3. SIZING OF STRUCTURES

As mentioned in the first paragraph the sizing of the structures is on one hand governed by the site conditions in nature and the concerned developed layout and on the other hand on the economical analysis of the proposed project.

The decisive parameter in this context is the design discharge. The choice of the design discharge has the significant impact on the structures of the hydropower project. The quantities of the structures and thereby its costs increase with increasing design discharge. The costs of the quantities are calculated according to a unit price list, which differs from country to country.

The work can be simplified with help of computer programs. For this reason a program was developed by GTZ, which calculates the quantities and size of structures on basis of standardized structures with various design discharges. The program is called HPC (Hydro Power Costing) and will be introduced in detail in the next paragraphs. Once the geometrical data such as canal length, tunnel length, etc. as well as the boundary conditions are defined, dimensions of structures and quantities are automatically calculated with the input parameter of the design discharge. With help of the unit price list the costs of each structure can be calculated and thereby the complete construction costs of the hydropower development.

This approach is applied in the different stages of the project, such as identification, feasibility and tender. For identification and feasibility stages, the computerized procedure can easily be applied. Some more detailed work is needed for the tender stage, where the size of the power plant is already fixed.

The comparison between the total project costs and the benefits in producing power is used to determine the optimum design discharge of the considered layout. As mentioned before, this kind of investigation and supplementary studies in the field yields a design discharge, which makes an adaptation of the layout or even a complete new layout necessary. Sometimes only a few structures have to be changed according to new knowledge of boundary conditions. In such a case, a new design discharge variation has to be repeated again, based on the adapted concept of hydropower scheme as well as on the change in benefits.

For this reason the sizing of the power plant is the core of engineering in hydropower development. Experience is needed, therefore this topic is described with help of examples. Moreover working with the software program as a tool gives a feeling for the cost development depending on various design discharges. This will be trained in computer application exercises in the course.

4. PRELIMINARY COST ESTIMATION AND PLANT SIZE OPTIMIZATION

4.1 PRELIMINARY COST ESTIMATION

4.1.1 GENERAL

After carefully defining the different project layout alternatives and sizes preliminary cost estimation is to be done in order to screen the number of alternatives on the cost basis. The quantity estimation and selection of plant size and comparison can be accomplished in conventional way by hand. As this part is very time consuming exercise due to the large number of alternative layouts, the preliminary cost estimation for small or medium size hydropower projects may be carried out by means of standardized computer programs.

Although there are many useful programs available in the market for this purpose, we will basically deal with a computer program called HPC (Hydro Power Costing) which has been tested in many other countries in Asia and Latin America and systematically introduced in Pakistan by GTZ for the preliminary cost estimation and sizing of the hydropower plants. This program was initially developed for the identification and ranking purpose of medium size high head hydropower schemes which was later developed and adopted for extended size and planning study. The following paragraphs briefly describe this program. An example is also given at the end to visualize the use of this program.

4.1.2 COST ESTIMATION PROGRAM HPC

HPC is a multilingual and a powerful program, specially designed for the preliminary cost estimation and plant sizing of standard high head medium sized hydropower plant. The cost estimate is some how in the higher range of about 15 to 20% which is considered to be sufficiently adequate for elaborating a ranking list to compare alternatives [Inventory and Ranking of High-head Hydropower, 1992].

Although the Hydro-mechanical part in this program is sufficiently accurate and can be used for feasibility study, the real cost of civil parts needs to be elaborated for feasibility study based on detail field investigation and with some modification of the dimensions in the standard civil structures. A user's manual is also available to guide step-by-step for data input and running the program [HPC User's Guide].

4.1.2.1 INPUT DATA ACQUISITION

Identification Sheet: This standardized format (**see Annex....)** should be filled by an experienced civil engineer in co-operation with geologist, environmentalists and hydrologists etc. The input data is structured into general data input and the structured data input as follows:

1. **General Data:** The type of scheme (Peak or run-of-river), Drainage area (km^2), Up- and downstream water levels (m.a.s.l.), Discharge for headrace (m^3/s), and Design discharge (m^3/s) should be filled in the general data column.

2. **Structured Data:** The HPC program is basically designed for standard structures of hydropower components. Before starting the program, it is necessary to define the required components of the project, or in other words the layout alternative should be fixed. However, there is a possibility to add or delete any extra component which may require during the execution of the program. It has also the possibility to add additional structural components which is not mentioned in the structured data column. Both latter mentioned procedures are usually not used. The costs of structures are separately calculated and included in the concerned column. Following are the standard hydropower components included in the HPC program:

   - **Access:** It includes the truckable roads and tunnels for access to the powerhouse, dams, weir, intakes, surge tank or other locations.

- **Other Access:** Data should be given, if there is any other access other than above mentioned (viz., airport, stole etc.)

- **Reservoir:** Data is given only for a storage type project such as water levels upstream and downstream etc.

- **Weir, Intake and Flood Control:** It includes a choice of standard structures such as Tyroler weir, weir with lateral intake, concrete gravity dam, rockfill dam, concrete arch dam. It also allows to add other type of structures if any.

- **Sand trap:** This is required for the run-of-river schemes only and the program calculates the cost for an open surface sand trap. For underground sandtrap, separate estimate is to be prepared and should be included as the cost of other structures.

- **Headrace conduit:** It includes the number of options such as rectangular canal, trapezoidal canal, free surface tunnel, pressure tunnel and pipe tunnel.

- **Surge tank or Bay:** Depending upon the type of conduit chosen the surge tank or bay should be selected and data is provided.

- **Penstock of Pressure shaft:** A choice is given for embedded or supported steel pipe in case of penstock and pressure shaft in case of underground powerhouse structure.

- **Tailrace:** A choice is given only for rectangular canal.

- **Indirect cost:** Indirect costs such as mobilization, erection, engineering and supervision, administration, overhead, import charge, and contingencies are provided as percentage of direct cost of civil, hydro-mechanical and electrical equipment. There is also possibility to add any other indirect cost.

- **Other Structures:** It includes the cost of any structure other than the above mentioned standard ones.

- **Marginal conditions:** These are the conditions in terms of marginal factors imposed by the physical constraints which may not be otherwise quantifiable. This is the basic requirement for a cost estimate by the HPC computer program. It should be inputted with high accuracy. This accuracy depends on the details of field investigation.

  There are five codes (1 to 5) for the definition of each of the following marginal conditions [see user's manual] such as degree of difficulty, natural slope, vegetation factor, land factor, geological condition for structures, tunnelling, permeability, seismicity etc.

- **Unit Price:** A price analysis is to be performed in separate programs such as spreadsheet to calculate the unit price of the construction of specified items. The price analysis should be based on the local market rate of labour, equipment and materials specific for the project area. Then this unit price should be incorporated into the HPC program and kept in the data bank.

3. Assumptions

Following assumptions are made in the HPC program:

- Calculation of quantities is based on the simplified empirical formulae.
- Quantities determined by these formulae may increase by a percentage of 10 to 30%.

- The dimensions of standard structures are only meant for finding quantities and irrelevant for construction purpose.
- In certain cases the input for the flood discharges does not correspond to the value form hydrology [refer HPC User's Manual]. The reason is that the program uses standard structures such as weir, for example, for the calculation of dimensions and quantities, which may not correspond to the actual design. Therefore, some adjustments have to be made either by increasing or decreasing the input values for the flood or the cost has to be added for additional structures.

- **Turbine selection and execution of program:** After data input, appropriate turbine is selected for the execution of the program.

4.1.2.2 DATA OUTPUT

The HPC displays the data output in terms of costs of individual project components as well as the summary of the project base cost. The project base cost is the summation of the total direct cost and the total indirect cost.

The compilation of cost estimates for all alternatives is to be done in a separate spreadsheet and a specific cost for different alternatives is calculated. From this table some of the competitive alternatives could be eliminated only on the basis specific cost (i.e., cost/kWh) and qualitative criteria, which were set in the alternative locations to reduce the number of alternatives to be further scrutinized. As in the case of Khan Khwar feasibility study, 12 alternatives out of 30 alternatives were eliminated only on the specific cost basis (see case study of Khan Khwar feasibility study in the example below).

4.2 QUANTITIES AND COSTS IN DIFFERENT STAGES OF WORK

During identification stage standard structures are mostly used. In feasibility stage quantities are based on a preliminary design of all components with corresponding tentative calculations and analyses, such as stability analysis, hydraulic calculations, structural analysis etc. Calculation of the major quantities, activities and material requirements is according to geometrical dimensions and unit requirements respectively. Major quantities are usually

- excavation of soil and rock
- filling
- concrete
- reinforcement
- cement
- diaphragm walls
- sheet piles
- geotextile
- rip-rap / stone apron
- steel for hydraulic structures
- hydromechanical equipment
- electrical equipment

The direct costs can be calculated by multiplication of quantities with unit rates, unit rates can be evaluated analysing and comparing following informations:

- Unit price list of HPC
- Available ICB of similar projects
- Electricity schedule of rates
- Budgetary prices

Indirect cost can be calculated for different items by percentages, such as:

- Transportation 7%-10%

- Erection 15% M, 7% E
- Contingencies
- Eng./sup. 4% C,2.5% EM
- Administration, audit and accounting 4% C
- Miscellaneous 1.5% C

The base cost of the project is equal to the sum of direct and indirect costs.

At the tender stage the quantities are calculated exactly, based on a detailed design of all components of the power plant with corresponding detailed calculations and analysis such as stability analysis, hydraulic calculations, and structural analysis. A detailed calculation of all required quantities, activities, material, manpower and equipment according to their geometrical dimensions, weights and/or unit requirements respectively is needed.

The costs of the project area are determined analogically to the feasibility stage with engineers estimate. The bids from the various tenders are received and costs are compared.

4.3 OPTIMIZATION AND SELECTION OF THE PLANT SIZE

4.3.1 GENERAL

For the purpose of optimisation, the project base cost (PBC) is disbursed into several construction years and the respective Import charges (IC) and Interest During Construction (IDC) are added in a separate spreadsheet to determine the total construction cost of the project. The IC man be obtained form the custom office of respective countries. The IDC can be calculated as follows:

1. Fix the tentative construction period (4 years)
2. Fix the disbursement percentage of base cost for the construction period (d_1)
3. Fix the interest rate (R)
4. Calculate the project base cost for first year PBC1 = PBC * d_1/100
5. Calculate the second year cost PBC2= PBC1 * d_2/100
6. Calculate the third year cost PBC3= PBC2 * d_3/100
7. Calculate the forth year cost PBC4= PBC3 * d_4/100
8. Calculate the IDC= R/100 (3.5* PBC1+2.5*PBC2+1.5*PBC3+0.5*PBC4)

or, can be expressed as $IDC = \frac{R}{100} \sum_{i=1}^{n} (n - i + 0.5) PBC_i$ **(4.1)**

A preliminary screening of the project layout on the basis of specific cost of different alternatives and their advantages and disadvantages is done to arrive with more comprehensive alternative layouts for final project sizing. The power and energy for peak and off-peak operation have to be calculated suitable to reservoir, or run-of-river projects with or without the tunnel storage taking into consideration the public or private sector investment scenario.

The project sizing of the power plant under different flow scenarios has to be carried out for the following activities:

- Optimisation of tunnel diameter on the basis of marginal cost,
- Optimisation of design discharge on the basis of marginal cost and the average cost of generated unit,
- Sensitivity analysis concerning hydrology and project cost overrun for both above mentioned
- Finally the selection of optimised parameters on the basis of maximum benefit and minimum cost.

According to which the optimum installed capacity is proposed for final dimensioning of the plant size.

The main aim of the project sizing is to recommend a robust and stable solution for the so-called optimum installed capacity of the project.

There are different models for project sizing used by various institutions. However, we will mainly focus on the model used in the HEPO/GTZ, in Pakistan. This model is systematically explained taking the example of the Golen Gol Hydroelectric Project's Feasibility Study in the following paragraph:

4.3.2 MARGINAL COST AND BENEFIT ANALYSIS

Marginal cost of the power supply is defined as the change in total cost of service resulting form small change in demand. This cost depends on the place and time of use. In economic analysis of power utilities frequently the term Long Run Marginal Costs (LRMC) is used to define the economic efficiency of the project. LRMC can be defined as the cost of serving additional or incremental demand in the long run, when investment can be made to minimize total cost. There are three main components of LRMC:

1. Marginal energy cost (peak and off peak)
2. Marginal capacity cost of generators
3. Marginal capacity cost of transmission and distribution

This will be dealt in detail in the Chapter 4 of this module.
Fig. 4.1 briefly describes the model used in the Golen Gol high head hydroelectric project.

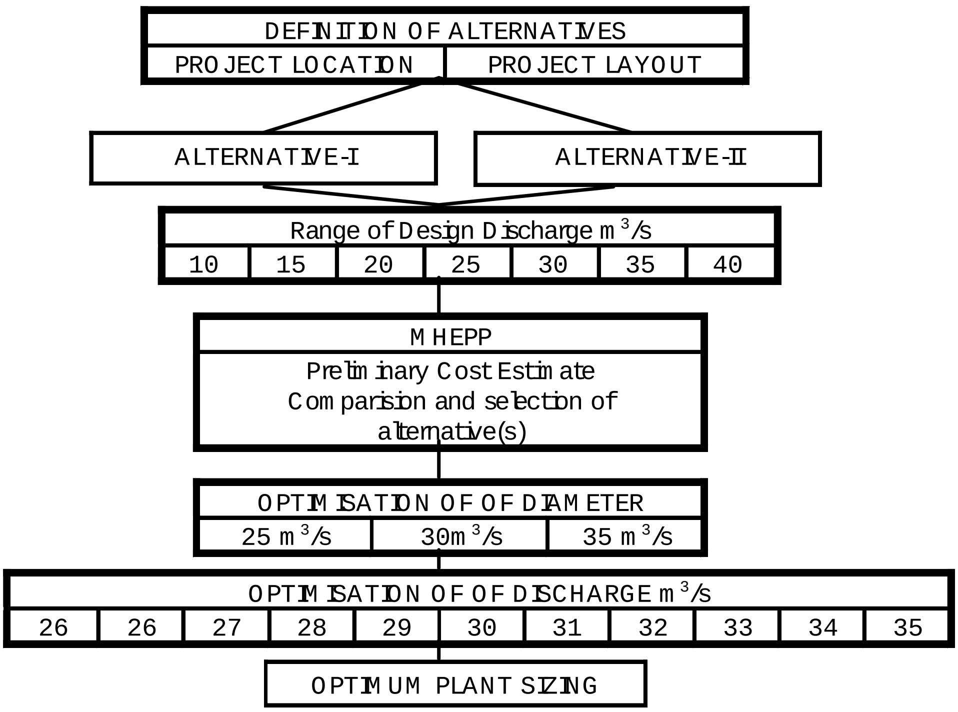

Fig. 4.1: Flow Chart of Golen Gol Feasibility Study

4.4 GOLEN GOL HYDROPOWER PROJECT

In the Golen Gol hydroelectric project the marginal cost of peak and off-peak capacities is calculated form the values derived in the study "Integrated Operations and Tariff study for

WAPDA and KESC", prepared by Coppers and Lybrand-Deloite (C&LD) in 1990 and the National Power Plan of Pakistan (NPP) in 1994. The capacity cost per kW in used by C&LD is 50 US $, where as the NPP proposes 72 US$. The corresponding energy costs per kWh peak and off-peak in US cents for each month proposed by C&LD and NPP is given in the Tab. 4.1 and Tab. 4.2 respectively.

Tab. 4.1: The Energy Cost per kWh proposed by C&LD

Energy	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Peak	3.490	3.490	3.490	3.490	3.490	3.490	3.490	3.490	3.490	3.490	3.22	3.22
Off P.	2.98	2.98	2.98	2.98	3.17	3.17	2.98	2.98	2.98	2.98	2.75	2.75

Tab. 4.2: The Energy Cost per kWh proposed by NPP

Energy	Jan	Feb.	Mar	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Peak	5.63	5.63	5.63	5.63	5.63	5.63	5.63	5.63	5.63	5.63	5.63	5.63
Off P.	4.093	3.207	3.207	3.053	3.045	3.021	2.843	2.922	2.803	2.799	2.908	3.050

The purpose of this analysis with two sets of marginal cost was to establish the impacts of different assumptions on the recommended installed capacity of the project. The main aim of the project sizing, as said earlier is to find out an optimum installed capacity, which should not be unstable due to the change in the basic assumption. The basic assumptions, which were used in the analysis of the marginal cost values used by C&LD and NPP, are based on the scenario, which are likely to occur in Pakistan during the useful life of the project[1]. However, the selected values of project size should remain the same for the life period of the project. Therefore, sensitivity analysis was also carried out for both sets of marginal cost assuming costs overruns and pessimistic hydrologic conditions. The sensitivity analysis is done by increasing the project cost by 25% and by increasing or decreasing mean monthly flows by 25%.

Similarly, it may be necessary to check the robustness of selected project size in terms of average cost of generated unit. Therefore, an average cost of generated unit has to be carried out. The reason is that in the private investor's point of view the optimum capacity of the project is the one which minimizes the average cost of generated unit. The average cost is also important from the consumer's point of view, when one likes to pay on flat rate basis to the power producers for the energy delivered.

In this case, it is also necessary to perform the sensitivity analysis of cost overrun and pessimistic hydrologic conditions.

As Golen Gol was proposed to have storage facilities in the tunnel, various ways of daily operation were considered for low flow season to improve the generating capacity according to demand. The options considered in the analysis were:

- Run-of-river
- One peak of four hours duration
- Two peaks of two hours duration

It is to be noted here that in this exercise, due to its lengthy arithmetical operations, a spreadsheet program in Microsoft Excel-5 software was developed by HEPO/GTZ in 1997. This

[1] The description of the assumption for marginal cost analysis is the out of scope of the present manual. Interested should review the document "Integrated Operations and Tariff Study for WAPDA and KESC" [C&LD, 1990 and NPP, 1994].

spreadsheet program is a powerful tool to determine the peak and off-peak power and energy calculation as well as optimisation of tunnel diameter and the design discharge. Since this process is iterative and requires performing many mathematical operations at a time, it is advisable to follow the sequence described in the Fig. 4.1.

In case of reservoir type scheme the program "PEACE" is used to determine the peak and off-peak power and energy production. After this, a similar spreadsheet can also be developed to perform the optimisation of reservoir and design discharges for the optimal plant sizing.

In Golen Gol hydroelectric project it was also possible to show that the overall benefits of peaking are more than those of run-of-river for certain design discharge range. Furthermore, it was found that the two peaks of two hours were more beneficial than one peak of four hours a day. This was possible because of the small storage capacity of the tunnel [Golen Gol feasibility project 1997].

Project Base Cost: The cost of the project was calculated from the base cost of project and the base cost of transmission line including the respective values of IDC with the interest rate of 12 %. The total cost of the project was then divided by the power and annual energy to get the specific cost of the project. The cost variation was analysed with 25 % increase in cost.

Optimisation of Tunnel Diameter: The tunnel diameter optimisation was performed using three different design discharge scenarios. These discharges were considered to optimise the diameter of tunnel for which the difference between benefit and cost is maximum. Eleven diameters raging from 3.3 to 5.3 m were selected and for each of these discharges costs were computed using HPC. The benefits were computed using the marginal cost value from the NPP and C&LD for mean monthly, 25% increase, and 25% decrease in flow scenarios. This computation was performed in the spreadsheet. Simultaneously, the power and energy calculation was also performed. It was obtained that the net benefits from NPP data are higher than the net benefit from C&LD. Optimum tunnel diameter was then selected from the NPP scenario.

Optimisation of design discharge: A range of design discharge form 25 to 35 m^3/s was selected and project base cost was calculated using HPC. By adding IDC the total project cost was obtained with and without transmission line scenarios. The average generation and marginal cost were estimated for different hydrological scenarios and cost over run by 25% as well as for different mode of operation were considered. The result of marginal cost and average generated cost analysis show that the optimum design discharge was in the range of 29 m^3/s to 31 m^3/s. The sensitivity analysis and the mode of operation have no influence on the design discharge. An average value of 30 m^3/s was selected as optimum discharge to determine the plant output and to dimension the various components of the project. The design discharge provide the following project parameters:

Optimum Installed Capacity	106 MW
Annual Energy	435 Gwh
Plant Factor	47%

Plant Sizing:
Finally, on the basis of estimated monthly flows, a range of output generated by power plant was performed. The discharge scenario of 25 % increase and 25 % decrease in mean monthly flow as well as different mode of operation such as run-of-river, two peaks of two hours and one peak of 4 hours duration were considered to calculate their impact on the output. It was concluded that the optimum capacity of power plant i.e., 106 MW will be available with any mode of operation during summer months of July and August. However, the change in availability of discharge will change the power output accordingly. Similarly, since the energy output is directly proportional to the volume of water stored in the tunnel, there will be less

energy output during winter months and will be maximum in summer months. The mode of operation has no significant influence on energy output.

4.5 KHAN KHWAR HYDROPOWER PROJECT

General: To fulfil the requirements of feasibility study, a comparison of alternatives including preliminary plant layout was done considering a range of alternatives of dams and weir sites along Khan Khwar valley and Powerhouse locations along Indus River. Subsequently, a preliminary plant dimensioning (sizing) for the determination of main project features for the feasibility design was done after optimisation and selection of plant layout considering economic evaluation parameters updated hydrological data, environmental aspects and types of project requirements. The following figure shows the steps that were taken in the selection of preliminary plant size.

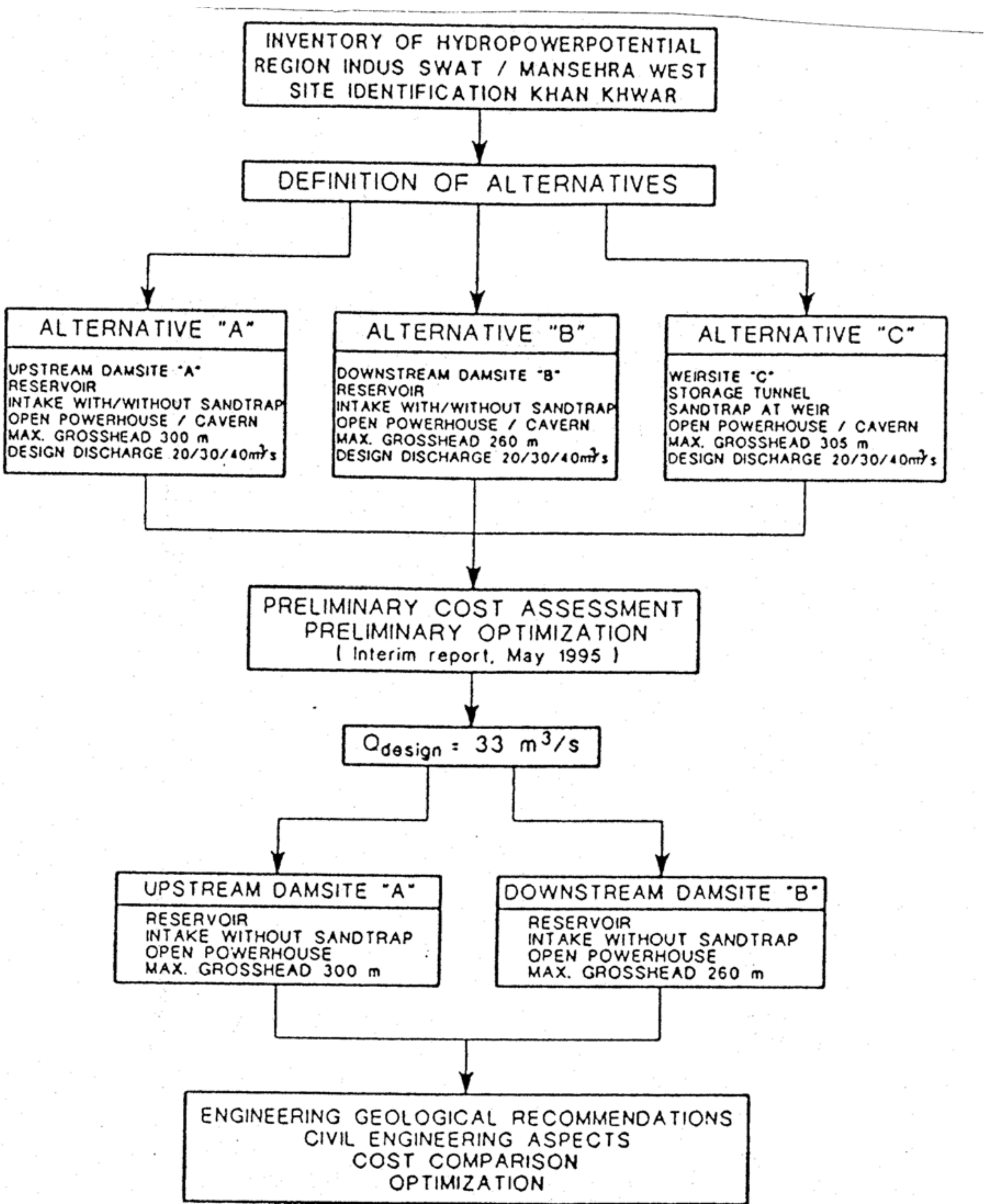

Fig. 4.2: Flow Chart for Plant Sizing (Khan Khwar Hydroelectric Project)

Selection of Alternatives and data compilation: Determination of alternatives was done even during field reconnaissance and additional variants were introduced after several meetings in 1994. Due to its good topographical characteristics of the site, the main objectives of the selection of alternative were to find out the favourable head. To judge the cost effectiveness structures with reservoir, intakes with or without sand traps, external or cavern type powerhouse, weirs, headrace with low pressure or storage tunnel type were considered and respective data were compiled.
The compilation of data input for preliminary cost estimation for plant sizing is presented in Annex.....

Preliminary Cost Estimate: :HPC was used for the preliminary cost estimation and plant sizing.

Optimisation and selection of plant size: After this, using a program on spreadsheet a tentative economic analysis of the alternatives was done to determine the optimum size on economical parameters. Optimum was defined as the size where the marginal benefits equal the marginal cost. Benefits were derived from marginal cost of peak and off peak energy. Peak was defined as 4 hours per day 90 % available energy over the year.

On the basis of cost comparison and net present value of all alternatives, many options of alternative A and B were eliminated. The alternative C was completely discarded giving some appropriate reasons (SHYDO/GTZ, 1996, Selection of plant layout). Selected Alternatives A and B were again scrutinized on the basis of geological investigation and additional information. After the technical, cost and economic comparison, the Alternative B was selected for the engineering design.

4.6 CASE STUDY OF ALLAI KHWAR HYDEL DEVELOPMENT (CONCEPTUAL STUDY)
Introduction: An excellent example of the project screening and determination of project alternatives can be taken from a conceptual study which was conducted by the Allai Khwar consultant (Allai Khwar 1996). This study was carried out to evaluate alternative possibilities for developing the hydropower potential between the Allai Khwar and Indus rivers in order to select appropriate alternatives for the feasibility study. This study can also be called as pre-feasibility study. An inventory and ranking study of which was initially completed by SHYDO/GTZ in 1991.

The available head, which is in the order of 700 to 740 m with the tunnel length of 3.5 km, makes the Allai Khwar site very attractive for high head hydropower development. The favourable ratio of about 4 to 5:1 between water ways length and head makes the scheme

suitable as a peaking power plant provided the daily, monthly or even seasonal storage. Therefore the following two principle project options have been studied:
1. A Peaking storage option with high dam
2. A Run-of-river option with daily pondage capacity.

Study Methodology:
The following methodology was undertaken:
1. Comprehensive site investigation and analysis of data
2. Definition of project alternatives and initial screening
3. Preliminary optimisation and evaluation of alternatives with the help of computer program EVALS (similar to HPC)
4. Conceptual design and cost estimate at pre-feasibility level.
5. Economic and Financial analysis of the project alternatives taking into account of private and public sector funding.

Alternatives: For the initial screening purpose, five dam (A_{ROR}, A_{ROR} with storage, A3, A2, A1 and A4 all with storage) and two powerhouse sites (PH-Jambera and PH-GTZ) were considered [see Alli Khwar Consultant (1996)]. During the course of study dam sites A2 and A3 as well as PH-GTZ were excluded from further study for the geological reason. For the project alternative to be developed with the remaining dam and powerhouse sites, following specific site conditions were considered:

1. Very low dry season flow and large wet season flow regime of the Allai Khwar requires the design of pondage as well as flood handling structures.
2. Substantial amounts of sediment in the river necessitate to provide sediment handling structures at the dam and the power intake for the protection of waterways and turbines.
3. The existence of the Main Mantle Thrust (MMT) and the seismicity in the Allai valley which may have major impact on the design of structures. A narrow ridge separating the Allai valley from the Indus valley which may also provide seepage path from Allai reservoir to Indus River in the case of high dam.
4. Large tailwater fluctuation of the Indus River for the setting of turbine axis.
5. Diversion of the Natai Khwar into the reservoir in case of A_{ROR} and A1 to increase power and energy generation.
6. Possible access to project area from Karakoram highway and its limitations.
7. Inundation of village of Telus defines the maximum operating level of the project's reservoir.

Keeping the above mentioned site specific conditions following two options were considered for preliminary economic evaluation:

1. **The Run-of-River Option** (with Dam Site A_{ROR}) will not adversely affect the village of Telus.
2. **The Storage Project Options** with
   - Dam Site A1 with the storage which inundates the village of Telus;
   - Dam Site A4 with the storage which does not inundates the village of Telus.

Furthermore, some sediment retention possibilities and other small hydropower possibilities were also investigated during the study.

Overall Layout of Allai Khwar-Indus Alternatives: Subsequently, the following criteria were applied to develop the overall layouts of the alternatives:
- Common features of all alternatives
- Topographical conditions
- Geological and seismic conditions
- Sedimentation aspects

- Consideration of the requirements of the village of Telus
- Dam sites and powerhouse site identified during site investigations
- Criteria to determine waterways' alignments
- Consideration of the Natal Khwar catchment
- Sediment retention possibilities in the Allai Khwar catchment

The general features of each alternative are summarized in

Tab. 4.3Tab. 4.3:

Tab. 4.3: General Features of the Allai Khwar Alternatives

Feature	Project Alternatives		
	Site A4	**site A1**	**site AROR**
Reservoir • Volume required (m3) • Full supply level (m a.s.l.)	min. 40-50x106 1,255	min. 40-50x106 1,255	For daily pondage (≈240,000) 1,238
Nati Khwar diversion?	not required	no (MMT)	yes
Dam • Location • Type • Max. operating level compatible with requirements of village of Telus? • Second intake required for future operation • Diversion system	downstream of Alli/Natai confluence CAGD/(CAD) yes yes tunnel	≈4 km downstream of Telus CAGD/(CAD) no yes tunnel	≈2 km downstream of Telus CGD yes no channel
Desanding basin • Initially required? • In the future required	no yes	no yes	yes yes
Waterways	dia. optimised	dia. optimised	min. diameter
Powerhouse • Location • Type	upstream site (Jambera) shaft	upstream site (Jambera) shaft	upstream site (Jambera) shaft
Transmission • Voltage (kV) • to Substation • Length (km)	132 Mansehra 87	132 Mansehra 87	132 Mansehra 43
Layout drawings • Plan • Section	E4.2/001 E4.2/009	E4.3/001 E4.3/011	E4.4/001 E4.4/001