head type. As the two types differ radically in respect of nature of civil works as well as type of generating plants. The practices of works and plant for these 2 types are considered.

3.2.1 Type-1 : Medium High Head

The civil components of this type of development of small hydro (in which water is taken from a stream and conveyed at a high level to a convenient position from where it can be taken sharply down to the turbines at the power station) are:-

(i) Diversion and intake
(ii) Water conductor system
(iii) Desilting tank
(iv) Forebay/balancing Reservoir
(v) Penstock
(vi) Power House
(vii) Tailrace

The design of these structures should be based on utilisation of locally available construction material to maximum extent possible and be simple enough to avoid deployment of heavy construction equipment and highly skilled labour in view of poor infrastructure facilities available in the far-flung inaccessible areas where most of the sites are located.

3.2.1.1 Factors Requiring Special Consideration

Due consideration should be given in the design of small hydro schemes of this type specially in the Himalayan region to the large boulders and heavy silt load carried by the stream during the monsoon season and flash flood of high intensity cannot be ruled out. These factors require special consideration and study.

3.2.1.2 Diversion Weir and Intake

The diversion structures should be as simple as possible and least expensive. The diversion structure may be of two types (i) solid boulder structure comprising boulders and (ii) trench type weir. The hill stream generally carry big boulders during flood season which destroy the overground structure constructed across the river and this aspect restricts the choice of adoption of overground structure alternatives. Further if solid boulder type structures weir or a conventional weir alternative is provided in non-rocky foundation maintenance and repair of damages due to scour may create problems. The diversion weir should be capable of diverting all the design flows and the structure should be reasonably safe during monsoon floods. The adoption of Trench Type weirs for diversion structure has solved this problem to a significant extent as this type is suitable where rock is not available in the river bed as is usually the case. Solid overground weir structure could be adopted where rock is available within one meter below the river bed. If situation permits this, consideration could be given to examine if pondage could also be incorporated at reasonable cost.

3.2.1.3 Solid Weir Structure Comprising Boulders

The solid weir structures are constructed by encasing boulders in G.I wires, piling them up to form weir and covering the same with cement concrete reinforced by 10 mm steel basis 100 mm centre to centre on the faces. Figure 3.1 (refer page 66) shows typical layout of this type of diversion structure. Figure 3.2 (refer page 66) shows the details of boulder/weir.

3.2.1.4 Trench Type Weir

Where the river bed is not rocky (as is usually the case) and ground structures are not safe unless costly elaborate foundation arrangements are made, trench type weirs have been found to be successful. It is a simple trapezoidal trough made up of masonary or concrete, covered with a trashrack. The trashrack is given a slope of about 1 in 10 in in the flow direction so that stones or pebbles do not settle on the trashrack but roll down with the stream flow. The rack itself is designed to withstand loads due to rolling boulders. The trashrack is removed periodically after monsoon season to clear any deposited material. The trench itself is provided with a Bed slope of not less than 1 in 25 in the flow direction of the diverted waters so that sufficient velocity is generated to carry away small stones and heavy silt that may find entry into the treshrack openings. The intake located at the end of a trench type weir is connected to the water conductor in a gated well structures constructed in R.C.C. or Masonary. The intake gate should permit the release of water to the desired extent. A flushing sluice connected to a desilting pipe with gate control is provided to eject out the rolling bed material. The duct should be so dimensioned as to develop adequate velocities for flushing when the gate is fully open. Thus, the intake gate is provided with two gates, one for flushing the rolling bed material during monsoon and the other for feeding the flow to the water conductor. The flushing sluice is kept lower than the opening for the water conductor to provide the necessary head for flushing the silt and coarser material through the desilting pipe. The following should be checked during design:-

(i) The waterway is adequate to pass the desired flood and the gate operation control are above the maximum flood level.

(ii) The trashhrack area of opening is adequate to draw the design discharge even if 50% of the effective area of the trashrack is clogged.

(iii) Adequacy of the longitudinal slope to develop velocities capable of flushing out bed load entering the trench. Flushing discharge of about 20-25 percent of the design discharge may be provided in diversion structure to meet the flushing requirements at the intake and the desilting tank. Suitable gate controls for intake and flushing sluices should be provided. The design of the flushing outlet requires careful consideration taking into view the particular silt in each one. Figure 3.3 (refer page 67) shows a Typical layout of a trench weir and intake arrangement.

3.2.1.5 Water Conductor System

Water conductor system is the life-line of the system. The choice of the type of water conductors depends on the topographical and geological Particulars of the şide capacity of the water conductor. In initial reaches the water conductor may have to be of cut and cover section to protect the same from flood water in the stream. The rest of the reach could be of cut and cover section or open channel section or a combination of both depending on the site conditions. The selection of the left bank or right bank of the stream for the water conductor would be on consideration of.comparatively superior accessibility, stabler hill slopes, fewer nalahs to be used and better location for forebay/penstock and Power House. While the water conductor system should ensure least loss of head flow velocity should be adequate to prevent reduction of discharging capacity due to settling of silt. Fig. 3.4 & 3.5 (refer pages 68 & 69) show typical cross sections of canal. The canal can be lined with LDPE film additionally where it traverses through pervious strata. Fig. 3.6 (refer page

70) shows a detail of power channel lining with LDPE film. Unlined channels are not recommended due to loss of water by seepage and also instabilities of the hill side caused by water logging and slope failure. Sufficient catch water drainage should be provided in the hill side so that transverse flow from hill slopes during rains are carried safely away to nearby natahas. These catch water drains may be protected by stone pitching. Hume pipes are best suited to serve in steep hill slopes since they could be provided in a cut and cover trench and the hill slopes are less disturbed. Main disadvantage may be higher cost and transport to the location of their placement. Reinforced concrete box section can also be provided in such hill slopes. The power channel should be confined within a formation cutting of 10m. The foundation width should include construction of a service road.

3.2.1.6 Desilting Tank

To trap the pebbles and suspended matter, desilting tank is provided in the initial reaches of the water conductor. The velocity of flow in the desilting tank is reduced to about 0.25 m/sec. to allow the suspended matter to settle down in the drain provided in the bottom of the chamber. The sediment flushes out in the valley occasionally through a pipe from the drain operated by a gate. The desilting tank is designed to exclude particles less than 0.25 mm. Fig. 3.7 (refer page 71) shows the typical general layout of a desilting tank.

3.2.1.7 Forebay

The forebay in a small hydro scheme provides some storage against sudden fluctuations in demand. Generally, 2 Minute storage provision for a drawdown of 1 m to 3 m, is considered sufficient. The forebay should generally be located on comparatively flat terrain which would not involve more than about 10 m cutting for excavation. Creation of pondage is preferred in cutting and when it is done by constructing embankments, the same should be done with caution. Suitable spillway channel should be provided to safely dispose off the excess inflows during load rejection. The spillway capacity should be equal to the design discharge of the water conductor. Automatic gates are required to be provided for the spillway enabling instantaneous opening of the gates during load rejection. Intake arrangements for the penstock flows are an integral part of the forebay which needs adequate planning and design. Typical layout of the forebay is shown in Fig. 3.8 (refer page 72).

3.2.1.8 Penstock Intake

Penstock intakes are provided at the forebay. Commonly a Bell mouth entry is provided to reduce the head losses and to ensure a smooth entry of water. The intake opening has a rectangular section and is followed by a transition so as to convert the rectangular to circular shape wherefrom the penstock liner is embedded control gate is provided at the throat section. The intakes are provided with trashracks which prevent trash debris etc. from entering into water. Flow velocity through trashrack is kept 0.6 m. to 0.8 m. per minute so that head losses are not significant. Clogging to an extent of 50 percent of the trashrack area may be considered in the design.

3.2.1.9 Penstock

The penstocks can be of Indian Hume pipes, ERW or steel pipes. The penstock rests on saddles. Fig. 3.9 (refer page 73) shows the Longitudinal section of Penstock profile and position of saddles. Flexible coupling expansion joints are necessary when the penstock is laid on the surface to permit elongation/ contraction due to temperature variations. These are provided between two Anchor Blocks generally next to uphill Anchor. Generally, one penstock pipe is provided from the intake to a suitable point upstream of the power House where manifold is provided to feed individual generating units where more than one unit is provided. The pipes may be joined by welding or by providing dresser couplings. The pipes should be supported by Anchor Blocks at the bends. If the pipe is buried, expansion in joints may not be provided. Victaulic couplings may be provided to take care of the expansion if pipe is laid overground. These couplings besides, permitting the expansion, introduces some flexibility which helps greatly in laying the pipes.

3.2.1.10Sluice Valve and Control Gates

Controls are provided at the penstock intake to close the waterflow to undertake any repairs for penstock. Valve arrangement is provided along with an upstream stop log to enable repair of valves. Slide gates could also be adopted along with upstream stop log arrangement.

3.2.1.11Power House

Power House is a simple structure housing the generating units, and auxiliary equipments and suitable outlets for tail water discharges to the tailrace. Centre to centre distance between the units depends upon the physical dimensions of the machines. G.I. sheets or asbestos roofing are adopted generally on consideration of reliability and quick construction. Walls could be of brick or stone masonary. Fig. 3.10 (refer page 74) shows a typical layout of power house.

3.1.2.12Tail Race

The tail race channel is a simple water channel or a cut and cover structure transporting the water from the Power House back into the river. The tailrace channel should be designed for adequate capacity and sufficient slope to clear the discharges from the generating units. The individual tailrace channel of each unit is connected to a common channel outside the power house building.

3.2.2 TYPE - 2

(A) Category-1

3.2.2.1 Small Hydel schemes can be conceived generally in the existing irrigation canal system and in those under construction or under planning stage. For this relatively larger discharges are required to be handled involving larger sizes of civil structures as compared to medium/high head mini hydro projects. The civil structures should therefore be designed as economically as possible.

3.2.2.2 Factors Requiring Special Consideration

The Power House may preferably be located on the canal alignment with intake on the upstream and tailrace on the downstream of the fall. In most of the running existing canals it may not be possible to locate the power house on the canal alignment itself, which may require the closure of canal for considerable period during the construction. In such a condition, the power house may be located on a by-pass channel. The ledge may be removed after the completion of the construction after closing the canal, which would be only of short duration. The main canal in such alternative would serve to bypass the discharge when generating units are not in operation. The bypass channel should be as close as possible to the existing canal from consideration of economy. However, the stability of the excavated slopes/embankment of the canal in the bypass should be of prime consideration in deciding the layout of the scheme. The bypass may be taken at an angle of 30° to 45° to the main canal.

The planning of incorporation of small hydro should be such that the minimum period of shut down should be envisaged. The low head Hydro can also be incorporate in the main canal itself. Provision of the bypass in the same structure should be provided with stilling arrangement. Regulating gates should be provided in the Power House portion as well as in the bypass. The width of the canal in this portion should be increased to accommodate these in the same structure. Figure 3.11 (refer page 75) shows a general layout of power house located in the bypass channel. Figure 3.12 (refer page 76) show power house located in the main canal itself. Figure 3.13 (refer page 76) shows a typical cross section of intake structures and power house. Basic and common components of a low Head small hydel project:-

(i) Intake structures
(ii) Power channel/tailrace channel
(iii) Power House

3.2.2.3 Intake Structure

Figure 3.14 (refer page 77) shows a typical intake structure. A bell mouth entry is provided to reduce head losses and to ensure a smooth entry of water. The control gate is provided with trashracks to prevent debris from entering the waterways. Flow velocity through the trashrack is kept within 0.6 to 0.9m/sec. Clogging of trashrack to about 50% of the effective area is considered in the design. In the case of regulator in a bypass canal system a simple type falling shutters may be provided. Typical details are shown in Fig. 3.15 (refer page 78). However, if canal flow requires regulation, other suitable gates are used.

3.2.2.4 Power Channel and Tailrace Channel

The section of the channel could be similar to the existing irrigation channel. Figure 3.16 (refer page 79) indicates typical cross section of such a channel.

3.2.2.5 Power House

In low head schemes, a tubular unit Power House generally provides maximum benefit at minimum cost. The width and centre to centre distance between the units will vary according to the size of the Runner. Figure 3.17 (refer page 80) indicate the typical layout of the power house. Figure 3.18 (refer page 81) indicates typical cross section of the power house.

(B) Category - 2

3.2.2.6 Small Hydel schemes can be conceived downstream of an existing irrigation dam by incorporating suitable provision so as to take advantage of the higher water level in the reservoir due to storage and the downstream water level in the canal. A short water conductor have to be planned at the abutments leading from the reservoir to the power house and from the power house to the canal. The water conductor can be an open cut channel or a tunnel. The choice would depend on the depth of excavation stability of excavation slopes and geological strata. Where exca-vation is too deep and the geological strata is suitable for tunnel-ling a tunnel may be preferred on grounds of economy or safety.

3.2.2.7 Factors Requiring Special Consideration

Construction planning assumes importance as the civil works for the approach channel inside the reservoir has to be executed in underwater condition suitable coffer dam or alternatively shaft construction would require to be considered and the best option chosen. Similarly the connection of the tailrace channel from the power house to the canal has to be planned with care to cause least disturbance to the existing canal structure and minimum period of closure during this item of work execution. Basic and common components of this type would be similar to category 1 except that the civil works in some cases may involve a tunnel. In case a tunnel alternative is chosen, careful evaluation of tunnel support system and monitoring during tunnel driving is a special requirement to anticipate and take timely remedial measures to meet geological uncertainties. Typical layouts and cross sections of schemes of this category, are indicated in Figure 3.19 and 3.20 (refer pages 82 & 83).

3.2.2.8 Decision of Basic Parameter for Designing Civil Works and Power Plant

The elements of civil works for an SHP discussed in the preceding paras and for power generating equipment and power house to be considered in paras to follow, have to be designed for specific basic parameters of head and discharge applicable in each case. This in turn is dependent on the Kilowatt capacity of the machine chosen for installation in the particular case after consideration of hydrological data and gates use, head given by topography and consideration applicable to use of the power output in the system etc. Other factors such as features of topography and geology, floods etc, also have influence on designs. The type and rating of generating units applicable to case relevant arrangement of power house also is material.

In order to take up design of a Hydro Project, therefore, studies to decide the installed generating capacity are the first step. These studies have to consider optimisation of capacity from the following four angles:

(i) Hydrological data giving wastes flows expected to be available for use with' different dependability.

(ii) Consideration relating to power supply to system.

(iii) Optimal stretch of stream to be utilised and corresponding head.

(iv) Number, rating, type of generating unit, power station, electrical layout and location and arrangement of power house. These studies are considered in Chapter-1. The results of some would supply the basis for design of works and plant.

3.3.1 Power Plant and Power House Layouts

Hydraulic conditions form forebay to turbine location, and then the tail water variations downstream from turbine have to be taken into account to decide the applicable head, head range, tail water conditions and variations. This will enable in deciding whether power house should be located above maximum flood or lower to take advantage of head. This point is also associated with the type of turbine which is chosen to be used for the power station on head considerations. The consideration of transients of the hydraulic system would also have to be seen in looking at possible variants of power plant layout. Alternatives of layouts have to be made for choosing suitable stable penstock slope and proper location of Power House with easy accesibility.

Based on studies for power potential referred above, which will take into account pondage if any, is available, the type, number and rating of generating units to be used will be given. The power house layouts will have to be selected to suit the selected plant. Thus, in case of high and medium head plants, francis Pelton turbine units could be applicable. For small plants, generating horizontal units will be used, but vertical could also be thought of especially of physical size is bigger. The power house floor will be lower for turbine units generally. In case of low head plants variants of vertical and horizontal units are available.

3.3.2 Factors Involved in Machine Selection

It may be recapitulated that hydraulic turbines with 3 basic hydraulic designs are presently employed for hydroelectric power generation. These 3 types are listed in the table below, in which the head ranges far from application of each type is also indicated in two columns: one applicable for large and medium machines and the other for small machines:-

TABLE

Type of Turbine	Head range for large/medium machines	Head range for small/machines	Usual generating unit arrangement for small/ medium
Pelton	Above 300 m	Above 150 m	Horizontal
Francis	30 to 500 m	20 to 200 m	Horizontal
Kaplan (Propellor)	3 to 50 m	3 to 40 m	Horizontal of special design bulb or 'S'-Type.

NOTE:

(i) Vertical arrangements may be adopted for small Francis and Kaplan units, if the rating is somewhat large or for special reasons.

(ii) Some other types of turbines are also used for small H.E. Projects, to a limited extent. These are:-

Turgo impulse (150 m and above)
Cross flow (For small low head plants also called Michel, Bank or Ossberger type).
Discussions of practices for selections of type, rating and particular of generating units is presented in Chapter-4 dealing with standard plant etc.

3.4 ELECTRICAL LAYOUTS, SWITCHING ARRANGEMENTS, CONTROLS

The generator used for small H.E. plant can be conventional synchronous type, or can be of induction type. The choice requires, interaction with the power system authorities. Induction machine simplifies the power plant and reduces cost but needs various forms of support from system. Frequent tripping of system in rural lines also has to be taken into account. This problem also affects synchronous machine installation, but in a slightly different way. The generator voltage will broadly be:-

415 V for very small sets.
3.3 kV for generators upto 3 MVA appx.
6.6 kV for larger generators.

The transmission normally will be at 11 kV or at 33 kV. Under special conditions when some high voltage like 66 kV or 132 kV is present in the vicinity, linkage to same is likely to be required.

It is a common practice to arrange generator voltage switching and synchronising. Station output is transformed by one transformer and sent out in smaller stations. With bigger stations other arrangements have to be considered.

It is desirable to keep switch gear and protection of simple and conventional designs so that suitable maintenance skills can be found in the local area.

Control Automation : Control Systems and Equipment for similar reasons should also be simple and use conventional elements. The main controls for starting and stopping of the units are usually integrated on the switchboard of the Power Station.

Economical automation system suitable to the cost levels of small HEP is not yet available. Otherwise, if cost is not a consideration, small HEP can be equipped even for full remote operation. This has been effected in case of many major H.E. power stations in the world, where automation is commensurate with the cost involved.

Variants of automation may need to be considered in case of small HEP.

3.5 ENVIRONMENTAL ASPECTS:

Small Hydro Power are distinct from the conventional and medium H.E. Projects due to simple layout and mostly non-interference with the regime of flowing water. Bulk of SHP in India would be run-of-river type developments utilizing higher heads with or without small pondage. The other category of low head schemes may utilize the storage created as part of irrigation/drinking water facility. First category would involve very little submergence, rehabilitation, deforestation etc., and have practically no adverse effect on environmental and ecology of the area. The other category utilizes the waters from the existing water body and hence no additional environmental aspects are associated. SHP involving capital outlay upto Rs.50 crores have been exempted for obtaining environmental clearance from MOEF. Forest clearance, if applicable, and clearance from the Pollution Control Board, are required to be obtained.

The following are some of the main environmental concerns pertaining to SHP:-

- Submergence of settlements and re-location of people
- Failure of water body i.e. dam, forebay etc.
- Effects of construction
- Effects on fisheries and other aquatic life
- Effects of storage of water in the dam or water quality and vectors of diseases
- Downstream effects due to less or heavy discharges
- Loss of flora and fauna and their habitat
- Encroachment into genetic reserves and wild life parks

The environmental impact could be due to project location, project design, project construction or project operation. The impacts due to project location include rehabilitation and settlements, encroachment into genetic resources and wild life parks, encroachment into forests, soil erosion etc. Impact due to project design mainly include water quality, seismicity and safety of structures. During project construction the impacts are mainly due to soil erosion, siltation, etc. In project operation, the environ-mental impacts are often due to variation in flows, water quality, water logging and salinity etc. If it is desirable to carry out an environmental study, concurrently with the feasibility study, the following objectives need to be considered:-

(i) Assessment and analysis of the positive and negative environmental impacts of the proposed project.

(ii) Selection of a project alternative which may have substantial positive environmental impact and limited adverse impact.

(iii) Preparation of a implementable environmental management and monitoring programme.

(iv) Provision of the basis for making the decisions as to whether the project should proceed as proposed or whether some modifications are necessary before approval or whether it should be abandoned.

The examination of above aspects at the feasibility stage would reveal whether the project should be pursued further or abandoned. The parameters or criteria on the basis of which a project may be abandoned must be documented with great care. If it is decided to go ahead with the project and cost of the project is expected to be more than Rs.50 crores then an environmental impact assessment (EIA) must be carried out.

EIA provide more comprehensive information on relative environmental issues which are essentially required for decision making. It requires identification and baseline data collection, prediction of likely changes expected due to direct and indirect consequences of that development activity and a management mitigation plan for dealing with major environmental issues. Such study could be carried out by a reputed consultancy organization.

Guidelines issued by IREDA for (I) Environmental Analysis and (ii) Social Impact Assessment of Small Hydro Project, are given at Appendix-3.1 and 3.2 (refer pages 59 to 65), which would be helpful in carrying out a detailed study. A questionnaire issued in this regard by the Department of Environment for River Valley Project, may also be referred to. These guidelines are generally applicable to SHP costing more than 50 crores.

GUIDELINES FOR ENVIRONMENTAL ANALYSIS OF SMALL HYDRO PROJECT

These guidelines identify points that would be reviewed in the environmental screening of small-hydro projects, including related works on civil, mechanical and electrical engineering to provide water, diversion dams, power houses, water intake structures, water conveyance structure, electrical system, grid interconnection, etc.

SCOPE OF WORK FOR ENVIRONMENTAL ANALYSIS

PROJECT PLAN:

1. Provides a general project plan and its schedule and provide two maps drawn on scale, one of the general area and the other for the project area.

CLIMATE:

2. Describe climate type and meteorological data for temperature, rainfall (seasonal), wind (direction, speed, seasonal).

GEOLOGY:

3. Describe land morphology, topography and geologic structure. Is project located in an earthquake zone ? If so, provide quantitative data for the frequency and intensity of earthquakes.

HYDROLOGY:

4. Provide river stream flow rates (monthly maxima and minima from historical records).

5. Provide data area describing water availability in all seasons and if available, give surface and groundwater quality data during all seasons. Indicate surface and ground water recharge areas, all use of water (including irrigation, industrial and other uses), sources of water for drinking, bathing, clothes washing.

6. If the water availability for the different uses is impaired by the project, describe the impact and propose mitigation measures to provide this water of the same quality.

7. Describe river flow disruption during the dry season caused by the project. Describe high sedimentation during construction and immediately after construction and measures proposed to mitigate the situation. Describe the impacts on aquatic organisms during

construction (with high sedimentation) and after implementation of the project.

8. A minimum flow of 100 litres/second should be maintained in the bypassed river section during normal plant operation.

LAND AND SOIL:

9. Describe land stability, adaptability, layer and use, land allotment, protected lands and soil types, structures and texture.

10. Does the project has an impact on the land stability? If so, describe measures to stabilize the land.

FLORA AND FAUNA:

11. Describe types of flora and fauna (land and water), and types of protected flora and fauna.

12. Describe impact of projects on wildlife.

13. Are surveys available describing endangered biological species that might be threatened by the proposed small-hydro power plant (SHPP)?

HEALTH:

14. What are local health facilities and are there surveys of communicable diseases in the local communities that could be affected especially during the construction phase of the project?

15. Will imported labour force be checked on communicable diseases?

16. What will be the impact of the project on water-borne diseases and parasites. Especially for those sections of the river that will fall dry during construction periods, or that the project will fully use available river water.

CONSTRUCTION:

17 Provide a list of project activities, including construction, land clearing, land excavation, access road construction, transmission line installation, etc.

18. Provide on estimate of the size of the area used for the project activities, including the main structures, roads, transmission lines, and penstocks. Indicate what percentage of the area, allocated for the project, will be restored to conditions prevailing prior to commencement of construction activities. Restored land should

not be fenced and/or considered the project developer's property.

19. List the heavy equipment to be used in the project construction activities.

20. Describe the impact of this equipment on existing roads and measures to be taken to repair any damage.

21. Describe in a general way the various building materials, mainly construction aggregates, to be used (type, quantity or volume), where these materials are to be found and how collected, their means of being transported to the site and their storage and the final disposal system for any wastes generated.

22. Describe the environmental impacts on the sites where these materials are collected, or quarried.

23. Describe how the hydro power plant will be operated, including any special environmental management controls.

24. Describe the types of equipments used in operating the generation system, including giving the plant's capacity rating.

25. Describe fully the environmental impact of the construction activities.

26. Describe the number of construction workers and the education and expertise requires, and whether or not these workers can be hired locally, where they will reside during the construction and their ages and sex.

27. Describe any training that will be given to workers.

28. Describe the number of operating employees and the education and expertise requires, and whether some people can be hired locally.

29. Describe any training that will be given to operators.

30. Describe noise intensity around the power house, how much it is over ambient noise levels and what measures will be taken to mitigate a noise problem.

31. Describe any existing activities adjacent or near the project that could have a positive or negative effect on the project.

32. Do project plans provide for an adequate buffer between project (construction and operation) and any conflicting adjacent land use? What mitigation is planned for such cases (vegetative screening)?

CULTURAL - ECONOMIC - AESTHETIC IMPACTS

33. Describe population profiles (age, sex, education, religion, income, health), altitude and perception of the community toward

development, condition of the socio-cultural heritage and other relevant information.

34. Are there surveys for the area's archaeological, aesthetic and cultural resources that might be threatened by the hydro-power plant?

35. Describe cultural impacts (including on local religion, on local archaeological treasures and loss of riparian on vegetation used for artisan or medicinal purposes).

NOTE :

It should be noted that not all the impacts mentioned above will prevail in all the smalll hydro projects under consideration. Even so, the Environemtal Review should state that impact does not exist. Some other impacts could also be quite positive and should be mentioned as such.

GUIDELINES FOR SOCIAL IMPACT ASSESSMENT OF SMALL HYDRO PROJECT

These guidelines identify points that would be reviewed in the social impact screening of small-hydro projects, including related works on civil, mechanical and electrical engineering to provide water, diversion dams, power houses, water intake structures, water conveyance structure, electrical system, grid interconnection, buildings and structures to house related offices and maintenance staff, and access roads to these structures.

Key Words **SIA** **Social Impact Assessment**
IPDP **Indigenous People Development Plan**
PAP **Project Affect Persons**
RAP **Resettlement Action Plan**

PROJECT PLAN AND LOCATION:

1. Provides a general project plan and its schedule and provide two maps drawn on scale, one of the general areas and the other for the project area.

2. Give details of the proposed location of the project. State/ District/Village, etc.

LAND DETAILS:

3. Give the total area of the land required for the physical components of the project.

4. Describe the type of land (e.g., agricultural, residential), the crop, vegetation, etc.

5. Ownership of land (government, Private), traditional population, encumbrance details, etc.

6. Current land use in the proposed area and surroundings.

7. Possible land use change expected after project implementation.

8. Proposed strategy for procurement of land - Government lease, direct purchase, negotiated settlement or compulsory acquisition, etc. Give detailed description of the area falling under each category.

PEOPLE AFFECTED:

9. Number of people and families affected (give details as necessary).

   (a) including those loosing homes, land, or livelihood;
   (b) those deriving benefits (employment, electricity, etc.) from the sub-project; and
   (c) those who may be adversely affected by the imposition of an external population or local cultures (e.g. woman, tribals).

10. Describe the nature of impacts expected (positive and negative)

11. Identify and describe cultural impacts, if any, in the population due to the land acquisition and the proposed project.

REHABILITATION AND RESETTLEMENT PLANS:

12. Establish the need for rehabilitation and resettlement based on the above descriptions and any other issues.

13. Explain the actions taken and proposed for the above so as to ensure restoration/improvement of living standards.

14. Describe the national and State legal framework existing quoting the relevant provisions and applicability for the specific case as identified above.

15. Give a flow chart of actions for the entire RAP along with the time frame and identified responsibilities of each player such as the developer, Government agency, etc.

16. Provide the Entitlement calculations for payment of compensation for various losses of replacement value.

PEOPLE'S PARTICIPATION:

17. Existing and proposed mechanisms/efforts for public consultation and disclosure of information. Statutory requirements, if any, for the above may also be explained.

18. Explain how public participation is ensured during the entire project cycle.

19. Mention the requirement of RAP and where appropriate IPDP.

GRIEVANCE MECHANISM

20. Describe the grievance redressal mechanism legally available as well as socially acceptable.

21. Remedies available through Lok Adalats, Village Panchayats, NGOs, etc.

INSTITUTIONAL ARRANGEMENTS

22. Institutional arrangements made for monitoring and implementation of RAP.

23. Manpower, system and costing for the above activities.

24. Please mention whether the estimated costs have been incorporated in the project cost with sufficient contingency.

CONCLUSION

25. Conclude with the overall view with respect to social impacts and Action Taken covering the following points:-

    (i) Register all people to be affected by land acquisition
    (ii) Inform and consult the affected population, and organise appropriate grievance mechanisms.
    (iii) Monitor the formal process of land acquisition and payment of compensation, and provide relevant assistance, if needed.
    (iv) Implement resettlement and rehabilitation of affected people as per approved plans.
    (v) Establish collaboration with local NGOs which represent the developer's employees and their families and other local interest group.

NOTE:

It should be noted that not all the impacts mentioned above will prevail in all the small hydro projects under consideration. Even so, the Social Impact Screening should state that impact does not exist. Some other impacts could also be quite positive and should be mentioned as such.

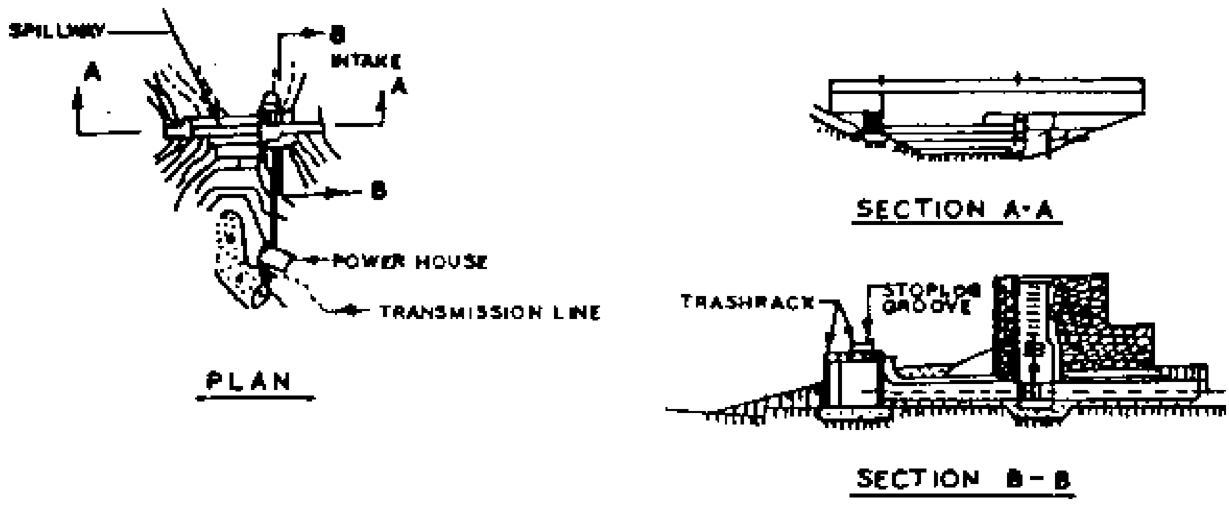


FIGURE 3.1 : TYPICAL ARRANGEMENT OF MINI MICRO HYDEL SCHEME

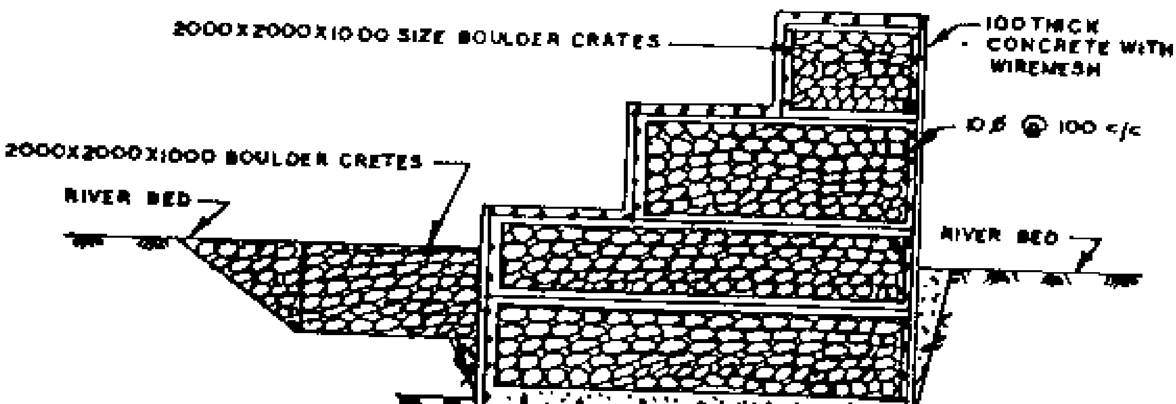


FIGURE 3.2 : DETAILS OF BOULDER WEIR

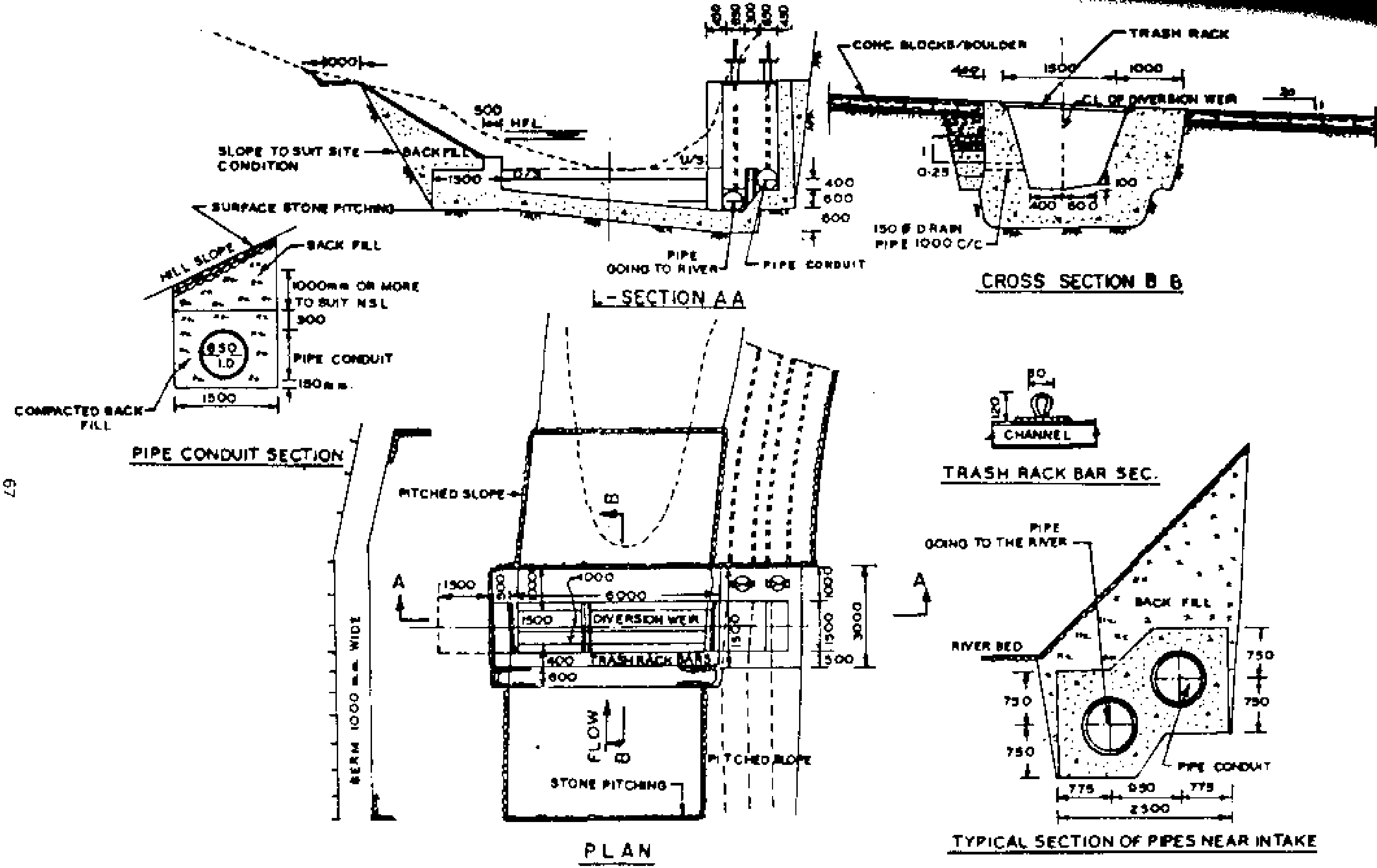
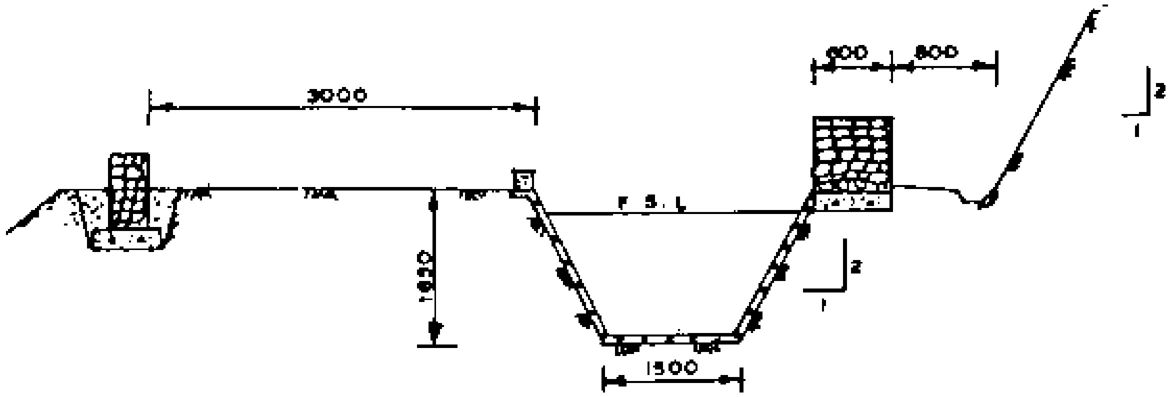
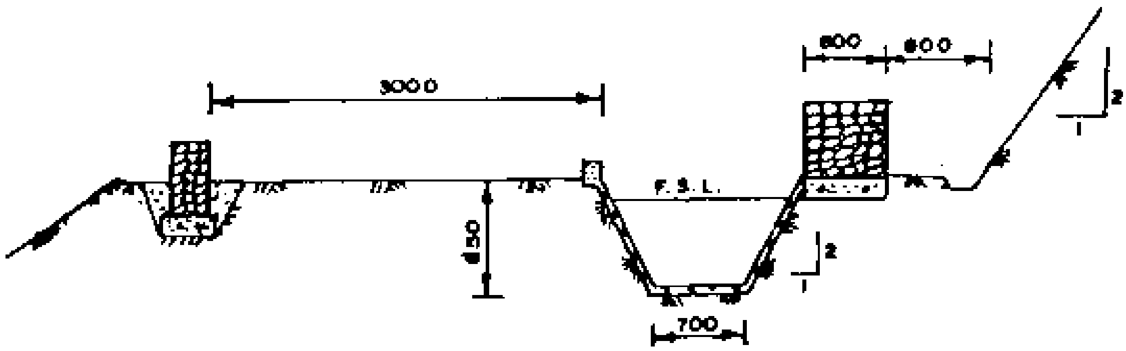


FIGURE 3.3 : TYPICAL LAYOUT OF TRENCH WEIR AND INTAKE STRUCTURE (FOR DISCHARGES UPTO 500 LITRE/SEC)

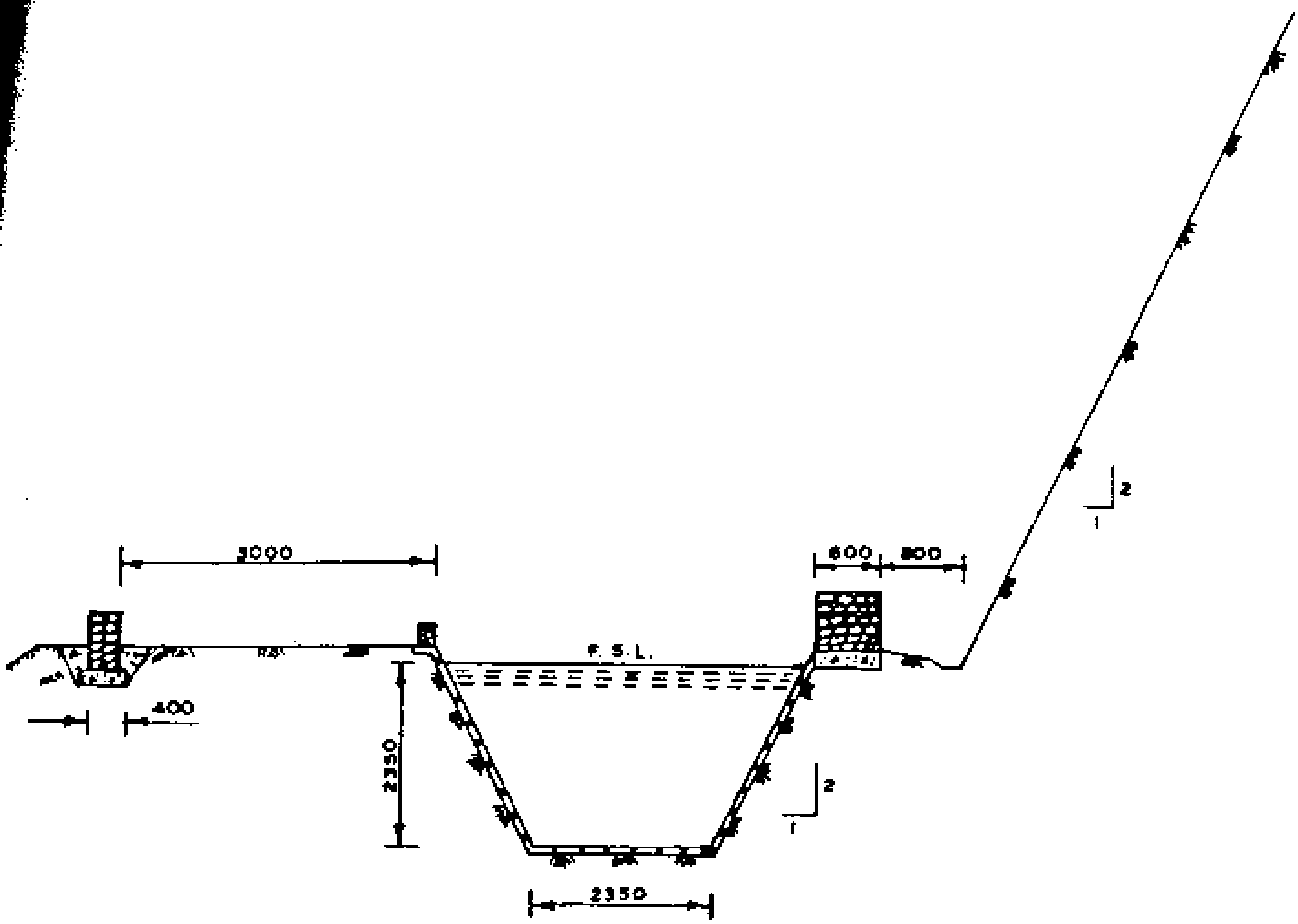


TYPICAL SECTION FOR 5 CUMECS DISCHARGE

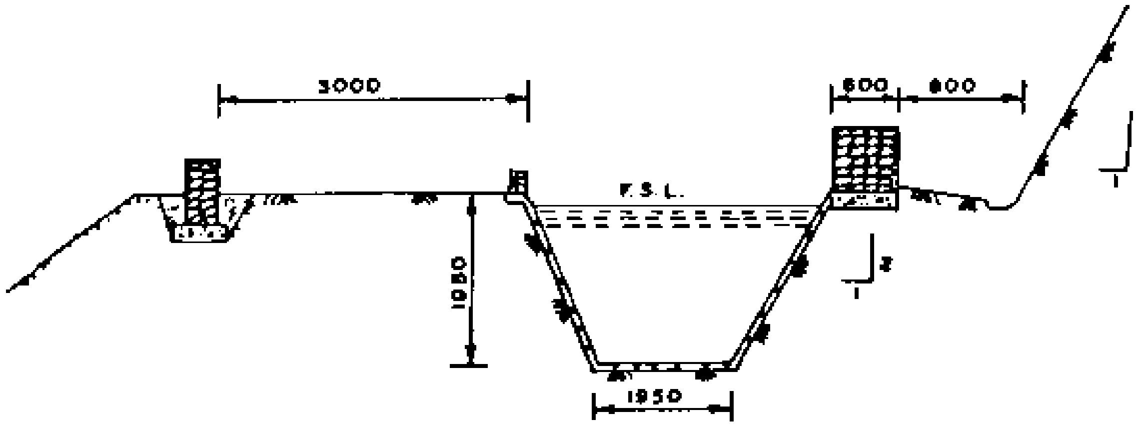


TYPICAL SECTION FOR 1 CUMECS DISCHARGE

FIGURE 3.4 TYPICAL-CROSS SECTIONS OF POWER CHANNEL

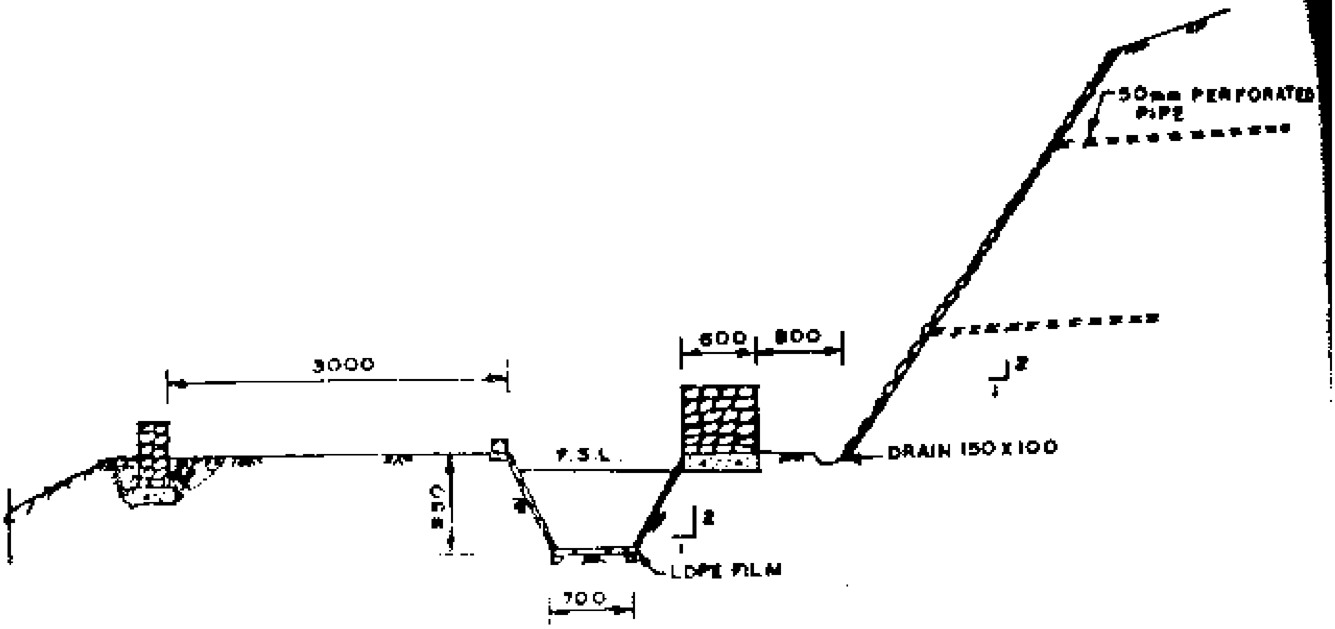


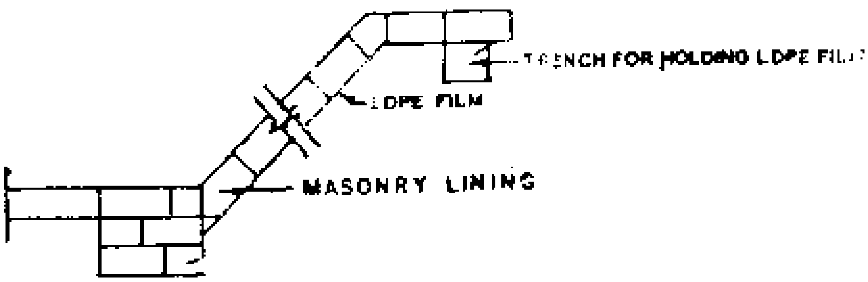
TYPICAL SECTION FOR 12.5 CUMECS DISCHARGE



TYPICAL SECTION FOR 7.5 CUMECS DISCHARGE

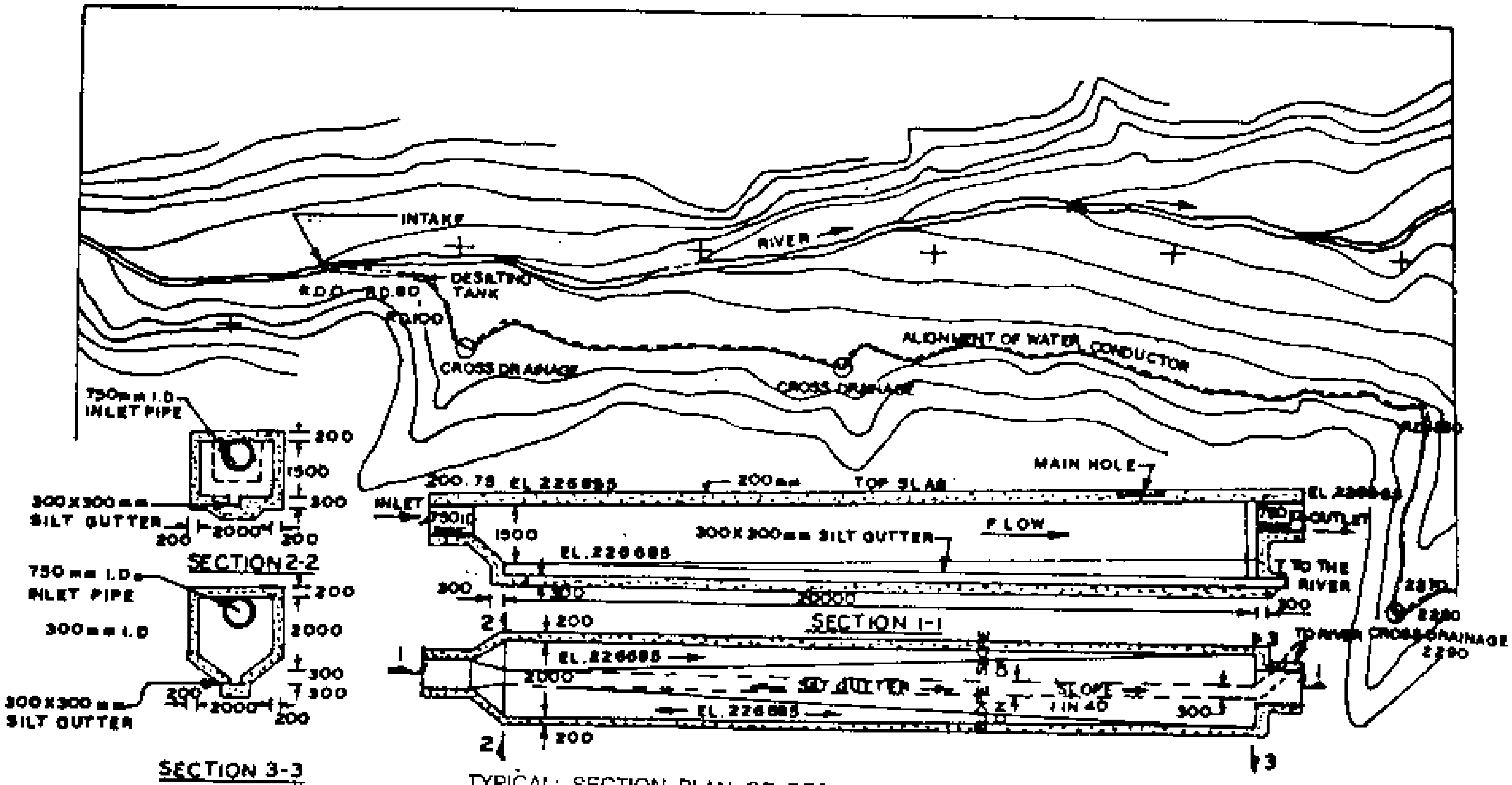
FIGURE 3.5 : TYPICAL-CROSS SECTIONS OF POWER CHANNEL





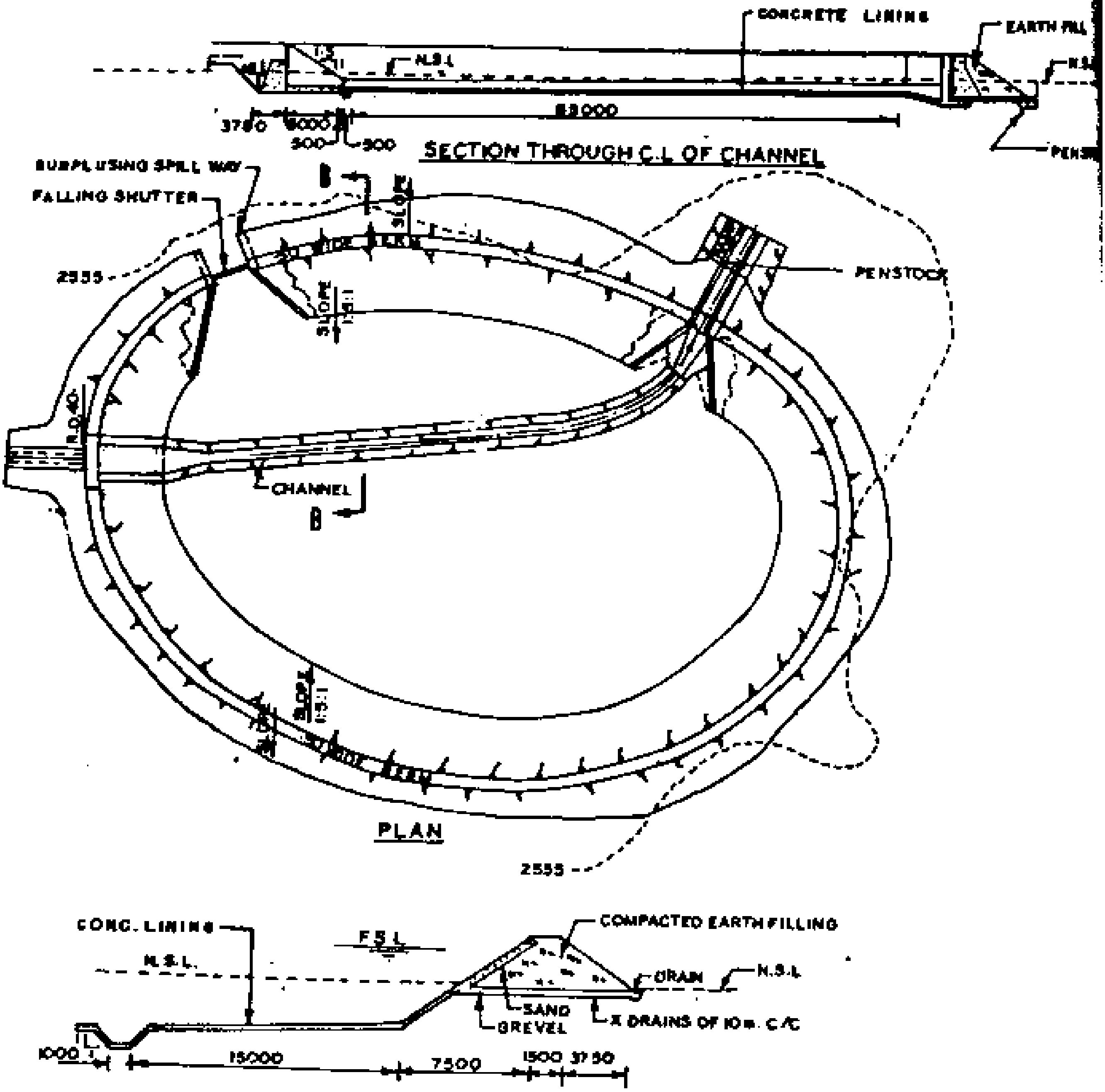
DETAILS OF TILE LINING WITH LDPE FILM

FIGURE 3.6 : DETAILS OF LINING WITH LDPE FILM



TYPICAL; SECTION PLAN OF DESILTING TANK

FIGURE 3.7 : TYPICAL LAYOUT OF DESILTING TANK



SECTION B-B

FIGURE 3.8 : TYPICAL FORE-BAY DETAILS

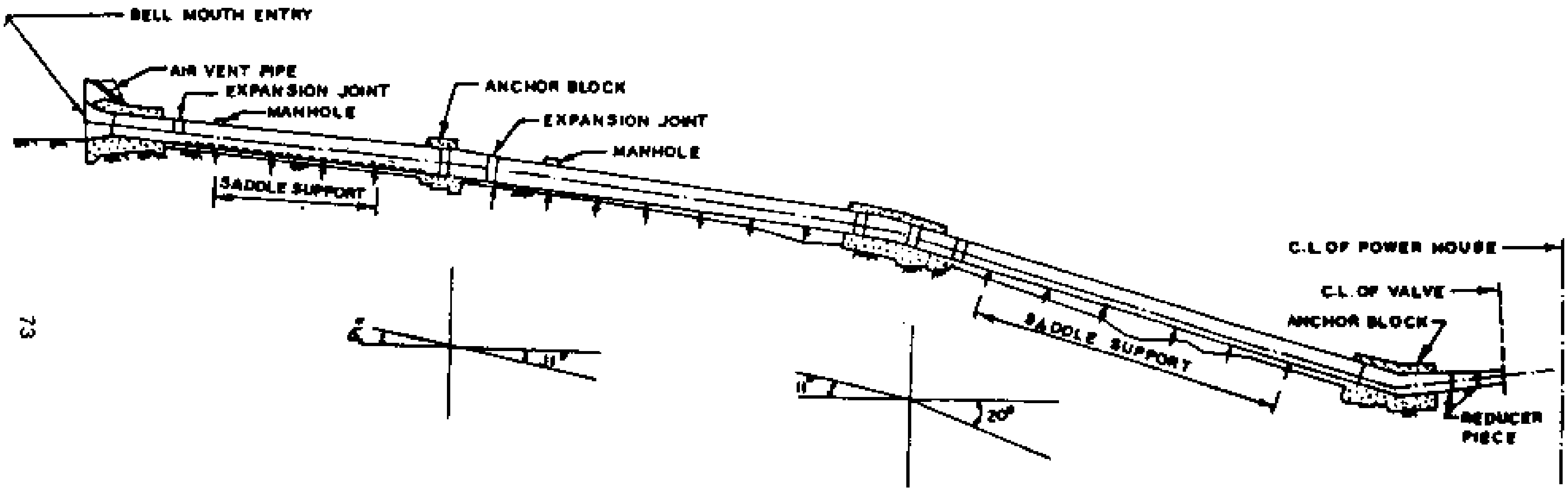


FIGURE 3.9 : TYPICAL L - SECTION OF PENSTOCK PROFILE

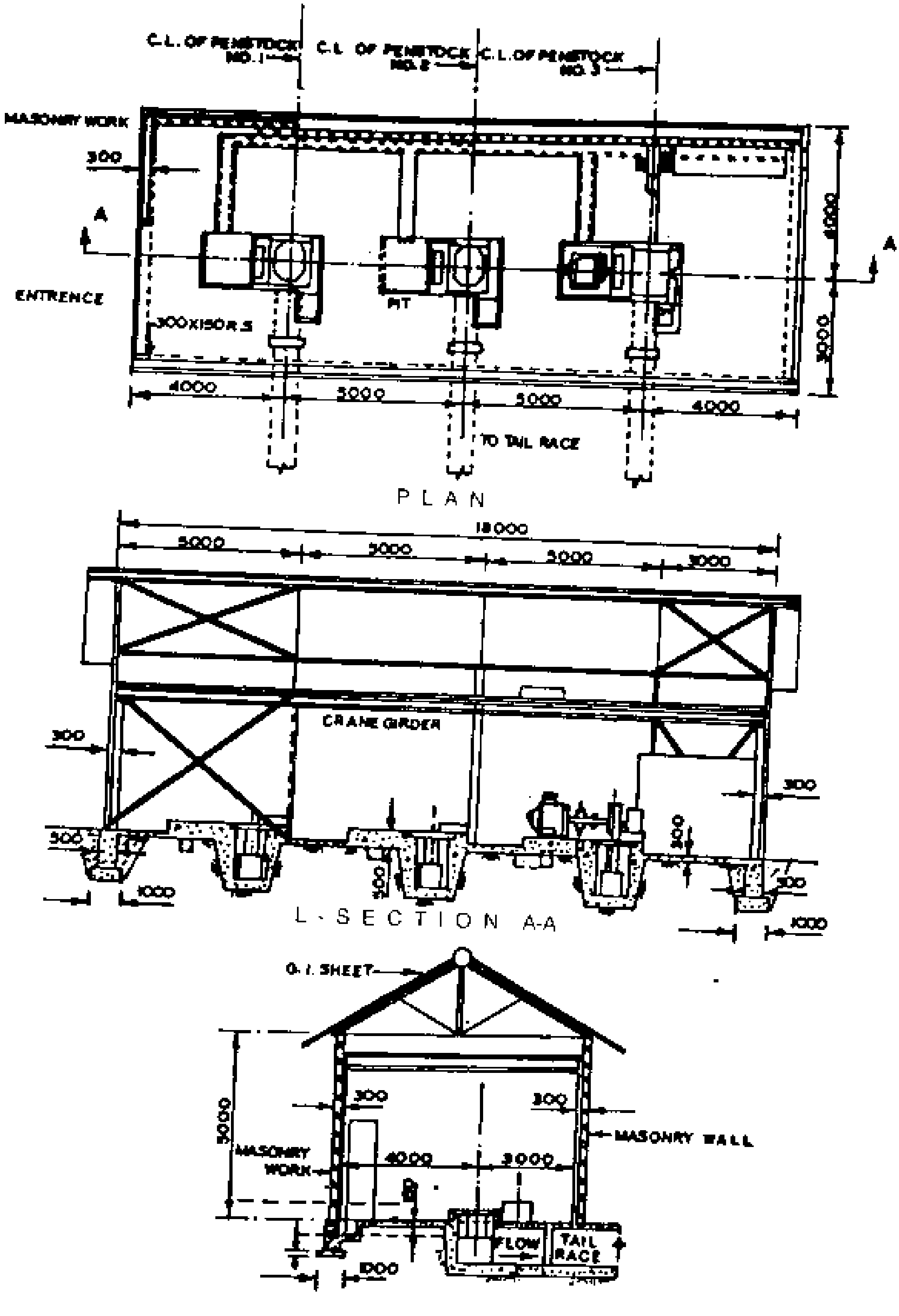


FIGURE 3.10 : TYPICAL LAYOUT OF POWER HOUSE FOR MEDIUM AND HIGH HEAD PROJECTS

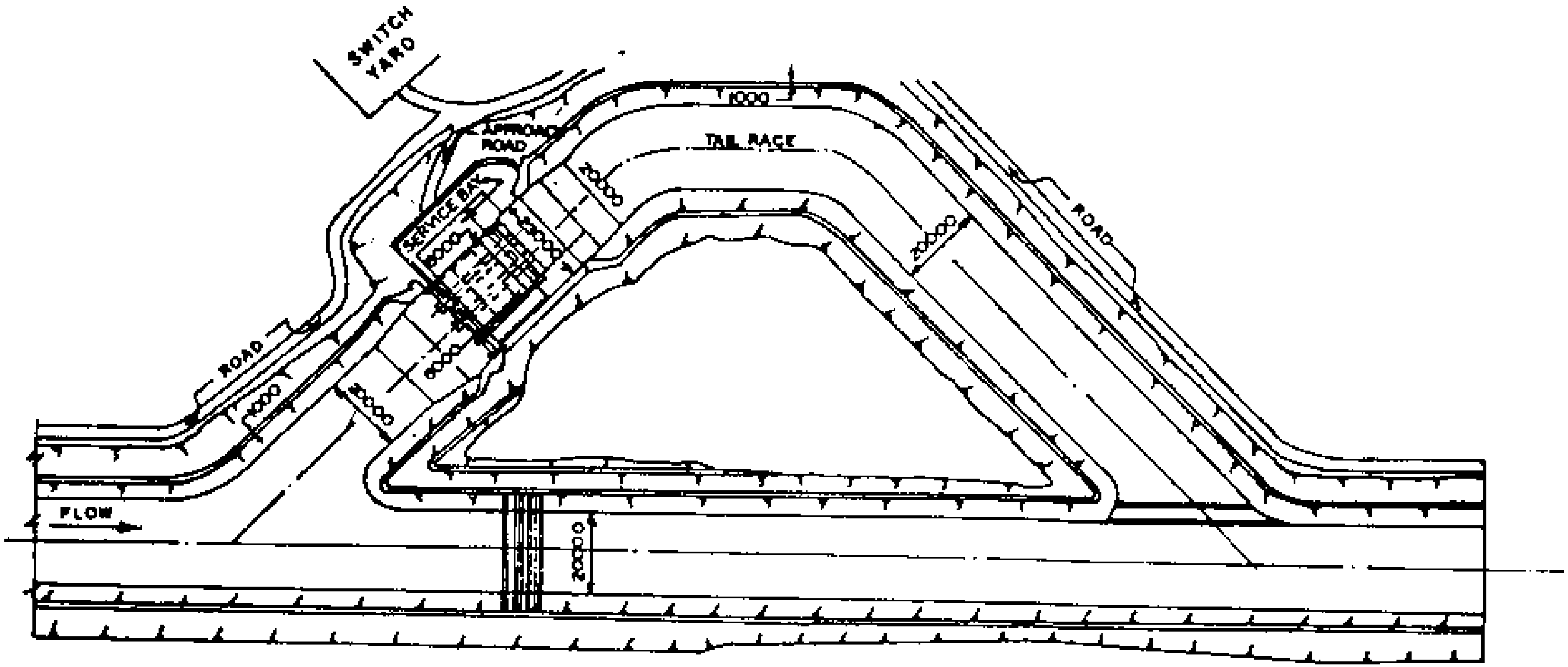


FIGURE 3.11 : GENERAL LAYOUT PLAN OF CANAL POWER HOUSE

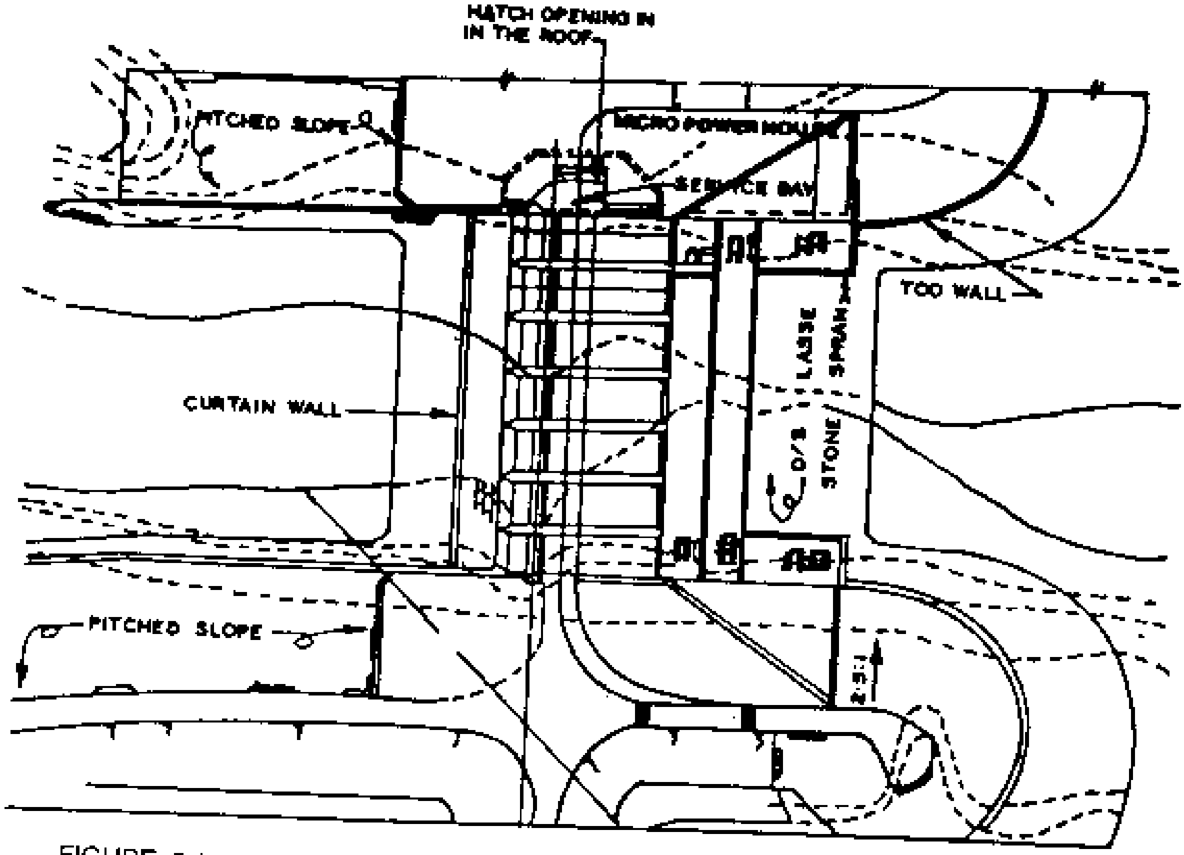


FIGURE 3.12 : LAYOUT PLAN OF MICROHYDEL PROJECT ON THE SIDE OF ABUTMENT OF THE BARRAGE UNDER CONSTRUCTION

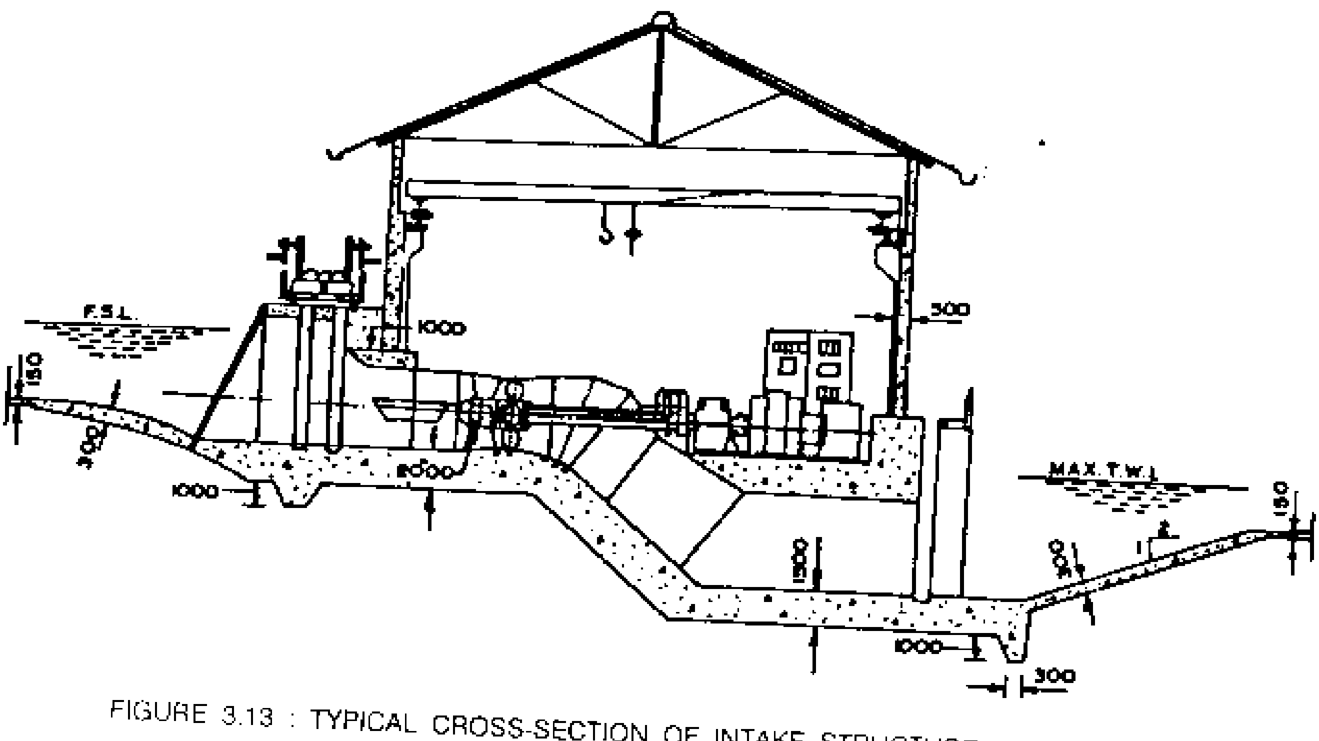
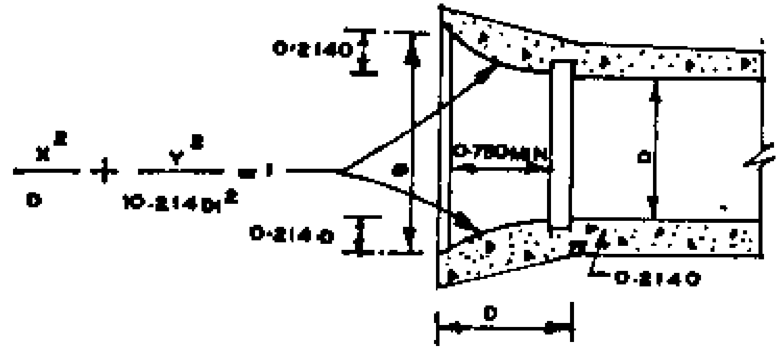
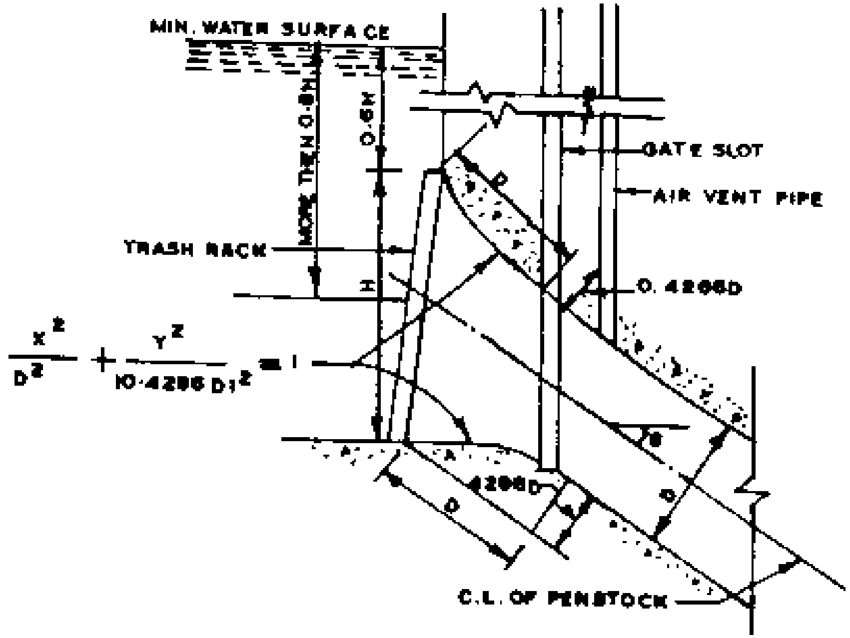


FIGURE 3.13 : TYPICAL CROSS-SECTION OF INTAKE STRUCTURE AND POWER HOUSE



PLAN



ELEVATION

S.NO.	DIAMETER OF PENSTOCK (D) IN M.M.	HEIGHT OF BELL MOUTH OPENING IN M.M. H = 2D	LENGTH OF BELL MOUTH OPENING IN M.M. = D	MIN. DISTANCE OF GATE SLOT FROM TRASH RACK IN M.M. 0.75D	WIDTH OF BELL MOUTH OPENING IN M.M. B=1.42-87D
1	300	600	300	225	429
2.	1000	2000	1000	750	1429
3.	1400	2800	1400	1050	2000
4.	1600	3200	1600	1200	2286

FIGURE 3.14 : DETAILS OF BELL MOUTH ENTRY FOR DIFFERENT DIAMETERS OF PENSTOCK

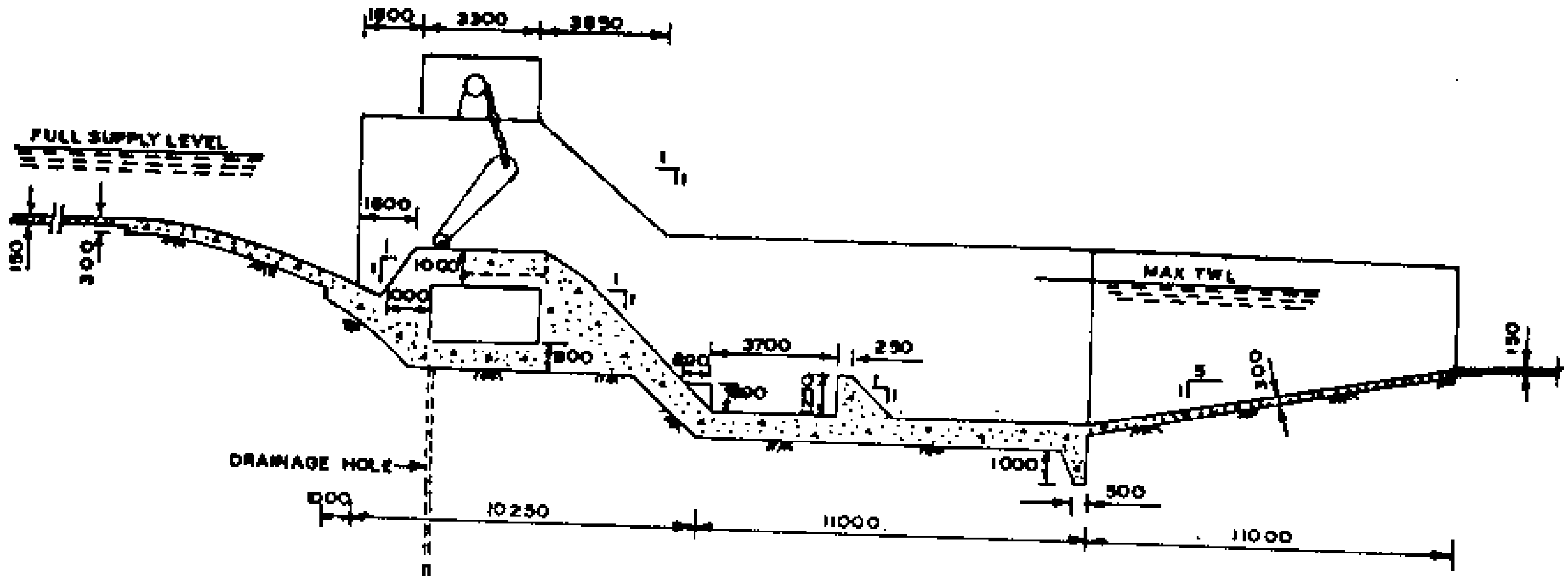
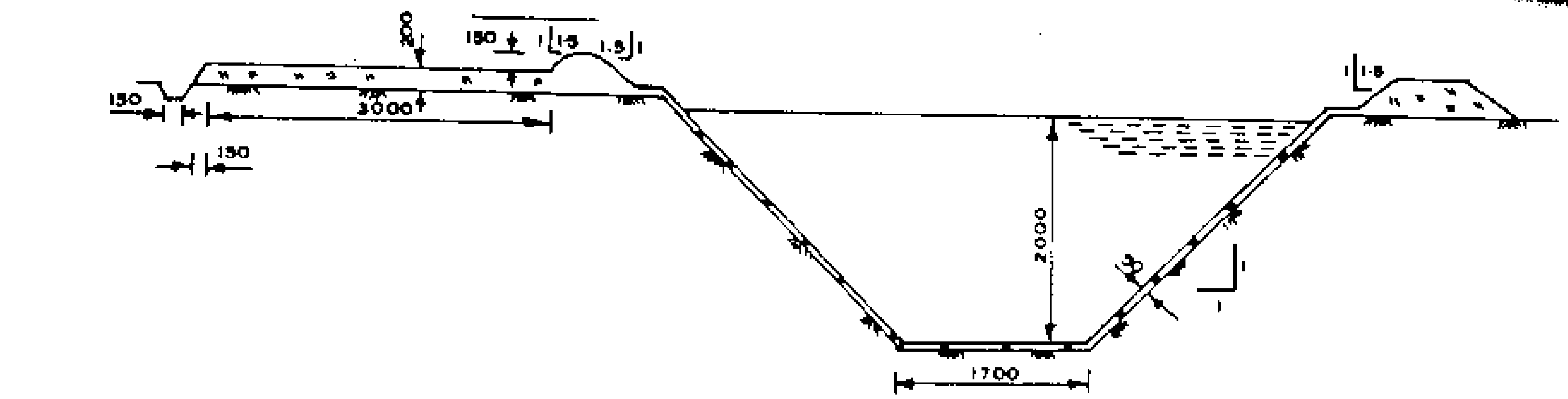
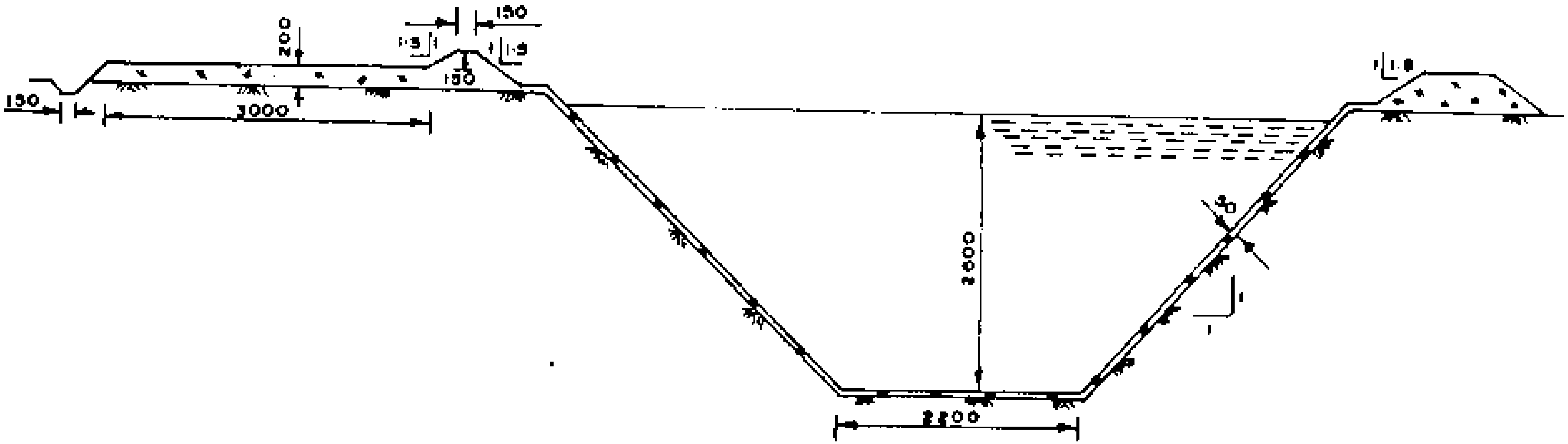


FIGURE 3.15 : SHOWING TYPICAL DETAILS OF FALLING SHUTTERS



DISCHARGE 7.5 CUMECS



DISCHARGE 12.5 CUMECS

FIGURE 3.16 : TYPICAL SECTION OF POWER CHANNEL AND TAIL-RACE CHANNEL FOR 7.5 TO 12.5 CUMECS

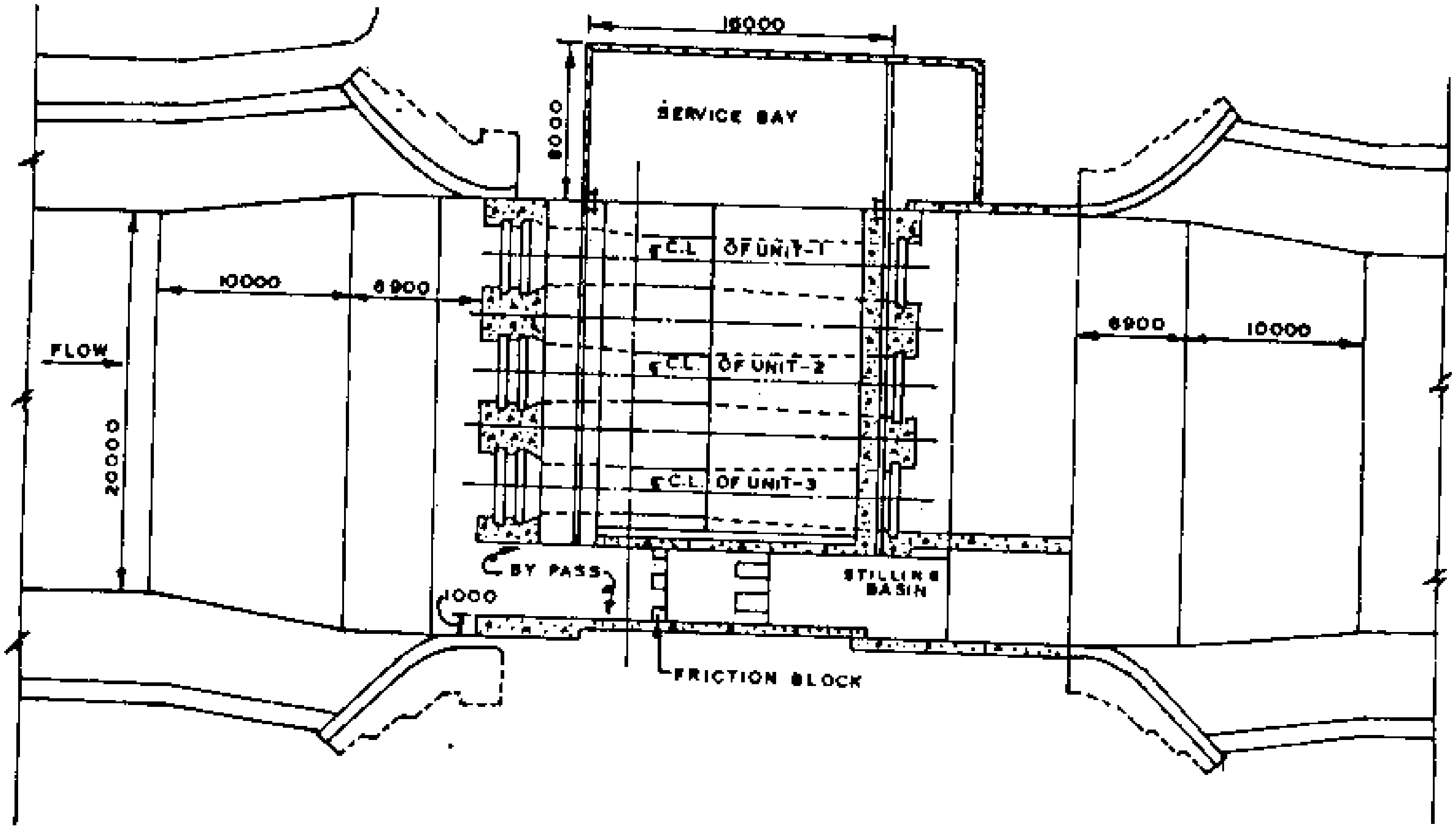
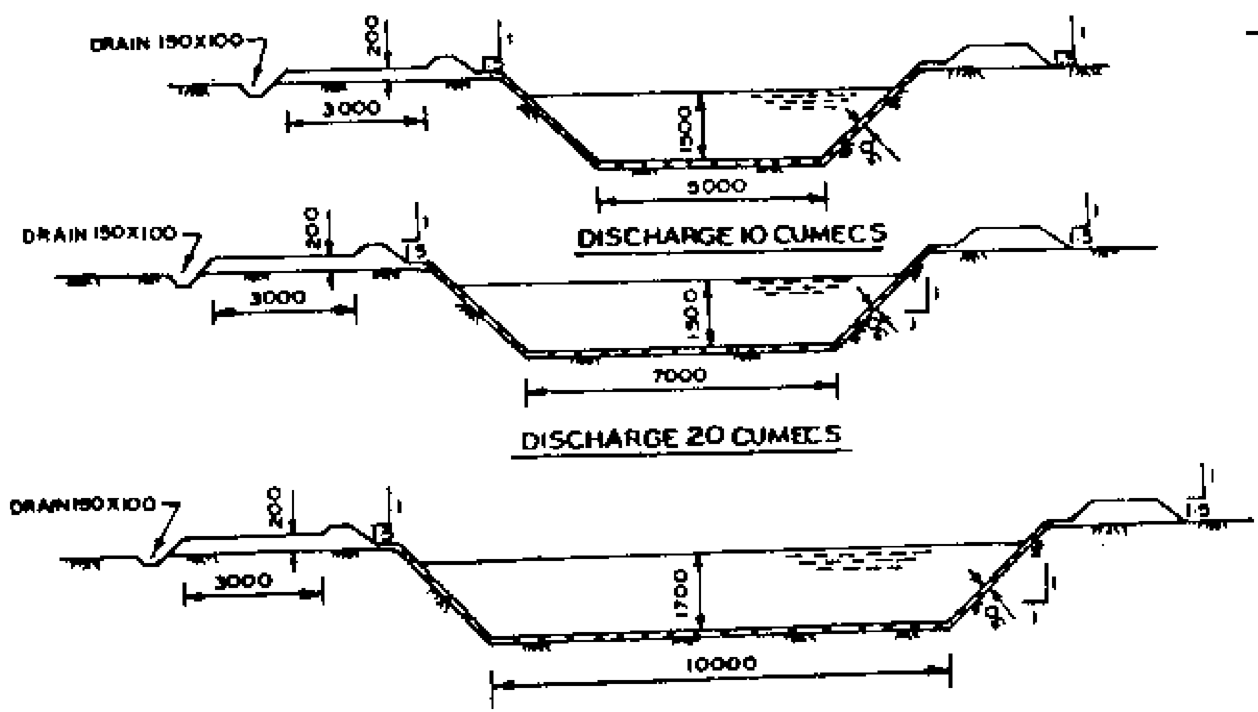


FIGURE 3.17 : LAYOUT OF LOW HEAD CANAL POWER HOUSE



DISCHARGE 30 CUMECS

FIGURE 3.16 : TYPICAL CROSS-SECTION OF POWER CHANNELS FOR LOW HEAD HYDEL PROJECTS

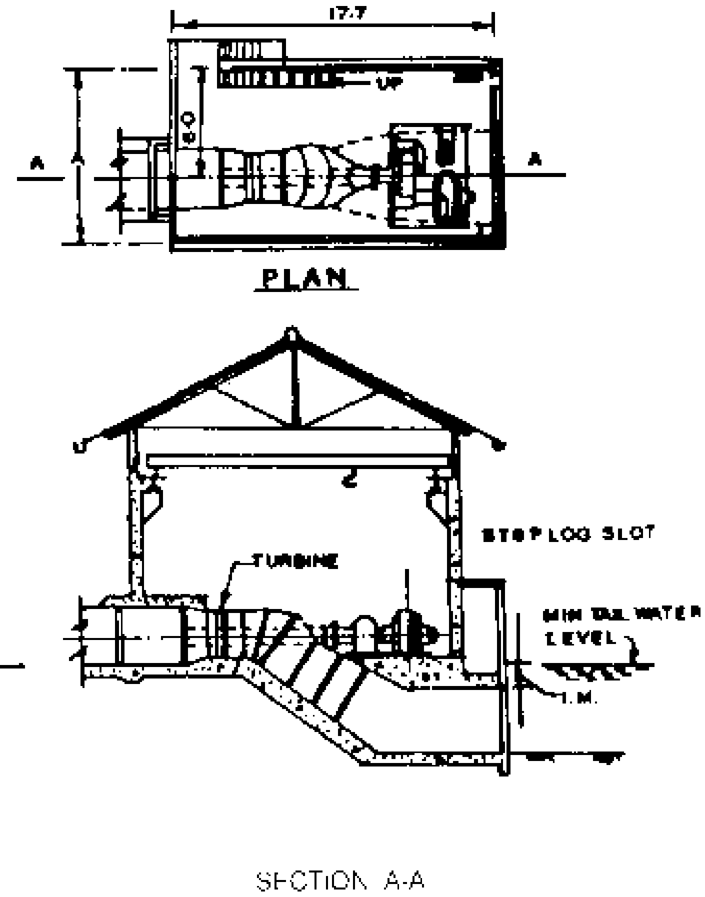
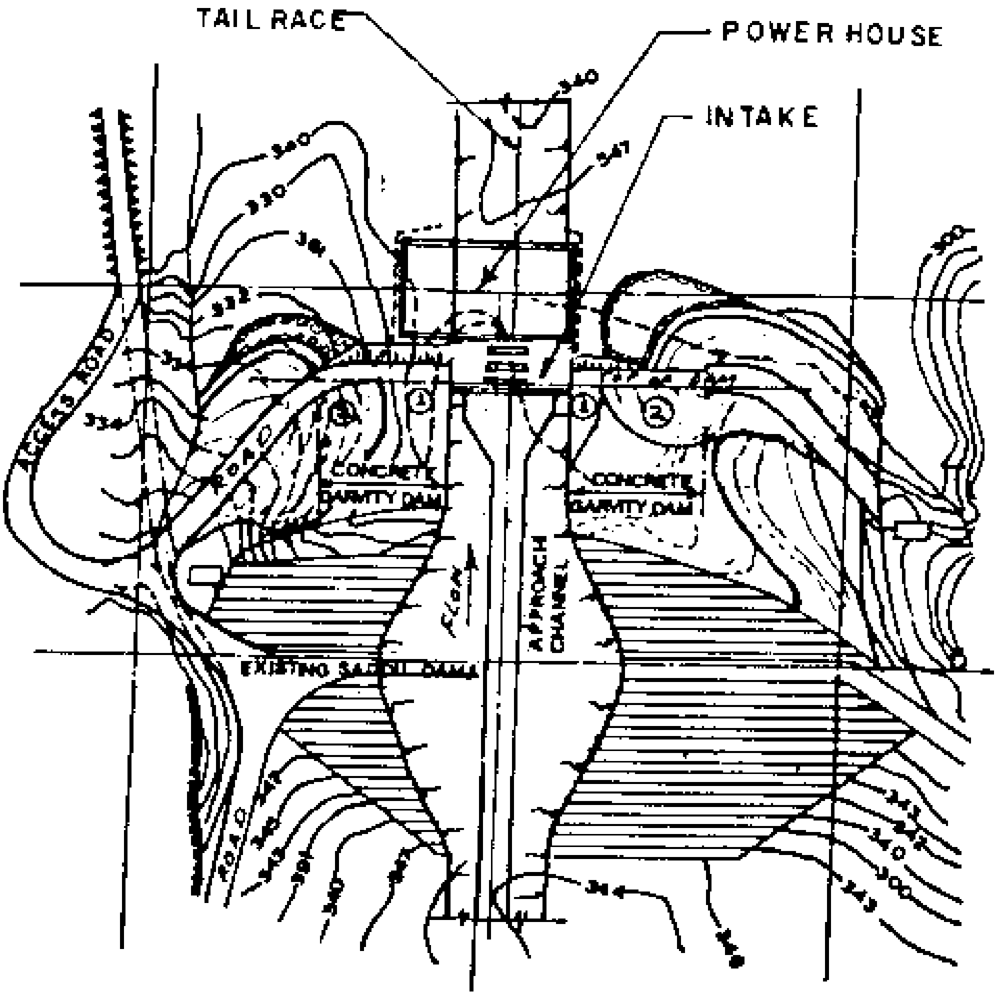


FIGURE 3.18 : TYPICAL CORSS SECTION OF POWER HOUSE



GENERAL LAYOUT

FIGURE 3.19 : SMALL HYDRO ELECTRIC SCHEME

① CONCRETE DAM

② CONCRETE DAM WITH EARTH RAPAROUND

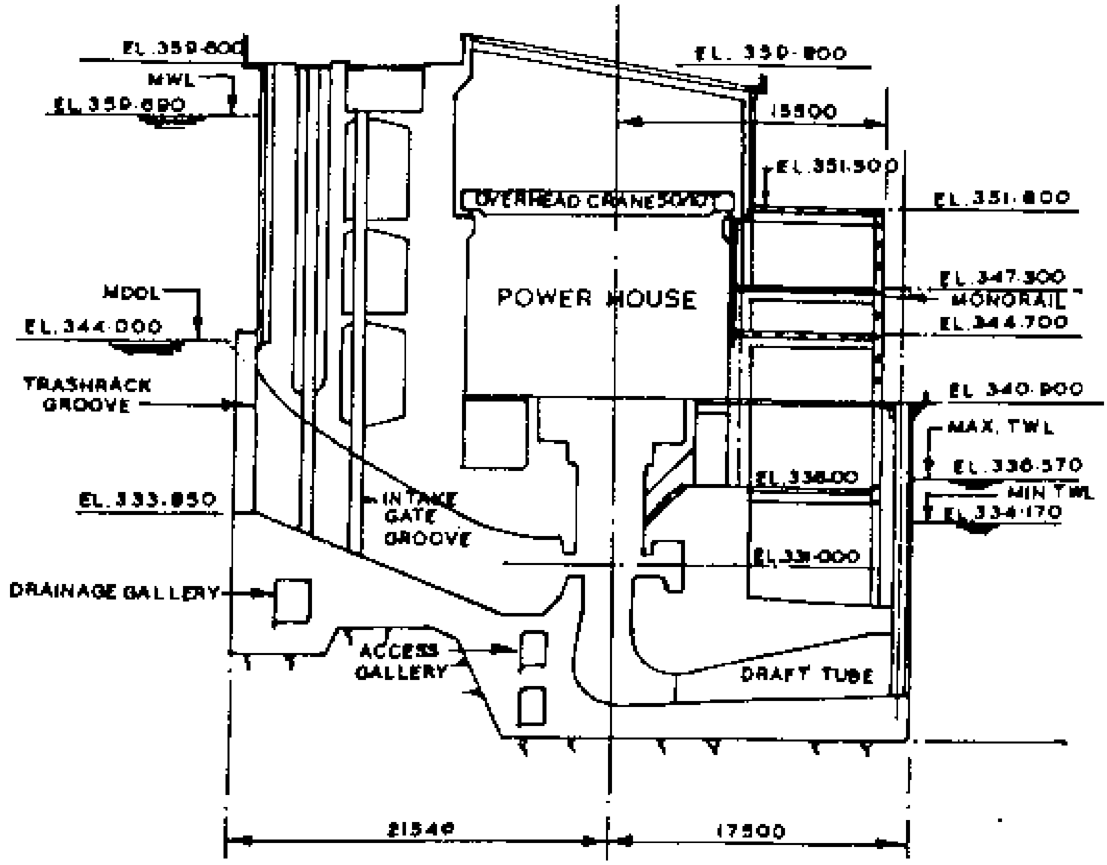


FIGURE 3.20 : POWER HOUSE CROSS SECTION SMALL HYDRO ELECTRIC SCHEME

CHAPTER - 4

STANDARD CAPACITIES AND EQUIPMENTS

4.0 INTRODUCTION

The hydro equipment is usually designed to suit the conditions of head, discharge and topography. The custom built design normally required longer delivery periods apart from its higher cost. In order to get over these difficulties, for ranges encountered for small hydro projects standardisation of electrical and mechanical equipment is required. This is possible as the ratings are low and some sacrifices in respect of performance may be permissible. But the standardisation can be done only to a certain extent as the heads and discharges encountered even for the small hydel projects have a large range requiring a variety of equipment. Standardisation of Turbines in High/ Medium Head where speeds of 600 RPM-1500 RPM are used takes placw with a small sacrifice of effiiciency. In the low head range use of geared drives permit using runner over wider head range and achieve standardisation. A large number of manufacturers in India are producing Generating Plant and Equipment suitable for Small Hydro Projects. A list of such manufacturers is indicated in Annexure 4.1 (refer page 90).

4.1 MAIN TYPES OF TURBINES

With experience over the years, the industry has crystallised the following 3 main types of turbines for use over different head ranges.

Type of Turbine	Class of Head	Head range for large/medium sets (m.)	Head range for small sets (m.)
Pelton (impulse)	High Head	Above 300 m	Above 150 m
Francis (reaction)	Medium Head	30 to 500 m	20 to 200 m
Kaplan (Axialflow)	Low Head	3 to 50 m	3 to 30 m
Special types of above e.g. Tubular Turbine, S-Type Turbine etc.	"	3 to 40 m	? to 25 m

In addition to above types, which are manufactured by most turbine anufacturers, some types of turbines are made by a few manufactures. These are:-

Turgo impulse (High Head) 40 to 200 m - usually for small sets

Cross flow (Low Head) Very small low head application

Further, pipe type axial flow turbines of low head are made in a number of variations e.g.

(i) Upstream bulb
(ii) Down stream arrangement
(iii) 'S'-Type arrangement with geared generator
(iv) Rim generator drive
(v) Rim generators (Straflow)
(vi) Inclined axis arrangements

No general advantages can be attributed to any of these arrangements and the merits will have to be considered in individual cases.

In case of vertical axis scroll low head Kaplan machines, Siphon setting is also possible.

4.2 BASIC FACTORS OF STANDARD DESIGNS

4.2.1 Technical Factors of Hydraulic Design of Water Turbines

The main parameters determining the performance of a particular turbine runner are: hydraulic design of the runner, head, discharge, characteristic dimension (Diameter) and speed. The hydraulic design is developed by the designer to give efficient performance for a selected value of head and discharge and it will have a particular diameter and speed - which should be a synchronous speed for large machines.

Now based on principles of turbine homology, the same hydraulic design of runners will give equally good performance if one or more of the other factors are changed, but maintaining inter-se relations of homologous conditions. Thus, the same runner will give a higher output if operated at a higher head provided the speed is changed to suit. It will of course take higher discharge to get the required energy output.
Keeping in mind the above principles, one diameter runner of one design of turbine can be used over a range of combinations of head and discharge. A range of combinations of head and discharge can thus be covered with a few sizes of turbine runners in slightly less then the best way. The following position will be applicable:-

(i) The optimal speed for the application may not be synchronous; this can be overcome in cases where geared generator drive will be used.

(ii) In case however, direct drive is being used there may be a small sacrifice of efficiency which could be acceptable if there is overall economy of time and cost.

The above in essence describes the reasoning, basis and extent of standardisation that is done in case of small H.E. Generating units.

4.2.2 Generators

If geared drives are applicable, standard speed generators can be used off the shelf, taking care to see that runaway speed is matched. Brushless exciters are appropriate. If direct drive generators need to be applied, again speeds for small sets will work out to 600,750,1000 or 1500 rpm. This will be available from standard manufacturing ranges.

4.2.3 Preliminary Check Chart for Turbine

A consolidated chart giving scope of application of different types of turbines over relevant range of head, discharge and output is indicated in Annexure-4.2 (Appendix 1).

Catalogue information as provided by a few manufacturers in India giving information of runner diameter, speed, head and discharge is enclosed in Appendix-4.2 to Appendix 4.9. Most of this data is taken from CBI&P Publication No.175 - Small Hydro Stations Standardisation. In addition, some new information obtained from manufacturers now is also included. A list of the tables is included at the beginning for easy reference. It is to be emphasised that the information in these charts from some manufacturers is only typical for enabling designs.

The diagram in Appendix 1 of the Anneuxre 4.2 shows the combinations of head discharge at any site on the basis of which a particular type of turbine - such as Kaplan, or Francis or bulb, will be appropriate to be used. Thus it can be seen from the diagram that a block marked out near the right bottom corner shows that for heads from 60 to 500 m and low discharges from lowest values like 0.05 m^3/sec and upto 2 m^3/sec, Pelton turbines are the right choice. Going down to somewhat lower heads down upto 15 m and for higher discharges, francis turbines will be employed. Near the top left hand corner of diagram which covers lowest heads and highest values and discharges is the application range for conventional Kaplan or its variants like bulb turbines, S-turbines, bevel gear turbines etc.

The use of the catalogue information of Manufacturers given in Charts in Appendices 2 to 10 (refer pages 93 to 102) will be clear by taking one example say from Appendix 2. This table for turbine range of BHEL manufacture. There are 5 columns in the table which have the diameter of the runner of the S-Type turbine at the top, for which particulars are given in that column. Below that, the rows shows the head in meters and the range of output and discharge which could be got if this particular runner was to be used. Thus if we look at the 5 m row, we could obtain a turbine output (Pt) in the range of 369 to 578 kW with a 1500 mm dia runner, and the discharge used will lie between 9.37m³/sec to 14.69 m³/sec. The other tables in the Appendices have similar data except that these give only a single value of output of machine for each listed value of head. One manufactucturer, Best and Crompton, who make turbines to Beacon-Neyrpic design has also given a graph supplementing their tabular data. They can arrange their turbines in 3 variants - a conventional S, an upstream elbow and a vertical pipe arrangement called "Saxophone" by them. These variants apply for very small machines.

As already mentioned, the preliminary information of this nature whether taken from this reference or from manufacturers Catalogue would be sufficient for preliminary designs. Definite designs should be based on information gathered from likely suppliers.

The sketches included in the different Appendices will help in making preliminary layout drawings of the power station.

Equations of turbine homology - The following equations relate to the various parameter of turbine viz Diameter 'D', Head 'H', Discharge 'Q', Speed 'n' and Output 'N'.

Output 'N' (kW) = 9.81 ηQH (where n is unit efficiency)

For same machine working under a different head H_1

$n_1 = n\sqrt{H1/H}$, $Q1 = Q\sqrt{H1/H}$ and $n1 = n\sqrt{H1/H}$

and for 2 geometrically similar machines of diameter, D1 & D2 operating under the same head H

$$n_2 = \frac{n1D1}{D_2},\quad Q2 = Q1\left\{\frac{D_2}{D_1}\right\}^2 \text{ and } N_2 = N_1\left\{\frac{n_1}{n_2}\right\}^2$$

4.2.4 Utilisation of Information Relating to Standard sets for Project Planning & Formulation:

The method for working out the optimum installed capacity at any SHP site has been discussed in Chapter-1, by which the number and rating of generating units needed in the particular project would be found. The rating of unit so found should however then be compared with the output at similar head from a turbine in the data of manufacturers, and marginal adjustment made, if felt to be necessary. The particulars can be firmed up by getting more specific information regarding output and dimensions for similar rated machines from manufacturers. The basic guiding dimension viz the diameter of the runners could also be found with the help of standard reference books. After obtaining or computing the turbine dimensions by any of these ways the preliminary design of Power House can be made.

It may be mentioned that minor adjustments in energy potential may be called for after this step. Later, more specific information about rating, output, dimensions etc. could be obtained from manufacturers to firm up designs. It is to be noted that if a query is made of manufacturers without doing preliminary studies, the results could be vague replies.

4.2.5 Specifications for Generating Units:

After crystallising the number, type and rating etc. of the generating units, specifications for procurement of generating plant can be made.

One important caution is however necessary: since the output of 'Standard' turbines of different manufacturers may vary marginally, it is desirable to allow flexibility to them to quote for nearest standard set. The cost/benefit of such marginal variations may be covered in evaluation of tenders.

4.2.6 Guidelines for Specifications for Generating Units

Specifications for generating Plant and equipment for small H.E. Projects should, as mentioned above, be made only after preliminary designs of the project have been made. This will enable a clear idea being given in the specifications regarding the hydraulic system with which the plant will have to work, the consequent picture of head, head variation, pressure rise, surges, tail water conditions, operating requirements etc.

The particulars included in the specification eg. Guarantees, penalties, delivery, transportation etc. should be in harmony with the practice to be adopted for procurement of equipment and works as discussed in Chapter-9 of this manual. The mainly technical portion of the specifications for generating plant and equipment would contain provisions relating to following aspects:-

(i) General conditions of contract - This part of the specifications deals with technical provisions of a wider nature such as standards, Patent rights, changes in order, default, transport, insurance etc. This section of specifications may also contain a description of the project and its hydraulic and electrical system, and also provisions which may be applicable to related technical matters of different suppliers.

(ii) Special conditions of contract - This section is introduced to give provisions on quotation of prices, price evaluation, security deposits, warranty, payment, penalties etc.

(iii) Specifications and schedules of requirements - one or more sections are included to give adequate technical particulars of the turbine, generator, switchgear and other items of plant and equipment required including rating, numbers, type, operating condition and requirements, tests, guarantees and spares etc.

Comprehensive guidelines for the above mentioned aspects have been prepared by IREDA and CEA/CBI&P and should be utilised in preparing procurement specifications for generating Plant and equipment for small Hydro Electric Projects. The following documents may be referred to in this respect:-

a. **Model Tender Document** for Small Hydro Power Developers - Procurement of electrical and mechanical equipment - IREDA - Particularly for items (I) & (ii) mentioned above.

b. **Small Hydro Stations Standardisation** - Publication No. 175 - Central Board of Irrigation and Power - particularly for item No. (iii) above.

c. **Guidelines for Small Hydro Power Developers** - Preparation of Detailed Project Report and Selection of Technical Designs and Specifications - General guidance on layouts and schemes and specifications for equipment. IREDA publication.

The publication at No.(b) above, contains comprehensive material on purchase specifications for turbines, generators, transformers, switchgear associated equipments, related control and instrumentation etc. and can be made use of quite directly.

MANUFACTURERS/SUPPLIERS OF HYDRO ELECTRIC

Machinery in India

(An Indicative List)

No.	Indian Manufacturers/Suppliers	Foreign Collaborators
1.	M/s Larsen & Toubro	Voith, Germany
2.	M/s Flovel (P) Ltd.	Sulzer, Germany
3.	M/s Bharat Heavy Electricals Ltd.	-
4.	M/s Tata Projects Ltd.	-
5.	Triveni Engineering Works Ltd.	ESAC, France; Lito Stroj, Slovenia
6.	M/s Jyoti Ltd.	-
7.	M/s Boving Fouress (P) Ltd.	Kvamer Boving, U.K.
8.	M/s Beacon Neyrpic Ltd.	Neyrpic, France
9.	M/s Voest Alpine India (P) Ltd.	Voest Alpine, Austria
10.	M/s Asea Brown Boveri Ltd.	Asea Brown Boveri, Sweden
11.	M/s Punjab Power Generating Machines Ltd.	Voest Alpine, Goesler, Austria
12.	M/s Steel Industries Kerala Ltd.	Goesler Gmbh, Austria.
13.	M/s Batliboi	Gugler, Austria
14.	M/s DLF Industries Ltd.	CKD Blansko, Czech
15.	M/s Technip Ganz Machinery India (P) Ltd.	Ganz, Hungary

INFORMATION ON SMALL TURBINES

***(Source:** CBIP Publication 175 – Small Hydro Standardisation and Additional Data from Manufacturers)*

LIST OF DATA SHEETS

Appendix 1 – Range of Application of Different Turbine Types-Sulzer Flovel.

Appendix 2 – BHEL-Standard Tubular Turbines

Appendix 3 – Flovel-Standard Tubular Turbines - Semi Kaplan
Standard Tinilar Tirnomes - Full Kaplan

Appendix 4 – Jyoti-Standard Tubular Turbines

Appendix 5 – Flovel Standard (Axial Flow) Rim Drive Turbine

Appendix 6 – Best & Crompton-Kaplan Turbines Elbow Type

Appendix 6B – Application Chart for above

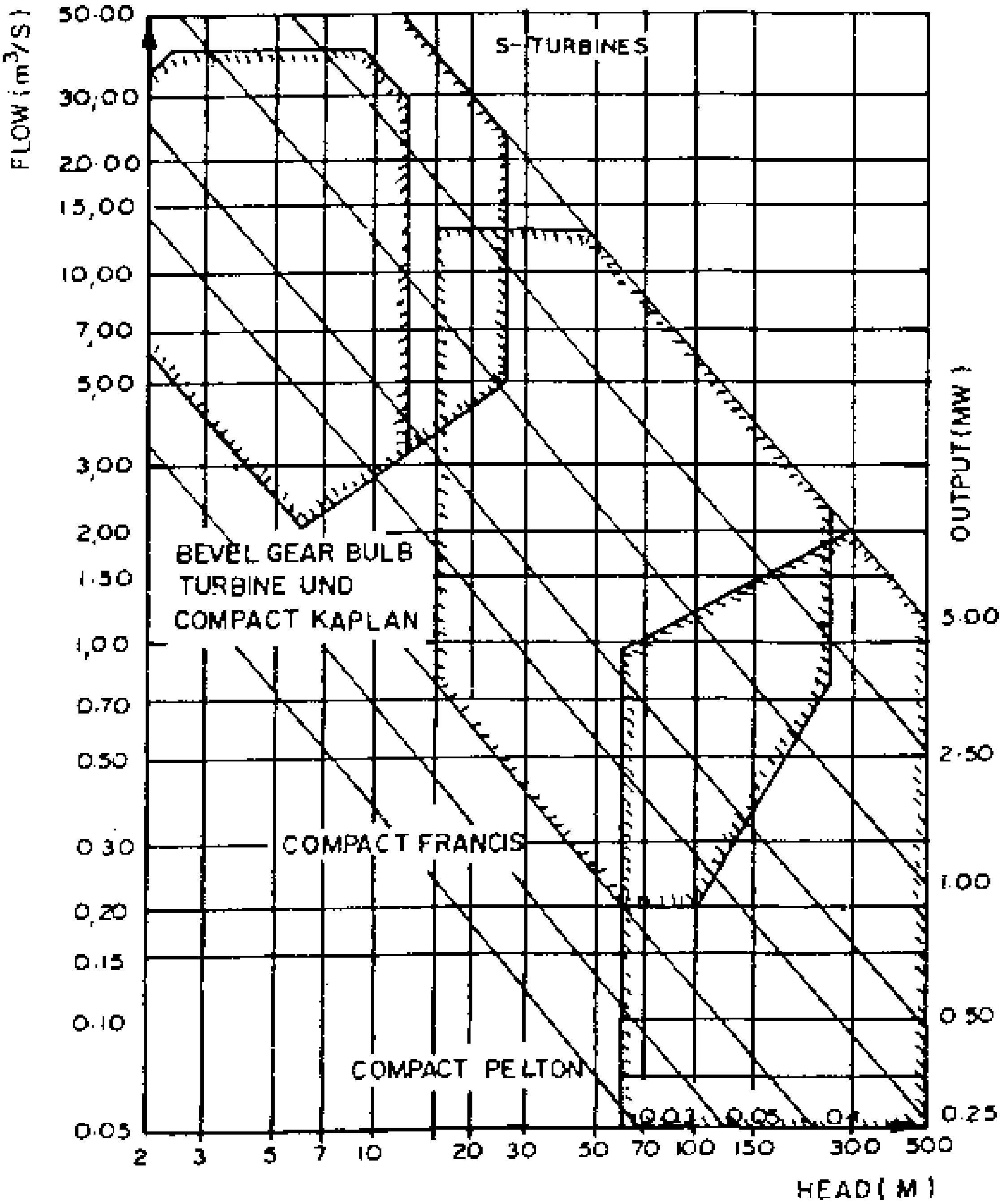
Appendix 7 – Flovel-Standard Francis Turbines (Spiral Casing Type)

– Jyoti-Standard Francis Turbines

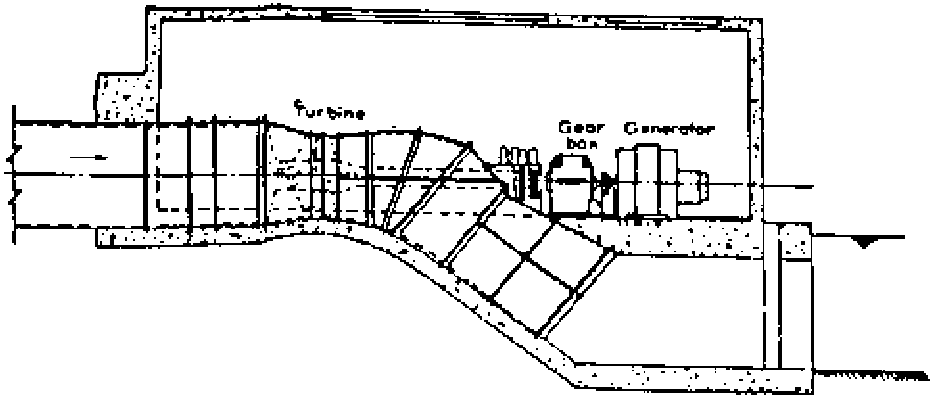
Appendix 8 – Flovel-Standard Pit Type Francis Turbines

Appendix 9 – Flovel-Standard-Open Flume (Axial Flow) Turbines

Appendix 10 – Jyoti-Standard Pelton Turbines
Jyoti-Standard-Turbo Impulse Turbines



RANGE OF APPLICATIONS OF DIFFERENT TURBINE TYPES & SIZES (SULZER)



Tubular (S-type)— turbine generator

BHEL — Standard Tubular Turbines

Runner dia (mm) / Head (m)		1500	1800	2000	2200	2500
		Unit Output Pt (kW) and discharge Q m³/sec				
3.0	Pt	105 to 248	248 to 359	359 to 440	440 to 550	550 to 688
	Q	7.0 to 10.5	10.5 to 15.15	15.16 to 18.66	18.60 to 23.32	23.32 to 29.15
4.0	Pt	275 to 413	413 to 578	578 to 715	715 to 908	908 to 1155
	Q	8.75 to 13.11	13.11 to 18.56	18.56 to 22.74	22.74 to 28.85	28.85 to 36.72
5.0	Pt	309 to 578	578 to 825	825 to 1018	1018 to 1239	1238 to 1595
	Q	9.37 to 14.09	14.09 to 20.10	20.10 to 25.88	25.88 to 31.48	31.48 to 40.57
6.0	Pt	468 to 715	715 to 1045	1045 to 1293	1293 to 1595	1595 to 2063
	Q	9.90 to 15.16	15.16 to 22.15	22.15 to 27.40	27.40 to 33.80	33.80 to 43.71
7.0	Pt	578 to 880	880 to 1293	1293 to 1595	1595 to 159	1953 to 2530
	Q	1049 to 1598	1598 to 2349	2349 to 2897	2897 to 3548	3548 to 24507
8.0	Pt	551 to 866	866 to 1260	1260 to 1523	1523 to 1590	1590 to 2415
	Q	8.74 to 13.78	13.78 to 20.03	20.03 to 24.20	24.20 to 30.05	30.05 to 38.39
9.0	Pt	650 to 1050	1050 to 1523	1523 to 1864	1861 to 2255	—
	Q	9.27 to 14.84	14.84 to 21.51	21.51 to 26.33	26.33 to 31.90	—
10.0	Pt	777 to 1234	1234 to 1579	1579 to 2153	—	—
	Q	9.88 to 15.69	15.09 to 22.37	22.37 to 37.37	—	—
12.0	Pt	893 to 1416	1418 to 2048	2048 to 2520	—	—
	Q	9.46 to 15.03	15.03 to 21.70	21.70 to 26.71	—	—
14.0	Pt	1165 to 1785	1785 to 2600	—	—	—
	Q	10.49 to 16.21	16.21 to 23.69	—	—	—
16.0	Pt	1313 to 2100	—	—	—	—
	Q	10.44 to 16.70	—	—	—	—

Flovel-Standard Tubular Turbines — Semi-Kaplan

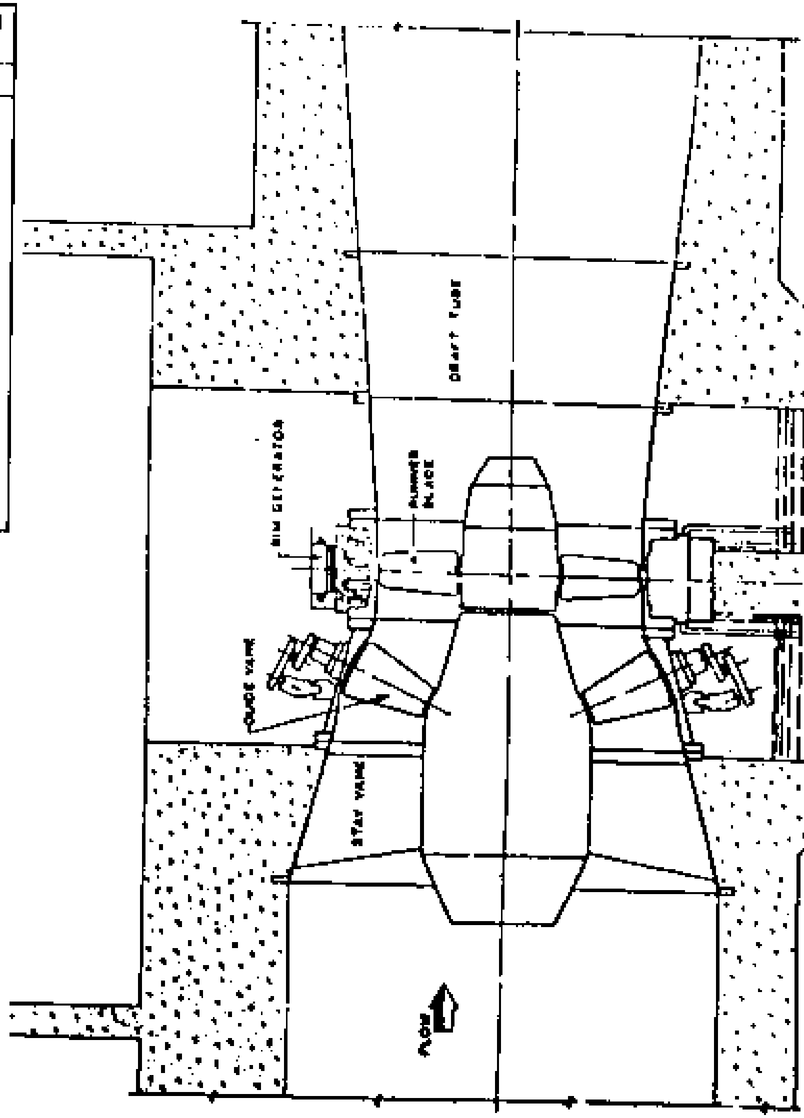
Runner dia (mm) / Head (m)	900	1150	1400	1650	1900	2150	2400	2650	2900	3200
	Turbine/Generator Output (kW)									
3	100	125	175	280	350	425	550	650	800	1000
4	100	175	275	380	500	550	800	1000	1250	1500
5	150	225	350	500	650	825	1100	1350	1600	1900
6	200	320	450	525	875	1200	1430	1700	2000	2400
7	240	380	550	800	1100	1400	1750	2000	2400	3000
8	275	420	700	950	1250	1650	2000	2375	2900	3500
9	320	520	800	1150	1500	1900	2250	2750	3400	4000
10	380	600	850	1250	1650	2100	2600	3250	3800	4500
12	420	750	1100	1450	1850	2600	3200	4000	4800	5000
14	500	800	1200	1600	2100	3000	3700	4600	5600	6500
16	500	800	1200	1700	2750	3150	4100	4600	5600	6700

Flovel-Standard Tubular Turbines— Full-Kaplan

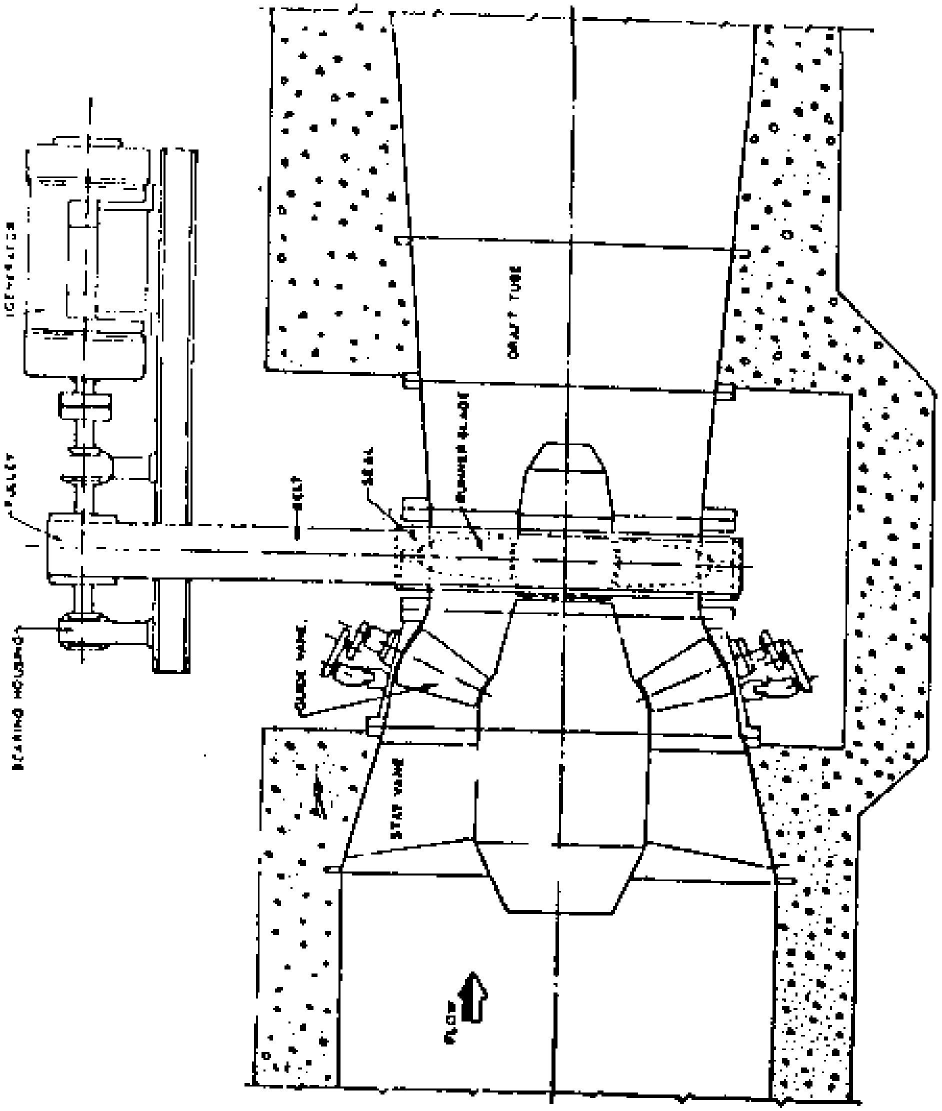
Runner dia (mm) / Head (m)	1400	1650	1900	2150	2400	2650	2900	3200
	Turbine/Generator Output (kW)							
3	200	300	400	500	650	800	1000	1200
4	300	420	550	725	900	1050	1300	1500
5	400	550	750	925	1160	1450	1700	2000
6	500	700	950	1200	1500	1800	2150	2500
8	750	1000	1400	1725	2050	2500	3000	3600
9	800	1200	1600	1950	2400	3050	3600	4300
10	1000	1300	1700	2250	2750	2400	400	4900
12	1150	1500	1900	2750	3400	4200	5000	6200
14	1200	1650	2100	3200	3850	4600	5650	7000
16	1200	1650	2220	3300	4200	4900	6200	7500

Jyoti — Standard Tubular Turbines

Runner dia (mm)	260	600	750	1000	1200	1400	1650	1900	2200	2500
Head (m)	Turbine/Generator Output (kW)									
3	5	28	48	75	125	175	240	330	430	550
4	8	45	80	130	200	280	380	520	730	925
5	11	65	115	190	300	400	560	800	1505	1350
6	15	90	150	250	400	540	750	1000	1400	1800
7	17	115	190	300	460	700	900	1200	1650	2150
8	19	130	210	340	525	750	1000	1400	1900	2500
9		150	240	400	600	825	1150	1600	2150	2900
10		165	270	450	650	920	1250	170	2350	3200
12.5		205	320	545	800	1200	1600	2200	3100	4000
15		240	380	650	1000	1400	1850	2700	3700	4700
20		320	480	830	1300	1800	2450	3550	4600	6000
25		400	560	900	1450	2250	3150	4200	5900	7200



TURBINE WITH RIM GENERATOR



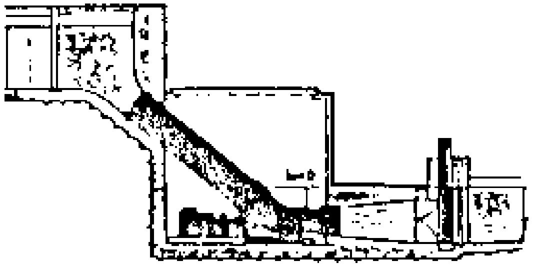
TURBINE WITH RIM BELT DRIVE

Flovel-Standard (Axial Flow) Rim Drive Turbines

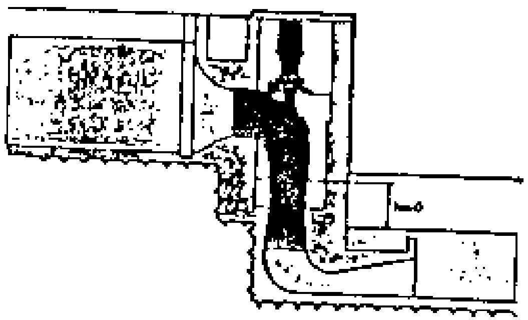
Runner dia (mm) / Head (m)		1000	1200	1400	1600	1800	2200
		Output Pg (kW) and speed Nt of Turbines					
3	Pg	125	150	175	220	275	425
	Nt	300	275	250	200	200	360
4	Pg	150	200	250	350	425	650
	Nt	400	340	300	250	230	200
6	Pg	250	350	500	600	750	1200
	Nt	500	430	350	320	300	250
8	Pg	350	500	700	900	1000	1500
	Nt	500	410	350	300	300	250
10	Pg	500	700	1000	1250	1500	2500
	Nt	540	460	375	300	300	250
12	Pg	650	1000	1250	1500	2000	3000
	Nt	600	500	428	375	300	250

Note Recommended speeds of generators 1000 to 1500 rpm. For synchronous rim, generators of output 750 kW and above recommended speeds are the same as turbine speed

Downstream elbow



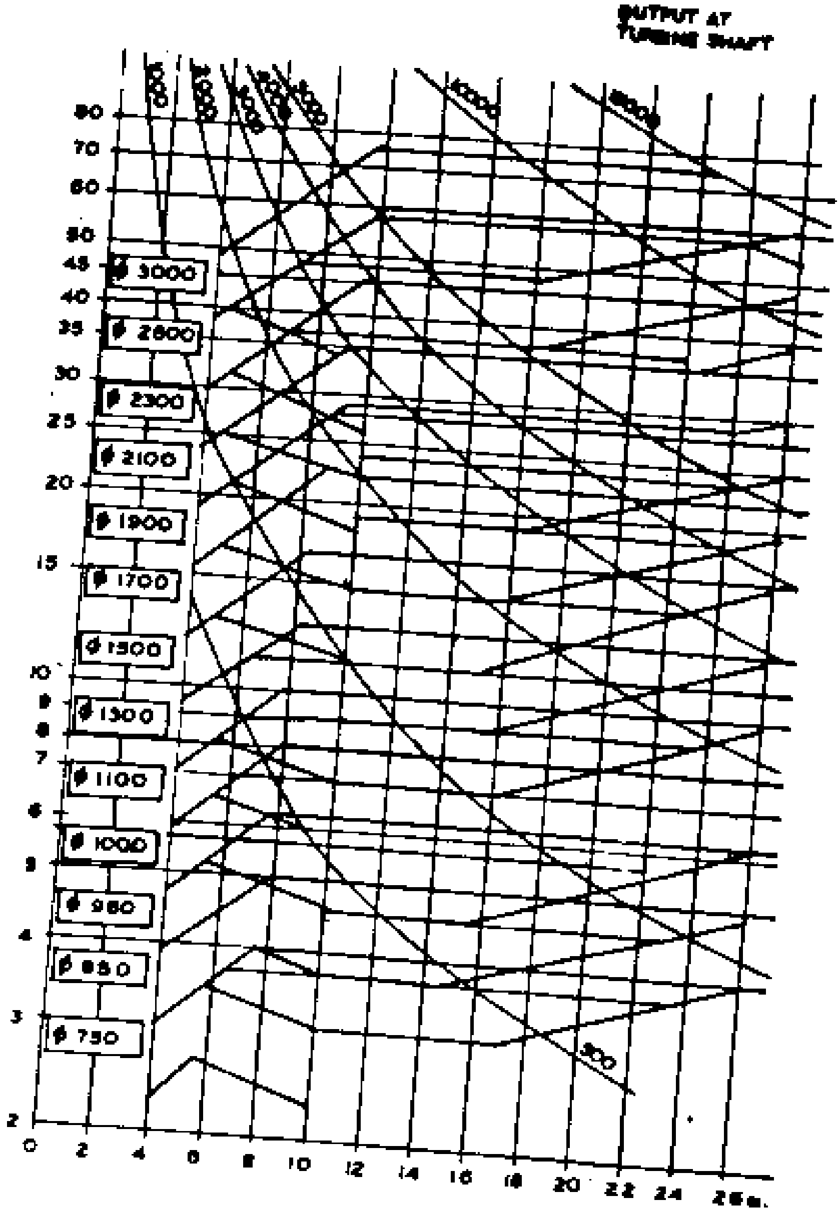
Upstream elbow

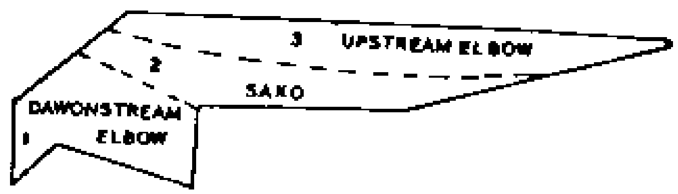


Saxo

BEST & CROMPTION - Kaplan Turbines (Elbow Type)

Runner Size mm	Head Range m	Discharge m³/sec	Output kW
750	4 to 26	2.5 to 4.0	80 to 900
850	4 to 26	3 to 5	100 to 1100
950	4 to 26	4 to 6.5	150 to 1500
1060	4 to 26	5 to 8	175 to 1900
1180	4 to 26	6 to 10	200 to 2250
1300	4 to 26	7 to 13	250 to 3000
1500	4 to 26	9 to 17	300 to 3750
1700	4 to 26	12 to 22	450 to 24750
1900	4 to 24	15 to 28	500 to 5000
2120	4 to 21	19 to 35	700 to 5000
2360	4 to 18	24 to 46	900 to 5000
2650	4 to 16	30 to 57	1000 to 5000
3000	4 to 12	37 to 67	1500 to 5000





BEACON NEYRPIC KAPLAN TURBINES ELBOW TYPE

Flovel-Standard Francis Turbine (Spiral Casing Type)

Runner Size dia (mm)	450	650	800	1000	1200	1400	1600
Head Range (m)	15 to 250	15 to 300	20 to 200	20 to 150	20 to 90	20 to 70	20 to 50
Output (kW)	100 to 1500	200 to 3000	500 to 6000	1000 to 7000	1500 to 8000	2000 to 8000	3000 to 8000
Range of speeds (rpm)	1000 1500	500 750 1000	400 500 600 750	375 420 500 600	300 375 428 500	250 300 333	200 250 300

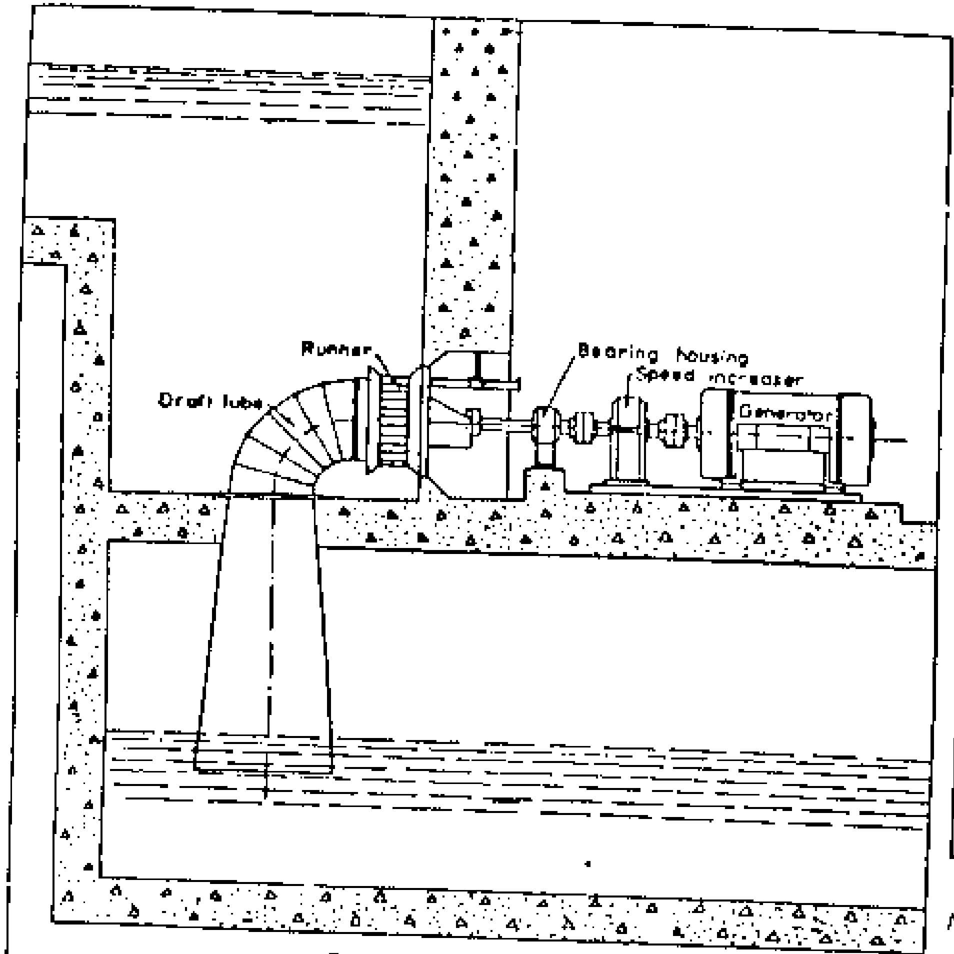
JYOTI STANDARD FRANCIS TURBINES

Runner dia (mm)	350	425	500	650	800	1000
Head (m)			Turbine output in kilowatt			
10	25	35	95	160	245	385
20	70	105	270	457	695	1085
30	130	190	495	840	1270	1990
40	200	290	560	955	1450	2265
50	270	400	640	1080	1950	2530
60	360	550	840	1415	2560	4000
70	460	675	940	1580	2400	3750
80	550	825	1150	1930	2900	4530
90	670	985	1370	2300	3485	5445
100	785	1150	1600	2700	4090	6390
110	890	1015	1410	2380	3605	—
120	—	1150	1600	2710	4105	—
130	—	1300	1810	3060	4635	—
140	—	1455	2025	3465	5245	—
150	-	1615	2250	3800	5760	—
160	—	1780	2475	4180	6335	—
170	-	1950	2700	4565	—	—

FLOVEL-STANDARD PIT TYPE FRANCIS TURBINE

Runner dia (mm)		800	1100	1400
Head (m)		*Turbine/Generator Output P (kW) and Turbine Speed N (rpm).*		
3	P	36	75	125
	N	170	120	100
4	P	60	100	200
	N	220	170	120
6	P	100	175	350
	N	280	210	150
8	P	175	300	500
	N	300	230	180
10	P	250	450	750
	N	350	250	200

Note: Recommended generator speed - 1000 to 1500 rpm



Pit type francis turbine

Flovel-Standard Open Flume (Axial Flow) Turbines

Runner dia (mm)	900	1150	1400	1650	1900	2150	2400
Head (m)			Output (kW)				
2	40	60	100	125	175	200	275
4	100	175	250	350	500	600	750
6	200	300	450	650	750	1000	1250
8	275	450	650	1000	1250	1500	2000

Jyoti-Standard Pelton Turbines

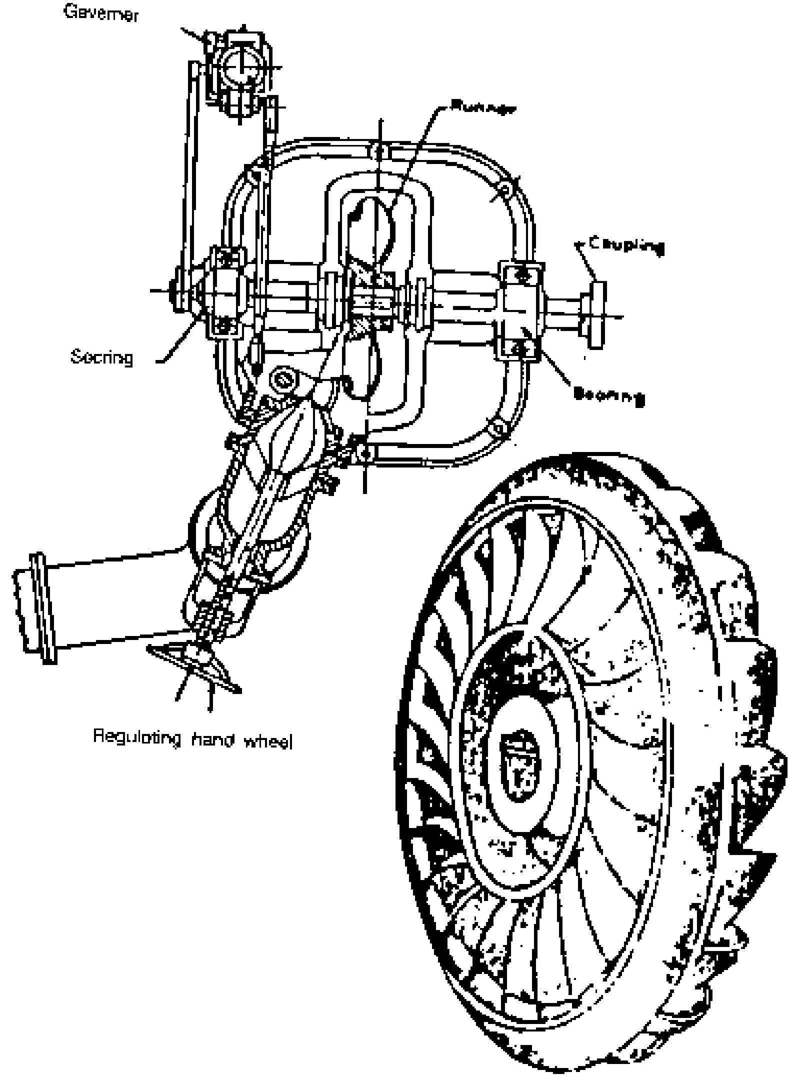
Runner dia (mm)	300	425	600	750	900	1100
Head (m)		Turbine Output in Kilowatts				
100	20	40	90	120	190	275
110	25	50	105	140	215	320
120	30	55	120	160	250	366
130	32	60	130	180	285	410
140	35	70	150	205	320	465
150	40	80	165	225	355	515
160	45	85	180	245	390	570
170	50	95	180	245	390	570
180	55	100	215	295	460	675
190	60	110	235	325	510	740
200		120	255	345	550	790
225		140	300	415	645	940
250		165	355	485	760	1100
275		190	410	560	880	1275
300		215	465	635	1005	1450
325		245	525	715	1125	1635
350		275	585	800	1255	1825
375		305	650	890	1395	2030
400				975	1535	2235
425				1080	1695	2465
450				1165	1830	2660

Note Output will be double of above figures for two jet pelton

Jyoti-Standard Turgo Impulse Tubine

Runner dia (mm)	225	275	350	425	450	525	600	675	750
Head (m)	Turbine Output in Kilowatts								
40	17	26	41	61	68	100	131	168	207
50	23	35	57	86	96	140	184	233	290
60	31	48	75	113	126	185	241	308	382
70	40	62	94	141	158	232	304	388	481
80	47	73	115	174	195	284	373	473	587
90	56	87	137	207	232	338	444	564	702
100		109	161	242	271	397	521	622	822
110		126	186	279	312	458	601	764	948
120		144	212	319	357	521	684	868	1078
130		161	239	359	402	589	772	982	1217
140		180	267	402	450	658	862	1097	1360
150			295	446	500	727	956	1212	1509
160			325	491	549	801	1053	1336	1663
170			356	537	602	878	1152	1465	1822
180			388	585	655	957	1255	1596	1986
190			421	635	711	1038	1361	1731	2153
200			455	687	770	1126	1475	1879	2327

Note: Output will be double of above figures for two jet turgo impulse turbine.



Turgo Impula Turbine

CHAPTER - 5

COST ESTIMATES, EVALUATION AND FINANCIAL ANALYSIS

5.1 INTRODUCTION

Most of the small hydro electric projects are being preferred for turnkey contract. An accurate assessment of the expected cost is considered a most important activity in order to ascertain its economic feasibility and to prepare a viable financing plan and to negotiate the EPC contract. No mathematical formulae will give exact cost. At best, the estimate can only be a close approximation of the cost.

To arrive at the total cost of the project, estimates are generally made separately for civil works including hydro-mechanical works and generating plant including E&M works. The list of items to be covered, wherever applicable, are listed in Annexures 5.1 and 5.2 (refer pages 122 & 123). A general abstract of total project cost is to be enclosed in the DPR as per format given in Annexure 5.3 (refer page 124).

5.2 ESTIMATE FOR ELECTRICAL WORKS

Costs of turbines and generators are to be based on the budgetary enquiries made from manufacturers. Costs of other equipments such as transformers, switchgear, E.O.T. crane etc. are to be based on recent data relating to prices of similar items gathered from suppliers. Provision will also be made for items such as excise duty, sales tax, transport and handling, insurance, erection, commissioning, inspection etc.

5.3 ESTIMATE FOR CIVIL WORKS

5.3.1 Determination of Quantities

The quantities of major items of work e.g. excavation, earth filling, masonry, concrete etc. have to be determined from preliminary drawings, which are to be given by the Design team for all major components of work (indicated in Annexure -5.1) (refer page 122).

5.3.2 Collection of Local/Site Specific Data

A visit to the site by those associated with cost estimate is a must to collect the relevant data/information, principally on the following aspects:-

- Labour wages for skilled and unskilled labour. The basic labour rates will be adjusted to allow for the effects of statutory on-costs to be incurred by the contractor. These generally cover paid holidays, temporary site accommodation, transportation to and from work site, emergency medical aid, accident compensation etc. A percentage enhancement of 15% to 30% over the basic wages is suggested to cover these costs.
- Costs of materials such as stone, sand aggregates, cement, steel, explosives etc. Along with the costs, sources from which these materials could be obtained have to be found out. Basic costs of materials obtained from their sources will be enhanced with allowance for sales tax, excise duty, carriage, cartage, loading and unloading charges, storage etc. to arrive at the costs of materials at site.
- Information on existing approach roads to the site, improvements/upgrading/extensions required to the existing roads may also be collected. Where approaches do not extend to the sites proper, distances for haulage by head loads have to be ascertained.

5.3.3 Analysis of Item Rates

The unit rates for items of work will be analysed by considering the requirements of labour, material, fuel equipment and their prices. Schedule of rates followed by P.W.D. or local authorities may not be of much use, as these are generally not prepared for types of work involved in a hydro project, and also may not have been updated to latest costs. A reasonable percentage to cover the overheads and contractors profit (suggested as 20 - 30%) has to be added to the prime cost to get the overall item rate.

5.3.4 Cost of Works

Detailed estimates for civil structures (indicated in Annexure - 5.1) can then be worked out from the quantities and rates of item determined as explained earlier Lump-sum provisions for certain items, which cannot be quantified at the stage of project preparation should be based on experience. Provision of 5% towards contingencies is generally added to cost abstract of each work to arrive at the final cost.

5.4 MISCELLANEOUS PROVISIONS

In addition to cost of structures, estimate for civil works will also include provision for certain supporting works, detailed below.

5.4.1 Preliminaries

Provision will cover cost of pre-construction and construction stage surveys and investigations pertaining to topography, geology, hydrology and construction materials etc. Studies for and preparation of project report, and consultancy charges will also be considered. Experience has shown that cost on account of these activities range between 2 to 3% of the total cost.

5.4.2 Land

Land required to be acquired will be determined under different categories viz. Forest, cultivated barren etc. Cost of acquisition will then be worked out by considering land rates to be found by local enquiry or in consultation with Revenue authorities. Provision at 30% of cost of private land will be made as statutory charges for compulsory land acquisition.

It is unlikely that any structures/properties will fall within the land to be acquired for a small hydro project. In case these are present, cost of acquisition thereof will also form part of the estimate for land.

5.4.3 Miscellaneous

Provision under this will cover the cost of amenities and facilities for staff & workmen, running and maintenance of inspection vehi-cles, workmen's compensation, construction power, security mea-sures and other miscellaneous costs not considered elsewhere.

5.4.4 Roads and communications

Costs to be considered cover construction/upgrading/ improvements of approach roads footpaths, bridal paths. The requirements may be assessed after reconnaissance of the area.

5.4.5 Ecology & Environment

A small hydro project generally does not disturb/degrade the environment. Provision may however be made for compensatory afforestation, re-clamation of construction sites, studies relating to ecology etc.

5.5 ECONOMIC AND FINANCIAL EVALUATION

The economic and financial evaluations are made utilizing the pre-defined criteria and assumptions agreed to by the approving authority.

5.5.1 Economic Evaluation

In an absolute sense, the economic viability of a small Hydro electric projects is determined by comparison with the cost of alternative sources at the same place considering therein all elements such as cost of transmission/distribution etc. In isolated areas, it is often compared with diesel or other source available for affording the same energy benefits. The economics of the project, where existing facility is also required to meet the demand, could be worked out considering total system cost. In isolated system, energy absorption is an important aspect and could be computed considering system requirements and ability of the scheme for meeting the same. However, when a SHP is to be developed by an independent Developer, he would have to see the appropriateness of returns to him considering all factors such as rate offered to him by Public Authorities, any subsidies and concessions available for funding or otherwise. This is of great relevance since SHP is being encouraged by authorities under various policies.

The Evaluation could be carried out by opting the following methodologies:-

- Cost of energy generation
- Benefit Cost Ratio (B/C ratio)
- Net Present Value (NPV)
- Economic Internal Rate of Return (EIRR).

5.5.2 Cost of Energy Generation:

The cost of energy generation is considered as the most preferred option for judging economic viability. The economic viability is judged by comparison with the cost of generation from alternative options. To compute the levellised cost of generation over the life span of the project, the cash flow streams of the cost and energy benefits are developed. The cash flow stream would need the phasing of expenditure, the annual operation and maintenance charges, the salvage value etc., while the energy stream would have the expected energy benefits over the life of the project. The cost of energy is computed at different discount rates by discounting the cost stream and the energy generation over the life of the project. In computation credit is given for salvage value during the last year of operation. If the system cost of energy generation is to be computed corresponding cost and benefits have to be considered. In isolated system, the energy that is expected to be absorbed in the system, rather than the energy generation, is considered. The difference would comprise self-consumption and system energy losses, as well as any energy required to be supplied without charge by way of fees and also energy remained unutilised. The cost of energy so computed is compared with other sources of energy.

In the above computation, if required, escalation in cost, escalation in O&M etc., could also be considered. The sale rate of energy could be computed after allowing for auxiliary consumption, transmission/ distribution losses, wheeling and banking charges, royalty on water use, if any and the profit element*. A sample format for computing the cost of energy generation is given at Appendix-I (refer page 113).

5.5.3 Benefit Cost Ratio

The benefit cost ratio is the ratio of the present value of the cash inflows (benefits) to the present value of the original and subsequent cash outflows. The ratio is computed by considering the actual revenue and the actual expenses consisting of O&M, depreciation and interest charges. If the ratio is found greater than the one, the project is considered viable. This method does not cover the value of money over the project life span.

5.5.4 Net Present Value (NPV)

The difference between the revenue and the expenses discounted at a pre-determined rate is the net present value (NPV) of the investment. The computation is done over the life of the project. The merit order could be established between different projects in order of decreasing NPV. Where the NPV is negative, project could be rejected.

5.5.5 Economic Internal Rate of Return

The economic Internal Rate of Return is determined from the view point of the financial institutions (viz. World Bank etc.). While computing, the following cash flow stream, over the life of the project is considered:-

- The economic cost of the project (Not the financial) by considering economic (or shadow) price rather than market price. To arrive at the economic capital costs, the domestic component of capital costs for equipment and civil works are adjusted by applying a standard conversion factor of 0.8, and removing taxes, duties, government levies/ subsidies etc.

- The net economic benefits from the project (to the extent possible quantify all the benefits and convert into rupee terms)
- Annual operating and maintenance costs (say 1 to 2%)
- Economic Life of the project (say 35 years)

Based on the above, the cash inflow stream and outflow stream are carried out and the net cash flow stream is arrived at. The EIRR is the discount rate at which the cost stream equals the benefits (cash inflow) stream. If the EIRR is above the prescribed limit (say 12%), the project is accepted. Further sensitivity analysis is also carried out with respect to change in various parameters i.e. cost of equipment and material, construction period etc.

5.6 FINANCIAL EVALUATION

The financial evaluation is undertaken to assess the financial viability/soundness of the project from the point of view of developers and financial institutions. For evaluation of a project, the following aspects assume significant importance:-

- Capital investment
- Construction period and phasing of expenditure
- Economic Life of the project
- Financial package i.e. amount of debt/equity, interest rate, moratorium period, repayment period and repayment schedule.
- Amount and timing of cash flows.

In addition to above, the stipulation of the Government like royalty, lease, banking and wheeling charges, tax concessions, grant, subsidies, are also taken into account.

Capital investment is made up of base cost (at the time of formulation of project), escalation in cost during construction, interest during construction, debt servicing/fund management charges and margin working capital. It also includes the capitalised initial spares. Escalation is taken at 8 to 10% and margin money for working capital is often taken at 25% of the total working capital requirements. The working capital include one month's O&M expenses, spares for one year and receivables for two months. Fund management expenses normally comprise of upfront fees @ 1% on loan from Indian Financial Institutions as well as foreign loan (other than suppliers credit) and about 5% on loan and equity to be raised from public. The interest during construction is computed on loan component based on phasing of expenditure and interest rate agreed to with various lenders. The economic life of the project is taken as 35 years.

The financial package should be as per the Government of India resolution dated 22nd October, 1991 dealing with Financial and Administrative Environment for hydro-electric project. As per this resolution, Debt Equity Rates upto 4:1 is permissible, that is a minimum of 20% of the total outlay should be the equity component; at least 11% of the total outlay must come through promoter's contribution. In the rest of the total outlay, less equity, which may be upto 80% of the total project cost, an amount not exceeding 40% of total outlay may come from Indian Public Financial Institutions, but the remaining amount should be met from other sources. Further, upto hundred percent (100%) foreign equity participation can be permitted for projects set up by foreign private investors.

The following approaches for computing the financial viability are considered:-

- The Rate of Return Method
- The Pay Back Period Method
- The Financial Internal Rate of Return Method
- The Net Present Value Method

The First two represent approximate methods for assessing financial worth of a project. The latter two, based on discounted cash flow method, provide a more objective basis for evaluating financial soundness of a project over its life. These methods take account of both magnitude and timing of expected cash flows in each period of a project life and hence considered preferred methods for financial evaluation.

5.6.1 Financial Internal Rate of Return (FIRR)

To evaluate the FIRR the following cash flow stream over the life of the project is considered:-

- The financial cost of the project based on market prices, tax, duties, Government subsidies
- The debt servicing
- The other cost like O&M cost etc.

- The revenue stream (in the form of sales)
- The salvage value etc.
- Tax payment, concessions/exemption on tax etc.

The FIRR for an investment proposal is the discounted rate that equates the present value of the expected cash outflows with the present value of the expected inflows. The FIRR is then compared with the required rate of return or cut of rate say 12%. If the FIRR exceeds, the required rate, the project is accepted, if not, it is rejected.

The FIRR is carried out for the following scenarios:-

- On total capital (100% equity)
- On total equity - pre-tax (including debt servicing, excluding corporate tax)
- On total equity - post tax (included debt service and corporate tax.

A simple method of financial evaluation is given at Appendix 2 (Table 1 to Table 4) (refer page 114-119).

5.6.2 Net Present Value Method

Under this method, net cash flows discounted to present using the required rates of return. If the sum of these discounted cash flows is equal to or greater than zero, the proposal is accepted, if not, it is rejected.

5.6.3 IREDA Practice

The economic and financial appraisal of a project is carried out by IREDA considering the following. The key assumptions made for the studies are listed in Appendix-4 (refer page 124).

(i) Cost of generation
(ii) IRR of project
(iii) Debt service coverage ratio (CSCR)
(iv) Pay back period

Item (i) and (ii) above has already been dealt above. The project is considered viable if the IRR is more than 12%.

DSCR is computed by calculating the gross cash flows (Gross Revenue - O&M expenses including insurance - interest on working capital - income tax) and debt servicing expenses - interest on loan and term loan installment.

Pay back period determines the number of years required for the capital to be recovered by the net revenues accruing from the project. The net revenue is computed after deducting the annual working expenses from the constant value money capital. Annual surplus deficit is then computed by deducting interest from the net revenue. The sum at charge which is the sum of capital and annual surplus or deficit gives the number of years required for the capital to be recovered. This method does not take into account the value of money at different time and taxes etc.

5.7 SALE RATE OF ENERGY AND TARIFF FORMULATION

5.7.1 Sale Rate of Energy

The sale rate of Energy for the first year of operation could be worked out as given in Appendix-3 (refer page 120). Based on the provisions of the PPA, necessary modifications could be incorporated.

5.7.2 Tariff Formulation

The sale price of energy is computed considering provisions of agreement signed between Developer and the Government, the policy guidelines of the Government of India and the proposed financial package. In case where sale price of energy is fixed by Government or purchaser, the computation could be made to evaluate the return on equity. Some of the basic and normative parameters requiring approval of the approving authority and used for the above computation, are listed below:-

⇒ Estimated cost

⇒ Annual energy

⇒ O&M (including insurance)

⇒ Escalation in cost

⇒ Depreciation (based on Notification dated 29th March, 1994 by Deptt. of Power)

⇒ Advance against depreciation

⇒ Auxiliary consumption

⇒ transformation losses

⇒ Free power to state

⇒ Financial package

⇒ Subsidy/Grant.

The two part tariff for hydro electric project is computed based on the provisions outlined in Notification dated 13th January, 1995 by the Ministry of Power. The two part tariff for sale of energy from hydro shall comprise the recovery of annual capacity charge and energy charge consisting of the following:-

(1) **Annual capacity charge**

⇒ Interest on loan capital

⇒ Depreciation

(2) **Annual Energy Charge.**

⇒ O&M Expenses (inclusive of insurance charges)

⇒ Tax on income reckoned as expenses at actuals

⇒ Return on equity at 16% on the paid up and subscribed capital

⇒ Cess/levy on water charges at actuals

⇒ Interest on working capital

The sources of repayment of loan are depreciation including "Advance against Depreciation" which has to be withdrawn in such a manner that the total depreciation during any year does not exceed 1/12 of the total loan amount and has to be limited to the actual loan liability during the year. Further, the total depreciation including advance against depreciation should not exceed 90% of the capital cost.

DISCOUNTED CASH FLOW - COST OF ENERGY GENERATION

-3	71.60		71 60		1?1.76		117.65		123.73	
-2	190.63		190.63		256.52		265.44		274 5[illegible]	
-1	140.26		140.25		162 71		165 51		169.32	
0		10.41	10.41	61.00	10.41	61.00	10 41	61.00	10.41	61.00
1		10.41	10.41	61.00	8.96	52.59	8.82	51.69	8.68	50.83
2		10.41	10.41	61.00	7.74	45.33	7.48	43.81	7.23	42.36
3-18		166.61	166.61	976 00	43.87	256.97	38.61	226.16	34 20	200.35
19	-23.63	10.41	-13.22	61.00	-0.79	3.64	-0.57	2 63	-0.41	1.91
Total					601 19	419.52	613 35	385 29	625.67	356 45
Cost of Engergy (Rs. /KWh)					1.43		1.59		1 76	

Table -I
Input Data and Assumption

Installed Capacity (MW)	:	16
Annual Energy Generation (Gwh)	:	69.76
Auxilary Consumption (%)	:	0.5
Whealing Fee (%)	:	12.0
Royalty on Water	:	—
Tax on Electricity	:	—
Sale of Power (Rs.)	:	1.66 in IV Year
Power Price Escalation (%)	:	10.0% per annum
Project Capital Cost Include IDC (Rs. million)	:	472.58
Interest during Constuction (Rs. million)	:	70.08

Financial Package (Rs. million) :

	% Share	Amount	Interest Rate %
Equity	26.3	124.29	–
IREDA Loan	44.4	209.83	12.5/15.5
Other Loan	29.3	138.46	18.0

Term Loan	:	10 Years include 3 year moratorium
Salvage Value (%)	:	5.0
Anual O&M Cost (% of Capital Cost)	:	2.0
Annual Insurance Costs (% of Capital Cost)	:	0.5
O&M Escalation (% per Year)	:	5.0
Marginal Tax rate (%)	:	46.0 (Full Tax Hoilday for 1st 5-years 30% Tax Examption for next 5-years)
Depreciation Rate Equipment	:	20 Years
Depreciation Rate Others	:	20 Years
Duty Imported Equipment (%)	:	0.0
Construction Period (Years)	:	3.0

Table - 2

Phasing of Expenditure (Current Rupees)
Captial Cost Extimate (Current Rupees)

Note : The figures shown are for example only

S.I. No.		Year 1	Year 2	Year 3	Total
1.	Land	1.000	0.000	0.000	1.000
2.	Civil Works	36.750	49.000	36.750	122.500
3.	Machinery, Equpment	21.000	126.000	63.000	210.000
4.	Installation, Start-up	0.000	0.180	.0120	0.300
5.	Engineering, consultancies	4.500	4.500	0.000	9.000
6.	Tech. Assis. and Training	0.000	0.000	1.000	1.000
7.	Project Management	2.333	2.333	2.333	7.000
8.	Others	0.520	3.120	1.560	5.200
9.	Taxes and Duties	0.000	0.000	30.000	30 000
10.	Contingencies	5.500	5.500	5.500	16.500
11.	Total	71.603	190.633	140.263	402.500
12.	Interest Durng Constr.	7.908	22.484	42.685	70.076
13.	Total Including Interest	76.511	213.117	182.948	472.576

Note: The Figures shown are for examples only.

Table - 3

Financial Evaluation Table

Note : The figures shown are for example only

Sl. No	Details	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
1	Energy available for sale				61.08	61.08	61.08	61.08	61.08
2.	Sale Price				1.66	1.83	2.01	2.21	2.44
3	Revenue (1 x 2)				101.62	111.79	122.97	135.26	148.79
4	Other revenue				-	-	-	-	-
5	Total revenue (3 + 4)				101.62	111.79	122.97	135.26	148.79
6	O&M Expenses				8.05	8.45	8.88	9.32	9.79
7.	Insurance				2.36	2.36	2.36	2.36	2.36
8.	Other Expenses				0.00	0.00	0.00	0.00	0.00
9.	Total Operating Expenses (6+7+8)				10.41	10.81	11.24	11.68	12.15
10.	Net Operating Cashflow (5+9)				91.21	100.98	111.73	123.58	136.64
11.	Capital Cost	71.60	190.63	140.26	-	-	-	-	-
12.	Total Net Cashflow (10+11)	-71.60	-190.63	-140.26	91.21	100.98	111.73	123.58	136.64
13.	Ufinancial Evaluatio on total Capital ⇒ FIRR on Net Cashflow : 27.6% ⇒ FNPV on Net Cashflow @ 12% : Rs. 662.84 Million								
14.	Interest Payment on Loan(s)	-	-	-	47.53	40.35	33.18	26.00	18.83
15.	Depreciation				16.88	16.89	16.88	16.88	16.88
16.	Profit Before Tax (10+14+15)				26.80	43.75	61.67	80.70	100.93
17.	Corporate Tax normal				-	-	-	-	-
18.	Corporate Tax with concessions, if any				-	-	-	-	-
19.	Equity Investment	12.41	31.02	80.85	-	-	-	-	-
20.	Net Operating Cashflow (same as 10)				91.21	100.98	111.73	123.58	136.64
21.	Annual Repayment of loan (Principal+Interest)				97.31	90.14	82.96	75.79	68.62
22.	Interest during construction	4.91	22.48	42.68	-	-	-	-	-
23.	Sales Tax benefit, if any	-	-	-	-	-	-	-	-
24.	Total net Cashflow before tax (20-21-22+23)	-17.32	-53.50	-123.33	-6.10	10.84	28.77	47.79	68.02
25	Financial Evaluation on Equity Capital - Before Tax ⇒ FIRR on Net Cashflow 29.3% ⇒ FNPV on Net Cashflow @ 12% Rs. 295.44 Million								
26	Corporate Tax (as in 18)	-	-	-	-	-	-	-	-
27	Net Cashflow after tax (24-26)	-17.32	-53.50	-123.33	-6.10	10.84	28.77	47.79	68.02
28	Financial Evaluation on Equity Capital - After Tax ⇒ FIRR on Net Cashflow 24.23% ⇒ FNPV on Net Cashflow @ 12% Rs. 267.85 Million								

Note: The Figures shown are for examples only.

Table - 3
Financial Evaluation Table

Note : The figures shown are for example only

Sl. No.	Details	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16
1.	Energy available for sale	61.08	61.08	61.08	61.08	61.08	61.08	61.08	61.08
2.	Sale Price	2.68	2.95	3.24	3.57	3.92	4.32	4.75	5.22
3.	Revenue (1 × 2)	163.67	180.04	198 04	217.84	239.63	263.59	289.95	318 94
4.	Other revenue	-	-	-	-	-	-	-	-
5.	Total revenue (3+4)	163.67	180 04	198.04	217.84	239.63	263.59	298.95	318.94
6.	O&M Expenses	10.27	10.79	11.33	11 89	12.49	13.11	13 77	14 46
7.	Insurance	2.36	2.36	2.86	2.36	2.36	2.36	2.36	2.36
8	Other Expenses	0.00	0.00	0.00	0.00	0 00	0.00	0.00	0.00
9.	Total Operating Expenses (6+7+8)	12.63	13.15	13.69	14.25	14.95	15.47	16.13	16.83
10.	Net Operating Cashflow (5+9)	151.04	166.89	184.35	203.59	224.78	248.12	273.82	302.12
11.	Capital Cost	-	-	-	-	-	-	-	-
12.	Total Net Cashflow (10+11)	151 04	166.89	184.35	203.59	224.78	248.12	273 82	302 12
13.	**Financial Evaluation on total Capital** ⇨ FIRR on Net Cashflow : 27.6% ⇨ FNPV on Net Cashflow @ 12% : Rs. 662.84 Million								
14.	Interest Payment on Loan(s)	11.66	4.48	-	-	-	-	-	-
15.	Depreciation	16.88	16.88	16.88	16.88	16.88	16.88	16.88	16.88
16.	Profit Before Tax (10+14+15)	122.50	145.53	167.47	186.71	207.90	231 24	256.94	285.24
17.	Corporate Tax normal	39 44	46.86	53.92	60.12	66.94	106.36	118.19	131 21
18.	Corporate Tax with concessions, if any	39.44	46.86	53.92	60.12	66.94	106.36	118 19	131 21
19.	Equity Investment	-	-	-	-	-	-	-	-
20.	Net Operating Cashflow (same as 10)	151.04	166 89	184.35	203.59	224 78	248.12	273.82	302.12
21.	Annual Repayment of loan (Principal+Interest)	61.44	54 27	-	-	-	-	-	-
22.	Interest during construction	-	-	-	-	-	-	-	-
23.	Sales Tax benefit if any	-	-	-	-	-	-	-	-
24.	Total net Cashflow before tax (20-21-22+23)	89.60	112.62	184.35	203.59	224.78	248 12	273 82	302.12
25.	**Financial Evaluation on Equity Capital - Before Tax** ⇨ FIRR on Net Cashflow : 29.5% ⇨ FNPV on Net Cashflow @ 12% : Rs 295 44 Million								
26	Corporate Tax (as in 18)	39.44	46.86	53 92	60.12	66 94	106 36	118 19	131 21
27.	Net Cashflow after tax (24-26)	50 16	65 76	130 43	143.47	157.84	141 76	156.63	170 91
28	**Financial Evaluation on Equity Capital - After Tax** ⇨ FIRR on Net Cashflow 24 20% ⇨ FNPV on Net Cashflow @ 12% Rs 267.85 Million								

Note: The Figures shown are for examples only.

Table - 3
Financial Evaluation Table

Note : The figures shown are for example only

Sl. No.	Details	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23
1.	Energy available for sale	61.08	61.08	61.08	61.08	61.08	61.08	0.00
2.	Sale Price	5.74	6.32	6.95	7.65	8.41	9.25	9.25
3.	Revenue (1 × 2)	350.84	385.92	424.51	466.98	513.66	565.03	0.00
4.	Other revenue	-	-	-	-	-	-	23.63
5.	Total revenue (3+4)	350.84	385.92	424.51	466.98	513.66	565.03	23.63
6.	O&M Expenses	15.18	15.94	16.74	17.57	18.45	19.37	19.37
7.	Insurance	2.36	2.36	2.36	2.36	2.36	2.36	0.00
8.	Other Expenses	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.	Total Operating Expenses (6+7+8)	17.54	18.30	19.10	19.93	20.81	21.73	19.37
10.	Net Operating Cashflow (5+9)	333.30	367.62	405.41	447.03	492.85	543.30	4.26
11.	Capital Cost	-	-	-	-	-	-	-
12.	Total Net Cashflow (10+11)	333.30	367.62	405.41	447.03	492.85	543.30	4.26
13.	**Financial Evaluatio on total Capital** ⇨ FIRR on Net Cashflow : % ⇨ FNPV on Net Cashflow @ 12% : Rs.							
14.	Interest Payment on Loan(s)	-	-	-	-	-	-	-
15.	Depreciation	16.88	16.88	16.88	16.88	16.88	16.88	16.88
16	Profit Before Tax (10+14+15)	316.42	350.74	388.53	430.15	475.97	526.42	(-)12.62
17	Corporate Tax normal	145.55	161.34	178.72	197.86	218.94	242.14	(-) 5.81
18.	Corporate Tax with concessions, if any	145.55	161.34	178.72	197.86	218.94	242.14	(-) 5.81
19.	Equity Investment	-	-	-	-	-	-	-
20.	Net Operating Cashflow (same as 10)	333.30	367.62	405.41	447.03	492.85	543.30	4.26
21.	Annual Repayment of loan (Principal+Interest)	-	-	-	-	-	-	-
22.	Interest durring construction	-	-	-	-	-	-	-
23.	Sales Tax benefit, if any	-	-	-	-	-	-	-
24	Total net Cashflow before tax (20-21-22+23)	333.30	367.62	405.41	447.03	492.85	543.30	4.26
25	**Financial Evaluation on Equity Capital - Before Tax** ⇨ FIRR on Net Cashflow : % ⇨ FNPV on Net Cashflow @ 12% : Rs.							
26.	Corporate Tax (as in 18)	145.55	161.34	178.72	197.86	218.94	242.14	(-) 5.81
27.	Net Cashflow after tax (24-26)	187.75	206.28	226.69	249.17	273.91	301.16	10.07
28.	**Financial Evaluation on Equity Capital - After Tax** ⇨ FIRR on Net Cashflow : % ⇨ FNPV on Net Cashflow @ 12% : Rs.							

Note: The Figures shown are for examples only.

Table - 4
DEBT SERVICE COVERAGE RATIO

Note : The figures shown are for example only

A-SERVICE		Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Total
1.	Net profit after Tax	26.80	43.72	61.66	80.69	100.92	83.05	98.66	
2.	Depreciaton	16.89	16.89	16.89	16.89	16.89	16.89	16.89	
3.	Int. on T/L	47.53	40.35	33.18	26.01	18.83	11.66	4.48	
4.	Total - A	91.21	100.97	111.73	123.58	136.64	111.59	120.03	795.75
B-DEBT									
1.	Inst on T/L	24.89	49.79	49.79	49.79	49.79	49.79	49.79	
2.	INT. ON T/L	47.53	40.35	33.18	26.01	18.83	11.66	4.48	
3.	TOTAL -B	72.42	90.14	82.97	75.79	68.62	61.44	54.27	505.65
DSCR		1.26	1.12	1.35	1.63	1.99	1.82	2.21	1.57

COMPUTATION OF COST OF SALE OF ENERGY

(Figures are for example only)

S.No.	Particulars	Unit	Values
1.	Cost of Project with out IDC	Rs. Lakhs	402.500
2.	Interest during construction	Rs. Lakhs	70.076
3.	Project cost including IDC (a) Loan component (b) Equity component	Rs. Lakhs	472.576 348.499 124.077
4.	Annual Energy generation	Gwh	69.76
5.	Auxiliaries consumption, transformation and transmission losses	Gwh	0.349
6.	Wheeling & Banking charges	Gwh	8.329
7.	Net annual energy generation (4-5-6)	Gwh	61.082
8.	Fixed annual charges: (i) Interest on loan (ii) O&M expenses (iii) Depreciation (iv) Leasing charges (v) Any other charge TOTAL :	Rs. Lakhs Rs. Lakhs	 51.152 8.05 16.885 — 2.363 78.450
9.	Return on equity (16%)	Rs. Lakhs	19.852
10.	Royality and levies	Rs. Lakhs	—
11.	Total annual charges (8+9+10)		98.302
12.	Cost of Energy sale (11÷7) per unit	Rs./Kwh	1.61

KEY ASSUMPTIONS FOR ECONOMIC AND FINANCIAL STUDIES

1.	Share equity	≥ 25% of capital
2.	Salvage value	5% of capital cost
3.	Annual O&M cost	2% of capital cost
4.	Annual insurance cost	0.5% of capital cost
5.	O&M escalation	5% per year
6.	Wheeling fee	2.10% on actual
7.	Royalty on water	As applicable
8.	Tax on electricity	As applicable
9.	Power price escalation	10% per annum
10.	Depreciation rate equipment	20 years
11.	Depreciation rate other	20 years

SMALL HYDRO PROJECTS
ITEMS TO BE CONSIDERED FOR CIVIL WORKS

1. Preliminary Expenses

2. Land Acquisition

3. Civil Structures:

   - Diversion weir & intake
   - Desilting basin
   - Water Conductor system
   - Forebay including spillway
   - Escapes
   - Penstock
   - Power house (civil works)
   - Tail race
   - Switch yard (civil works)

4. Miscellaneous

5. Roads/Communications

6. Ecology & environment/total cost of civil works

SMALL HYDRO PROJECTS

(Installed Capacity upto 25 MW)

S.NO.	ITEM
1.	Preliminary expenses, including design & consultancy
2.	Turbine rated for -- complete with governing & lubricating oil systems, high pressure compressed air system, etc., including spares for 5 years troublefree operation
3.	Generators rated for -- complete with PMG, AVR, excitation system, cooling, CO_2 equipment, neutral earthing & surge protection equipment, etc. including spares for 5-years trouble-free operation
4.	Generator-Transformers connection, bus-ducts/cables, current transformers, potential transformers, instrumentation & protection complete
5.	L.T. & H.T. switchgear for auxillary power supply to power house and switchyard
6.	Unit Auxiliary transformers
7.	Station service transformers
8.	Control & Relay panels for incoming & outgoing feeders, complete with synchronising equipment, annunciating & alarming equipment etc.
9.	Lead-acid, batteries, charging equipment, D.C. distribution board complete
10.	Fire protection equipment
11.	Power & Control cables, with cable racks, supports, etc.
12.	Illumination of power house & switchyard
13.	Electric Over-head travelling crane complete
14.	Step-up transformers rated for including oil for first filling
15.	Station grounding equipment & materials
16.	Air/Oil circuit breakers
17.	Isolators with/without earthing blades
18.	Current transformers
19.	Potential transformers
20.	Lighting arresters
21.	Bus-bar materials, including ACSR conductors insulators, connectors etc.
22.	Switchyard structures
23.	Miscellaneous
	Total Generating Plant & Equipment (Item 2 to 23) Rs.

Note : All above costs include various provisions needed upto installation and commissioning

GENERAL ABSTRACT OF PROJECT COST

1. Preliminary Expenditure
2. Land and Site Development
3. Civil Works
4. Electro Mechanical Works
5. Transmission Line
6. Construction Supervision and Management
7. Preliminary and Development Experts
8. Detailed Design and Engineering Charges
9. Financing Cost
10. Contingencies
11. Total Project Cost

CHAPTER-6

FINANCING ARRANGEMENTS AND APPROVAL

6.0 INTRODUCTION

Timely availability of finances is a pre-requisite for completing a project in a prescribed time schedule. The finances could be arranged by the developer from various financial institutions based on his legal eligibility and credit worthiness. The financial institution would also like to examine the proposal from view point of loan repayment capability, management capability etc. All financial institutions have different procedures and norms for extending loan facility and these could be obtained from them. Each State Government/Nodal Agencies have prescribed norms for making equity participation which is varying from 20% to 30% of the project cost. This is required to be considered while arranging finances for the project.

6.1 SOURCES OF FINANCING

Financial assistance could be provided by the following institutions with a view to promote, support and accelerate the development of small hydro electric projects (SHP):-

(i) Indian Renewable Energy Development Agency (IREDA)
(ii) Rural Electrification Corporation (REC)
(iii) Power Finance Corporation (PFC)
(iv) Industrial Finance Corporation of India(IFCI)
(v) Industrial Development Bank of India (IDBI)
(vi) Indian Financial Institutions
(vii) Infrastructure Development Corporation Limited

6.1.1 Indian Renewable Energy Development Agency (IREDA)

IREDA since 1994 is financing small hydro power with the aid of some renowned international and bilateral agenices. These mainly includes World Bank, Global Environment Facility (GEF), Danish International Development Agency (DANIDA), Asian Devalopment Bank etc. World Bank has offered a line of credit worth US $ 70 Million from International Development Association (IDA) to be utilized during 1993-99. Assistance under the scheme is available to private and Public sector entrepreneurs, but not to State Electricity Boards and Government Departments. The assistance covers grid connected SHP being developed at the existing irrigation canals, dam toe and run-of-the rivers with a maximum station capacity of 15

MW. The terms of financing inter-alia stipulate that the promoters contribution should be a minimum of 25% of the project cost and the loan assistance from IREDA could be 100% of cost of civil, electrical, mechanical and hydro-mechanical equipments limited to 75% of project cost. The loan attracts an interest of 16.5% per annum and can be repaid within 10 years (maximum) including moratorium of 3 years (maximum). IREDA has also announced promotional incentives in the form of interest subsidy for projects, payments for preparation of D.P.R.s and other fiscal incentives. These are briefly summarized in table 6.1. In order to have streamlined uniform policies to be adopted by various States, MNES has issued certain guidelines that can be followed by the State Governments and implemented by the concerned nodal agencies. The policies and incentives that have been declared by the various State Governments are given in Table 6.2 (refer page 130).

6.1.2 Financial institutions mentioned above at Sl.No.ii to vii (Para 6.1) (refer page 157) also provide rupee term loan for construction of small hydro project. The developer could have an interaction with these institutions to know norms and procedure for obtaining loans. All financial institutions require the statutory and non-statutory approvals including power purchase agreement, environmental clearance etc.

6.2 NECESSARY APPROVALS

6.2.1 The following approvals are required either from Nodal agencies/ State Government/Govt. of India:-

(i) Agreement with Nodal agency/State Government for executing a project and submission of a feasibility report within a stipulated time.

(ii) Approval from State Forest Department for carrying out surveys, if required.

(iii) Approval of the feasibility report by Nodal Agency

(iv) Power Purchase Agreement with Nodal Agency/State Government.

(v) Approval from M/o Environment & Forests, if required.

(vi) Agreement with agency owning the grid for Banking and wheeling of Energy

(vii) Approval for storing and purchasing of explosives.

(viii) Leasing/acquiring of land.

(ix) Third Party Sale Agreement.

The above are in addition to the registration of the Company under Companies Act, 1956.

6.2.2 When a project is floated by the State Government for private participation and a developer is selected for undertaking the same, an agreement/understanding is signed between the developer and the Nodal agency of the State Government for undertaking the project with the stipulation that the detailed feasibility shall be prepared by the developer for approval of the Nodal agency within the stipulated period. The project is subsequently taken up for detailed surveys and investigations leading to preparation of detailed feasibility report.

6.2.3 For carrying out the investigations, if required, State Forest Department permission is obtained. This is required when some damage due to construction of path or cutting of trees is expected.

6.2.4 The Detailed Project Report (DPR) is the basic document on the basis of which an approval for execution of a project is accorded by the Nodal Agency/State Government. The report contains all features of the project, cost-estimates, economic and financial viability, construction schedule, financial package etc. If the cost of the project is more than 50 crores, an EIA study is also appended.

6.2.5 After the feasibility report is accepted and approved by the Nodal agency, a power purchase agreement is signed with the State Government. This includes all stipulations required for execution, operation, and sale of energy from the project such as leasing of land, use of infrastructure facility already existing, use of waters, royalty on sale, evacuation arrangements, wheeling and banking charges, sale rate of energy, terms of payments etc. It is a basic legal document between State Government and developer and contains all legal and technical provisions required for successful operation of the plant over the stipulated period reconciling the varying interests of the participants and stake holdeers.

6.2.6 If the cost of the project is more than Rs.50 crores, approval of the Ministry of Environment and Forests is required from environmental considerations. In this context an EIA study (which entails collection and analysis of large data base) is required.

6.2.7 If the developer intends to sell power to a third party, then agreement with the State Electricity Board for wheeling and banking of energy shall be required. The agreement would spell out the modalities of banking and wheeling and their charges, metering arrangements, modes of payments, guarantees, penalties etc.

6.2.8 Explosives are essentially required for excavation of rock. Its storage requires construction of a strong room called magazine as per security standards. Permission has to be obtained from the State Government (Controller of Explosives) for purchasing and storing the explosives. It is a quite involved procedure and takes a few months. Arrangements for the security of the explosive is also the responsibility of the EPC contractor/ developer.

6.2.9 Acquisition of Land for the project and for dumping of excavated material is necessary before start of construction at the site. In certain states, land is made available on lease while in other cases it has to be acquired. The developer has to make necessary arrangements in this regard. If the land belongs to the Govt. than the procedure is simple otherwise it is time consuming.

6.2.10 If the power in full or part thereof is proposed to be sold by the developer to a third party, the developer has to enter into a Power Purchase Agreement with the purchaser. This agreement would be in line with the directives issued by the State Government in this regard.

TABLE - 6.1

FISCAL INCENTIVES FOR SMALL HYDRO

⇒ Schemes involving capital upto Rs.100 crores need no prior clearance from the CEA even if they are single sourced.

⇒ Schemes involving capital upto Rs.50 crores need no Environmental Clearance from MOEF.

⇒ Income Tax holiday for 5 years for Power generation projects.

⇒ Term loans through IREDA for schemes upto 25 MW.

⇒ Concessional customs duty @ 20% & for Non-Captive Use @ 10%

⇒ No excise duty for turbines upto 15 MW.

Additional Incentives under
MNES - Small Hydro Programme for projects ≤ 3 MW

◊ **Incentives for Preparation of DPRs.**

Grant-in-Aid of 50% of the DPR costs subject to certain ceilings depending upon the type of schemes.

◊ **Interest Subsidy Scheme through Financial Institutions.**

a) For Hilly Regions: North Eastern and A&N Islands Rs.1.12 Crores/MW (Applicable Project Cost: Maximum Rs.6 crore/MW)

b) For Non-Hilly (Other) Regions: Rs.38.3 Lacs/MW (Applicable Project Cost: Maximum Rs.4 Crore/MW).

◊ **For Schemes Upto 100 kW: (In Hilly Regions, NE and A&N Islands).**

Capital Subsidy of Rs.15,000/kW.

TABLE 6.2

POLICY/INCENTIVES FOR SMALL HYDRO SECTOR

ITEMS	MNES GUIDELINES	ANDHRA PRADESH	TAMIL NADU	KARNATAKA	ORISSA	KERALA	UTTAR PRADESH	MADHYA PRADESH	PUNJAB	HIMACHAL PRADESH
RATES/CHARGES										
a. Power Wheeling	2%	2%	15%	- 2% upto 1 MW - 5% upto 3 MW - 10% above 3 MW	- 2% upto 3 MW - 8% upto 15 MW	12%	- 2% (Captive) - 25% (Third party)	2%	2%	2%
b. Power Banking	one year	Allowed for one year for captive	Allowed for captive	To be negotiated	At mutually agreed rate	At mutually agreed rate	Upto 1 year to be negotiated	Not allowed	Not allowed	Allowed with additional charges
c. Buy back by SEB (per kWh)	Rs.2.25	Rs.2.25	At mutually agreed rate	Rs.2.60	At mutually agreed rate	At mutually agreed rate	Rs.2.25	Rs.2.25	Rs.2.25	Rs.2.25
d. Third party sale	Mutually agreed rate	Allowed at a price lower than SEB HT tariff	Not allowed	Allowed	—	Allowed	Allowed	Allowed	Allowed	Allowed
e. Royalty on water	10% of select tariff	As pere rates fixed by concerned deptt. of Govt.	Included in 1(a) above	Nil	Included in 1(a) above	Included in 1(a) above	10% of electricity generated	—	—	- 1-3 MW-10% - 3-15 MW - 12% Exemption for first 5 years upto 1 MW
INCENTIVES										
a. Capital subsidy	—	Upto 15 lacs per project Upto 20 lacs on backward area	10% of cost of equipment - Max. 15 lacs	As extended to other industries Max.8 lacs Additional subsidy 5% of cost of equipment (Max.5 lacs)	As given to other industries	—	—	—	—	—
b. Electricity Duty Exemption	Exemption of electricity duty	—	—	Exemption for 5 years for captive	—	—	—	Exemption for 5 years for captive	Exemption for 5 years for captive	Exemption for 5 years for captive
c. Sales tax exemption	Exemption from sales tax and other concessions applicable to industry/ backward area	—	—	New industry incentives	—	—	—	Exemption from sales tax and other concession applicable to new industry	Exemption from sales tax and other concession applicable to industry/backward area	No sales tax on power generation and transmission equipment and building material for power projects
d. Demand charge exemption	upto30%	—	—	—	—	—	—	Upto 30%	Upto 30%	Upto 30%
e. Promotional agency	—	APSEB	TNEB	KREDL	OPGCL	KSEB	UPLJVN/UPSEB/NEDA	MUUVN	PSEB/PEDA	HPSEB/HIMURJA

CHAPTER-7

PREPARATION FOR IMPLEMENTATION

7.1 INTRODUCTION

After identification of the site, pre-feasibility studies and allotment of the site by the State Government, the Developer has to go through a few more stages, before the project is ready for construction/implementation. These are described in subsequent paras.

7.2 PRE-FEASIBILITY STUDIES

Technical data on hydrology, geology, topography, available infrastructure facilities may be collected and studied. Preliminary layout of the project components is to be prepared. Power potential studies are to be carried out and optimum installed capacity determined. Rough cost estimates will be prepared which will form the basis for judging economic viability. Based on these studies, a Feasibility Report will be prepared, which is expected to establish, whether the project is technically and economically viable or not. This report will form the basis for acceptance of the scheme by the concerned Government Agencies.

7.3 DETAILED PROJECT REPORT (DPR)

After acceptance of the Feasibility Report, the next step will be preparation of a D.P.R. The work of formulation of a DPR for a small hydro project should be entrusted to a competent team consisting of a surveyor, hydrologist, geologist, civil engineer, electrical and mechanical engineer. The team could utilise the services of a qualified economist to evaluate the economic viability of the scheme in line with the Government practices for private sector participation. The site investigations to be carried out will cover:-

(a) Topographical Survey
(b) Hydrological & Silt data collection
(c) Geological mapping & exploration
(d) Sub-surface exploration
(e) Availability of construction materials
(f) Access to different components of scheme
(g) Environment Impact Assessment for project costing more than Rs. 50 crores

Detailed guidelines for these investigations, which have been issued by the Central Electricity Authority, Ministry of Power, Government of India and also by Indian Renewable Energy Development Agency (IREDA). Based on the above investigations, a Details Project Reporet (DPR) has to be prepared, based on the survey drawings and collected data.

The power potential studies will be firmed up based on the computed head and discharge and energy generated. The selection of generating plant, design features of electrical works and power house will be done as discussed in Section-III and IV. The cost estimates will be worked out.

Formats for preparation of DPR for Small Hydel Projects have been issued by CEA and IREDA in 1983. Based on these formats the DPR for Small Hydro Projects would coprise the following sections:

- Check List
- Salient Features
- Main Reports

The format for the above three sections are given in Annexures 7.1, 7.2 & 7.3 (respectively)(Page 134 to 147)

7.4 FINANCIAL ARRANGEMENT

After preparation of a DPR, the total cost of the project is known, and the funding of the project can be arranged through Financial Institution and Banks and power purchase agreement can be signed with the SEB.

7.5 APPROVAL/CLEARANCES FROM STATUTORY AUTHORITIES

All hydel projects costing below Rs. 100 crores are exempt from CEA clearance. Also the Ministry of Environment & Forests have exempted hydel projects with an outlay of less than Rs. 50 crores from environmental clearance. However, the projects have to obtain 'Forest Clearance' from the State Forest Department and the Ministry of Environment & Forests, in case Forest land is involved.

7.6 ADVANCE ACTION

Before start of actual construction, advance action is needed on the following issues:-

(i) Acquisition of licence for explosives required for blasting operations, arrangements for their transportation and storage.

(ii) Acquisition of rights for quarrying of agreements and sand.

(iii) Land acquisition formalities, negotiations with private owners.

(iv) A detailed construction programme be drawn up in respect of each activity.

CHECK LIST

NAME OF THE PROJECT

LOCATION

(I) State
(ii) District
(iii) Taluka

CATEGORY OF THE PROJECT

Small Hydel Hydroelectric Schemes with a total installed capacity upto 15 MW.

PLANNING

Has the overall development of the stream/canal been prepared and stages of development discussed briefly ?

Have the alternative proposals been studied and their merits and demerits discussed ?

Have the detailed topographical surveys been carried out for the following items and drawings prepared as per prescribed scales ?

(I) Stream/Canal Surveys
(ii) Head works surveys (weir or diversion structure)
(iii) Plant site and camp site
(iv) Water conductor system
(v) Power house. Switchyeard, Tailrace
(vi) Penstock surge shaft, if necessary
(vii) Communication etc.

GEOLOGY

Have the geological surveys for Head works, Power house and tail-race, etc., been carried out and report on general geology of the area and on geology of the sites of principal structures appended ?

FOUNDATION INVESTIGATIONS

Have the foundation investigations for the major civil structures and of the schemes, etc., been carried out ?

MATERIAL SURVEYS

Have the surveys and laboratory tests for construction merial, like previous and impervious soils, sand, aggregate etc., been carried out? (wherever necessary).

HYDROLOGICAL & METEOROLOGICAL INVESTIGATIONS

Have the hydrological and meteorological investigations been carried out and status of data discussed in report?

(I) Rain-fall in the catchmeent
(ii) Gauge and discharge data of the stream/canal.

HYDROLOGY

Have hydrological studies been carried out to establish the availability of water for the benefits envisaged, and what is the dependability of the potential ?

LAND ACQUISITION & RESETTLEMENT (Wherever applicable) :

Have the provisions for land acquisition and resettlement been considered ?

Have the socio-economic problems involved in resettlement been investigated and discussed ?

DESIGN

Has the laybout of the project area, viz. location of diversion structure, workshop sheds, offices, camps, etc. been finalised ?

Have the preliminary designs prepared for the following components:

(I) Diversion structure or weir etc.
(ii) Penstocks and water conductor system, etc.
(iii) Power house and Switchyard.
(iv) Power house equipmeent, LT/HT switching equipmeent and control and protection equipment.

POWER BENEFITS

Have the following points been discussed ?

(i) Total energy production and installed capacity of the grid system.
(ii) How does the scheme fit into overall development of power

of the region? (if applicable).

(iii) Energy generation from the project, firm power, seasonal power and total power.

(iv) Proposals for transmission and or connecting to the existing system, etc. (wherever applicable).

(v) Cost of generation per KW installed, per Kwh generated, as compared to the various micro-hydel projects and various services in the region to justify the economic viability of the scheme.

CONSTRUCTION PROGRAMME

Are the major components of work proposed to be done departmentally or through contractor ?

Have the year/month-wise quantities of the following items been worked out for various components of the project ?

(I) Excavation - soft and hard strata
(ii) Earth work in filling (wherever applicable)
(iii) Stone for masonry
(iv) Coarse aggregate for concrete
(v) Steel of various sizes and type of reinforcement
(vi) Cement
(vii) Other materials - P.O.L. Electricity.

ESTIMATE

Is the estimate prepared ?

Have the analysis of rates for various major items of works for the major components of the pojrect been furnished, with the basis of analysis and the price index at which the estimate is based ?

ECOLOGICAL & ENVIRONMENTAL ASPECTS

Is the area likely to have any environmental and ecological problems due to the altered surface water pattern and preventive/corrective measures discussed? (wherever applicable).

CAMPS AND BUILDINGS

Has the planning of the camps/buildings been done ?

SOIL CONSERVATION

Is the need for soil conservation measures in the project discussed ?

SALIENT FEATURES

1. LOCATION

(I) State

(ii) District

(iii) Taluka

(iv) Village

(v) Access - Road
- Rail

(vi) Geographical co-ordinates
- Latitude
- Longitude

2(A) RIVER CATCHMENT

(i) Catchment

(ii) River

(iii) Tributary

(iv) Sub-tributary

(B) CANAL FALL/LOW HEAD

(i) Project

(ii) Canal System

3(A) HYDROLOGY

(i) Catchment area of the stream/nallah

(ii) Catchment area at the diversion site:
- Gross
- Intercepted in the upstream, if any
- Free catchment

(iii) Precipitations:

	Annual	*Monsoon (June-Oct.)*
Average rainfall		
Max. rainfall		
Min. rainfall		
Co-efficient of variation		
Snowfall		

(iv) Dependable yield (wherever applicable)

Percentage	*Annual*	*Monsoon (June-Oct.)*
50%		
75%		
90%		

(v) Climate data:

	Normal	*Maximum*	*Minimum*
Atmospheric			
Temperature (deg. C)			
Humidity (%age)			
Wind (Km/hr)			

(vi) Floods

Historical — Location & Elevation

Maximum discharge estimated (cumecs)

Date of occurrence

Observed — Location & Elevation

Maximum water level

Max. discharge estimated (cumecs)

Date of occurrence

Standard projected flood (cumecs)

Design flood (cumecs)

Head works/Diversion on site

Max. design flood (cumecs)

Stream/nallah flows (min. observed)

Water level (EL m)

Discharge (Cumecs)

Months of 'Nil' flow

(b) CANAL FALLS/LOW HEAD SCHEMES

(i) Design discharge

(ii) Water availability

4(A) MEDIUM/HIGH HEAD PROJECTS
(Not applicable for Canal Fall Scheme)

(a) Diversion Structure (Head works)

(i) Type of structure
Weir/barrage
Concrete
Masonry
Any other type

(ii) Length (M)
Over-flow section (wherever applicable)

Non-over flow section

(iii) Tail water level (EL m)
Maximum
Minimum

(iv) Maximum discharging capacity (cumecs)

(v) Gates
Number of gates
Types of gates
Size of gates

(b) Head Regulator:

(i) Total Length (m)

(ii) Height above deepest foundation (m)

(iii) Length of bay (m)

(iv) Sill Level (El m)

(v) Number of gates

(vi) Size of gates

(c) Water Conductor System:

(i) Length (m)

(ii) Shape

(iii) Size (m)

(iv) Full supply depth (m)

(v) Thickness of lining (mm)

(vi) Design discharge (cumecs)

(vii) Free flow under pressure (m)

(d) Forebay:

(i) Size of forebay (m)

(ii) Sill level of forebay (El m)

(iii) Full forebay level (El m)

(iv) Maximum forebay level (El m)

(v) Number of off-takes:
- Size (m)
- Invert level (El m)
- Capacity

(vi) Maximum discharging capacity (cumecs)

(vii) Diurnal Storage (m3)

(e) Penstocks:

(I) Number

(ii) Diameter (m) and thickness (mm)

(iii) Length (m)

(iv) Size of gate/valve (m)

(v) Bifurcations, if any, at lower end

(vi) Invert level (m)

(vii) Design discharge (Cumecs)

4(B) LOW HEAD/CANAL SCHEME

(a) Shape

(b) Size

(c) Capacity of canal (Cumecs)

(d) Full Supply Level (El m)

(e) Lining details (m)

(f) Fall Structure (m)

(g) Height of fall (m)

(h) By-pass arrangements

(i) Bridges if any

(j) Annual closure period of canal (days)

5. POWER HOUSE

(i) Type

(ii) Head (m):

— Maximum
— Minimum
— Average
— Design

(iii) Size of power house:

(a) Length (m)
(b) Width (m)
(c) Height (m)

(iv) Installed capacity

(v) Turbine(s):

- Type
- Number
- Capacity (KW/HP)

(vi) Type of Generator:

(a) Excitation System
(b) Regulation System

(vii) Power house crane/Lifting tackle capacity

6. TAILRACE

(i) Shape

(ii) Size

(iii) Length (m)

(iv) Water level (El m):

- Maximum
- Minimum

(v) Number and size of draft-tube gates

7. POWER

(i) Installed capacity

(ii) Firm power (KW) - Load factor - in percent

(iii) Seasonal (max.) power 9KW)

(iv) Annual energy (kWh)

- Firm
- Seasonal
- Total

8. SWITCHYARD

(i) Voltage level/Basic undulation level

(ii) No. of days

(iii) Size (a) Length
(b) Width

9. ESTIMATES OF COSTS

(i) Total cost (Rs.__________lakhs)

(ii) Cost per KW installed (Rs.__________lakhs)

(iii) Cost of generation per kWh (__________paise)

(iv) Benefit cost ratio

(v) Break even period

(vi) Percentage return after break even period (shall not less than 11.5%)

MAIN REPORT

(A) SMALL HYDRO PROJECTS - TYPE 1

CHAPTER - 1 INTRODUCTION

- Geographic Disposition
- Topographical Features
- River Systems
- Location of the Project Area
- Socio-Economic Aspects
- Necessity - Needs and Opportunities of Development
- Choice of the Scheme - Alternative Studies
- Scheme Proposal
- Plant of Development

CHAPTER - 2 PROJECT PURPOSES

- Existing Power Facility in the Area
- Existing Transmission & Distribution Lines in the Area
- Power Demand Forecast
- Expected Benefits from the Project

CHAPTER - 3 INFRASTRUCTURE FACILITIES

- Location of Project Site
- Available Access to Project Site
- Infrastructure Available
- Additional Facilities of Access and Instructures Required to be Provided

CHAPTER - 4 SURVEYS AND INVESTIGATION

- Topographical Surveys
- General Layout
- Diversion Site
- Water Conductor

- Desalting, Forebay Penstock, Power House & Tailrace Sites
- River Cross Sections at Diversion Site and Power House Site

CHAPTER - 5 HYDROLOGY

- Catchment Area
- Discharge Observations Data
- Rainfall Data
- Correlation Studies for Assessing Design Discharge
- Flood Studies
- Sediment Studies

CHAPTER - 6 GEOLOGY

- Regional Geology
- Geological Assessment of Abutment Slopes of Diversion Site Hill Slope Stability along the Alignment of Water Conductor, Penstock Stope Stability
- Geological Exploration Studies for the Various Features of the Scheme
- Seismicity

CHAPTER - 7 POWER POTENTIAL AND INSTALLED CAPACITY

- Monthwise Flow and Energy Benefits in a 75% Dependable year.
- Monthwise and Energy Benefits in a 50% Dependable year.
- Installed Capacity
- Number of Units and Capacity of Each Unit

CHAPTER - 8 CIVIL WORKS

(1) Diversion Structure
- Layout
- Design Criteria
- Hydraulic Design Calculations

(2) Water Conductor
- Layout
- Design Criteria

— Hydraulic Design Calculations

(3) Desitting Tank

— Layout
— Design Criteria
— Hydraulic Design Calculations

(4) Foreby

— Layout
— Hydraulic Design Criteria

(5) Penstock

— Layout
— Design Criteria
— Hydraulic Design Calculations

(6) Power House

— Layout
— Design Criteria

(7) Tailrace

— Layout
— Hydraulic Design Calculations

CHAPTER - 9 ELECTRO MECHANICAL WORKS

— Description of Generating Equipment and Auxiliaries, Transformers, Switchgear, Control and Relay Panels, Switchyard, Crane, Single Line Diagram

CHAPTER - 10 CONSTRUCTION PROGRAMME

— Material Planning

— Plant & Equipment Planning

— Manpower Planning

— Dewatering Arrangements (if required)

— Workshop and Transport Equipment

— Mode of Construction

— Organisational Set-up

— Services and Utilities (Colony, Water Supply Power Supply, Construction Power, Sanitation) during Construction Phase & during Post Construction Phase

— Procurement of Materials

— Work Programme (Season-wise)

— Bar Chart Showing Quantity Wise & Item-wise Target of Construction

CHAPTER - 11 CONSTRUCTION MATERIALS

— Requirements - Quantities of Principal Construction Materials

— Sources and Tests Carried Out

— P.O.L., Explosives, etc.

CHAPTER - 12 ENVIRONMENTAL ASPECTS

— Site in Relation to Environmental Concerns

— Preventive/Corrective Measures (if required) and Estimation for these Measures

CHAPTER - 13 ESTIMATES OF COSTS

— Abstract of Costs

— Quarter-wise Phasing of Expenditure

CHAPTER - 14 BENEFITS AND FINANCIAL RETURNS

— Direct Benefits

— Indirect Benefits

— Financial Aspects

(B) SMALL HYDRO PROJECTS - TYPE 2

Certain items listed above in respect of civil works like desilting tanks, forebay etc. are not applicable. There could be other items specific to the project. The write up could be suitably modified to suit the features of the project.

The list of drawings to be appended is given below

Small Hydro Project - Type 1

— Index Map of the Scheme Showing the Location of Major Components

— Catchment Area Plan Showing Location of Hydro-meteorological Stations (if applicable)

— X sections of River at Head Works

— Plan Showing Location of Boreholes Drilled (if applicable) and Pits Excavated, Site Geology and Bed Rock Contours etc.

- Logs of Drill Holes (if applicable) and Trial Pits at the various
- General Layout Plant of the Scheme
- Diversion Structure at Head Works (Plan and Sections)
- Water Conductor - Plan, Cross Sections & Longitudinal Section
- Desilting Tank - Plan and Sections
- Forebay Plan and Sections
- Penstock Intake Plan and Sections
- Penstock - Plan, Longitudinal Section and Cross Section
- Tailrace - Plan and Sections
- Colony - Layout Plan
- Single Line Diagram
- Bar Chart Showing Construction Programme

Small Hydro Projects Type 2

Certain drawings listed above like desilting tank, forebay etc. may not be applicable. There could be other items specific to the project. The list indicated for type 1 may be suitably modified on this account.

CHAPTER-8

IMPLEMENTATION, PLANNING AND SCHEDULING

8.1 INTRODUCTION

In Chapter-7, the activities involved in planning stage of a small H.E. Projects have been detailed. In this chapter, the aspects requiring close attention during the construction phase of the project are dealt.

8.2 NEED OF A CONSTRUCTION SCHEDULE

Before start of the construction, a detailed construction programme needs to be drawn up. This should detail the starting point and completion time for each activity and all components of the project. A typical schedule for a run-off-river small HEP is enclosed at Annexure-8.1. (Page No. 152) In fact, based on the programme of the field construction activities a fuller schedule covering other related activities such any remaining investigations, designs, invitation of tender and placement of orders etc. should also be made. For having close co-ordination of different activities, it would be better if PERT network is developed for project execution.

8.3 PERT CHART

Pert (Programme evaluation and Review technique) is one of the most convenient and commonly used tool for scheduling project activities to optimise construction time and resources. It also helps the Project Managers to know the status of the project at a glance at any point of time and provides a meaningful schedule/basis for monitoring. The pert chart is essentially a realistic construction schedule which is made keeping in focus the sequence of linked activities as well as inter relation of various groups of activities. It can be compared to a road map of the area from which a shortest route to a destination can be determined. To illustrate this, let us consider the work of concreting in a powerhouse sub-structure, which can only be started after embedded parts of turbo-generation equipment are installed. Such sequences are kept in view when programming any activity for incorporation in a PERT chart.

The first step in preparing a PERT chart will be to enumerate all the activities involved in the project from commencement to commissioning.

The time schedules are then then developed for each invidual activity keeping in view time required for the activity itself, necessity at a given time and inter dependence with other activities. The chart incorporating these schedules in an appropriate sequence constitutes a PERT chart. Each activity is to be given two dates, early date and later date for start as well as completion. The difference between the two dates viz. early and later dates of an event is known as slack period. The activities having no at very little slack period are treated as critical, requiring close attention, as any delay in their completion can upset the programme os subsequent activities.

The selection of contractors and award of contracts must confirm to the accepted PERT chart to enable synchronisation of the different phases of the construction and equipment procurement activities. A PERT may also firm a part of the contract and payments released on achieving certain milestones indicated in the chart. Periodical reviews, say every 3 months or so, will help in identifying the critical activities which are slipping in ther targets and likely to affect such activities which have to follow in succession. Corrective steps can be initiated in time so that the overall completion date of the project is adhered to.

8.4 LAND ACQUISITION

Negotiations with private parties and interaction with Government agencies (Revenue and Forest) for acquisition of land required for works should be conducted as a part of pre-construction activities. The aim is to make the land available to the construction agencies in time and as and when required.

8.5 ELECTRO-MECHANICAL EQUIPMENT

Orders for turbo-generators equipment should be placed well in time, so that supply is ensured at the right time when installation is proposed to be started. Design of all relevant electrical systems, specifications etc. should be made at coordinated timings. Design data for structural details will be needed for finalising construction drawings and actual construction of some civil structures. Such data has to be obtained from suppliers well in advance.

8.6 CONSTRUCTION MATERIALS

During the planning stage, sources of materials would have been identified. After commencement of construction, flow of construction materials such as explosives, aggregates, cement, steel etc., should be ensured. In some remote locations, the approaches to the site may be cut off on account of natural phenomenon like heavy rains, land slides, or snow fall. It will, therefore, be desirable that at least one months requirements of materials is available at the site to guard against temporary dislocations.

8.7 EXPLOSIVES

Acquisition of licence for explosives to be used for rock excavation, and arrangements for their transportation and storage is required to be arranged.

8.8 GEOLOGICAL UNCERTAINTIES

During excavation and exposing of foundations, geological surprises may be encountered, necessitating provision of treatment works or change in designs. It is suggested that services of a competent geologist be made available during the implementation stage to deal with geological problem during implementing stage.

8.9 TIME AND COST OVER-RUNS

Considering the varied nature and complexity of works there could be possibility of unexpected delays in the completion of projects resulting in cost overruns. For minimising/eliminating these risks, close and constant monitoring of the activities is required.

8.10 The availability of construction machinery at site is importance since the locations are often in remote areas. Any breakdown would require considerable time if some parts are to be procured and brought to site. In order to minimise the breakdown time, it is suggested that essential spare parts be stored at site. A small workshop at site would also be of immense help.

8.11 INSPECTION

Arrangements have made for inspection of Hydro-mechanical, electro-mechanical equipments and turbines and generators in various stages of manufacture. This will ensure quality and satisfactory performance.

8.12 STORAGE OF EQUIPMENT/SPARES

The electro-mechanical equipment, when received at the site has to be carefully stored, before erection. An inventory may be made of all the parts received and proper records of receipt/ consumption maintained. This would also be applicable to any other mechanical equipment such as gates, hoists etc.

8.13 MONITORING

Timely completion of the project within the estimated cost is of vital importance to the Developer/Promoter of a small H.E. Project. To achieve this, close and constant monitoring of various activities in planning as well as implementation stage is essential.

8.14 EXPERIENCE OF SUCCESSFUL DEVELOPERS

In the recent past a few Small Hydro Projects have been successfully commissioned. An attempt has been made to collect the experience of the successful developers in executing these projects. Some developers who have responded to our request suggest the following measures, which in their opinion could accelerate the development of this resource.

1. Before handing over a project to a Developer the state government should carry out detailed investigations (including carrying out hydrological assessment and preparation of DPR).
2. The site should be handed over after acquiring of land and providing necessary infrastructure upto the project area i.e. roads, electricity, etc. if private land to be acquired, co-operation of the state government should be extended.
3. A Nodal Committee should be set up by the state government to, extend help to a private developer during execution of the project.
4. The procedure for storing and purchasing of explosures should be made more practicable and simple.
5. Security arrangements at site or for explosive made by state government free of cost.
6. For small hydro royalty in water should be dispensed with.
7. Construction of transmission line for interconnection should be the responsibility of State Electricity Board. The cost of the same could be indicated at the time of allotting the project to the Developer.
8. The procedure for providing funds and various clearances may be further simplified.
9. The single window agency should get clearance from environmental/irrigation and other concerned departments.
10. A list of consultants who are competent and have proper background and experience in Small Hydro could be published.

CONSTRUCTION SCHEDULE
SMALL HYDRO POWER PROJECT

S.NO.	ITEM	YR.	1ST YEAR				IIND YEAR				IIIRD YEAR	
		Qr.	1	2	3	4	1	2	3	4	1	2
1.	Preliminary and Infrastructure Development											
1.1	Construction Plan											
1.2	Land acquisition											
1.3	Approach ropads to weir, powerhouse, construction camp sites											
1.4	Tenders and allotment of civil works											
2.	Civil Works											
2.1	Trench Weir and Intake											
2.2	Water conductor system and desilting tank											
2.3	Foreby											
2.4	Penstock											
2.5	Power House											
3.	Electromechanical Equipment											
3.1	Tenders and award of EPC contract											
3.2	Procurement and Installation											
4.	Testing and commissioning											

CHAPTER - 9

PROCUREMENT OF EQUIPMENT AND WORKS

9.1 In case of a small H.E. Project, selection of the right agency for implementation is of paramount importance. Failure to do so may result in time overrun, cost overrun or bad workmanship, which singularly or collectively can jeopardise the economic viability of the project various contract procedures followed in the country and available to the development are described in this chapter, to enable selection in a suitable procedure, appropriate to the requirements of a particular project.

9.2 CIVIL WORKS

The various modes of contract are:-

- Item rate contract
- Lump sum contracts

Item rate contract is the most commonly used by Environmental Departments in India. The rates quoted by the contractor are evaluated with reference to the estimate already prepared covering quantities as well as rates of items.

Any variation in quantities during actual construction due to any reason such as inadequate investigations, geological uncertainties change in designs etc. can result in extra claims and increase the amount payable to contractors.

Under lump sum contracts, the scope of all works have to be well defined, as otherwise any deviation in the scope can cause large variations in the contracts.

Pre-requisite for success of the above contract practices is that the developer should have in-house facilities for design, engineering and project management.

9.3 ELECTRO-MECHANICAL EQUIPMENT

The contract procedures could be any of the following types:-

i. Manufacture and supply
ii. Manufacture, supply and delivery
iii. Manufacture, supply, delivery and erection
iv. Supply & delivery
v. Supply, delivery and erection
vi. Erection.

Generally, the option listed at (iii) above is more preferred, as it involves a single point responsibility.

9.4 TURNKEY E.P.C. CONTRACTS

Though widely practised in other countries, their advent in India is of recent origin in this system, the site is handed over to the contractor who is to execute civil, electrical and mechanical works for emission the lower house and hand over to the owner for operators and maintenance. The practice has an advantage that the developer need not have in-house capabilities for design engineering and construction. Also the need for effecting co-ordination between various agencies is eliminated, and a single agency is answerable for all the activities. Since the turnkey contractors who do come forward to take up a job on turnkey basis are found not equipped with their own civil design, electrical design and construction organisations, they let out design and construction of civil works to different agencies.

If the turn-key contractor is not available, the option could be to have:

- a consultant to finalise the DPR and construction drawings and supervise the works
- a civil construction company to take up the civil works
- a manufacturer/supplier of equipment to deliver and erect the equipment
- an agency for taking up transmission line and sub-station works.
- very definite arrangements for coordination/correlation of interfaces must be madw with experienced personnel.

9.5 TENDERING PRACTICES

Various procedures in use for tendering are:-

- Short term tender notices
- Tenders with single bidding
- Tenders with two part bidding
- Tenders with initial prequalifications.

9.5.1 Short Term Tenders

These are resorted to in case of urgency. Due to limited reach, it may not be possible to get the contractor with enough resources and capability.

9.5.2 Tenders with Single Bidding

The tenders are invited for a particular work/or a group of works and a set of conditions and work specification are made known to the bidders. The evaluation of bids often pose problems, as the bidders often put forward their own conditions.

9.5.3 Tendering with Two Part Bidding

Here the bidder gives his offer in two separate covers one containing technical bids and the other containing price bids. In the first stage, technical bids are opened and evaluated. A pre-bid reference is held with the bidders before opening the price bid and all the technical and commercial conditions are brought to a commonly agreed level. The bidders are given another opportunity to revise their price bid in view of the technical clarification and quote for the extras or rebates.

9.5.4 Tenders with Initial Pre-Qualification

The notice for pre-qualification of eligible contractors is issued indicating the minimum acceptable technical and financial conditions. The technical capability, past experience and financial standing of the parties is called for and the eligible parties are shortlisted. Tenders are then invited only from the pre-qualified parties.

In conclusion, the mode of contracting has to be decided keeping in view the situation in the area and the factors described above.

9.6 TENDERING PROCEDURES FOR WORLD BANK AIDED PROJECTS

World Bank guidelines for procurement require L.C.B. or I.C.B. procedures which if followed require a long period for finalisation which the private developers of small HEP, may not be able to afford through the efforts of IREDA, the Bank has relaxed its norms. The procedures now allowed by the Bank for civil works and equipment are summarised at Annexure-9.1 & 9.2 respectively (refer page 196 & 197).

9.7 CONTRACT DOCUMENTS

Given below is the list of essential elements to be included in the contract document:-

- Notice inviting tender

- Schedule of quantities and specifications of items
- General terms and conditions
- Commercial terms and conditions
- Technical Specifications
- Drawings
- Contract Agreement Proforma
- Bank Guarantee Form
- Warranty Proformae (in case of electro-mechanical works)

9.8 CONCLUSION

In conclusion the mode of tendering/procurement has to be decided keeping in view the situation and in consultation with the financiers.

India : Renewable Resources Development Project
Civil Works Procurement Methods Allowed by World Bank

Sl. No.	Type of Tender	Estimated Value of Procurement Packages		Remarks
		Private Sector	Public Sector	
1.	International Competitive Bidding (ICB)	Above US$ 10 Million	Above US$ 10 Million	Invitation notice shall be published in UNDB journal at least 60 days before sale of bid documents --- Provide Invitation for Bid (IFB) copy to local rep & embassies and provide those evincing interest — Wide publicity in news papers both at local and international level — Bank's Standard ICB bid document shall be used and got it approved from World Bank before issue
2.	National Competitive Bidding (NCB)	US $ 10 Million and below	US $ 10 Million & below	— Competitive Bidding advertised locally in accordance with the procedures acceptable to the World Bank (NCB) — Wide publicity in local and national news papers — Bank's Standard NCB bid document be used and got it approved from World Bank before issue
3.	Established Commercial Practice (ECP)	US $ 5 Million and below		Established Commercial Practices, acceptable to the World Bank (ECP), which inter alia, shall include: — Some form of competition and evidence to this effect shall be presented to the WB; and — In case of direct contracting; or when no documentary evidence is available to demonstrate competition, IREDA shall furnish to the WB confirmation by independent engineers employed by IREDA that the contract amounts are reasonable
4.	Force Account	US $ 25,000 and below up to an aggregate amount of US $ 2,00,000		— Force Account procedures, or Direct Contracting or under contract awarded on the basis of comparison of price quotations obtained from at lease three qualified contractors, in accordance with procedure acceptable to the WB

India : Renewable Resources Development Project Equipment Procurement Methods Allowed by World Bank

Sl. No.	Type of Tender	Estimated Value of Procurement Packages		Remarks
		Private Sector	Public Sector	
1.	International Competitive Bidding (ICB)	Above US $ 5 Million	Above US $ 0.2 Million	— Invitation notice shall be published in UNDB journal at least 60 days before sale of bid documents — Provide Invitation for Bid (IFB) copy to local rep & embassies and provide those evincing interest — Wide publicity in news papers both at local and international level — Bank's Standard ICB bid document shall be used and got it approved from World Bank before issue
2.	Limited International Bidding (LIB)	US $ 5 Million and below		— Invitation sent to selected bidders after the list is approved by World Bank/IREDA — Provide Invitation for Bid (IFB) copy to local rep and embassies and provide those evincing interest — Bank's Standard ICB bid document be used and got it approved from World Bank before issue
3.	Request for Quotation (RFQ)	US $ 5 Million and below		— Request for Quotation (RFQ) is made according to procedures acceptable to the World Bank — Quotations at least three qualified Suppliers from at least two eligible countries shall be obtained for evaluation (Proof of despatch of Invitation to foreign suppliers is enough even if Quotes are from only from India)
4.	Established Commercial Practice (ECP)	US $ 50,000 and below		— Established commercial practices for the items shall be followed — The procedure shall be described and got approved
5.	National Competitive Bidding (NCB)		US $ 0.2 Million and below	Competitive Bidding advertised locally in accordance with the procedures acceptable to the World Bank (NCB) — Wide publicity in local and national news papers — Bank's Standard NCB bid document be used and got it approved from World Bank before issue

CHAPTER-10

CONSTRUCTION AND MATERIAL MANAGEMENT

10.1 CONSTRUCTION PLANNING AND SUPERVISION

A typical Small H.E. Project is likely to be located in a remote area with meagre transport and other relevant infrastructure facility, distant from a large town capable of providing support for industrial work. A considerable amount of advance planning and fore thought is needed for a smooth and uninterrupted execution of the works. The specific features of the project are also many, spread over a considerable distance. When such projects are executed by the Govt. including Public Sector Corporations, the standing organisations of the Department or the Corporation can be brought into play to make necessary advance reconnaisance, surveys, planning, etc. including that for facilities for construction and other infrastructure improvements.

Unlike the Government or Public Sector organisations, a private developer of a SHP may not have an engineering and construction organisation of his own. He will therefore need the help of a consultancy organisation having expertise in planning, design as well as execution of works who could co-ordinate with the EPC contractor and the different agencies engaged in implementing the project and also liaison with Government agencies, where required.

10.2 SCOPE OF CONSULTANCY SERVICES

The services of a consultant are to cover:-

(i) Feasibility Report
(ii) Detailed Project Report
(iii) Detailed Engineering; and
(iv) Construction Supervision

10.2.1 Consultancy services can be provided consultants experienced in execution of small H.E. Projects. In case a suitable consultant competent to handle all the four subjects is not available, it will be necessary to form a separate group for construction supervision. Such a group will also be responsible for quality control and material testing (field and laboratory)

10.3 QUALITY CONTROL

It is essential on the part of site engineers and technical staff to ensure the quality of work in accordance with the design assumptions and specifications of the structures. The materials are often variable in nature and variation in their characteristics has to be taken care of during their processing, handling, proportioning and placement operations. Excercising quality control, which comprises inspection and testing is of paramount importance and is aimed at reducing the variations in the end product to the acceptable minimum and bringing uniformity in the quality of materials, manufacture and placement of the final product.

Sub-standard materials and workmanship, may sometimes lead to failure of the structure or its inefficient functioning requiring costly repairs and rehabilitation measures. Control over quality of materials and workmanship is therefore of great importance. Particular attention needs to be given to approval of source of materials, testing of materials proportioning, testing of concrete, cuting examination of foundations before covering up, batching and mixing of concrete laying of reinforcement, inspection of plant and equipment etc. Quality control tests and procedures should have stipulation as part of the contract.

10.4 MATERIAL MANAGEMENT

- Cement
- Steel - Reinforcement
  - Structural
  - Plates
- Stone/Boulders
- Bricks
- Fine sand
- Coarse aggregate of different sizes
- Lime
- Explosives
- Detonators
- C.G.I. Sheets
- Pipes - Concrete
  - Steel
  - PVC
- P.O.L..
- Timber

The availability of required quantities of materials at site at the time required is important for timely completion of the works. The quantities of various materials required can be reasonably assessed from the estimate of item quantities which are based on design drawings. The sources from where the materials have to be procured should be identified in the pre-construction stage itself. Considering that the approach roads may be blocked due to natural causes, or there could be temporary problems in transportation of materials to the site, it may be worthwhile to store at least one to two months supply at site.

The materials to be used in works (soil, cement and aggregates) have to be tested in the field and laboratory, as required to ensure compliance with ISI norms or as stipulated in specifications of work. This testing can be got down by the consultants hired for construction supervision.

10.4.2 Testing of Materials

For quality assurance of civil engineering works, following tests on construction materials may be needed:

1. Cement
   - (i) Consistency test
   - (ii) Setting time
   - (iii) Soundness test
2. Coarse Aggregate
   - (i) Abrasion
   - (ii) Soundness
   - (iii) Grading Analysis
3. Fine Aggregate
   - (i) Fineness modulus
   - (ii) Silt content
   - (iii) Deliterous matter
   - (iv) Moisture Content
4. Concrete Mix

   Gradation of aggregates, water cement ratio, slump
5. Concrete
   - (i) Cube strength
6. Reinforcement Steel
   - (i) Tensile strength
7. Soil for Back Filling
   - (i) Optimum moisture content
   - (ii) Proctor density

Frequency of testing, and place of testing (i.e. whether at source of supply or in Field laboratory or at site of work) has to be decided as per the advice of consultants.

10.4.3. Tests on Generating Plant and Equipment

The Power House will comprise, besides the main turbine and generator plant, of a number of supporting and balancing equipment including values, gates, switchgear, electrical controls and safety features, communication, handling equipment servicing facilities, back up power etc. The consultants would have visualised the necessary systems and incorporated in procurement and erection specifications. In case of small HEP, it has been a common practice to order entire power house equipment and system on a turn key basis to limit inter-coordination problems. The purchasers supervisory engineer, assisted by the consultant, would have to make sure that all tests and checks as prescribed for manufacture and at site are carried out successfully.

10.4.4 Mechanical Equipment

Mechanical equipment such as gates, trash rack, etc. are to be installed at diversions structure, desilting facilities, forebay, tailrace, etc. Penstocks also are to be fabricated/procured and installed. A few values would also be involved. The work and method for these features will have to be similar to that discribed for generating Plant and equipment above.

10.4.5 Model Tests

Hydraulic model testing may not normally be required in small Hydro Projects. However, if it is needed in some particular cases help will have to be taken from one of the established research station.

CHAPTER-11

MONITORING AND EVALUATION

Implementation of a small hydro project involves fairly large outlays and multiple agencies, besides facing problems caused by remoteness, climatic conditions as also possible limitations to foolproof investigations. The gestation period for these projects is generally not more than 2-3 years. Delay in completion of any activity can upset the overall target of completion and result in time over-run and cost over-run. It is therefore, necessary to closely monitor the progress and take corrective action in time to keep the project commissioning to target.

Monitoring of any project would imply that detailed implementation schedule covering all important activities has been drawn up. This should cover all the activities involved upto the commissioning stage with their quantities, cost and the time frame for each. During implementation stage, continuous monitoring/review of each activity is done, so that no activity is allowed to lag behind if any slippage comes to light, timely corrective steps to remove the constraints has to be initiated.

The World Bank aided projects are monitored through the agency of IREDA. The project progress is monitored through quarterly progress report received from developers in prescribed formats. Sometimes interim reports are also called for during disbursement process. Site inspection are also made by IREDA officials to assess the progress and recommend release of loan instalments.

In case of small hydel projects financed by non-Bank Sources, it will be in the interest of the developer to monitor the progress through an independent monitor, who should be conversant with all the phases of the project. It is suggested that monitoring reports should be called for monthly in view of the relatively short construction time. It would be better if a PERT network is developed for project execution. Formats for Quarterly Progress Reports - physical and financial are suggested here in (Annexure 11.1 and 11.2) [refer pages 163 & 164]. These can be suitably varied/modified by the monitoring agency, keeping in view the project situation.

MONTHLY PROGRESS REPORT (Physical)

Item	Total	Quantity till current month	Progress last month	Progress during current month	Cumm ulative Progre-ssive	Short fall, if any.	Reasons for shortfall

MONTHLY PROGRESS REPORT (Financial)

1) Estimated cost of the Project
2) Total cost as now anticipated
3) Amount targeted to be spent till current month
4) Expenditure incurred till last month
5) Expenditure incurred during current months
6) Cumulative Expenditure during current month.
7) Shortfall/or cost over-run.
8) Corrective action suggested.

CHAPTER-12

ERECTION & COMMISSIONING

12.1 INTRODUCTION

The execution of a Small Hydro Electric Project (like that of a bigger one also), requires 'erection, testing and setting to work' of a number of items of equipment as well as a variety of steel fabrication located at different places in the project to make a complete working system. These different itme, in main groups are:-

(i) Turbines, generators, transtormers, switchgear control, protection and auxiliary equipment.

(ii) Power House Crane

(iii) Draft Tube State & hoists

(iv) Intake gate & hoists, trashracks, stoplogs etc. and miscellaneous steel fabrication

(v) Penstocks

The first item in the list is quite often referred to as electrical works. These works comprise dozens of discrete components linked together in a design to form an integrated working system.

The remaining items are often referred to as 'mechanical works'. Most of these items such as gates, penstocks, trashracks, cranes and custom designed to get the dimensions and operational parameters applicable to the particular project.

12.1.1 Practices Regarding Purchase and Installation

The modalities employed for erection and commissioning of plant and equipment as indicated above are broadly linked to the manner in which procurement of same is done. The options for procurement as available are:-

(i) Purchase of individual equipment, or a package of similar equipment e.g. set of gates, or cranes or turbines in power house along with annunciation equipment etc. in these modalities detailed specifications are made for each item of equipment based on detailed designs by consultants.

(ii) Procurement of all equipment of the power house on a turn key basis. In this case much larger design responsibility is left to the supplier and specification relies more on performance parameters.

(iii) Execution of entire project including civil works, mechanical works and electrical works on a turnkey basis by one agency. The single agency in this case is usable, the supplies of generating plant and be usually employs sub-agencies for other item. The purchasers control is through specification of performance factors.

Appropriate contracts have to be drawn up for the different cases setting down the technical, legal and safety responsibilities of the contractor/supplier for work at site, as also the requirements of tests and commissioning works so that the plant is handled ones to the Developer in a reliable and safe working condition. Consultant would help in drawing up suitable detailed document for the purpose.

12.1.2 Essential Requirements of Testing & Commissioning

Inspection and tests at site during erection and on completion of erection are to be carried out on any plant and equipment to establish that the guaranteed performance of each component and of the total assembly is attached after its installation at site. The main sub-divisions of such inspection and tests would be:-

(i) Inspection and checking of units e.g.dimensions, centering, remout, pressure test and standards.

(ii) Placing in operation of sub components and complete assemblies

(iii) Initial operation

(iv) Tests for abnormal conditions provided e.g. pressure rise, over voltage etc.

(v) Reliability tests; temperature use test etc.

(vi) Efficiency and other performance tsts

(vii) Load tests

While tests of all above kinds will be needed for plant of any rating, the details and serviceability will be suited to the plant rating, the testing possible at factory, cost and risk factors etc.

12.1.3 Supervision of Erection and Commissioning

In general, it is desirable to have the services of specialist engineers of the suppliers of turbine generator for the important stages of erection and particularly of commissioning of equipment. In case of turnkey, contracts or other similar arrangements this is inherent. If any other mode is adopted for installation work, provision for services of supervisors of the supplier for suitable steps of erection and commissioning should be made.

12.2 CONTROLS

Control and Instrumentation forms a very important feature of the Small Hydro Power Station due to its role in achieving the desired working of the station.

12.2.1 The term control and instrumentation for a power station is used to cover the equipment such as control switches, status indicators, indicating instruments etc. which are provided to make the generating units and other auxiliary equipment perform their stipulated functions from chosen location(s) in the power station. The term control also covers instruments and apparatus to provide indication of relevant positions and quantities, provide alarms in case of malfunctions and even shut down the equipment in case of malfunctions. It also includes generally the protective relays provided and could cover main switchgear in its scope if it is directly operated.

Controls can be of many varieties - From completely local to centralized and fully automatic. At the present time. Digital automatic control, are also available and are being applied very extensively in large power station and even remote control provisions are being made for some hydro-electric power stations.

In case of Small Hydro Electric Projects, however a judicious choice needs to be made of the control scheme to be adopted. The relevant factors to be considered are:-

(i) Manner of functioning visualised for the generating station.

(ii) Operational and maintenance consideration

(iii) Costs of the control systems.

In making a selection of control layout and scheme an important consideration will be the type of manning of the power station and the way it will be operated with the grid. As is well known, the cost of operation & maintenance personnel, if the operation is to be carried out in the manner of normal power station, becomes a very large component of running cost with the relatively small quantum of power generation in a small project.

Another relevant factor is the social one - the unwillingness of persons to work in remote isolated areas such as small hydro power stations in Hilly areas. The following extract from a paper dealing with similar topic from China very aptly illustrates the problems:-

> "Along with the rapid development of rural economy, people living standards are improved. People do not like to go to remote areas because of the concrete difficulties in seeing doctors, schooling of children, shopping, spare time education and even marriage problems of youngsters".

The paper further states that automation of SHP is a practical way of increasing safety and reliability performance complete sets of controllers have been developed in China.

The alternative of a largely automated power station using digital processing equipment shows its own drawbacks - in the shape of cost of automation equipment - not only the digital items but a number of servo systems which will need to be provided; as well as the requirement of a very reliable power supply which will be difficult to assure in such remote areas.

An intermediate position therefore needs to be looked for in these circumstances.

In the following paras the main control functions which are needed to be performed are set down. This is followed by narration of a few arrangement of control system which could be applied e.g. conventional relay based systems, partial automatic systems, digital electronic system etc.

12.2.2 Main Control Functions Required

A list of main control functions required on an SHP (not very different from that in a normal HEP) will be as follows - in which a number of component items such as for example governor, inlet valve turbine gates etc. have to operate in coordination for functions such as:-

(i) Start up of generating unit

(ii) Speed regulation

(iii) Synchronization

(iv) Regulation of kW, kVA, Voltage, frequency, limit of load, water discharge etc.

(v) Protection for mechanical malfunctions such as overstepped, sheer pin failure of grid valves, governor oil pressure problems. Turbine of generator bearing over temperature.

(vi) Protection for electrical malfunction and faults logging at suitable manned points is also required.

12.2.3 Effects of Operation of Small HEP on the Related Grid and the Possibilities of Choice of Controls Thereby:

At the present time, small HEP of rating upto 3 to 5 MW would form a very small fraction of the local grid in all parts of the country, assuming that local bottlenecks such as position and rating of transformer have been taken care of. In such cases, a tripping of the power station is not likely to cause any wider disturbance, other than loss of power/energy incoming from that station. For stations of 10 to 25 MW capacity perhaps more consideration will be necessary.

12.2.4 Conventional or Relay based Schemes

In a medium or large H.E. Power Station, it is conventional to have a control room where control and instruments for operation of the power station as a whole are located and where control boards for instruments and protection of separate units are housed.

In view of the limited dimensions of the generating plant as well as of the power house of small HEP as compared to larger power station and consequent better visibility of different items from a suitably selected point, the duplication of provision of instruments locally and in control room can be avoided to a good extent. A single point control can be adopted where the control board is placed in an eminent position on the machine hall floor. The main controls for turbines and generators and principal switchgear will be accommodated on this board. It may not be necessary to duplicate controls such as starting of governor oil pump or main inlet valve, if these are there which may be local for attended power stations; the matter will require consideration on the basis of ideas regarding operation. In cases where the main outgoing switchgear (11 kV or 415 V) is located in the power house, a common arrangement is to accommodate the same at end of service bay. In such cases, this board will become the main control station.

12.2.5 Partial Automation - Suggestion for Attendance Saving Level of Automation

A possible mode of operation for small HEPs (upto say 5 MW) will be to provide automation of a type which will safely shutdown the unit in case of an unattended fault of electrical or mechanical system. Arrangements could also be made to communicate such shut down to a designated station through a suitable channel of communication. The shut down should be possible through energy such as water from penstock, or weight etc. which do not depend on availability of electricity. The attending team can then come to the station at the earliest and restart the unit after fault removal. If a scheme of this type is adopted, a party having a cluster of stations within reasonable distance could have a team of 4 or 5 O&M personnel who could look after a few power station. Even in case of a single power station it could be thought of that one attendant resident in a nearby village could look after a power station. Maintenance help could be arranged in suitable way.

12.2.6 Digital Electronic Controls

Digital Electronic Controls, or System Control and Data Acquisition Systems (SCADA) are now well established and being widely used in process control applications in industry. These are also being extensively used in power stations and power systems. These are able to co-ordinate and monitor a large number of process variables minimizing requirement of attending personnel and many other relevant benefits.

However, available systems are primarily developed for large process applications. These in every case need to be adopted to individual applications and with provision also of appropriate sensors, transducers, servos etc. to make a composite working system. Infallible stored energy supplies including electricity supplies are also needed to prevent malfunction and to avoid failure or accidents.

In a small hydro station, the Process Variables and their control apparatus are relatively few. The following difficulties come up in using normal digital control systems:

(i) Cost of the normally available (off the shelf) equipment.

(ii) Specialized maintenance and spares requirement

(iii) Reliable power supplies for the digital systems and for the follower equipment.

(iv) Need of provision of suitable servos and cost of the same.

However, it is necessary to keep on watching for development and availability of simplified and less costly versions in future. In fact some collective efforts to develop a suitable system will be very desirable.

In case for some reason it is desired to use a digital electronic control systems in some particular case, it can be of a normal 'Distributed Digital Control' layout comprised of:

(i) A Central control and Data Acquisition Station for the power station as a whole to control all units and sub-station also providing for data records and fault records.

(ii) One local station for each generating unit.

(iii) One local units for sub-station if necessary.

The system will have to be provided with all requisite auxiliary, ancillary and service equipment.

CHAPTER-13

POST COMMISSIONING OPERATION AND MAINTENANCE

SOME DISTINCTIVE FACTORS APPLICABLE TO SMALL SCHEMES

13.1 A small Hyrdo Electric Plant, in principle should basically be similar to any small industrial installation of similar investment from the view point of operation and maintenance.

13.2 The special and distinctive factors, however, which come up in case of such plants are as follows:-

(i) Isolated location

(ii) Difficult access

(iii) Lack of Servicing infrastructure in vicinity such as industrial town, railway, airport.

(iv) Very few people stationed for operation and maintenance

At the same time it is necessary to keep the cost on personnel both direct like total salaries as well as indirect like housing etc, low in view of the small production from each individual site.

This is a distinct and challenging feature for successful exploitation of small hydro power.

Some measures that would be helpful

The following are some approaches which are likely to enable satisfactory manning with reduction in expenditure:-

(i) Use of local residents for normal operation of power station

(ii) Ownership of a group of a few small power station in a short radius, and thereby organizing group attendance

(iii) Building up group attendance teams to be located in central place, with equipment for mobility; setting up inspection/ maintenance practices for such purpose

(iv) Providing for remote annunciation of fault, automatic safe shut down.

In recent days fast developments are being reported in successful utilization of distribution voltage lines for data communication. Utilization of such facilities should facilitate adoption of group practices etc. which will help limit operation and maintenance costs for SHP.

13.3 Normal Operating and Maintenance Practices

Post Commissioning Operation and Maintenance

The main elements of Small Hydro Power Project requiring post-commissioning attention for operation and maintenance are :-

(A) CIVIL

(a) Medium and High Head (Type-I)

- (i) Diversion/Intake Structure
- (ii) Water Conductor System & Associated Works
- (iii) Desilting Chamber/Forebay
- (iv) Penstock
- (v) Power House
- (vi) Tailerace

(b) Low Head Type-II - Canal/Dam Toe Schemes)

- (i) Head Regulator/Intake Structure/Bypass Structure
- (ii) Water Conductor System and Associated Works
- (iii) Penstock
- (iv) Power House
- (v) Tailerace

(B) MECHANCIAL

- (i) Gates/Hoista/Valves
- (ii) Cranes
- (iii) Penstocks

(C) Electrical

- (i) Turbine - Generator
- (ii) Switchgear/Switchyard
- (iii) Controls and Instrumentation
- (iv) Sub-station

(D) Electronic

- (i) Controls/Automation

For canal based small hydro schemes, canal discharge releases for irrigation from the basis for utilisation of discharge for power generation. Close interaction, therefore needs to be maintained with the Irrigation Department authorities on this account during the post commissioning operation and maintenance period.

For operation and maintenance of a hydro power project is essential to periodically inspect the civil structures and electro-mechanical equipment and attend to necessary repairs, follow the instructions contained in the supplier's/manufacturer's manual and observe safetly aspects to ensure safety of personnel and works. Proper maintenance of log books containing information about the problems, abnormality occurrences and remedial action taken is considered vital. Some aspects needing attention by the operating staff in attending to Civil, Mechanical, Electrical and Electronic Works ar dealt below:

1.3.3.1 (A) CIVIL

Diversion Structure

Diversion structure should be inspected after the monsoon as early as possible for any possible damages. Inspection should also be made after any heavy stream flow at other times also. In the case of a weir, the upstream and downstream protection which are liable for damages should be closely inspected and necessary repair effected. The waterway immediately upstream as well as downstream of the diversion structure should be cleared of boulders blocking the flow. In the case of trench weir, the trashrack of the trench weir should be cleared and damage if any should be rectified. The trench itself should be inspected and silt if collected should be removed.

Water Conductor System and Associated Works

The water conductor should be periodically inspected, especially during the monssoon period and any blockages or distress to the water conductor due to landslips detected. Any damage observed should be rectified/repaired immediately. In case of any breach inflow of water should be stopped, by closing intake gate immediately.

Desilting Tank

The desilting tank should be inspected before the onset of the monsoon. The gate valve of the desilting pipe should be checked and proper functioning ensured before onset of the monssoon so that it is in good operational condition during the monsoon. After the monsoon the desilting tank should be inspected for removal of any accumulated silt in the desilting tank bottom drain.

Forebay

The forebay should be insepcted after the monsoon period to detect any distress due to landslips or leakage and necessary repairs carried out. The floating debris etc. which is stopped by the trashrack in the intake structure of the Forebay should be removed.

Power House

The power house complex including the penstock slopes should be inspected periodically. Any tendency of distress in penstock slopes should be attended to expeditiously. The power house complex should be maintained properly especially in regard to the roads, foot-paths, bridle paths, steps and drainage both inside the power house as well as outside around the power house. All the steel and wood works should be kept well pained. The power house building needs periodical painting and repairs.

Tailrace

The tailrace should be inspected after the monsoon and any blockages due to the monsoon flows removed to ensure smooth passage of water. The tailrace outfal should be inspected immediately after the monsoon and any damages observed should be rectified.

13.3.1 (B) MECHANICAL

Gates/Hoists/Valves/Cranes

In small hydro power house gates, hoists, valves, cranes, pumps etc. are provided. Porper checking of these equipments on a periodic basis is necessary to avoid any breakdown. frequent cleaning, greasing and changing or rubber seals for gates and valves to ensure proper function is necessary.

Penstock

Penstock should be regularly inspected and necessary maintenance such as occasional painting greasing of the saddle plates supporting penstock, etc. carried out. Anchor Blocks should be inspected for detection of any distress and necessary repairs carried out.

13.3.2 ELECTRICAL

Turbine-Generator

The turbine is the main equipment. The runer, guide bearing, guide vanes and bushes, seal, servomotor, etc. should be regularly checked and properly maintained. The instructions contained in the manual need to be systematically followed. The turbine runner tends to wear and tear in silt prone stream and needs frequent repair. For proper maintenance a set of spares of items recommended by manufacture must be kept in stock. Major repairs should be conducted during the period of closure or during scheduled shutdown.

The generator and its control is the most important equipment in the power house. Inspection of stator winding, cleaning of brush/slip ring, relays controls, leakage current, etc. on periodic basis is needed. Parts which are prone to wear and tear should be kept in reserve.

13.3.4 ELECTRONIC SYSTEM

This part protects the machine under any anticipated fault condition. These equipments need to be protected from dust and other such hazards and operators need to be instructed to handle the equipment very carefully. If any fault is noticed, it need to be repaired an experienced engineer.

13.4 SAFETY ASPECTS

The need to observe adequate measures to ensure safety of works, equipment and personnel in all phases of building and utilisation of small hydro power should be kept at a high priority. This may be particularly important for projects located in steep hilly areas. Some principal aspects to be considered could be:-

(i) During Construction Phase

Possible of land slides, falling boulders, loss of -

Access
Flooding
Fire hazard

(ii) During Operation

(a) For Project in General :

Same as (i) above.

(b) For Particular Structures:

Keeping a watch for incipient damage to any item of civil works or hydraulic structures

(c) For Power House Complex

Fire hazards, fore detection and alarm equipment should be provided. Fire Hydrants, portable fire protection equipment should be provided.

(d) For Electrical & Mechanical Equipment

These equipments are provided with automatic protection and alarm systems, electrical relays etc. which would detect abnormal cinditions and shut-down relevant equipment in case of dangerous levels.

These protective devices must be kept well maintained & monitored.

There are safety features in civil works like channel, forebay etc. which regulate water level. These should be monitored.

Log records of safety devices must be maintained.

(iii) Safety Requirements Prescribed by Authorities

Various requirements for inductrial safety are prescribed by official authorities such as factory inspector, electricity inspector, etc. These should be observed.

A power plant is visualized to operate all 24 hours for all days of the year. Its operation therefore needs to be monitored on 3 shifts basis. This will call for at least one operator and one helper per shift in a normal way. In addition maintenance personnel are needed for daily routine maintenance, periodic maintenance, annual overhaul and breakdown maintenance. Operation and Maintenance personnel required for a typical plant, is indicated below:-

(i)	Station Manager	-	1
(ii)	Senior Engineer	-	2
(iii)	Shift/Maintenance Engr.	-	6
(iv)	Foreman & other staff	-	6
	TOTAL :	-	**15**

The other casual labour/contractor could be hired as and when required. Annual maintenance or any major maintenance work be entrusted to contracting firm specialized in such work.

The extent to which a saving can be made in this by adopting any group approach, utilization of local residents etc. will constitute a saving bonus.

Spares and Consumable

Stocking of adequate spares of fast moving, slow moving and capital nature and maintenance and monitoring thereof, is a very important requirement. The spares for minimum 2 years operation must remain stocked and replenished.

The suppliers of generating plant must be asked to furnish experience based lists of spares at the time of tendering.

Particular attention is needed to stocking of spare runners for turbine, runner seals, shaft seals, guide valves etc. in case of installations in hilly regions. It will be desirable to have basis for getting such items made locally as it may become obsolete with original suppliers.

Operation and Maintenance Manuals

Operation and maintenance manuals for all equipment should be obtained along with the supply. These should be updated with specific particulars at the time of commissioning.

Adequate copies of such manuals should be made in durable format and kept in the power house as well as back-up location. One/two highly durable copies of manual and drawings must be kept in a safe manner at Headquarters of the organization.

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