MICRO-HYDROPOWER DESIGN AIDS MANUAL

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Small Hydropower Promotion Project (SHPP/GTZ)	**Mini-Grid Support Programme (MGSP/AEPC-ESAP)**

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NOTICE

These micro-hydropower Design Aids have been prepared to provide a basis for consultants to undertake calculations and prepare drawings as per the requirements set aside by Alternative Energy promotion Centre (AEPC) of His Majesty's Government of Nepal (HMG/N). It is expected that the use of these Design Aids will result in a standard approach to carrying out calculations and drawing on Peltric feasibility studies and preliminary and feasibility studies of micro-hydro projects.

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PREFACE

Thanks for using this Micro-hydropower Design Aids. Micro-hydropower Design Aids is a complete set of tools consisting of typical AutoCad drawings, typical Microsoft Excel spreadsheets and a users' manual recommended for using up to feasibility study level of micro-hydropower schemes up to 100kW. It is expected that the use of these Design Aids helps enhancing micro-hydropower sector of Nepal to a new level.

Why I Prepared the Design Aids
I approached this project with one goal in mind. To write an ultimate Micro-hydropower Design Aids that would appeal to all Nepali micro-hydropower stakeholders for hydropower sector development. That is a fairly ambitious goal. But based on the feedback I received from all the stakeholders (including my colleagues working with me) from the commencement of its preparation during SHPP-AEPC collaboration 2002-2004 to date, I think I have accomplished it.

I have been using spreadsheets for more than one and half decades and spent a lot of time designing a number of technical and financial spreadsheets. I started using Lotus 123 and Quatro in my initial career. Microsoft Excel is the present market leader, by a long shot, and it is truly the best spreadsheet available. Excel lets you do things with formulas and macros (Visual Basic for Application) that are impossible with other spreadsheets.

I have been using AutoCad since 1990 when I started my career as an Engineer in Butwal Power Company Limited. Autodesk AutoCad has been the best and suitable tool for creating digital drawings.

Although the above mentioned software are popular amongst all the micro-hydropower stakeholders, it is a safe bet that only about five percent of Excel and AutoCad users in Nepali micro-hydropower sector really understand how to get the most out of these software. With the help of these Design Aids, I attempt to illustrate the fascinating features of these software and nudge you into that elite group.

I have noticed that there are numerous independent technical tools and books related to micro-hydropower available in the market. A single set of tools for all calculations is not available at all. Moreover, the outcome of most of these tools are not adequately tested and verified. Most of the good software have no or only poorly illustrated manuals. The combined outcome may produce poor quality feasibility studies which lead to improper implementation decision. To overcome these ominous danger, I have prepared this manual in Acrobat pdf format along with the software.

The latest version of Micro-hydropower Design Aids (v 2005.10) is a shareware and can be downloaded from www.entec.com.np. Permission is granted to any individual or institution to use, copy, or redistribute the MHP Design Aids so long as it is not sold for profit.

What You Should Know
The Design Aids are prepared for practicing technical designers who have basic knowledge of hydropower features, technical calculation skills and who are familiar with Excel and AutoCad. I attempt to ornate these Design Aids in such a way that the users will learn Excel and AutoCad almost instantaneously. I also attempt to enhance skills and knowledge of these users.

What You Should Have
To make the best use of the Design Aids, you need a copy of Microsoft Excel (XP or later), Autodesk AutoCad (2000 or later) and Adobe Acrobat Reader (5.0 of later). The latest version of a free copy of Adobe Acrobat Reader can be downloaded from www.adobe.com.

How These Design Aids Are Organized
There are hundreds ways to organize these Design Aids materials, but I settled on a scheme that divides them into three main parts.

Part I: Drawings
This part consists of fifteen typical drawings of typical intake to transmission line. Since they are only typical drawings, additions of drawings and the level of details may be amended to fulfil specific needs of a particular project. Special efforts were made to maintain the level of consistency, compatibility and the extent of information in the drawings. It is expected that the presented feasibility drawings by consultants are complete and appropriate for micro hydropower plants and all the concerned stakeholders should be able to understand and implement the presented content.

Part II: Spreadsheets
This part consists of fourteen typical spreadsheets covering all calculations recommended by AEPC guidelines for subsidy approval of micro-hydropower schemes. These spreadsheets provide users to estimate hydrological parameters; design civil, mechanical and electrical components and analyse financial robustness of the perspective micro hydropower schemes in Nepal.

Part III: Users' Manual
This manual in Adobe Acrobat pdf format illustrates aspects set aside by AEPC guidelines, users manual for using presented drawings and spreadsheets and introduction and step-by-step calculations covering all technical and financial calculations required for micro-hydropower schemes up to feasibility study levels.

Download and Reach Out
Preparation of the Design Aids is a continuous process. I am always interested in getting feedback on these Design Aids. Therefore, valuable suggestions and feedbacks are expected from all the stakeholders/users so that the overall quality of the micro hydro sector is enhanced. Any suggestion and feedback can directly be sent to my email pushpa.chitrakar@gtz.org.np.

1. INTRODUCTION

1.1 GENERAL

Micro-hydropower Design Aids is a complete set of tools consisting of typical AutoCad drawings, typical Microsoft Excel spreadsheets and a users' manual recommended for using up to feasibility study level of micro-hydropower schemes up to 100kW. Alternative Energy promotion Centre (AEPC) of His Majesty's Government of Nepal (HMG/N) has officially recommended these Design Aids for its subsidized micro-hydropower schemes in Nepal. This set of Design Aids is a part of its publication ISBN 99933-705-5-X.

Under the Small Hydropower Promotion Project (SHPP/GTZ)[1] and Mini-Grid Support Programme (MGSP/AEPC-ESAP)[2] collaboration 2002-2004, these micro-hydropower Design Aids were prepared to provide a basis for consultants to undertake calculations and prepare drawings as per the requirements set aside by the procedural guidelines of AEPC-HMG/N. Since most of the stakeholders are familiar with Autodesk AutoCad (2000 or later) and Microsoft Excel (XP or later) application software, the Design Aids were prepared based on these software to make them simple and user friendly. During the preparation of these Design Aids, special efforts were made so that the skills and knowledge of practicing stakeholders such as consultants, manufacturers and inspectors are further enhanced by this Design Aids.

The Design Aids consist of a set of fifteen typical drawings and fourteen typical spreadsheets covering all aspects recommended by AEPC guidelines for its subsidized micro-hydropower schemes. The Design Aids provide users to estimate hydrological parameters; design civil, mechanical and electrical components and analyse financial robustness of the perspective micro hydropower schemes in Nepal. Procedural guidelines, detailed step by step calculations of all the calculations and manual for using the presented spreadsheets are presented in this users' manual in Acrobat pdf file format. It is also expected that the stakeholders will be using the electronic version of the Design Aids. The Design Aids are distributed in template/read-only forms so that the original copy is always preserved even when the users modify them.

The Design Aids are specifically prepared for micro hydropower schemes up to 100kW. Although, there are many common approaches and features in all hydropower projects, special care should be taken while using these tools for bigger schemes if the circumstances are unavoidable. Use of typical drawings should be restricted to micro-hydropower schemes. Most of the spreadsheets can however be used for components of bigger hydropower projects as well (refer to Table 1.2).

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Preparation and use of the Design Aids is a continuous process. SHPP/GTZ has been continuously enhancing the Design Aids and this update (version 2005.10) is the outcome of SHPP's efforts in hydropower sector development in Nepal. Therefore, valuable suggestions and feedbacks are expected from all the stakeholders/users so that the overall quality of the micro hydro sector is enhanced. Any suggestion and feedback can directly be sent to pushpa.chitrakar@gtz.org.np .

1.2 OBJECTIVES OF THE DESIGN AIDS

The main objective of the Design Aids is to enhance the quality of the micro hydropower sector in Nepal. Use of these Design Aids helps fulfilling the main objective because:

[1] Small Hydropower Promotion Project is a joint project of His Majesty's Government of Nepal (HMG/N), Department of Energy Development (DoED) and German Technical Cooperation (GTZ). Since its establishment in 2000, this project has been providing its services to sustainable development of small hydropower projects in Nepal (100kW to 10MW) leading to public private participation and overall rural development. It has also been providing technical support and backstopping to Nepali micro-hydropower stakeholders including AEPC.

[2] Alternative Energy Promotion Centre (AEPC) is a HMG/N organization established to promote alternative sources of energy in Nepali rural areas. MGSP of AEPC-ESAP is promoting Nepali micro-hydropower schemes up to 100kW.

1. The Design Aids function as a set of "Time Saver Kit" for precision and speed (e.g. hydrological calculations based on exact flow measurement date, Q flood off-take, friction factor of penstock pipes, etc.).
2. They provide required relevant references for micro hydro sector stakeholders for using and upgrading their skills and creativities. Any external references that may require referring during calculations are minimised by incorporating them in the cell notes, tables, figures, etc. All detailed calculation guidelines are further documented in the Users' Manual.
3. The depth of the study and presented reports by different consultants are uniform and their data presentations are to the required depth.
4. The Design Aids serve as templates so that there are sufficient rooms for further creativity and improvement to tailor for incorporating specific needs of particular projects.
5. In addition, the Design Aids are handy and user friendly. The user familiar AutoCad 2000 and MS Excel XP software platforms are used to develop the Design Aids.

1.3 SOURCES OF THE DESIGN AIDS

Since the Design Aids were prepared aiming to enhance the overall quality of the micro hydro sector, the prudent documents that were available and applicable for the specific purposes, studies of different preliminary and feasibility reports of different micro hydro plants, feedbacks and suggestions from the stakeholders were based during the preparation of the Design Aids. Reviews of following sources were carried out during the preparation of the Design Aids:

1. Updated AEPC micro hydropower guidelines and standards for Peltric and micro-hydropower schemes.
2. Review, assessment and appraisal of more than 300 preliminary feasibility, 200 feasibility and 50 Peltric set feasibility study reports during the SHPP/GTZ-AEPC collaboration.
3. Feedbacks from all stakeholders such as SHPP/GTZ-AEPC collaboration members, Reviewers, Consultants, Developers, Manufacturers and Installers.
4. Experience from other micro, small and large hydropower projects within Nepal and abroad.
5. Standard textbooks, guidelines and other standards.

1.4 DESIGN AIDS: TYPICAL DRAWINGS

As stated earlier, fifteen AutoCad drawings were prepared and incorporated in the Design Aids. The presented drawings cover from intake to transmission line. Since they are only typical drawings, additions of drawings and the level of details may be changed to fulfil specific needs of a particular project. The level of consistency, compatibility and the extent of information in the drawings are complete and appropriate for micro hydropower plants and all the concerned stakeholders should be able to understand and implement the presented content. The main features of the presented drawings are:

1. These drawings are recommended only for micro-hydro schemes.
2. Minimum required details such as plans and adequate cross sections are provided.
3. Recommended values of elements such as the minimum thickness of a stone masonry wall, the longitudinal slope of a settling basin, etc, are presented in the drawings.
4. Standard line types and symbols are presented.
5. Basic drawing elements such as a title box with adequate information and controlling signatories; scale; etc are presented.
6. All drawings with standard layouts for a specific printer (may have to be changed as per the actual available printer).

The dimensions and geometries of the presented drawings should be amended according to the project details. A set of all the drawings are presented in the appendix. For an example, a typical drawing of a gravel trap is presented in Figure 1.1. The drawings that are presented are listed in Table 1.1.

Table 1.1: Summary of Drawings

SN	Drawing Name (*.dwg)	Remarks
1	01 General Layout	General layout of project components except the transmission and distribution components.
2	02A Side Intake Plan	A general plan of headworks including river training, trashrack, intake, gravel trap and spillway.
3	02B Side Intake Sections	A longitudinal section along water conveyance system from intake to headrace, two cross sections of weir for temporary and permanent weirs respectively and a cross section of a spillway.
4	03 Drop Intake Plan	A general plan, a cross section across a permanent weir and a cross section of a drop intake.
5	04 Headrace	A longitudinal headrace profile showing different levels along it.
6	05A Gravel Trap	A plan, a longitudinal section and two cross sections.
7	05B Settling Basin	A plan, a longitudinal section and two cross sections.
8	06 Headrace Canal	Two cross sections for permanent lined canal and one for temporary unlined canal.
9	07 Forebay	A plan, a longitudinal section, two cross sections and penstock inlet details.
10	08 Penstock Alignment	A longitudinal section of penstock alignment.
11	09 Anchor & Saddle Blocks	Plans and sections of concave and convex anchor blocks and a saddle.
12	10 Powerhouse	A plan and a section of a typical powerhouse.
13	11 Machine foundation	A plan and three sections of a typical machine foundation.
14	12 Transmission	A single line diagram if a transmission/distribution system.
15	13 Single line diagram	A single line diagram showing different electrical components.

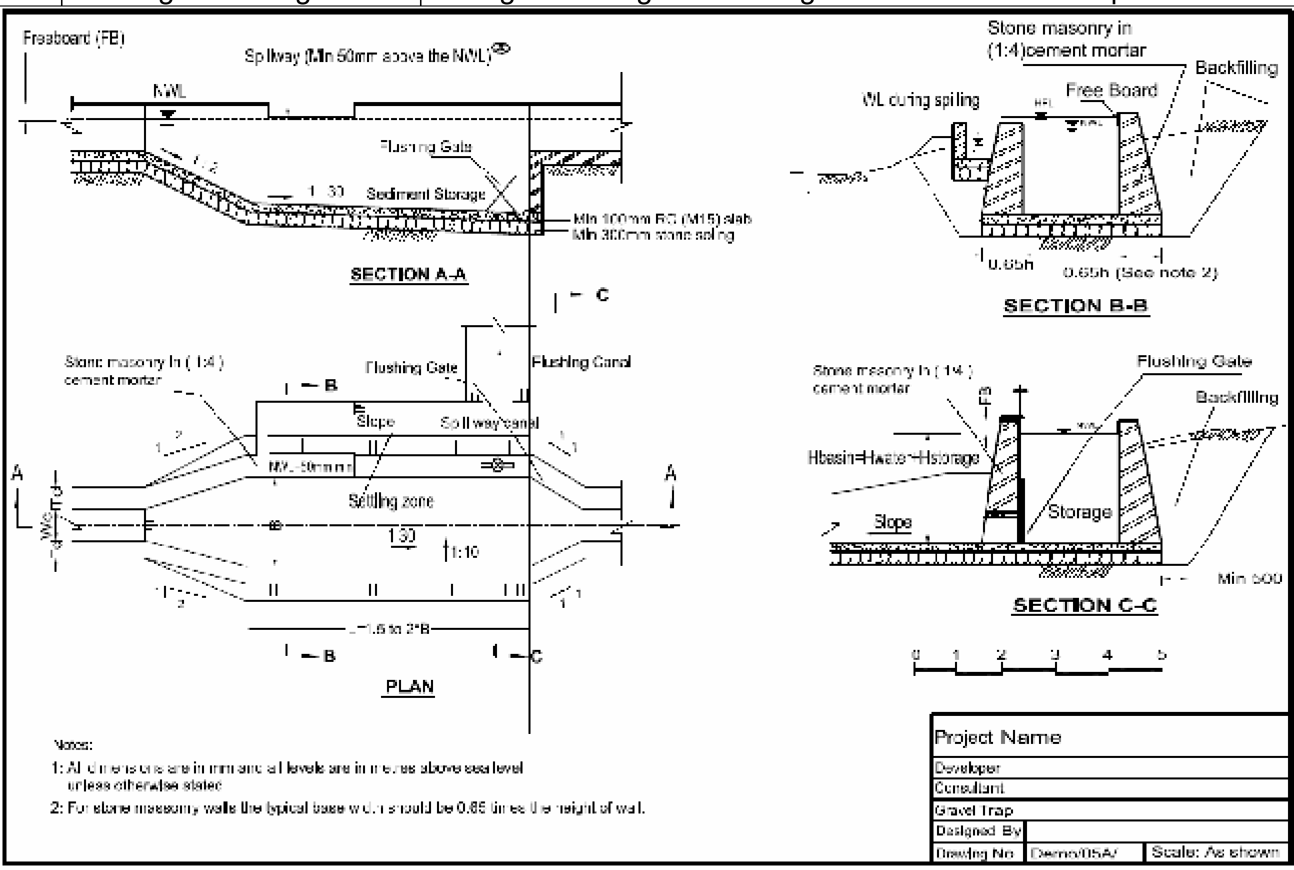


Figure 1.1: A typical Gravel Trap Drawing

1.5 DESIGN AIDS: SPREADSHEETS

As stated earlier, MS Excel XP is used to develop the spreadsheets. General as well as special features of Excel XP are utilized while developing the spreadsheets. There are thirteen main spreadsheets each covering a tool required for covering computations for an element of hydro power schemes. The "Utility" spreadsheet presented at the end of the workbook covers minor calculations such as uniform depth of water in a canal, loan payback calculations, etc. The list of the presented spreadsheets and their areas of coverage are presented in Table 1.2.

Table 1.2: Summary of Spreadsheets

SN	Name	Area of coverage	Uses
1	Discharge	Chapter 2: Computation of river discharge from Salt dilution method.	Micro and small
2	Hydrology	Chapter 3: Hydrological parameters calculations based on MIP and Hydest methods (Regression Methods)	Micro and small
3	Side Intake	Chapter 4: Design of side intakes including coarse trashrack, flood discharge and spillways.	All sizes
4	Bottom Intake	Chapter 4: Design of bottom intake including flood discharges.	All sizes
5	Settling Basin	Chapter 6: Design of settling basins, gravel traps and forebays with spilling and flushing systems with spillways, cones and gates.	All sizes
6	Canal	Chapter 5: Design of user defined and optimum conveyance canals with multiple profiles and sections.	All sizes
7	Pipe	Chapter 5: Design of mild steel/HDPE/PVC conveyance pipes.	All sizes
8	Penstock	Chapter 7: Design of penstocks with fine trashrack, expansion joints and power calculations.	All sizes
9	Turbine	Chapter 8: Selection of turbines based on specific speed and gearing ratios.	Micro
10	Electrical	Chapter 9: Selection of electrical equipment such as different types of generators, cable and other accessories sizing.	Micro
11	Transmission	Chapter 10: Transmission / Distribution line calculations with cable estimation.	Micro and small
12	Load Benefit	Chapter 11: Loads and benefit calculations for the first three years and after the first three years of operation.	Micro
13	Costing & Financial	Chapter 12: Costing and financial analyses based on the project cost, annual costs and benefits.	Micro
14	Utilities	Chapter 13: Utilities such as uniform depth, loan payment calculations, etc.	All sizes

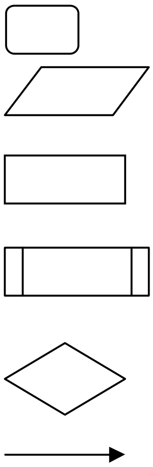
Since the design of anchor blocks and saddles are site and user specific and the rules of thumb are still valid for micro-hydropower schemes, anchor block calculations are not covered in these Design Aids.

The Design Aids are aimed at enhancing the quality of micro hydro schemes up to feasibility study level only; therefore, issues related to implementation such as detailed financing, manufacturing, etc., are not covered in greater details.

The spreadsheets not only speed up the computational processes with adequate level of precision but also provide adequate information (printable as well as references such as cell notes, etc). The main features of the presented spreadsheets are:

1.5.1 Flow chart notations

Standard flow chart notations are used describing the flows of programs and procedures. The following notations are mostly used:



Start and End

Input

Processing formulas and output

Processing and output from other sub routine

Conditional branching

Flow direction

1.5.2 Iterative Processes

The spreadsheets are prepared to save tedious and long iterative/repetitive processes during calculations. Repetitive processes are generally error generating and time consuming. A typical repetitive process is presented in Figure 1.2.

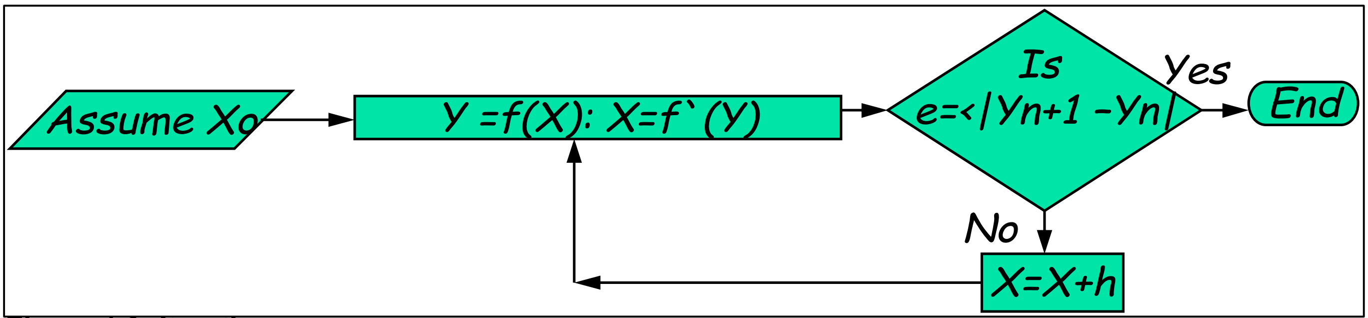


Figure 1.2: Iterative process

As shown in the figure, the initial assumed value of X_0 is amended until an acceptable error limit is reached. By default, Excel does not activate this kind of iterative process and generates Circular Reference Error. The iterative features in Excel can be activated by selecting Calculations tab (Tools->Options->Calculations>Tick Iteration (cycles & h)) and checking the iteration box. The Excel dialogue box with this features activated is presented in Figure 1.3.

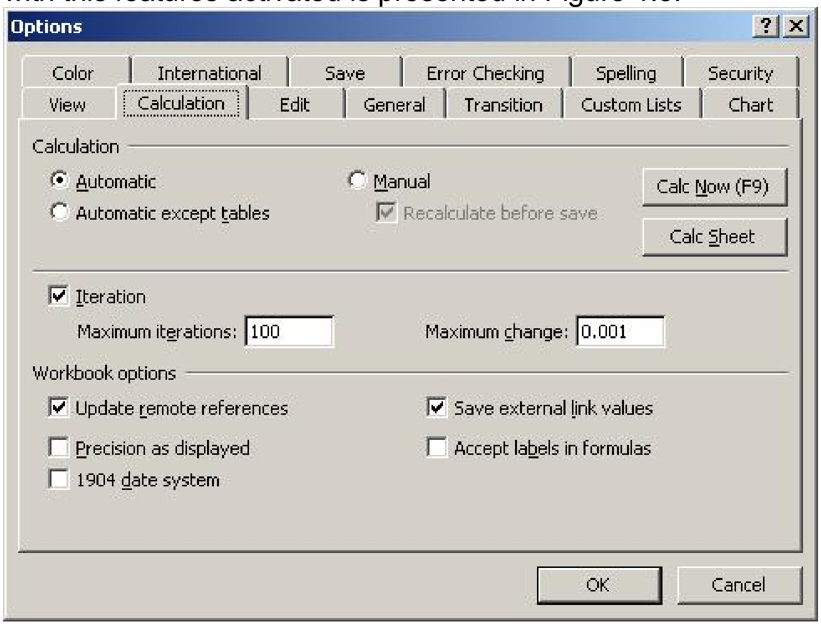
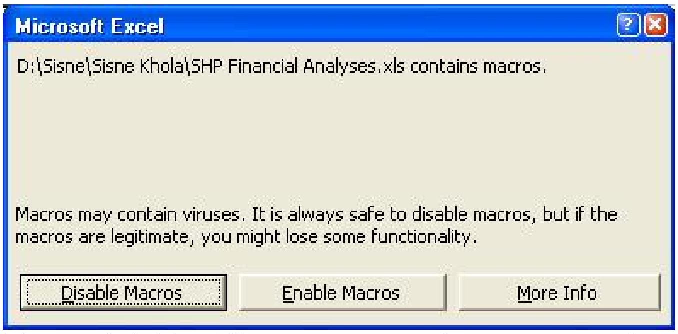


Figure 1.3: Activation of iteration (Tools => Option =>Calculations

1.5.3 Macro Security

The spreadsheets contain Visual Basic for Application (VBA) functions and procedures. Because of the safety reasons against possible virus threats, MS Excel disables such VBA functions and procedures by default. Setting security level to medium (Tools => Macros => Security => Medium) and enabling the macros during the opening of the Design Aids are required for the proper execution of the Design Aids. Dialogue boxes for setting security level to medium and enabling the macros are presented in Figure 1.4.



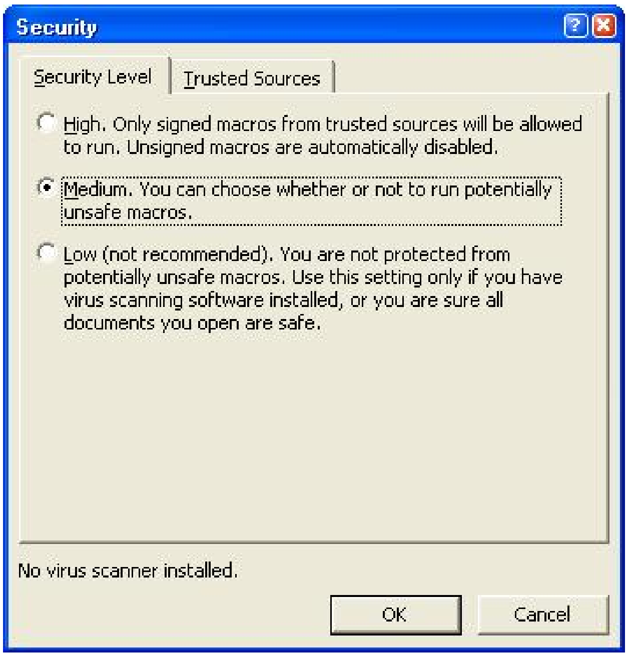


Figure 1.4: Enabling macros and macro security

1.5.4 Individual vs. linked spreadsheets

By default, the spreadsheets are designed in such a way that they can be used as linked spreadsheets for a single project. Therefore project related common inputs such as the project name is not needed to input on every spreadsheets. Some of the other processed data such as the design discharge or flood discharge are also linked by default. However, the users may change these values for specific calculations i.e., the spreadsheets can also be used as individual spreadsheets for independent calculations. It is recommended to save an extra copy of the workbook before manipulating such linked cell so that the saved copy can be used as a workbook with linked spreadsheets for a single project.

1.5.5 User specific inputs

Some parameters such as canal freeboards, width of a canal, factor of safety for a mild steel penstock, etc., have their standard optimum values. By default, the standard optimum values are computed. However, the user may choose to enter non-standard specific values under special circumstances.

1.5.6 Interpolated computations

Some of the parameters such as the coefficient of bend, coefficient of gate discharge, etc., have standard proven values for standard conditions. However, if the user input value is not of a standard tabulated value, the interpolated values with the help of curve fitting are used for the calculation. The users are cautioned to check the validity of such values whenever they encounter them.

1.5.7 Errors

Mainly three types of errors are known. One of them is NAME# error which is caused by not executing custom functions and procedures because of the macro security level set to high or very high level. In case such an error occurs, close the workbook, activate the macro security level to medium and enable the macros when opening the workbook again. A typical NAME# error occurs adjacent to the depth of water during flushing yfi (m) and d50f during flushing (mm) in the settling basin spreadsheet.

VALUE# error is the other error that is generated by the malfunctioning of circular references. When such an error occurs, select the error cell, press F2 and press Enter. Q intake Qf cumec in the side intake spreadsheet is an example of such an error.

REF# error in transmission line computation occurs due to the deletion of unnecessary rows in a branch. In such an instance, copy the second cell from the second line of any branch.

1.5.8 Cell notes

Adequate cell notes are provided for information explaining computational procedures, used formulas, mandatory requirement set aside by AEPC, references required for deciding proper values and criteria, etc.

For example, a cell with a cell formula for calculating specific speed of a turbine is presented in Figure 1.5. Similarly, the cell note in Figure 1.6 presents a basic table for selecting Manning's coefficient of roughness of a canal.

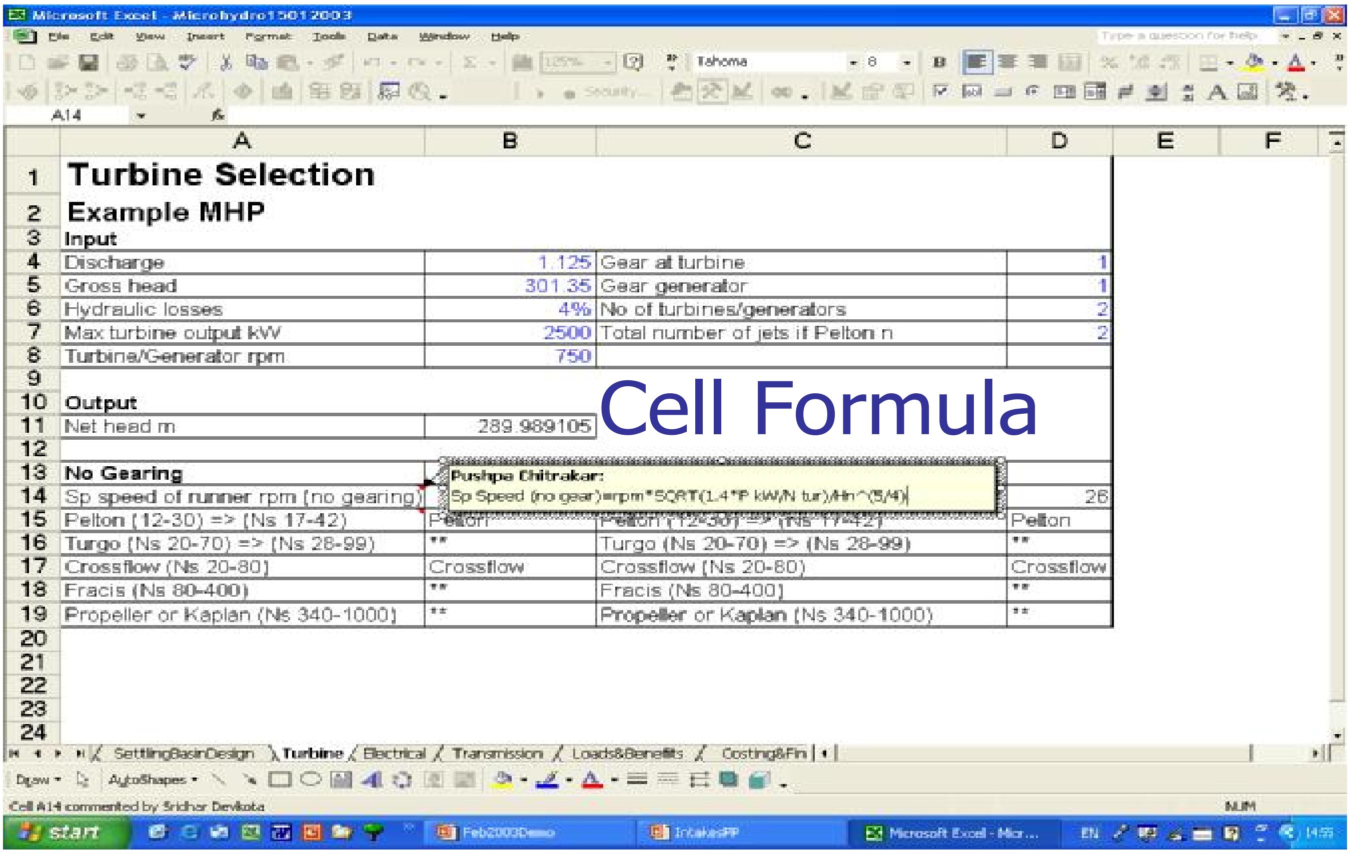


Figure 1.5: Cell formula incorporated in a cell note.

1.5.9 Cell Text Conventions

Three different colours codes are used to distinguish three different cells types. A typical example of colour coding of cells is presented in Figure 1.7. The colours and categories of these cells are:

Blue cells: These cells represent mandatory input cells. These cells are project dependant cells and project related actual inputs are expected in these cells for correct outputs. The mandatory input includes the name of project, head, discharge, etc.

Red cells: These cells are optional input cells. Standard values are presented in these cells. Values in this type of cells can be amended provided that there are adequate sufficient ground to do so. It is worth noting that care should be taken while changing these values. The optional values/ inputs include the density of sediment, sediment swelling factor, temperature of water, etc.

Black cells: The black cells represent information and or output of the computations. For the sake of protecting accidental and deliberate amendment or change leading to wrong output, these cells are protected from editing.

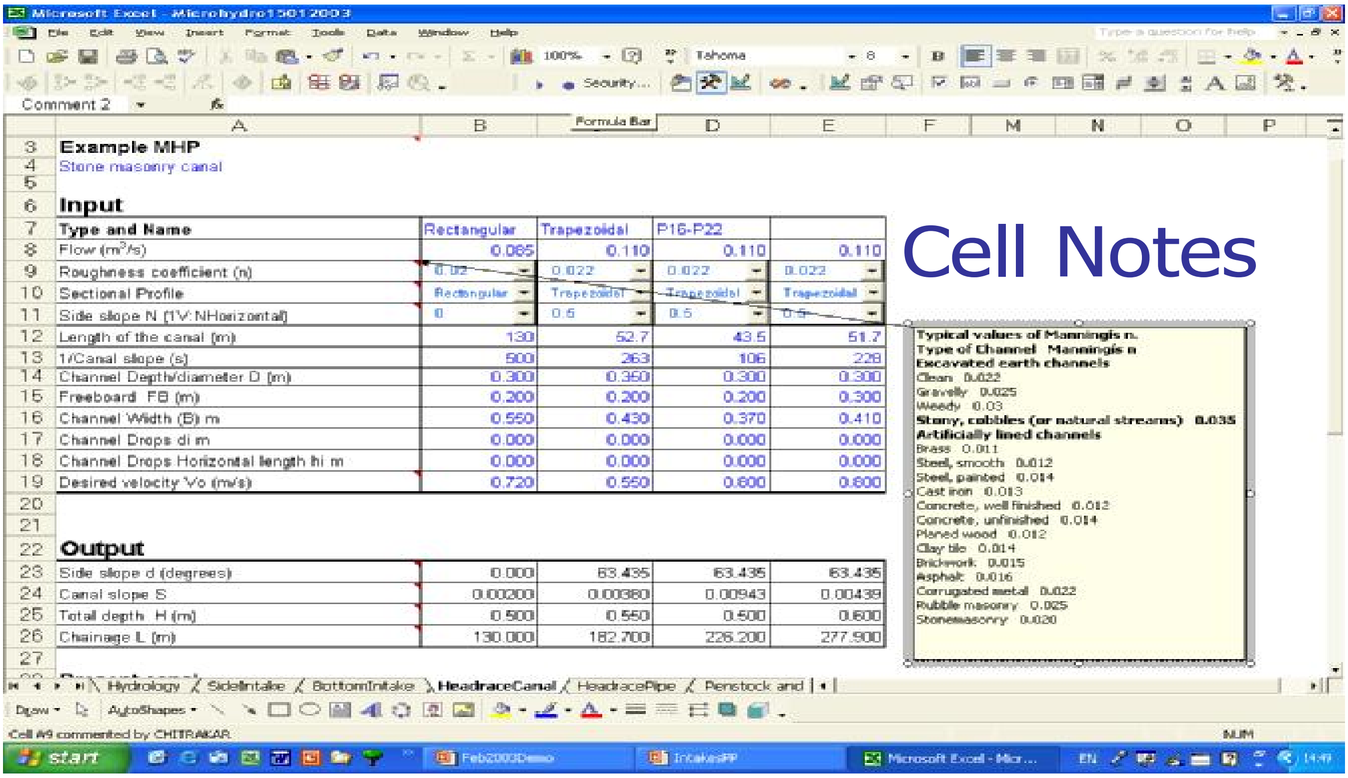


Figure 1.6: A cell note presenting typical values of Manning's n for different surfaces

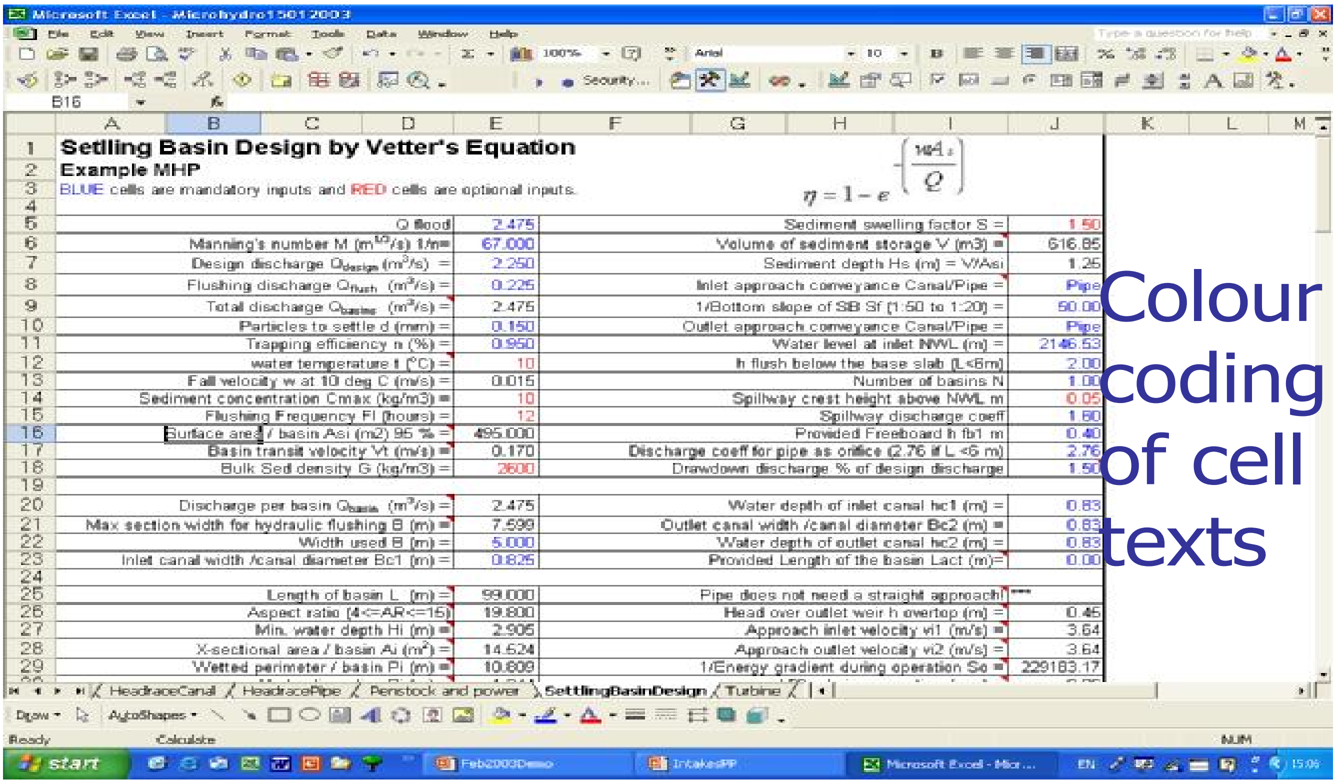


Figure 1.7: Colour coding of cell texts

1.5.10 Types of input values

Based on the nature of input, the inputs are categorised in to the following three groups:

1. ***User or project specific input***: The input variables that totally depend on the user and or the project are categorised as the user or project specific inputs. The programs do not restrict on or validate the values of such inputs. The name of the project, gross head of the projects, etc., are some of the examples that fall on this category. The crest length in the example presented in Figure 1.8 can have any value hence it is a user specific input.

2. ***Prescribed Input***: Some of the inputs have some standard values. The programs suggest using such values and give choices for the user to select. However, the programs do not restrict on or validate such variables. These inputs are termed as prescribed inputs. For example in Figure 1.8, with the help of a pull-down menu, different Manning's coefficients for different types of surfaces are suggested for selection. This will greatly reduce the need for referring external references. However, any specific values for specific need can be entered into this type of cells.

3. ***Mandatory Input***: Some inputs can have only some specific values and the programs need to validate such values for proper computations. These values are termed as mandatory inputs. Since Nepal is divided into seven MIP regions, the MIP region value can have an integer ranging from 1 to 7 only. In the example presented in Figure 3.9, the MIP region can have values from 1 to 7, the month can have a string from January to December and the date can have an inter ranging from 1 to 31. In case the user enters different values, the program will generate errors and prompts for the correct inputs.

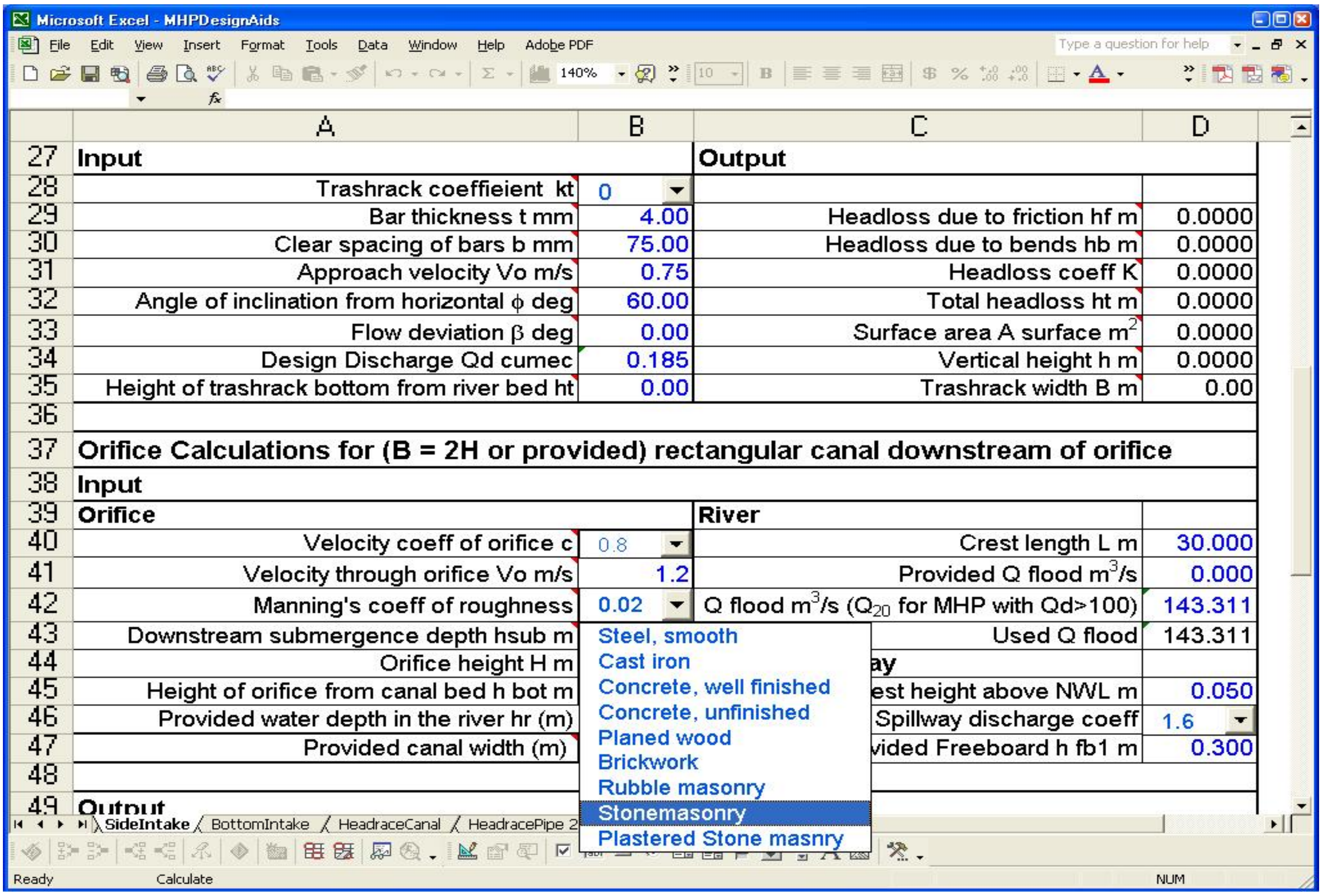


Figure 1.8: Different categories of inputs.

1.5.11 Pull Down menus and data validation

Some input cells are equipped with pull down menus to facilitate the users to input standard values related to the input cell. Pull down can have any user specific values than the stated standard values if the data cells are not of mandatory type. In Figure 1.8, the pull down menu for Manning's roughness coefficient (n) in cell B42 is activated. Different surface materials are listed in the pull down menu, stone masonry surface type is selected and the corresponding standard value of the Manning's coefficient of roughness of 0.02 is substituted in the corresponding cell. Since the value in this cell is not restricted, the user can enter any values for this cell.

Some inputs such as the name of the month, MIP hydrological region and dates in Hydrology spreadsheet can have specific values in their respective cells. Since the outcome of the computation will be erroneous if the input data does not match with the desired values, the spreadsheets are designed to reject such an invalid value and flag an error message with suggestions. For instance, Nepal is divided into seven MIP hydrological regions. It can have an integer value ranging from 1 to 7. If 8 is entered as a MIP region, the data is rejected and an error message along with suggestions will be flagged. This example is demonstrated in Figure 1.9.

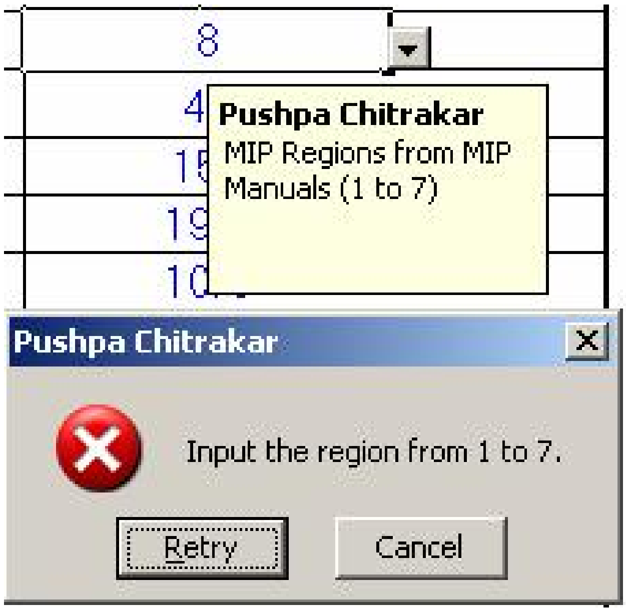


Figure 1.9: Different categories of inputs.

2 DISCHARGE MEASUREMENT

Almost all potential micro hydropower project sites in Nepal are located in remote areas where there is a complete lack of hydrological information. As per MGSP guidelines, at least one set of discharge measurement at the proposed intake site should be carried out between November and May. Bucket method for flow up to 10 l/s, weir method for a flow from 10 to 30 l/s and for flows larger than 30l/s salt dilution method (conductivity meter method) are recommended. This chapter deals with spreadsheet calculations based on the salt dilution method.

Since the salt dilution method is quick (generally less than 10minutes per set of measurement), easier to accomplish and reliable, its accuracy level is relatively higher (less than 7%), suitable for smaller fast flowing streams (up to 2000 l/s) easier for carrying in remote places, the Consultants have been using mainly this method even though AEPC guidelines have proposed different methods for different flows at the river. In this method, the change of conductivity levels of the stream due to pouring of known quantity of predefined diluted salt (50-300gm per 100l/s) are measured with a standardised conductivity meter (with known salt constant, k) at a regular interval (e.g., 5 seconds). For more information, please refer to MGSP Flow Verification Guidelines or Micro Hydro Design Manual (A Harvey).

The discharge calculation spreadsheet presented in the Design Aids can handle up to four sets of data and the individual as well as the average discharges are presented as outputs. The input parameters required for the discharge calculation are presented in Table 2.1. The typical input parameters considered in the example are presented in the adjacent column. The first set field readings are presented in Table 2.2.

Table 2.1: Input parameters for Salt Dilution Method

SN	Input parameters	Input for the cited (Example)
1	Project	Upper Jogmai, Ilam
2	Conductivity Meter	HANNA Instruments HI 933000
3	Date	12-Jan-04
4	Type of Salt	Iyoo Nun
5	Conductivity Constant (μ Siemens)	1.8 at 15^{o}C
6	Water temp	15^{o}C
7	Time Intervals (dt)	5sec
8	Weights of salt for sets 1 to 4 (M in g)	400g, 1580g and 1795g
9	Readings (μ & $\mu_{baseline}$) for sets 1 to 4	Presented in Table 2.2

Table 2.2: First set conductivity reading for Salt Dilution Method (Example)

	Time(sec)												
	5	10	15	20	25	30	35	40	45	50	55	60	Sum
Water Conductivity in μS	25	26	27	28	29	30	31	32	32	33	34	34	361
	34	35	35	35	35	34	34	34	33	33	33	32	407
	32	32	32	31	31	31	31	31	31	30	30	30	372
	30	29	29	29	29	29	29	28	28	28	28	28	344
	28	28	27	27	27	27	27	26	26	26	26	26	321
	26	26	26	26	26	26	26	25	25	25			257
												Total (μS) = $\Sigma\mu$	2062
												Total readings (nr)	70

With these input parameters, discharge at the stream can be calculated by the following procedures:

Stream Flow,

Q = M x k/A

Where,

Q = flow in litre/sec
M = mass of dry salt in mg (i.e.10^{-6} kg)
k = salt constant in (μS)/(mg/litre)
A is the area under the graph of conductivity versus time, after excluding the area due to base conductivity. The units for the area under the graph is sec x μS. The area is determined as follows:

Area (A) = ($\Sigma\mu$– nr x $\mu_{baseline}$) * dt

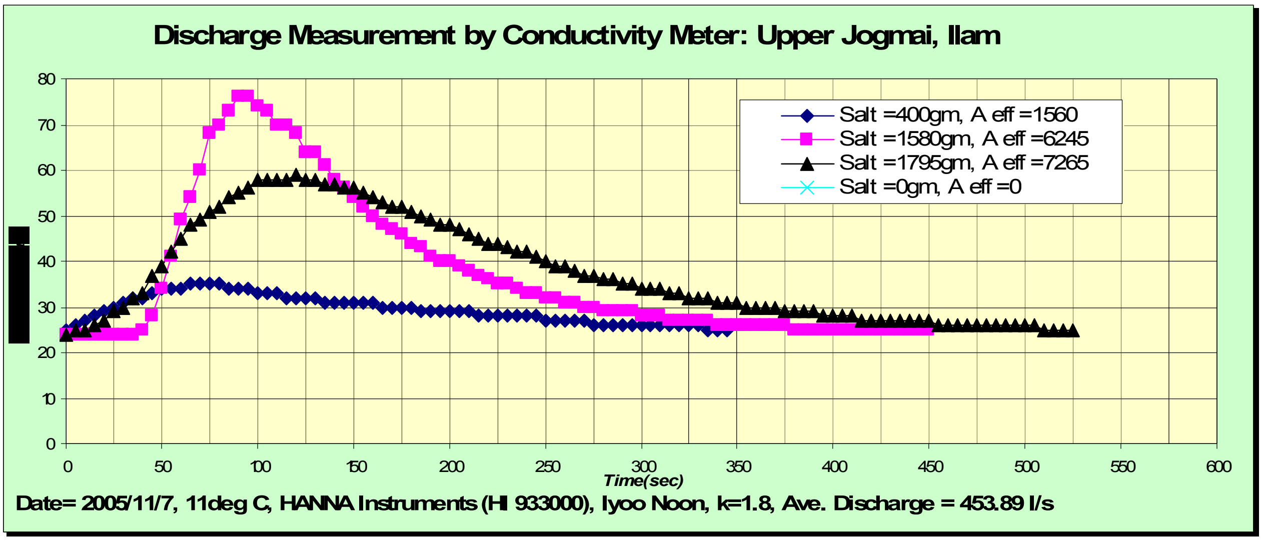
Weighted averages of the individual flows thus calculated are computed. A typical spreadsheet with partial conductivity readings is presented in Figure 2.1. The average estimated discharge will further be used by Medium Irrigation Project Method (MIP) to calculate long term average monthly flows. The calculation procedures for the first set of measurements (Set 1) are:

Area (A) = ($\Sigma\mu$– nr x $\mu_{baseline}$) * dt
= (2062-70*25)*5
= 1560 sec x μS

Discharge (Q) = M x k/A
= 400000*1.8/1560
= 461.54 l/s

Discharge Measurement by Conductivity Meter

Spreadsheet developed by Mr. Pushpa Chitrakar, Engineering Advisor, SHPP/GTZ				
Referances: 6,12,13,15,16	Date	07-Nov-2005		
SMALL HYDROPOWER PROMOTION PROJECT/GTZ	Revision	2005.10		
Project	**Upper Jogmai, Ilam**			
Developer	Kankaimai Hydropower P Ltd			
Consultant	EPC Consult			
Designed	Pushpa Chitrakar			
Checked	Pushpa Chitrakar			
Meter	**HANNA Instruments (HI 933000)**			
Salt	Iyoo Noon	Water temp:		11 sec
Given k	1.8	Time intervals		5 sec
Salt Const. (k)	1.8000			
Wt. of Salt	400 gm	1580 gm	1795 gm	0 gm
Nr of data	70	91	106	0
Baseline conductivity	25	24	24	0
Sum of readings	2062	3433	3997	0
Effective Area	1560	6245	7265	0
Discharge	462 l/s	455 l/s	445 l/s	0 l/s
			Average Discharge	**454 l/s**



Field Data

Time	Reading 1	Reading 2	Reading 3	Reading 4
0	25	24	24	
5	26	24	25	
10	27	24	25	
15	28	24	26	
20	29	24	27	
25	30	24	29	
30	31	24	30	

Figure 2.1: Discharge calculations by salt dilution method

3 HYDROLOGY

3.1 GENERAL

Hydrology is the science that deals with space-time characteristics of the quantity and quality of the waters of the earth. It is the intricate relationship of water, earth and atmosphere.

Tools developed for estimating hydrological parameters for such un-gauged catchment areas are mainly based on regional correlations. The outputs of these tools are quite comparable to the actual hydrological parameters for rivers having bigger catchment areas (100km^2 or more).

Almost all potential micro hydropower scheme sites in Nepal have relatively smaller catchment areas and are located in remote areas where there is a complete lack of hydrological information. MGSP guidelines require at least a set of actual measurement in dry season (November-May) for estimating comparatively reliable long term mean monthly flows. Long term mean monthly flows are estimated by the use of a regional regression methods called Medium Irrigation Project (MIP) method developed by M. Mac Donald in 1990. For micro hydropower schemes having a design discharge more than 100 l/s, flood hazards are generally critical and flood flows should be calculated. Long term mean monthly flows based on MIP method and flood flows based on 'methodologies for estimating hydrologic characteristics of engaged locations in Nepal, WECS/DHM 1990 Study (Hydest)" are incorporated in "Hydrology" spreadsheet. Brief introduction of these two methods are presented in the subsequent sub-sections.

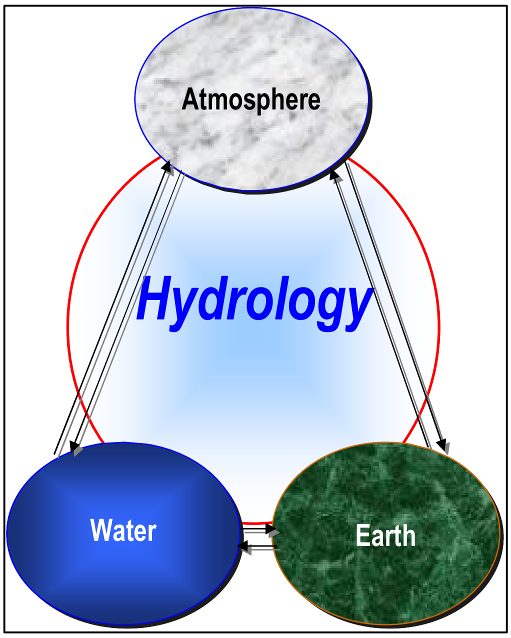


Figure 3.1: Hydrology .

3.2 HYDROLOGICAL DATA

As presented in figure 3.2, the hydrological data constitute of stream flow records, precipitation and climatological data, topographical maps, groundwater data, evaporation and transpiration data, soil maps and geologic maps. Large projects may need all the hydrological data. However, only the first three data are sufficient for the estimation of MIP monthly flows and Hydest floods in micro hydropower project.

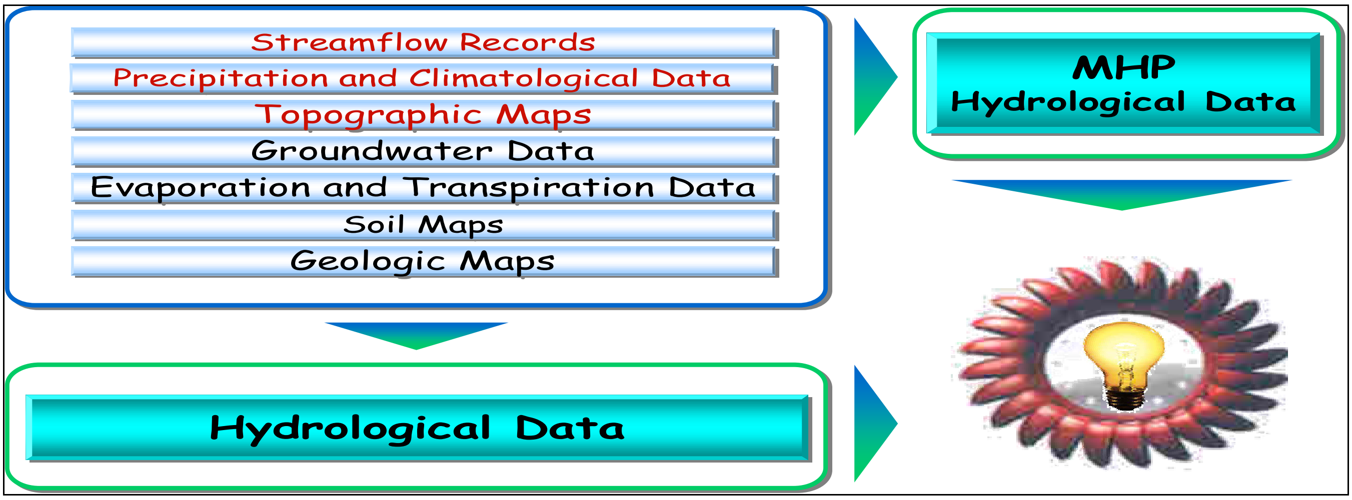


Figure 3.2: Hydrological Data and MHP

3.3 MEDIUM IRRIGATION PROJECT (MIP) METHOD

As stated earlier, this method is developed by M. Mac Donald in 1990. According to this method, Nepal is divided into 7 regions. Based on wading measurements by the Department of Hydrology and Meteorology (DHM, HMG/N), non-dimensional regional hydrographs were developed for each region. The month of April was used for non-dimensionalizing. Seven sets of average monthly coefficients for the seven regions for each month were prepared.

The seven regions are graphically shown in Figure 3.3 and the corresponding seven sets of mean monthly coefficients are presented in Table 3.1. It is worth noting that these monthly coefficients have to be interpolated to get the actual monthly coefficients if the flow measurement is not on the 15th of the month.

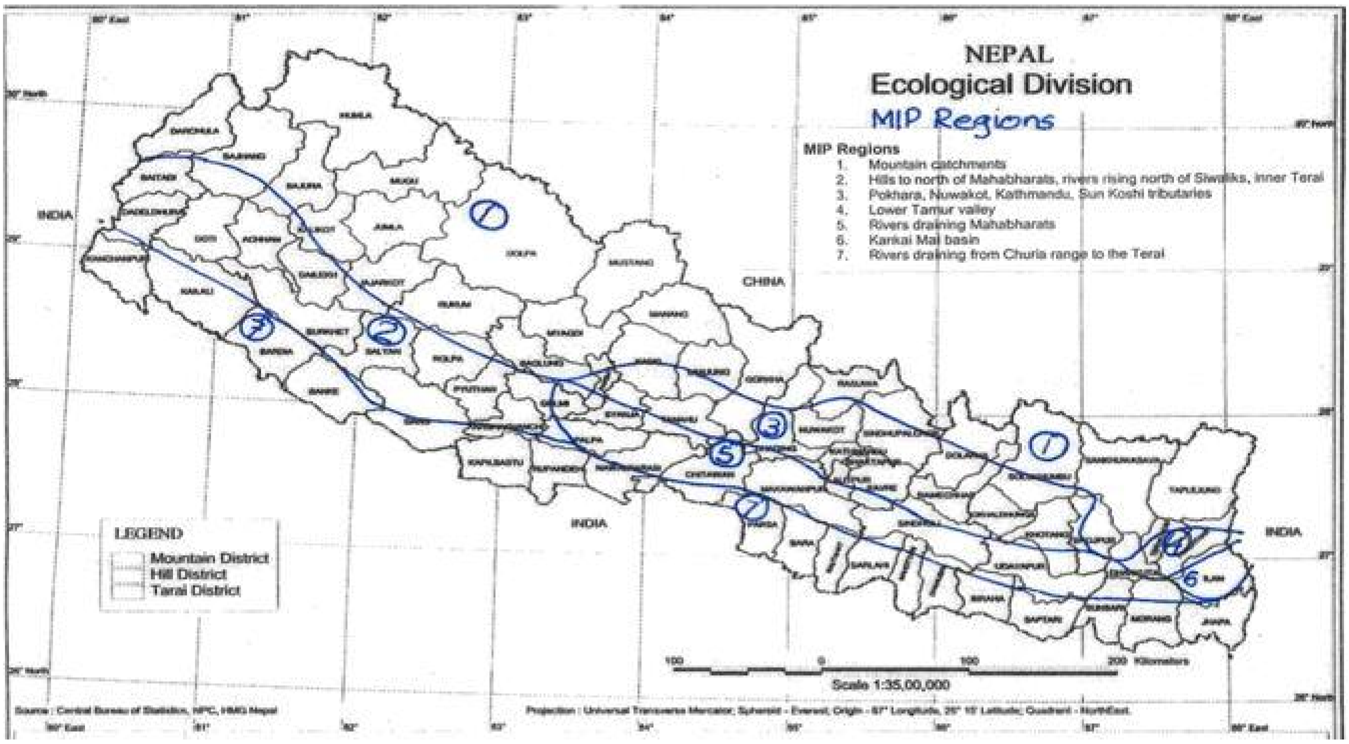


Figure 3.3: MIP Regions

Table 3.1: MIP regional monthly coefficients

Month	Regions						
	1	2	3	4	5	6	7
January	2.40	2.24	2.71	2.59	2.42	2.03	3.30
February	1.80	1.70	1.88	1.88	1.82	1.62	2.20
March	1.30	1.33	1.38	1.38	1.36	1.27	1.40
April	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
May	2.60	1.21	1.88	2.19	0.91	2.57	3.50
June	6.00	7.27	3.13	3.75	2.73	6.08	6.00
July	14.50	18.18	13.54	6.89	11.21	24.32	14.00
August	25.00	27.27	25.00	27.27	13.94	33.78	35.00
September	16.50	20.91	20.83	20.91	10.00	27.03	24.00
October	8.00	9.09	10.42	6.89	6.52	6.08	12.00
November	4.10	3.94	5.00	5.00	4.55	3.38	7.50
December	3.10	3.03	3.75	3.44	3.33	2.57	5.00

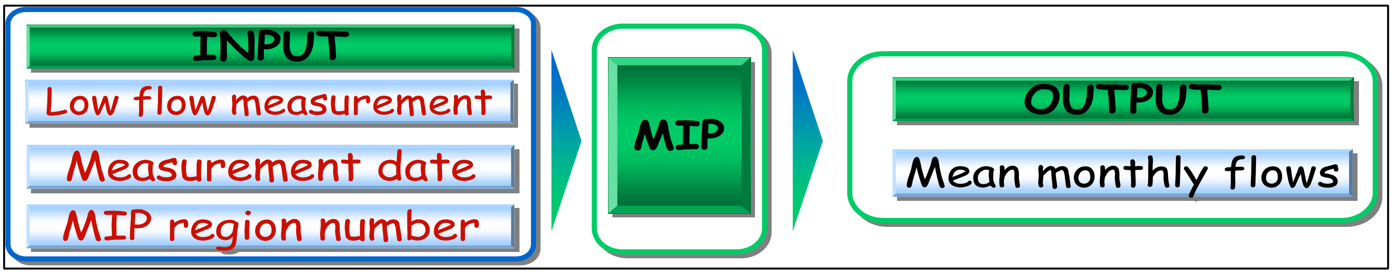


Figure 3.4: MIP model

Figure 3.4 represents a flow chart of the MIP model for calculating mean monthly flows based on a set of low flow measurement. As shown in the figure, this model takes low flow measurement, its date and MIP region number as inputs and process them for estimating mean monthly flows for that region. As stated earlier, the actual measurement date plays an important role in computing more realistic mean monthly flows. These mean monthly flows are calculated as:

Mean Coeff. for this month by interpolation if the date is not on 15th
April coef = 1/coeff this month
April flow = April coeff * Q
Monthly flows = April flow * coeffs ($Q_i = Q_{April} * C_i$)

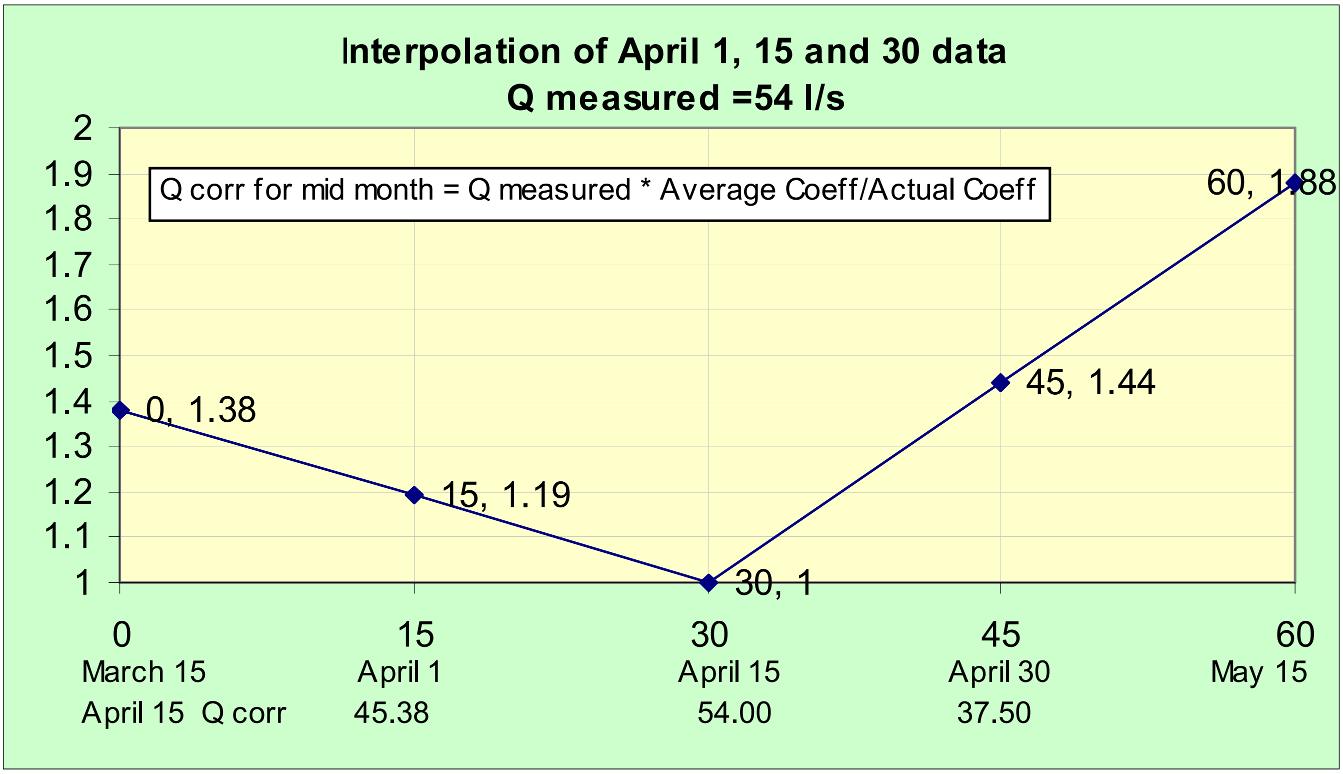


Figure 3.5: Need of interpolation for calculating mean monthly coefficient

The importance of considering the actual date of measurement and the need of calculating actual mean monthly flow of that month are further explained in Figure 3.5. The measured flow is 54 l/s. The corrected flows for April are 45.38 l/s, 54 l/s and 37.5l /s corresponding to the measurement dates as April 1, 15 and 30 respectively. Interpolation helps choosing an installed capacity of a feasible project as per ACPC criteria.

The fact that the mean monthly coefficient calculation plays major role in AEPC acceptance criteria is illustrated further by the following example.

Measured flow (m^3/s):	1
MIP region (1 -7):	3

Area of basin below 3000m elevation A_{3000} (km^2):	65
Turbine discharge (m^3/s):	1.173
Water losses due to evaporation/flushing (%):	15%

Figure 3.6 is the graphical representation of the outcome of the MIP method. For measurement dates on April 1, 15 and 30 are, corresponding probability of exceedance by using interpolated mean monthly coefficients are presented. The design flow exceeds 11 months and fulfills AEPC criteria if it is measured on April 15th. However, the design flow exceeds only 10 months and does not meet AEPC criteria if it is measured on either 1st or 30th of April.

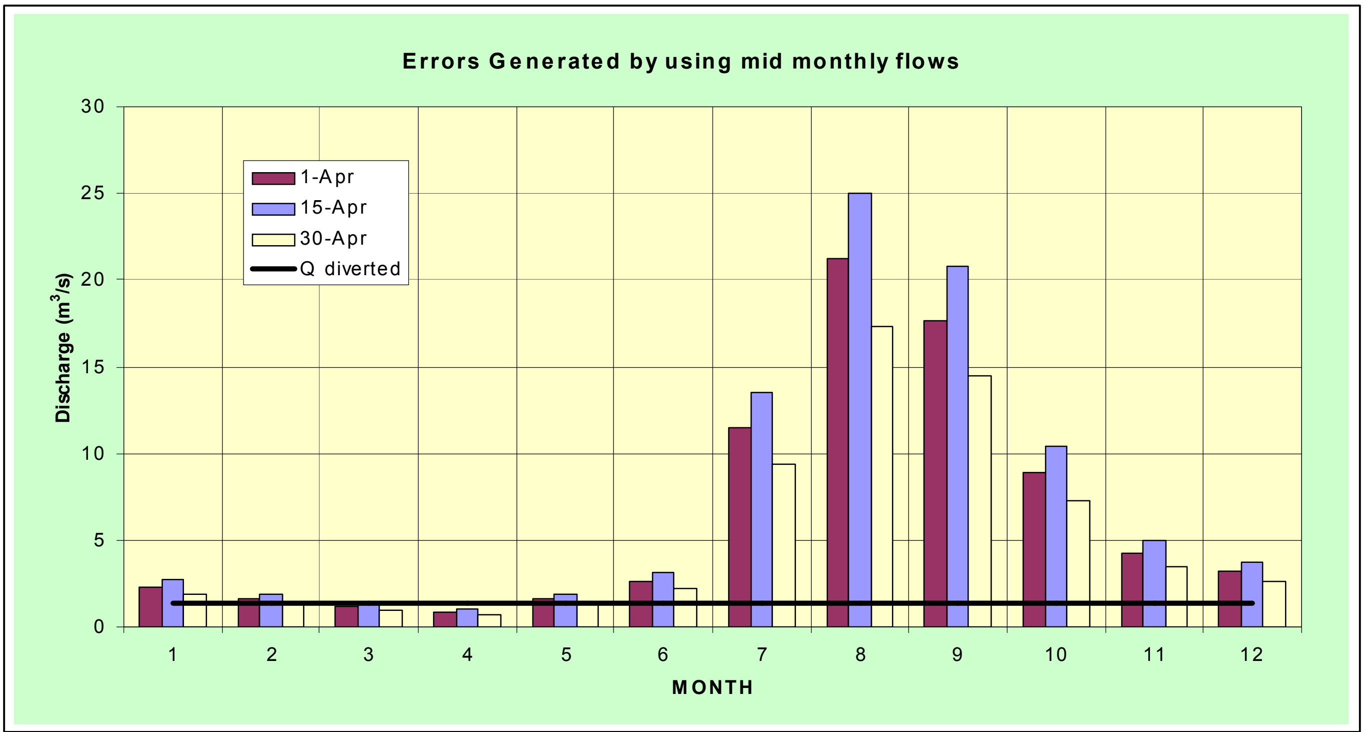


Figure 3.6: Effect of interpolation on mean monthly flows

3.4 WECS/DHM (HYDEST) METHOD

The WECS/DHM (Hydest) Method, which is also known as "Methodologies for estimating hydrologic characteristics of un-gauged locations in Nepal", is developed by WECS/DHM in 1990. Long term flow records of DHM stations (33 for floods and 44 for low flows) were used to derive various hydrological parameters such as the monsoon wetness index (June-September precipitation in mm). The entire country is considered as a single homogenous region. This method generally estimates reliable results if the basin area is more than 100 km^2 or if the project does not lie within Siwalik or Tarai regions.

Since the instantaneous and daily floods of 20-year return period are recommended to use while designing Nepali micro hydro intake structures, the flood calculations methods by this method are used in the presented spreadsheet.

3.4.1 Flood Flows:

The catchment area below 3000 m contour line is used for the estimation of floods of various return periods. 3000m elevation is believed to be the upper elevation that is influenced by the monsoon precipitation. This method has to be used with caution for catchments significant areas above the snowline. The 2-year and 100-year flood can be calculated using the following equations:

$$Q_{2\ daily} = 0.8154 \times (A_{3000} + 1)^{0.9527}$$

$$Q_{2\ inst} = 1.8767 \times (A_{3000} + 1)^{0.8783}$$

$$Q_{100\ daily} = 4.144 \times (A_{3000} + 1)^{0.8448}$$

$$Q_{100\ inst} = 14.630 \times (A_{3000} + 1)^{0.7343}$$

Flood peak discharge, Q_F, for any other return periods can be calculated using:

$$Q_F = e^{\left(\ln Q_2 + S \cdot \sigma_{\ln QF}\right)}$$

Where, S is the standard normal variant for the chosen return period, from Table 3.2, and

$$\sigma_{\ln QF} = \frac{\ln\left(\frac{Q_{100}}{Q_2}\right)}{2.326}$$

Table 3.2: Standard normal variants for floods

Return period (T) (yrs)	Standard normal variant (S)
2	0
5	0.842
10	1.282
20	1.645
50	2.054
100	2.326

As shown in Figure 3.7, the Hydest method requires different catchment areas and monsoon wetness index as inputs to estimate hydrological parameters such as the mean monthly flows, floods, low flows and flow duration curve.

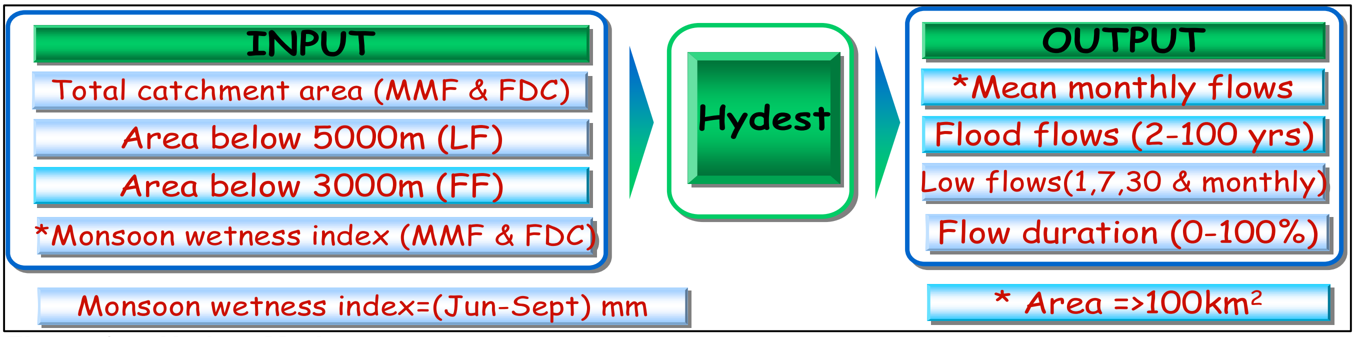


Figure 3.7: Hydest Model

3.5 AEPC MGSP/ESAP GUIDELINES & STANDARDS

The guidelines and standards for construction subsidy approval of micro hydropower projects in Nepal can be summarised as:

1. Discharge measurement at the proposed intake site should be between November and May.
2. The recommended discharge measurement methods for different discharges are:

Method	**Discharge (l/s)**
Bucket collection	<10
Weir	10-30
Salt dilution	>30

3. Mean monthly flows should be computed by using MIP method. Alternatively, HYDEST method may be used for catchment area equal to or more than 100 km^2.

4. The design flow should be available at least 11 months in a year (i.e., the probability of exceedance should be 11 months or more). The design flow corresponding to the installed capacity (Q_d) should not be more than 85% of the 11-month exceedance flow. Loses and environmental releases should also be considered if it exceeds 15% of the 11-month exceedance.
5. There is a provision of ±10% tolerance on Q_d at the time of commissioning a scheme.
6. Construction of flood wall against annual flood is recommended if the design flow exceeds 100 l/s.

3.6 PROGRAM BRIEFING & EXAMPLES

As per the standards and guidelines, the presented spreadsheet is designed to compute MIP mean monthly flows and exceedance of the design flow, Hydest floods and design discharges for different components of a micro hydro schemes. For simplicity, the program considers 30 days a month for all the months. The flow chart for the proposed hydrological calculations is presented in Figure 3.8.

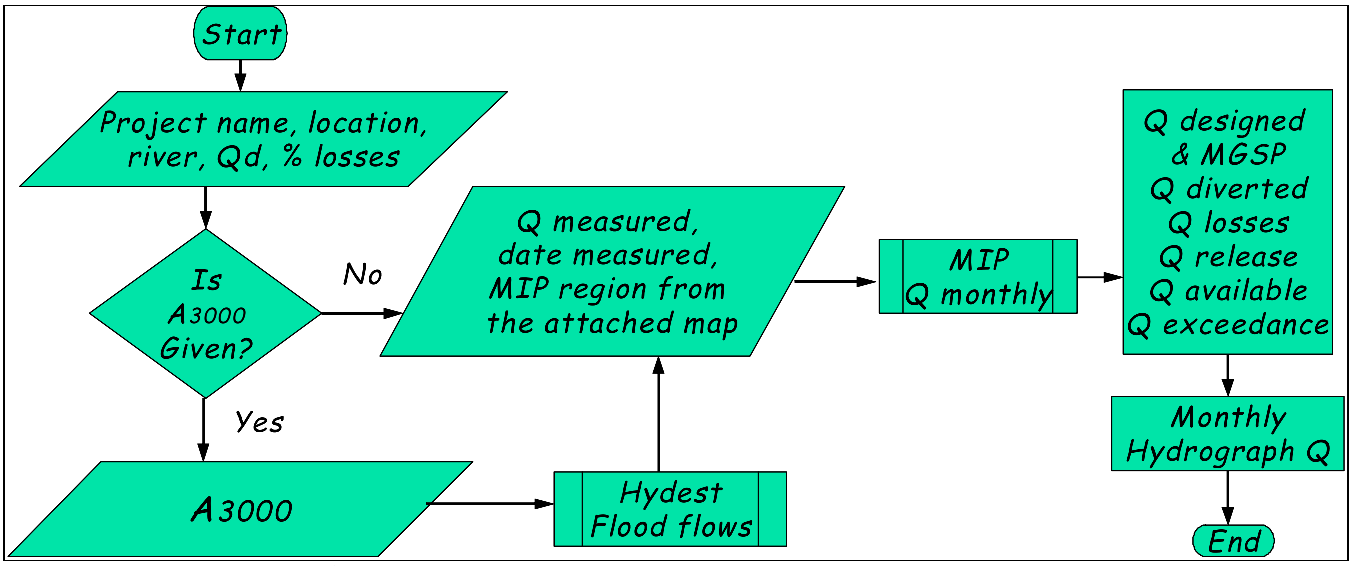


Figure 3.8: Flow chart of Hydrology spreadsheet

A typical example of the spreadsheet including inputs and outputs are presented in Figure 3.9. The information required for computations such as the MIP regions and the corresponding coefficients are presented in the spreadsheet. The MIP region for this project lies in MIP region 3. The measured discharge of 80 l/s on March 23 shows that the project is proposed to utilize a small stream. Although the floods are not critical to the project, they are calculated for sizing floodwall and other structures. The design discharge of 80 l/s has a probability of exceedance of 10 months only and hence does not qualify AEPC acceptance criteria. For AEPC to qualify this project, the turbine design discharge should not exceed 73.389 l/s. The procedures for the calculations are:

MIP mean flows:

Corrected coefficient and mid month discharges ($Kc_{December}$) for Region 3:
Since the measured date of March 23 lies in between March 15th and April 15th,

$K_{March} = 1.38$
$K_{April} = 1.00$

$$Kc_{March} = K_{March} + (K_{April} - K_{March})*(Date - 15)/30$$
$$= 1.38 + (1.00-1.38)*(23-15)/30$$
$$= 1.2787$$

$$Q_{March} = Q_{measured} * K_{March} / Kc_{April}$$
$$= 80 * 1.38/1.2787$$
$$= 86.34 \text{ l/s}$$

Q_{April} $= Q_{March} / K_{March}$
$= 86.34/1.38$
$= 62.57$ l/s

Q_{May} $= Q_{April} * K_{May}$
$= 62.57 * 1.88$
$= 117.62$ l/s

Other mid monthly discharges are calculated similar to the discharge calculation for the month of May.

Hydest flood flows:

The 2-year and 100-year floods are:

$Q_{2\ daily}$ $= 0.8154 \times (A_{3000} + 1)^{0.9527}$
$= 0.8154 * (1.5+1)^{0.9527}$
$= 1.952\ m^3/s$

$Q_{2\ inst}$ $= 1.8767 \times (A_{3000})^{0.8783}$
$= 1.8767 \times (1.5+1)^{0.8783}$
$= 4.197\ m^3/s$

$Q_{100\ daily}$ $=4.144 \times (A_{3000} + 1)^{0.8448}$
$=4.144 \times (1.5 + 1)^{0.8448}$
$= 8.987\ m^3/s$

$Q_{100\ inst}$ $= 14.630 \times (A_{3000} + 1)^{0.7343}$
$= 14.630 \times (1.5+1)^{0.7343}$
$= 28.669\ m^3/s$

Peak discharges for other return periods are calculated by using these formulas:

$$\sigma_{\ln QF} = \frac{\ln\left(\frac{Q_{100}}{Q_2}\right)}{2.326} \qquad Q_F = e^{\left(\ln Q_2 + S \cdot \sigma_{\ln QF}\right)}$$

$Q_{20\ daily}$ = EXP(LN(1.952)+ 1.645*(LN(8.987/1.952)/2.326))
$= 5.747\ m^3/s$

$Q_{20\ inst}$ = EXP(LN(4.197)+ 1.645*(LN(28.669/4.197)/2.326))
$= 16.334\ m^3/s$

Different discharge calculations (as per AEPC criteria are presented for examples):

$Q_{turbine}$ = 85% of the 11 month flow exceedance from the MIP flow if the designed flow is higher or the design flow.
= 73.389 l/s (since the design flow is higher and has 10 months exceedance only)

$Q_{diverted}$ $= Q_{turbine}$ / (1-%losses)
= 73.389 / (0.95)
= 77.252 l/s

Q_{losses} $= Q_{diverted} - Q_{turbine}$
= 77.252-73.389

= 3.863 l/s

$Q_{release}$ = $Q_{min\ MIP}$ *%release
= 62.57 * 0.05
= 3.128 l/s

$Q_{required\ at\ river}$ = $Q_{diverted}$ + $Q_{release}$
= 77.252+3.128
= 80.380 l/s

A hydrograph including the design flow, exceedance of the proposed design flow and the flow acceptable for AEPC is presented in Figure 3.9.

HYDROLOGICAL CALCULATIONS FOR UNGAUGED MHP RIVERS		
Spreadsheet developed by Mr. Pushpa Chitrakar, Engineering Advisor, SHPP/GTZ		
Referances:2,2,4, 6,12,13,15,16	Date	08-Nov-2005
SMALL HYDROPOWER PROMOTION PROJECT/GTZ	Revision	2005.10
Project:	***Upper Jogmai, Ilam***	
Developer	Kankaimai Hydropower P Ltd	
Consultant	EPC Consult	
Designed	Pushpa Chitrakar	
Checked	Pushpa Chitrakar	

INPUT

River name :	Chhyota Khola	
Location :	Barand, Sertung VDC 2, Dhading	
Measured flow for MIP method l/s:	80	
Month and day of flow measurement:	March	23
MIP region (1 -7) :	3	
Area of basin below 3000m elevation A_{3000} km^2 :	1.5	
Turbine discharge Qd l/s:	80	
Water losses due to evaporation/flushing/seepage % of Qd :	5%	
Downstream water release due to environmental reasons % of Q lowest :	10%	

OUTPUT

MIP monthly average discharge

Month	@ river	To plant
January	169.55	77.25
February	117.62	77.25
March	86.34	77.25
April	62.57	56.31
May	117.62	77.25
June	195.83	77.25
July	847.13	77.25
August	1564.13	77.25
September	1303.23	77.25
October	651.93	77.25
November	312.83	77.25
December	234.62	77.25
Annual av	**471.950**	**75.506**

Hydest Flood Flows

Return Period (yrs)	Flood Discharge (m^3/s)	
	Daily	Instantaneous
2	1.952	4.197
20	5.747	16.334
100	8.987	28.669

Discharges (l/s)	Designed	As per MGSP
Qturbine (Qd)	80.000	73.389
Q diverted Qd+Qlosses	84.211	77.252
Q losses 5% of Qd	4.211	3.863
Q release 10% of Qlow	6.257	6.257
Q min required @ river	90.467	83.508
Q exceedence (month)	10	11
Q turbine for 11m	73.821	

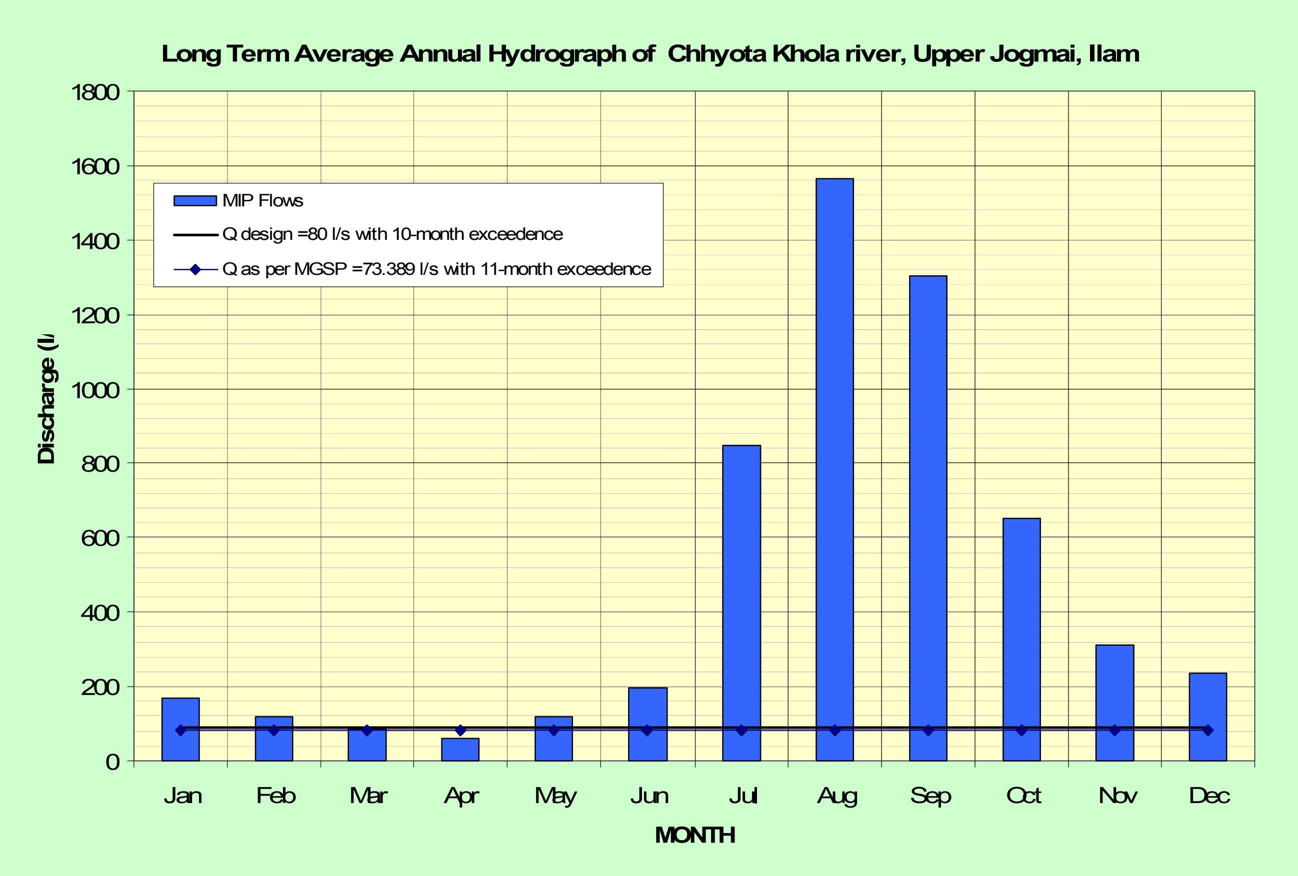


Figure 3.9: Typical example of a hydrological parameters calculation spreadsheet "Hydrology"

4 HEADWORKS

4.1 INTRODUCTION AND DEFINITIONS

Headworks
A headworks consists of all structural components required for safe withdrawal of desired water from a source river into a canal/conduit. Intake, weir, protection works, etc., are the main structural components. Indicators of an ideal headworks can be summarized as:

1. Withdrawal of desired flows (i.e., $Q_{diverted}$ and spilling in case of flood).
2. Sediment bypass of diversion structure (Continued sediment transportation along the river).
3. Debris bypass (Continued debris bypass without any accumulation).
4. Hazard flood bypass with minimum detrimental effects.
5. Sediment control at intake by blocking/reducing sediment intake into the system.
6. Settling basin control (settling and flushing of finer sediments entered into the system through intakes or open canals).

Intake
An intake can be defined as a structure that diverts water from river or other water course to a conveyance system downstream of the intake. Side intake and bottom intake are the common types of river intakes that are used in Nepali micro hydropower schemes.

Conveyance Intake is an intake which supplies water to a conveyance other than the pressure conduit to the turbine. Power Intake is an intake which supplies water to the pressure conduit to the turbine.

Side Intake
A structure built along a river bank and in front of a canal / conduit end for diverting the required water safely is known as a side intake. Side intakes are simple, less expensive, easy to build and maintain.

Bottom/Drop/Tyrolean/Trench Intake
A structure built across and beneath a river for capturing water from the bed of a river and drops it directly in to a headrace is known as a bottom intake. These are mainly useful for areas having less sediment movement, steeper gradient, and surplus flow for continual flushing. Inaccessibility of trashrack throughout the monsoon season and exposure of the system to all the bed load even though only a small part of the water is drawn are the common problems/drawbacks of drop intakes.

Weir
A weir is a structure built across a river to raise the river water and store it for diverting a required flow towards the intake.

Protection Works
Protection works are the river protection and river training works to safeguard the headworks against floods, debris and sediments.

Trashrack
A trashrack is a structure placed at an intake mouth to prevent floating logs and boulders entering into headrace. Coarse trashracks and fine trashracks are provided at the river intake and penstock intake respectively.

4.2 AEPC MGSP/ESAP GUIDELINES AND STANDARDS

According to AEPC MGSP/ESAP guidelines, the requirements set for headworks components such as weirs, intakes and trashracks are briefly outlines in this section.

4.2.1 Weir

- Type: A weir can be either temporary or permanent in nature. A dry stone or gabion or mud stone masonry can be termed as a temporary weir whereas a cement masonry or concrete weir can be termed as a permanent weir.
- Location: It is recommended that the weir should be 5m to 20m d/s of intake. This will assure that water is always available and there is no sediment deposit in front of the intake. A narrow river width with boulders is preferable for weir location.
- Height: The weir should be sufficiently high to create enough submergence and driving head.
- Stability: Permanent weir should be stable against sinking, overturning and sliding even during the designed floods.

4.2.2 Intake

- Type: Side intakes are suitable for all types of river categories whereas the drop intake is recommended for rivers having longitudinal slopes more than 10% with relatively less sediment and excess flushing discharge. The side intake is generally is of rectangular orifice type with a minimum submergence of 50mm. The side intake should be at:
  - Straight river u/s & d/s of the intake.
  - Alternatively, on the outer side of the bend to minimize sediment problems and maximise the assured supply of water.
  - Relatively permanent river course.
  - By the side of rock outcrops or large boulders for stability and strength.
- Capacity: According to the flushing requirement and tentative losses the intake has to be oversized than the design flow by 10% to 20% (or $Q_{diverted}$).
- A course trashrack should be provided to prevent big boulders and floating logs from entering into the headrace system.
- A gate/stop log should be provided to regulate flow (adjust/ close) during operation and maintenance.
- To optimize downstream canal and other structures, a spillway should be provided close to the intake.

4.2.3 Intake Trashrack

The recommended intake coarse trashrack is made of vertical mild steel strips of 5mm*40mm to 5mm*75mm with a clear spacing not exceeding 75mm. The approach velocity should be less than 1.0m/s. For transportation, the weight of a piece of trashrack should not exceed 60 kg. With respect to the combined effect of racking and hydraulic purposes, placing of trashrack at 3V:1H is considered to be the optimum option.

4.3 PROGRAM BRIEFINGS AND EXAMPLES

There are two spreadsheets for designing side intakes and bottom intakes respectively. The first part of the side intake calculates trashrack parameters while the second part of it calculates side intake parameters including spillways for load rejection and flood discharge off-take. The second spreadsheet calculates all the design parameters for a drop intake.

Since most of the program flow chart in this section is self explanatory or the calculation procedures are familiar to most of the practicing stakeholders, only important points are explained.

Figures 4.1 to 4.7 presents the assumptions, flow charts and typical examples for calculating trashrack parameters, side intake and drop intake dimensioning.

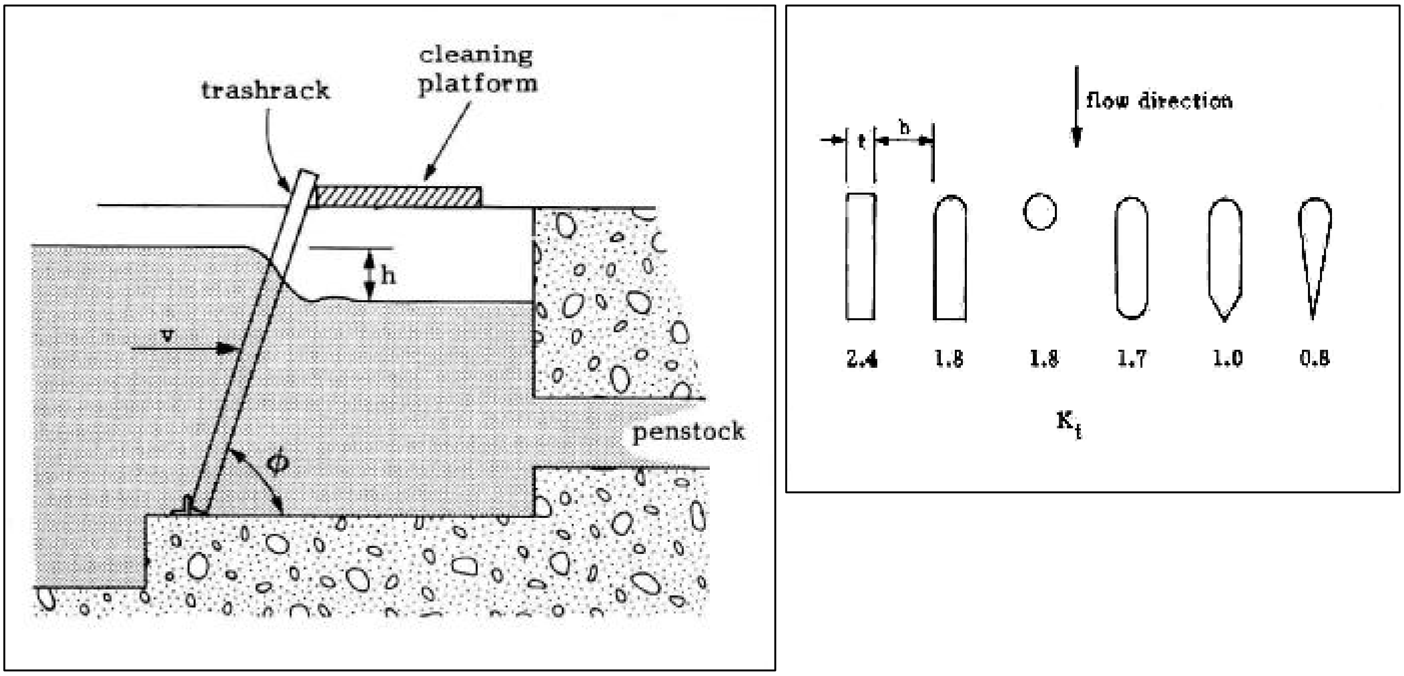


Figure 4.1: Trashrack parameters

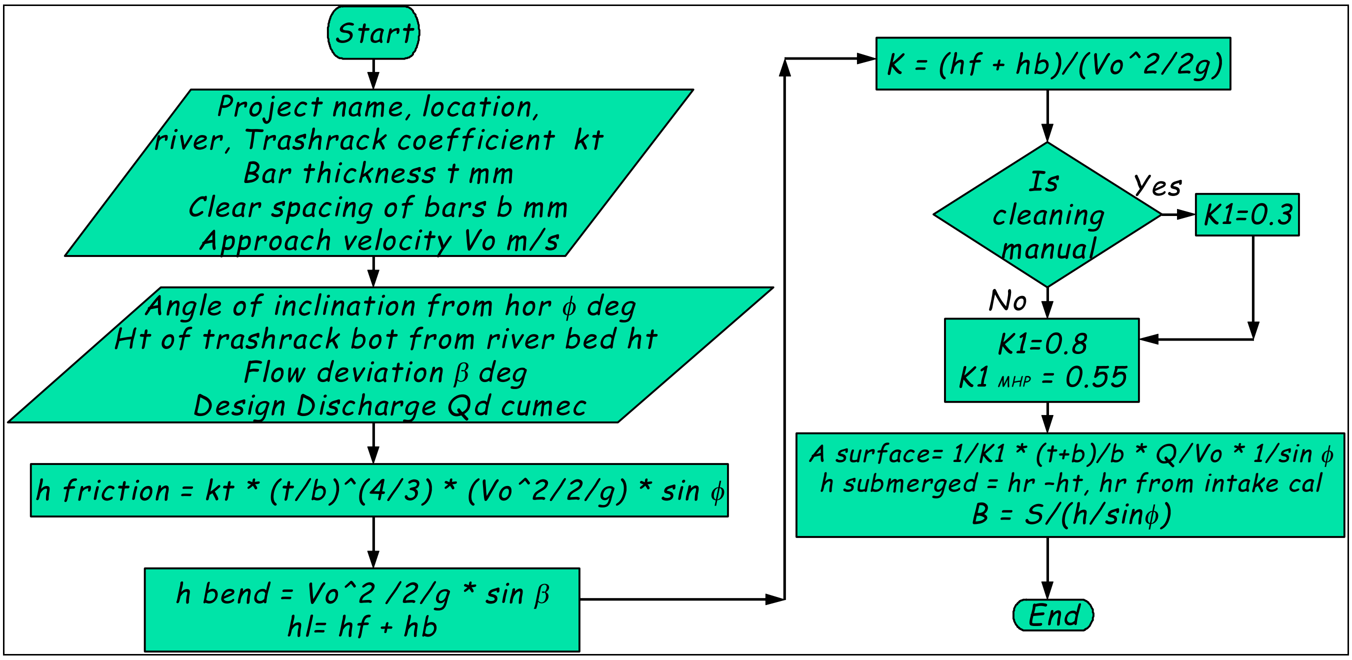


Figure 4.2: Flow chart for trashrack calculations

The trashrack coefficients for different cross section of the bars are presented in the pull down menu. Typical bar thickness, clear spacing and approach velocity are suggested in the respective cell notes.

According to the flow chart presented in Figure 4.2, the trashrack losses constitute of frictional and bend losses. The frictional losses depend on the geometry of trashrack such as the trashrack coefficient, thickness and clear spacing of bars, inclination of the trashrack and the approach velocity. The bend loss depends on the hydraulics of the approaching flow such as the approach velocity and its deviated direction with respect to the normal of the trashrack surface.

The trashrack surface area coefficient K1 for automatic racking is 0.8 whereas it is 0.3 for manual racking suggesting that the racking area for manual operation to recommended surface area is 3.33 times more than the theoretical area. Manual racking is recommended for Nepali MHPs. Since the consequence of temporary reduced trashrack area in micro hydro is not severe and the trashrack sites are generally accessible to operators all the year, the average of automatic and manual racking coefficient is taken for practical and economic reason.

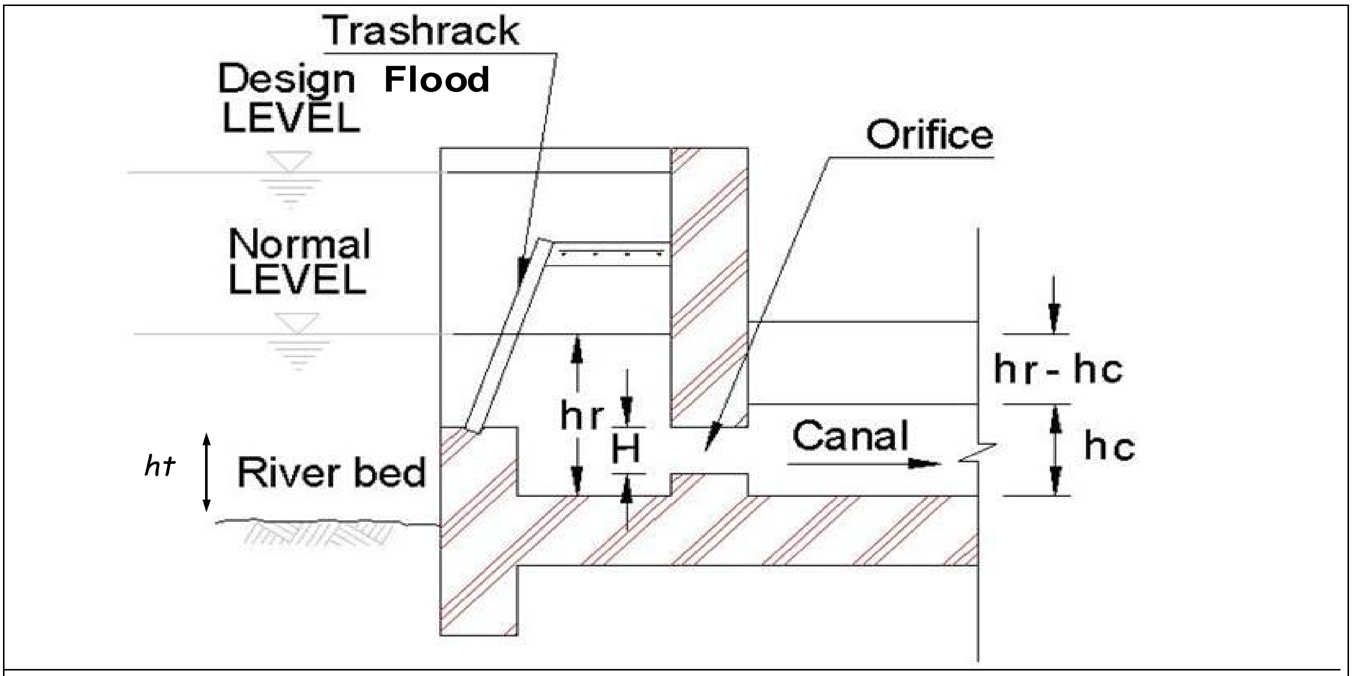


Figure 4.3: Side intake parameters

A typical side intake parameters considered in the spreadsheet is presented in Figure 4.3. The procedures for designing a side intake parameters are presented in with the help of a flow chart in Figure 4.4. An example is presented in Figure 4.6. The calculation processes for designing a typical side intake are also presented in the following section.

Trashrack Design:

Head losses,

h friction $= kt * (t/b)^{(4/3)} * (Vo^2/2g) * \sin \phi$
$= 2.4*(4/25)^{(4/3)} * (0.5^2/2/9.81) * \sin 60^o$
$= 0.0023m$

h bend $= (Vo^2/2g) * \sin \beta$
$= (0.5^2/2/9.81) * \sin 20^o$
$= 0.0044m$

h total = h friction + h bend
= 0.00232 + 0.0044
= 0.0067m

A surface S $= 1/k1*(t+b)/b * Q/Vo * 1/ \sin \phi$
$= 1/0.55*(4+25)/25*0.077*1/ \sin 60^o$
$= 0.3763\ m^2$

Width B $= S/(h/ \sin \phi)$
$= 0.3763/(.3/ \sin 60^o)$

= 1.09 m

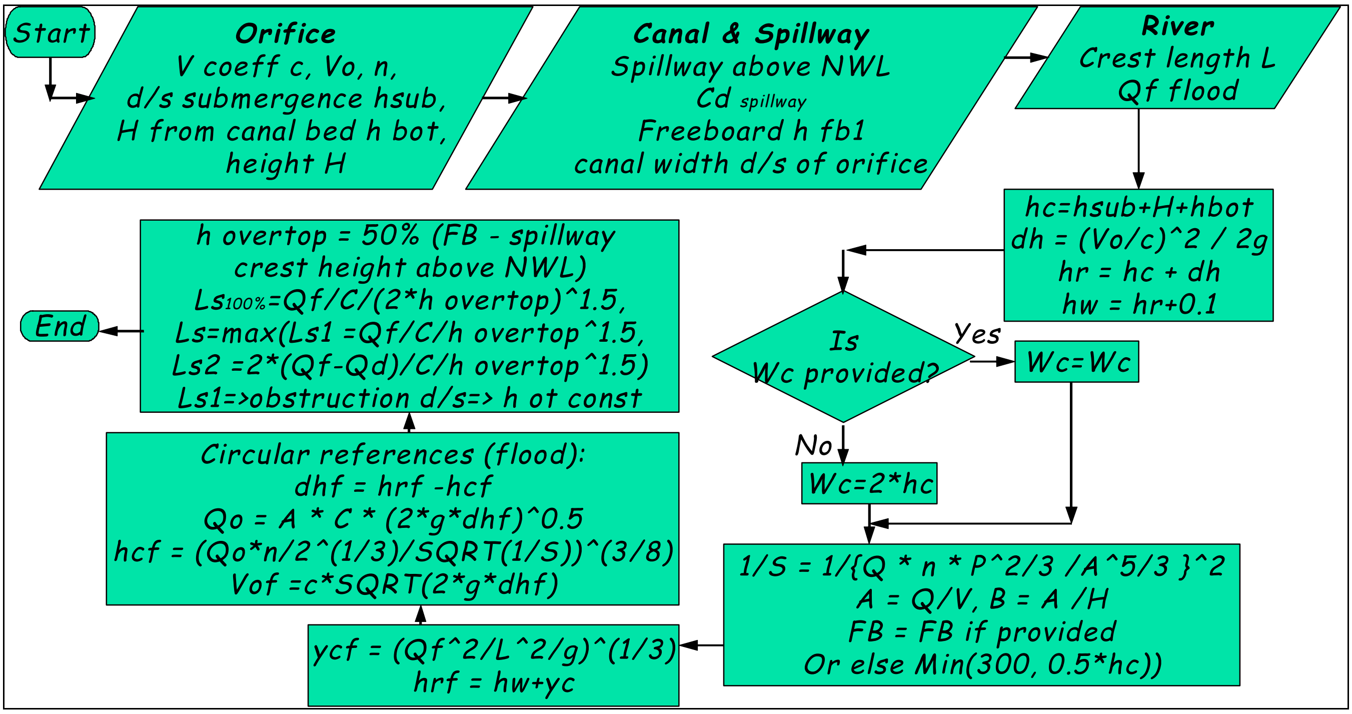


Figure 4.4: Flow chart for side intake calculations

Side Intake calculations:

Normal condition:

Depth @ canal (hc) = h submergence + height of orifice + height of orifice sill from bottom of the canal
= 0.05+0.2+0.2
= 0.45m

Driving head (dh) = $(Vo/c)^2/2/g$
= $(1.2/0.8)^2/2/9.81$
= 0.115 m

Head at river (hr) = hc+dh (this value can be provided)
= 0.45+0.115
= 0.565 m

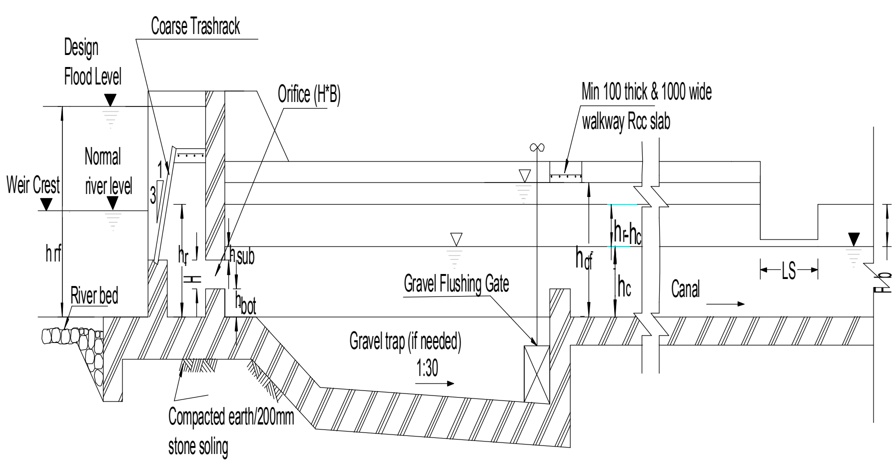
Height of weir (hw) = hr +0.1
= 0.565+0.1
= 0.665 m

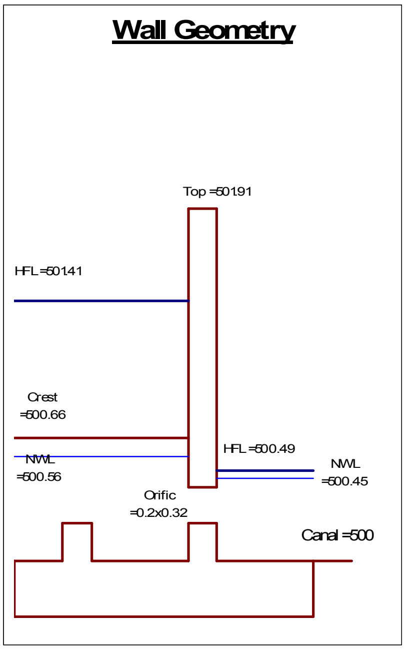
Design of Orifice Side Intake

Spreadsheet developed by Mr. Pushpa Chitrakar, Engineering Advisor, SHPP/GTZ

Referances: 6,12,13,15,16	Date	08-Nov-2005
SMALL HYDROPOWER PROMOTION PROJECT/GTZ	Revision	2005.10

Project	Upper Jogmai, Ilam
Developer	Kankaimai Hydropower P Ltd
Consultant	EPC Consult
Designed	Pushpa Chitrakar
Checked	Pushpa Chitrakar





Trashrack calculations

Input		Output	
Trashrack coeffieient kt	2.4		
Bar thickness t mm	4.00	Headloss due to friction hf m	0.0023
Clear spacing of bars b mm	25.00	Headloss due to bends hb m	0.0044
Approach velocity Vo m/s	0.50	Headloss coeff K	0.5226
Angle of inclination from horizontal φ deg	60.00	Total headloss ht m	0.0067
Flow deviation β deg	20.00	Surface area A surface m²	0.3750
Design Discharge Qd cumec	0.077	Vertical height h m	0.3647
Height of trashrack bottom from river bed ht	0.200	Trashrack width B m	0.8906
Canal invert level (m)	500.00		

Orifice Calculations for (B = 2H or provided) rectangular canal downstream of orifice

Input

Orifice		River	
Velocity coeff of orifice c	0.8	Crest length L m	5.000
Velocity through orifice Vo m/s	1.2	Provided Q flood m³/s	10.000
Manning's coeff of roughness	0.02	Q flood m³/s (Q_{20} for MHP with Qd>100)	16.334
Downstream submergence depth hsub m	0.050	Used Q flood	10.000
Orifice height H m	0.200	**Canal & Spillway**	
Height of orifice from canal bed h bot m	0.200	Spillway crest height above NWL m	0.050
Provided water depth in the river hr (m)	0.000	Spillway discharge coeff	1.6
Provided canal width (m)	0.500	Provided Freeboard h fb1 m	0.300

Output			
Normal Condition		**Flood**	
Canal witdth d/s of orifice	0.500	Critical depth of water at crest yc m	0.742
1/Slope of canal immediately d/s of orifice	1865	Flood head at river hf r = hw+yc m	1.406
Depth of water in canal hc m	0.450	Head difference dhf	0.916
Free board in canal h fb m	0.300	Velocity through orifice Vof m/s	3.392
Area of orifice A m^2	0.064	Q intake Qf cumec	0.218
Width of orifice B m	0.321	Depth of water at canal (hc f) m	0.490
Actual velocity through orifice Vo act m/s	1.200		
Canal width Wc m	0.500	**Spillway**	
Water level difference dh m	0.115	Ls for Qf m (d/s Obs & 100% hot -50)	1.521
Water depth in the river hr = hc + dh m	0.565	Length of spillway Ls1 for Qf m (d/s Obs)	3.078
Height of weir (hw = hr+0.1) m	0.665	Length of spillway Ls2 for Qf-Qd m	3.978
Spillway overtopping height h overtop m	0.125	Designed spillway length Ls m	3.978

Figure 4.5: An example of side intake calculations

Orifice area (A) = Q/V
= 0.77/1.2
= 0.064 m^2

Orifice width (B) = A/H
= 0.064/.2
= 0.322 m

Flood:

Critical depth at crest (yc)= $(Qf^2/L^2/g)^{1/3}$
= $(10^2/5^2/9.81)^{1/3}$
= 0.742 m

Head at river (hf r) = hw+yc
= 0.665+0.742
= 1.407 m

Water depth at canal during flood (by equating and iterating flow coming from orifice to that of canal flow) (hcf) = 0.490m

Q intake (Qf) = 0.218 m^3/s

Spillway overtopping height (h overtop) = 50%(Free board –h nwl)
= 0.5*(.3-.05)
= 0.125 m

Spillway length 100% (Ls for Qf) = $Qf/C/(2*h\ ot)^{1.5}$
= $0.218/1.6/(2*0.125)^{1.5}$
= 1.525 m

Spillway length 50% = $Qf/C/(h\ ot)^{1.5}$
= $0.218/1.6/(0.125)^{1.5}$
= 3.078 m

The cell containing the depth of water at canal hcf (m) sometimes can generate VALUE# error. Should such an error occur, select the cell, press F2 key and press Enter respectively.

Care should be taken while designing spillway lengths. Ls for Gfm (d/s Obs & 100% hot -50) is only applicable when full downstream obstruction for flood off-take is provided with the help of stop logs or gates. Otherwise, the gradually varying water profile at the spillway has to be considered.

Drop Intake calculations:

The example presented in Figure 4.7 follows the procedures presented in Figure 4.6. Although the calculation procedures for the drop intake are relatively straight forward and simple, it has more restrictions and limitations regarding the stream geometry and operational conditions.

Based on the flow conditions and the slope of rack, flow immediately upstream of the rack may be either critical or sub-critical. Critical depth at the entrance of the rack has to be considered if the rack is steeper (more than 15°). For more details, please refer to EWI UNIDO Standard.

The main differences for considering critical flow and normal flow condition are presented in the Table 4.1. In the presented spreadsheet, critical depth of upstream flow of the intake is calculated and presented if normal flow (sub-critical) is considered.

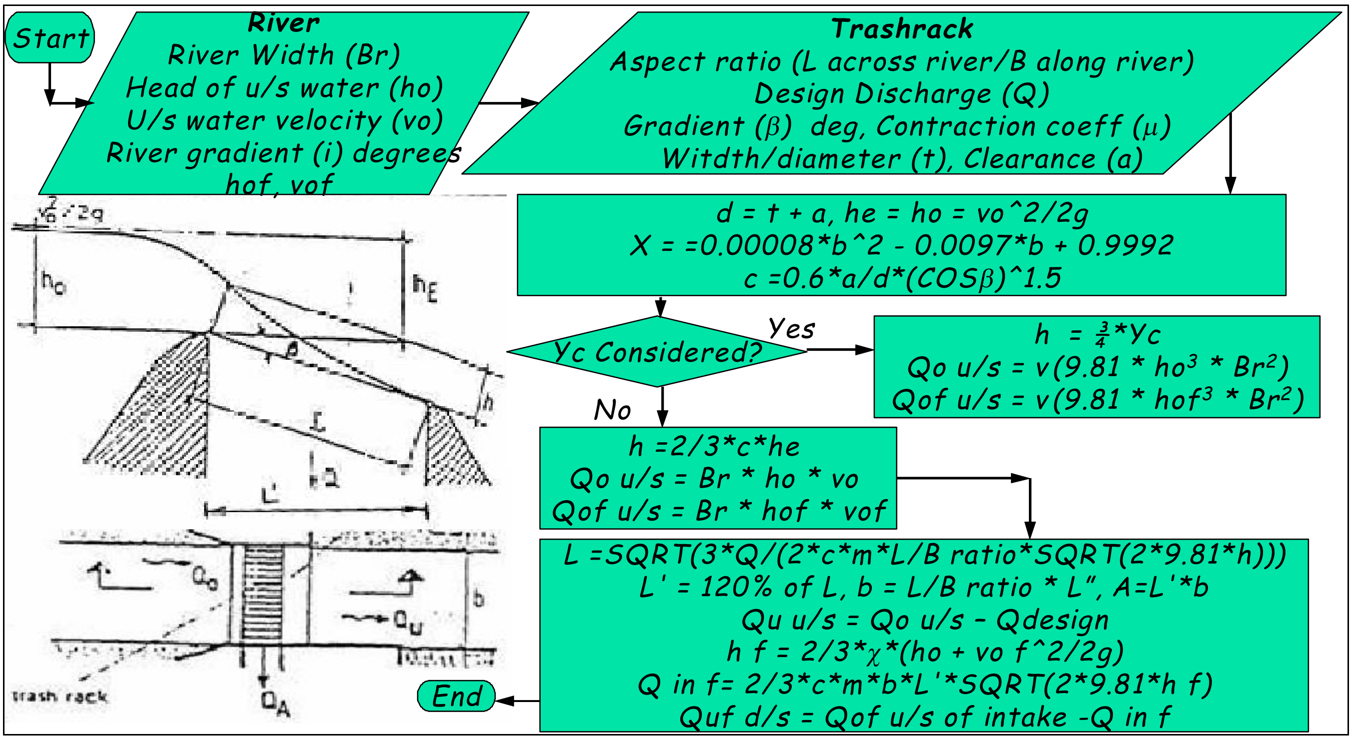


Figure 4.6: Parameters and flow chart of drop intake design

Table 4.1: Drop intake and upstream flow

Parameters	Normal flow	Critical Depth considered
Velocity head (h)	= 2/3 * χ * he	= ¾ * Yc
Qo u/s of intake (m^3/s) normal	= Br * Ho * Vo	= SQRT(9.81*ho ^{3}*Br ^{2})
Qo u/s of intake (m^3/s) flood	= Br * Ho f * Vo	= SQRT(9.81*ho f ^{3}*Br ^{2})

The calculations presented in Figure 4.7 are verified in the following section. In this example the flow upstream of the intake is considered to be of critical.

Normal condition:

c/c distance of trashrack bars d (mm)
= t + a
= 60+30
= 90mm

Kappa (χ) = 0.00008*β^2 - 0.0097*β + 0.9992(by curve fitting)
= 0.00008*36^2 - 0.0097*36 + 0.9992
= 0.749

Velocity head (h) m = ¾ * of Yc
= ¾ * 0.226
= 0.170 m

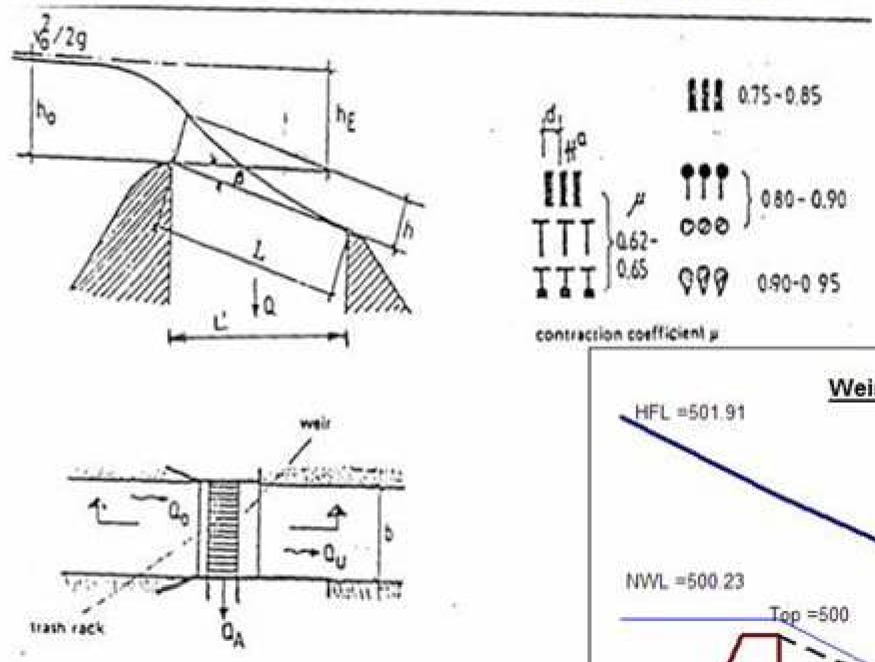
Correction factor (c) = 0.6*a/d*(COSβ)^1.5
= 0.6*30/90*(Cos 36)^1.5
= 0.146

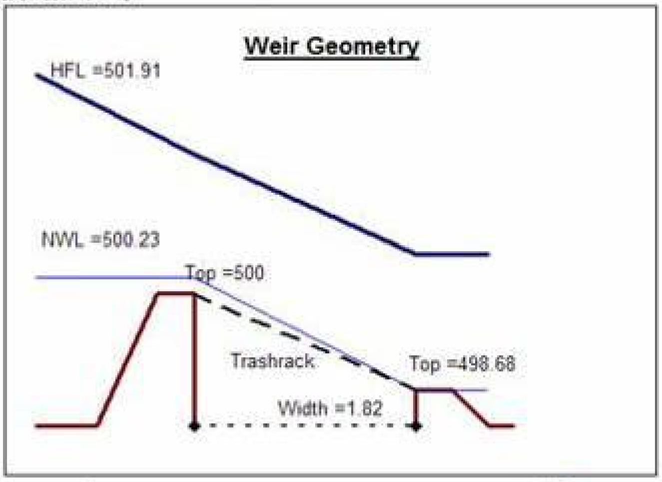
Length of Intake (L) m = SQRT(3*Q/(2*c*μ*L/B ratio*SQRT(2*9.81*h)))
= SQRT(3*2.7/(2*c*0.85*3.546468*SQRT(2*9.81*.170)))
= 2.249 m

Design of Bottom/Drop Intake

Spreadsheet developed by Mr. Pushpa Chitrakar, Engineering Advisor, SHPP/GTZ

Referances: 6,7,8,12,13	Date	08-Nov-2005
SMALL HYDROPOWER PROMOTION PROJECT/GTZ	Revision	2005.10
Project		Upper Jogmai, Ilam
Developer		Kankaimai Hydropower P Ltd
Consultant		EPC Consult
Designed		Pushpa Chitrakar
Checked		Pushpa Chitrakar





Input — Critical Depth Considered

		River Width flood (Brf) m =	20
River Width (Br) m =	8	ho flood m =	3.000
Head/Critical Depth of u/s water (ho)m =	0.226	vo flood m/s =	4
Upstream water velocity (vo) m/s =	1.494	Design Discharge (Qd), m³/s =	2.7
River gradient (i) degrees =	9.462	Trashrack width/diameter (t) mm =	60
Trashrack gradient (β) deg =	36	Trashrack clearance (a) mm =	30
Contraction coeff (μ) =	0.85	Invert level of crest (masl)	500
Aspect ratio (Length across the river/Breadth along the river) =			3.54647

Output

c/c distance of trash rack bars d mm =	90	Qo u/s of intake (m³/s) normal =	2.700
Total head (he) m =	0.340	Qu d/s of intake (m³/s) normal =	0.000
kappa (χ) =	0.749	h d/s normal (m)	0.000
velocity head (h) m =	0.170	h flood u/s=	1.906
Correction factor (c) =	0.146	h d/s flood (m)	1.864
Length of intake (L) m =	2.249	Qof u/s of intake = Br * hof * vof (m³/s) =	325.497
Length (L') m =	1.819	Q in flood m³/s =	7.318
Intake length across the river (b) m =	7.975	Quf d/s of intake (m³/s) =	318.178
Area of intake (A=L' *b) m² =	17.935		

Figure 4.7: An example of drop intake

Length (L') m = L*COS(β)
= 2.249*cos (36)
= 1.819 m

Intake length across the river (b) m
= L/B ration * L
= 3.546468*2.249
= 7.975m

Area of intake (A) m^2 = L * b
= 2.249 * 7.975
= 17.935 m^2

Qo u/s of intake (m^3/s) = SQRT(9.81*ho ^{3}*Br ^{2})
= SQRT(9.81*.226 ^{3}*8 ^{2})
= 2.7 m^3/s

Qu d/s of intake (m^3/s) = Qo u/s -Qd
= 2.7-2.7
= 0 m^3/s

Intake length across the river (b) m
= L/B ration * L
= 3.546468*2.249
= 7.975m

Flood:

h flood (hf) m = 2/3*χ*(ho flood+vo flood^2/2g)
= 2/3*0.749*(3+4^2/2/9.81)
= 1.906 m

Qo u/s of intake (m^3/s) = SQRT(9.81*hof ^{3}*Br ^{2})
= SQRT(9.81*1.906^3*20 ^{2})
= 325.497 m^3/s

Qo in (off-take) (m^3/s) = 2/3*c*μ*b*L *SQRT(2*9.81*h flood)
= 2/3*0.146*0.85*7.975*2.249*SQRT(2*9.81*1.906)
= 7.318 m^3/s (this discharge can be reduced by introducing a throttling pipe d/s of the intake)

Qu d/s of intake (m^3/s) = Qo u/s -Qd
= 315.497-7.318
= 318.178 m^3/s

5 HEADRACE/TAILRACE

5.1 GENERAL

A headrace or a tailrace can be defined as a conveyance system that conveys designed discharge from one point (e.g. intake) to another (e.g. forebay). Generally canal systems are used in all micro hydropower schemes whereas pipe systems are used for specific e.g. difficult terrain. A canal can be unlined (earthen) or lined (stone masonry or concrete). The typical canal cross sections used in micro hydropower schemes can be rectangular or trapezoidal or triangular or semi-circular in shape. Pipes used in MHP can be of HDPE or mild steel and it can be either open or buried.

For computing head losses, Manning's equation is used for canal whereas Darcy-Weisbach equation is used for pipe.

5.2 AEPC MGSP/ESAP GUIDELINES AND STANDARDS

5.2.1 Canal

a) Capacity: The canal should be able to carry the design flow with adequate freeboard, escapes to spill excess flow. A canal should generally be able to carry 110 to 120 % of the design discharge.

b) Velocity: Self cleaning but non erosive (≥ 0.3m/s).

c) Unlined canal: In stable ground for Q ≤ 30 l/s

d) Lined canal: For higher discharge and unstable ground, canals 1:4 Stone masonry / Concrete (short: crossings or unstable ground) is recommended. It is also recommended to minimize seepage loss and hence minimize the subsequent landslides.

e) Sufficient spillways and escapes as required.

f) Freeboard: Minimum of 300mm or half of water depth.

g) Stability and Safety against rock fall, landslide & storm runoff.

h) Optimum Canal Geometry: Rectangular or trapezoidal section for lined canal and trapezoidal section for unlined canal are recommended.

5.2.2 Pipe

a) PVC/HDPE: Buried at least 1m into ground.

b) Steel/Cast Iron: As pipe bridge at short crossings/landslides.

c) Pipe inlet with trashracks for a pipe length of more than 50m.

d) Minimum submergence depth of $1.5*v^2/2g$ at upstream end.

e) Provision of air valves and wash outs where necessary.

5.3 PROGRAM BRIEFING AND EXAMPLES

5.3.1 Canal

a) Permissible erosion free velocities for different soil conditions:

Fine sand	=0.3-0.4
Sandy loam	=0.4-0.6
Clayey loam	=0.6-0.8
Clay	=0.8-2.0

Stone masonry =0.8-2.0
Concrete = 1.0-3.0

b) Sectional profiles considered in the program are:
   1) Semicircular
   2) Rectangular
   3) Triangular
   4) Trapezoidal

c) Two parts of calculations for canals are provided for:
   1) Evaluation of the design parameters based on user specified inputs.
   2) Optimum canal parameters based on MHP Sourcebook by Allen R Iversin.

d) Two spreadsheets are included in the Design Aids for:
   1) Canal calculations: Calculations procedures are presented in Figure 5.1 with the help of a flow chart and a typical spreadsheet with an illustration is presented in Figure 5.2.
   2) Pipe calculations: Pipe calculation flow chart is presented in Figure 5.4. The calculation procedures are further illustrated in Figure 5.5.

5.3.2 Canal

Calculations for a rectangular stone masonry headrace canal for 185 l/s flow presented in Figure 5.2 are briefly described in the following section.

Present Canal:

Area A m^2 = D*B
= 0.3*0.5
= 0.15 m^2

Top Width T (m) = B+2*H*N
= 0.5+2*0.3*0
= 0.5m

Wetted Perimeter (m) = 2*D+B
= 2*0.3+.5
= 1.1m

Hydraulic Radius r (m) = A/P
= 0.15/1.1
= 0.136 m

Calculated flow (m^3/s) = $A*r^{2/3}*S^{0.5}/n$
= $0.15*0.136^{2/3}*0.01299^{0.5}/n$
= 0.226 m^3/s

Critical Velocity Vc m/s = sqrt(A*g/T)
= sqrt(0.15*9.81/.5)
= 1.72 m/s

Velocity V m/s = Q/A
= 0.185/0.15
= 1.233 m (Okay since it is less than 80% of Vc)

Headloss hl (m) = S*L + di (drops)
= 0.01299*20+0
= 0.260m

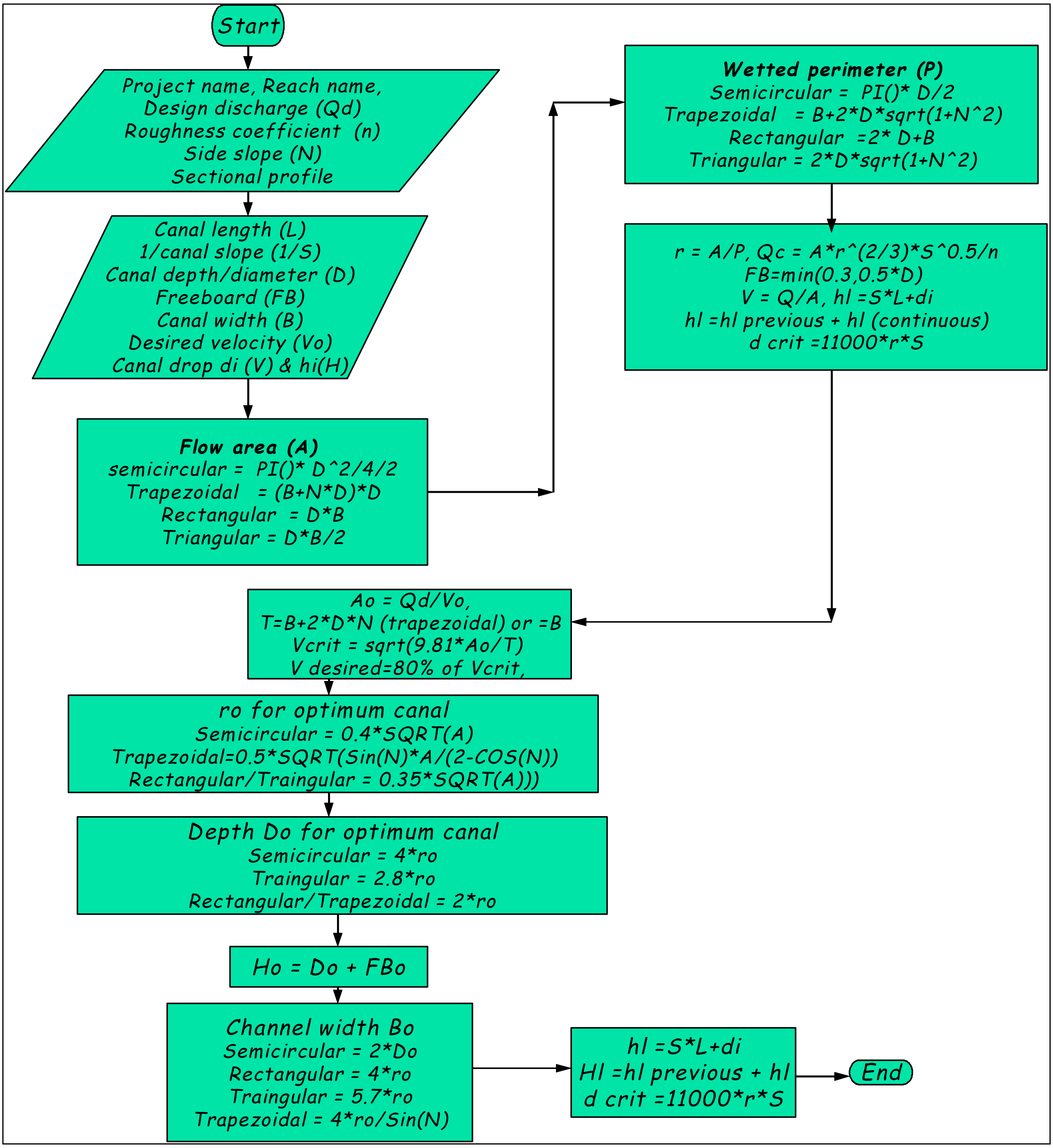


Figure 5.1: Flow chart for canal design

Critical dia of sediment d crit (mm) = 11000*r*S
= 11000*0.136*0.01299
= 19.48mm (i.e., it can self clean sediment of diameter 19.48 or less)

Optimum Canal:

Area A m^2 = Q/v desired
= 0.185/1
= 0.185 m^2

Hydraulic Radius ro (m) = 0.35*SQRT(A)
= 0.35*SQRT(0.185)
= 0.1505 m

Depth Do (m) = 2*ro
= 2*0.1505
= 0.301m

Top Width Bo (m) = 4*ro
= 4*0.1505
= 0.602m

Critical Velocity Vc m/s = sqrt(A*g/T)
= sqrt(0.185*9.81/.602)
= 1.74 m/s (Okay since the desired velocity of 1m/s is less than 80% of Vc)

Headloss hl (m) = S*L + di (drops)
= 0.0050*20+0
= 0.100m

Critical dia of sediment d crit (mm) = 11000*r*S
= 11000*0.136*0.0050
= 8.271mm (i.e., it can self clean sediment of diameter 19.48 or less)

Canal Design: Proposed design and optimum canal sections				
Spreadsheet developed by Mr. Pushpa Chitrakar, Engineering Advisor, SHPP/GTZ				gtz SHPP
Referances: 6,12,13,15,16		Date	09-Nov-2005	
SMALL HYDROPOWER PROMOTION PROJECT/GTZ		Revision	2005.10	
Project	**Upper Jogmai, Ilam**			
Developer	Kankaimai Hydropower P Ltd			
Consultant	EPC Consult			
Designed	Pushpa Chitrakar			
Checked	Pushpa Chitrakar			
Input				
Type and Name	Intake Canal	Tailrace	Main2	Main3
Flow (m^3/s)	0.185	0.145	0.145	0.145
Roughness coefficient (n)	0.02	0.017	0.02	0.02
Sectional Profile	Rectangular	Trapezoidal	Semicircular	Triangular
Side slope N (1V:NHorizontal)	0	0.5	0	0.5
Length of the canal (m)	20	40	150	120
1/Canal slope (s)	77	200	30	72
Channel Depth/diameter D (m)	0.300	0.525	0.300	0.300
Freeboard FB (m)	0.300	0.250	0.150	0.150
Channel Width (B) m	0.500	1.000	0.400	0.400
Channel Drops di m	0.000	0.000	0.000	0.000
Channel Drops Horizontal length hi m	0.000	0.000	0.000	0.000
Desired velocity Vo (m/s)	1.000	1.500	1.500	1.500

Output				
Side slope d (degrees)	0.000	63.435	0.000	63.435
Canal slope S	0.01299	0.00500	0.03333	0.01389
Total depth H (m)	0.600	0.775	0.450	0.450
Chainage L (m)	20.000	60.000	210.000	330.000
Present canal				
Area A m^2	0.150	0.663	0.035	0.060
Top Width T (m)	0.500	1.525	0.400	0.400
Wetted Perimeter P (m)	1.100	2.174	0.471	0.671
Hydraulic Radius r (m)	0.136	0.305	0.075	0.089
Calculated flow (m^3/s) & remarks	0.226 high	1.249 high	0.057 low	0.071 low
Comment on freeboard	ok	low	ok	ok
Velocity V m/s	1.233	0.219	4.103	2.417
Critical Velocity Vc m/s & Remarks	1.72 Ok	2.06 Ok	0.93 Not Ok	1.21 Not Ok
Headloss hl (m)	0.260	0.200	5.000	1.667
Total headloss H(m)	0.260	0.460	5.460	7.126
Critical dia of sediment d crit (mm)	19.481	16.769	27.500	13.665
Optimum canal				
Area Ao m^2	0.1850	0.0967	0.0967	0.0967
Top Width T (m)	0.6022	0.7636	0.9949	0.4867
Critical Velocity Vc m/s & Remarks	1.74 Ok	1.11 Not Ok	0.98 Not Ok	1.4 Not Ok
Hydraulic Radius ro (m)	0.1505	0.1180	0.1244	0.1088
Channel Depth/diameter Do (m)	0.301	0.236	0.497	0.218
Freeboard Fbo (m)	0.150	0.263	0.150	0.150
Total depth Hb (m)	0.451	0.498	0.647	0.368
Channel Width Bo (m)	0.602	0.528	0.995	0.487
Canal Slope	0.0050	0.0112	0.0145	0.0173
Headloss hlo (m)	0.100	0.449	2.175	2.079
Total headloss Ho(m)	0.100	0.549	2.724	4.803
Critical dia of sediment d crito (mm)	8.271	14.584	19.834	20.736

Figure 5.2: An example of canal design.

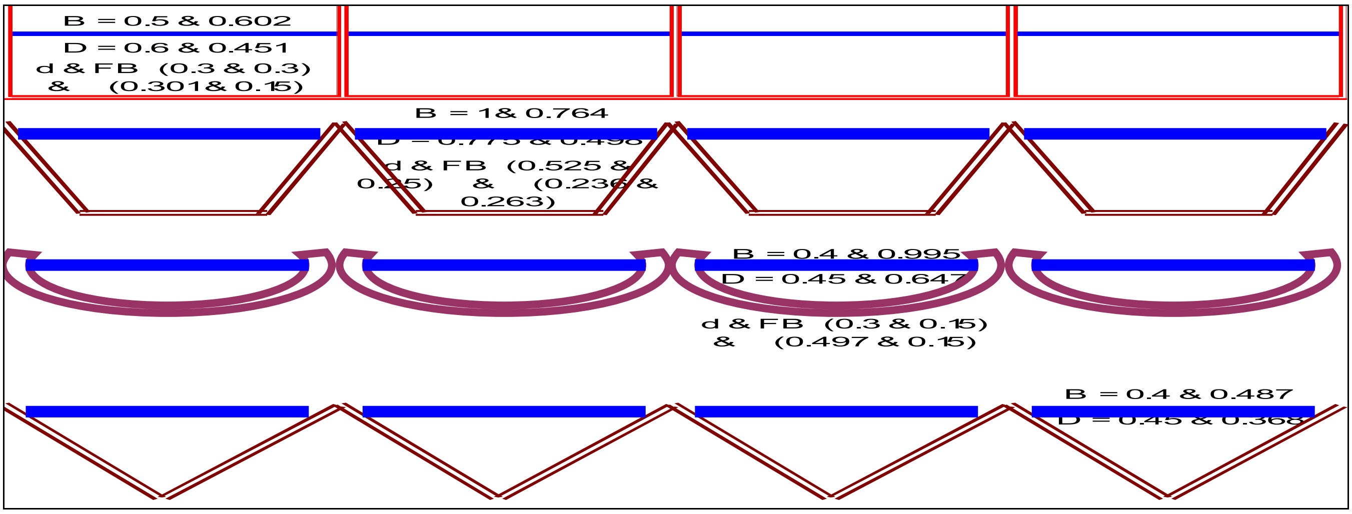


Figure 5.3: Illustrated canal type and their dimensions.

5.3.3 Pipe

Calculations for a headrace pipe presented in Figure 5.5 are briefly described in the following section. The trashrack calculations are similar to the trashrack calculations presented earlier in the intake design, hence it is not presented in this section. Trashrack loss of 0.02m is taken in this example. In this example, one 140m long HDPE pipe with 260mm internal diameter is considered for a design flow of 160 l/s each.

Sizing of headrace pipe

Headloss

HDPE pipe roughness, k =0.06 mm

$$\frac{k}{d} = \frac{0.06\,mm}{260\,mm} = 0.000231$$

$$\frac{1.2Q}{d} = \frac{1.2x0.160}{0.260} = 0.73846$$

From Moody chart (Appendix), f=0.0153. Based on an iterative method presented in Layman's Guidebook on How to Develop a Small Hydro Site, European Small Hydropower Association (ESHA), the presented spreadsheet calculates this friction factor and greatly speeds up the pipe selection decision for consultants by iterating following equations:

$$\alpha = \sqrt{1/f} \qquad \alpha = -2\log\left(\frac{e/D}{3.7} + \frac{2.51}{N_R}\alpha\right)$$

Friction loss $= f\frac{l}{d}\frac{V^2}{2g} = 0.0826 * Q^2 * f\frac{l}{d^5}$

$$h_{wall\,loss} = 0.0826 * 0.160^2 * 0.0153 * \frac{140}{0.26^5} = 3.82\,m$$

Turbulent losses considering, K entrance for inward projecting pipe= 0.8, Kexit=1.0 and Kbends based on the bending angles (see Table in the Appendix)

$$\therefore h_{turbulentlosses} = \left(K_{entrance} + K_{bends} + K_{valve} + K_{others} + K_{exit}\right)\left(\frac{V^2}{2g}\right)$$

$$= (0.8 + 0.57 + 0 + 0 + 1) * \frac{3.01^2}{2x9.81} = 1.10m$$

Total head loss= 3.82 m + 0.02+1.10 m = 4.94 m

Water level difference between intake and storage reservoir is 7m and 95% of this head is allowed for total headloss. Only 70.56% is estimated as the total headloss. Although the exiting water has some residual head, it is recommended to provide some marginal residual head for safety reason. The HDPE pipe does not need expansion joints and therefore not calculated.

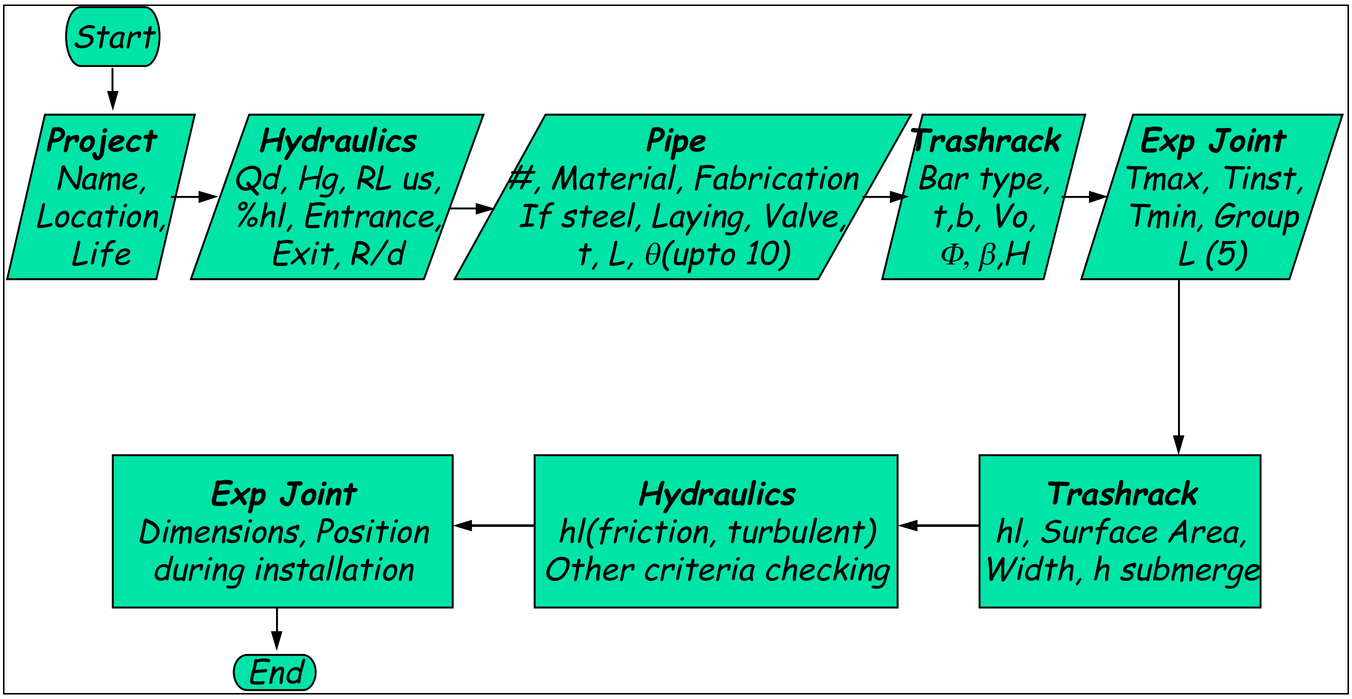


Figure 5.4: Flow chart for pipe design

HEADRACE PIPE CALCULATIONS

Spreadsheet developed by Mr. Pushpa Chitrakar, Engineering Advisor, SHPP/GTZ
Referances: 2,4, 6,12,13,15,16 — Date: 09-Nov-2005
SMALL HYDROPOWER PROMOTION PROJECT/GTZ — Revision: 2005.10

Project:	Upper Jogmai, Ilam	Location:	Jogmai
Developer	Kankaimai Hydropower P Ltd		
Consultant	EPC Consult		
Designed	Pushpa Chitrakar		
Checked	Pushpa Chitrakar		

INPUT

		Economic life (years)	15
Hydraulics:			
Diversion flow Qd (m^3/s)	0.160	U/S Invert Level (m)	1950.00
Flow in each pipe Qi (m^3/s)	0.160	% head available or headloss hlt (m)	95.00%
Gross head Hg (m)	7.000	Entrance Type	Inward projecti
		Bending radius (r/d)	5
Headrace pipe			
Pipe Material	HDPE	Exit (Yes/No)	Yes
Welded / Flat rolled if steel	NA	No of pipes	1.00
Rolled if steel	NA	Bending angle 01	20.00
Type if steel	NA	Bending angle 02	4.00
Burried or exposed	Burried	Bending angle 03	6.00
Type of valve	Spherical/No valves	Bending angle 04	20.00
Non standard ultimate tensile strength (UTS) N/mm^2	0	Bending angle 05	
Estimated pipe diameter d(mm)	**282**	Bending angle 06	
Provided pipe diameter d(mm)	260	Bending angle 07	
Min pipe thickness t (mm)	**NA**	Bending angle 08	
Provided pipe thickness t (mm)	3.0	Bending angle 09	
Pipe Length L (m)	140.000	Bending angle 10	

Trashrack

Flat	k	t	b	Vo	ϕ	β	Q	H
	2.40	6.00	20.00	1.00	60.00	0.00	0.160	3.00

Expansion Joints

Tmax (deg)	T installation	Tmin	1st Pipe length(m)	2nd Pipe L (m)	3rd Pipe L (m)	4th Pipe L (m)	5th Pipe L (m)
40	20	4	50.00	100.00	150.00	200.00	250.00

OUTPUT

Trashrack

hf	hb	H coeff	H	S	B	Min Submergence	CGL=1.5v^2/2g
0.0213	0.0000	0.4174	0.0213	0.8006	0.23	1.39	0.69

Turbulent loss coefficients

K inlet	0.80	K bend 05	0.00	K bend 10	0.00
K bend 01	0.16	K bend 06	0.00	K valve	0.00
K bend 02	0.13	K bend 07	0.00	K exit	1.00
K bend 03	0.13	K bend 08	0.00	K others	
K bend 04	0.16	K bend 09	0.00	K Total	2.37

Hydraulics

Pipe Area A (m^2)	0.053	U/S Invert Level (mAOD)	1950.000
Hydraulic Radius R (m)	0.07	D/S Invert Level (mAOD)	1943.000
Velocity V (m/s)	3.01	Is HL tot < HL available	OKAY
Pipe Roughness ks (mm)	0.06	Friction Losses hf (m)	3.82
Relative Roughness ks/d	0.00023	Fitting Losses hfit (m)	1.10
Reynolds Number Re = d V /Vk	687032	Trashracks and intake loss (m)	0.02
Type of Flow	Turbulent	Total Head Loss htot individual (m)	4.94
Friction Factor f	0.0153	% of H.Loss of individual pipe	70.56% Ok

Expansion Joints (mm) 0.0E+00

EJ number	1	2	2	4	5
dL theoretical	0	0	0	0	0
dL recommended	0	0	0	0	0
dL for expansion	0	0	0	0	0
dL for contraction	0	0	0	0	0

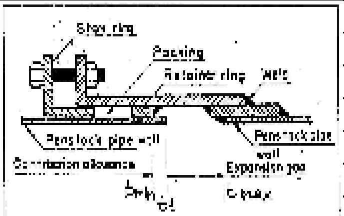


Figure 5.5: An example of pipe design

6 SETTLING BASINS

6.1 GENERAL

6.1.1 Sediment Settling Basins

A settling basin removes sediment (sand/silt) from water and settles down in the basin for periodical flushing back to natural rivers. Since sediment is detrimental to civil and mechanical structures and elements, the specific size of specified percentage sediment has to be trapped, settled, stored and flushed. This can only be achieved by reducing turbulence of the sediment carrying water. The turbulence can be reduced by constructing settling basins along the conveyance system. Since the settling basins are straight and have bigger flow areas, the transit velocity and turbulence are significantly reduced allowing the desired sediments to settle. The sediment thus settled has to be properly flushed back to the natural rivers.

Thus a settling basin:

1. Prevents blocking of headrace system assuring desired capacity of the system.
2. Prevents severe wearing of turbine runner and other parts.
3. Reduces the rate failure and O&M costs.

According to the location and function, a settling basin can be of following types:

1. Gravel Trap for settling particles of 2mm or bigger diameter.
2. Settling Basin for settling particles of 0.2mm or bigger diameter.
3. Forebay for settling similar to settling basin (optional) and smooth flow transition from open flow to closed flow.

Micro hydro settling basins are generally made of stone masonry or concrete with spillways, flushing gates, trashracks, etc., as and where necessary. However, functionally, all the settling basins should have following components:

1. Inlet Zone: An inlet zone upstream of the main settling zone is provided for gradual expansion of cross section for turbulent flow to smooth/laminar flow..
2. Settling Zone: A settling zone is the main part of a settling basin for settling, deposition, spilling and flushing (and trash removal).
3. Outlet Zone: An outlet zone facilitates gradual contraction of flow to normal condition.

A typical section of a settling basin with all the components (inlet, transition, settling and outlet zones) and accessories (spillway, gate) is presented in Figure 6.1.

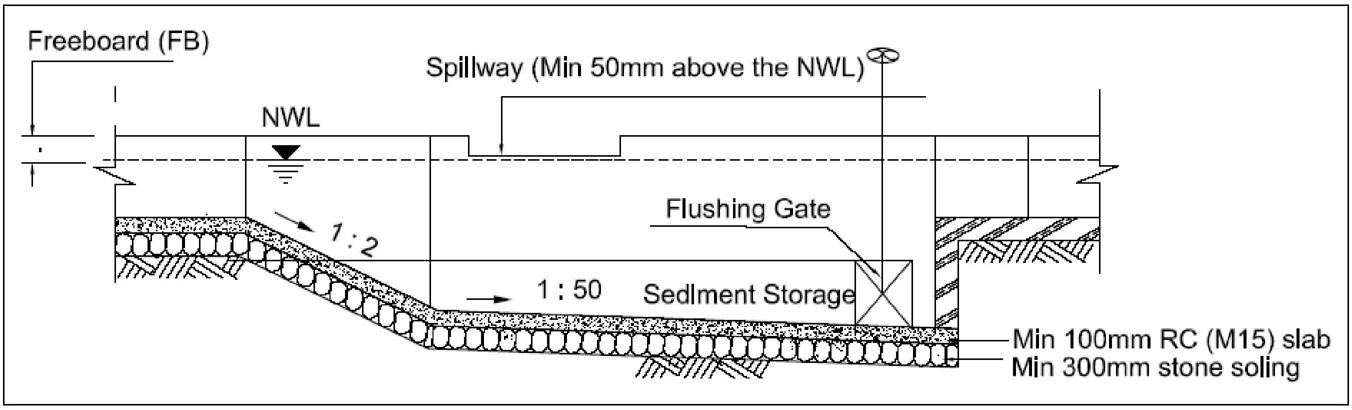


Figure 6.1: Typical section of a settling basin

6.2 SETTLING BASIN THEORY

An ideal settling basin is a basin has a flow flowing in a straight line (no turbulence, no eddy current). In practice, not a single basin is ideal. For an ideal basin shown in figure 6.3:

H/W = L/V
Or, B *H /W = B*L/V
Or, Ax/W = As/V
Or, Q/W = As = Surface area (i.e., the surface area is directly proportional to the discharge and inversely proportional to the settling velocity/sediment diameter/temperature).

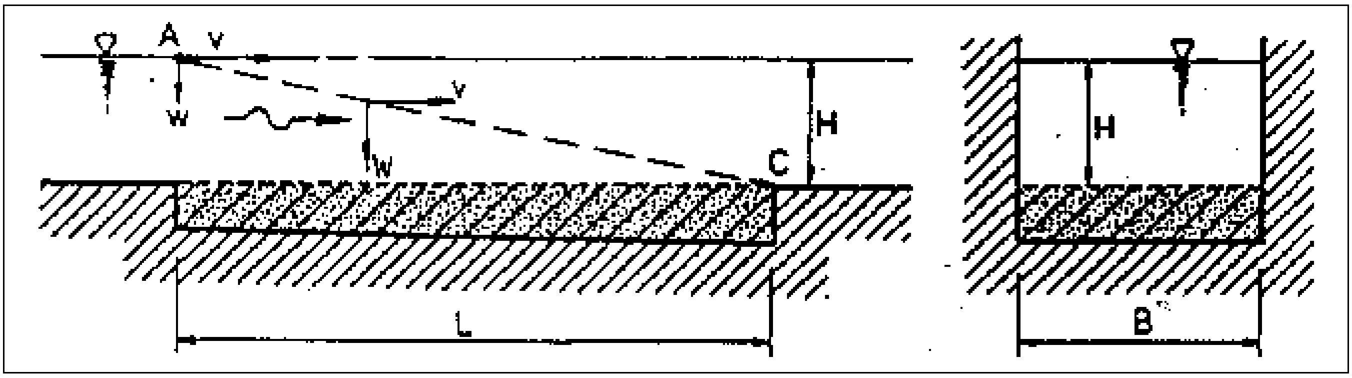


Figure 6.2: An ideal setting basin

As stated earlier a real basin never has an ideal flow. Efficiency of a real basin is generally 2 times higher than that of an ideal basin. This is mainly because of the following factors:

1. Presence of water turbulence in basin.
2. Imperfect flow distribution at entrance.
3. Flow convergence towards exit.

Vetter's Equation takes care of the factors stated above and hence recommended for use in settling basin design. According to Vetter's equation, trap efficiency (η) for a given discharge (Q), surface area (As) and falling velocity of critical sediment diameter (w) is:

$$\eta = 1 - e^{-\left(\frac{wA_s}{Q}\right)}$$

6.3 AEPC MGSP/ESAP GUIDELINES AND STANDARDS S

6.3.1 Gravel Trap

While designing a gravel trap, AEPC has outlined following points:

1. Location: Close to intake and safe.
2. Dimensions: Sufficient to settle and flush gravel passing through upstream coarse trashrack.
3. Spilling: Sufficient spillway/vertical flushing pipe.
4. Spilling and flushing: back to the river.
5. Material: 1:4 cement stone masonry with 12mm thick 1:2 cement plastering on the waterside or structural concrete of M15.
6. Recommended settling diameter and trap efficiency are 2mm and 90% respectively.

7. Sediment storage zone: Storage for 12 hours (flushing interval).
8. Drawdown: Drawdown discharge Capacity should be at least 150% of the design discharge.
9. Aspect ratio (straight length to width ratio): 1.5 to 2.

6.3.2 Settling Basin

While designing a settling basin, AEPC has outlined following points:

1. Location: Close to gravel trap/Intake.
2. Dimensions: Sufficient to settle and flush the designed sediment size.
3. Spilling: Sufficient spillway/vertical flushing pipe (layout dependent).
4. Spilling and flushing: back to the river.
5. Material: 1:4 cement stone masonry with 12mm thick 1:2 plastering on the waterside or structural concrete of M15.
6. Recommended settling diameter (trap efficiency) and head are presented in Table 6.1

Table 6.1: Settling diameter, trap efficiency and gross head

Settling diameter (mm)	Trap efficiency (%)	Gross head (m)
0.3-0.5	90%	10m
0.3	90%	10 to 100m
0.2	95%	more than 100m

7. Sediment storage zone: Storage for 12 hours (flushing interval)
8. Drawdown: Drawdown discharge capacity should be at least 150% of the design discharge.
9. Aspect ratio (straight length to width ratio): 4 to 10.

6.3.3 Forebay

While designing a forebay, AEPC has outlined following criteria:

1. Dimensions and functions: Similar to SB if u/s is open canal or the forebay functions as a combined settling basin cum forebay.
2. Submergence: Sufficient to prevent vortex (i.e. $1.5 * v^2/2g$).
3. Active Storage: At least 15 sec * Qd.
4. Freeboard: 300mm or half the water depth whichever is less.
5. Drawdown: A drain pipe/Gate.
6. Spilling capacity: Minimum of spilling Qd during load rejection.
7. Fine Trashrack:
    a. At the entrance of the penstock
    b. Inclination: 3V:1H
    c. Bars: Placed along vertical direction for ease of racking).
    d. Clearance: 0.5 * nozzle diameter in case of Pelton or half the distance between runner blade in case of Crossflow.

e. Velocity: 0.6 to 1m/s
f. Weight: =< 60kg (porter load)

6.4 PROGRAM BRIEFING AND EXAMPLES

6.4.1 Features of the spreadsheet

The spreadsheet is designed to cater for all types of settling basins and with all possibilities of spilling and flushing mechanisms. Some of the main features are listed below:

1. A single spreadsheet for:
    a. Gravel Trap
    b. Settling Basin (Desilting)
    c. Forebay-cum-Settling Basin
2. Settling of sediment using:
    a. Ideal settling equation
    b. Vetter's equation
3. Flushing of deposited sediment during:
    a. Normal operational hour
    b. Drawn-down condition
4. Sediment flushing with:
    a. Vertical flushing pipe
    b. Gate
    c. Combination of both
5. Spilling of excess flow due to:
    a. Incoming flood
    b. Load rejection
6. Spilling of excess flow with
    a. Spillway
    b. Vertical flushing pipe
    c. Combination of both
7. Drawdown / Dewatering with:
    a. Vertical flushing pipe
    b. Gate
8. Rating curve for the gate: According to Norwegian Rules and Regulations of Dam Construction, a gate rating curve for the designed parameters is computed. According to this manual, the flow through gate is of free flow type until the gate opening is two third of the water depth behind the gate. Beyond this level (i.e., the gate opening hither than 2/3 of the water depth behind the gate), the flow through gate is a pressure flow.
9. Multiple basins
10. Combination of approach canal / pipe options

6.4.2 Vertical flushing pipe

1. Overflow: Acts as a sharp crested weir. Discharge through the flushing pipe having a diameter d1 is:
   $Q_f = \pi * d1 * C_w * hf^{2/3}$ for $C_w = 1.6$
   $d_1 = Q_f/(1.6 * \pi * hf^{2/3})$

2. Drawdown / Dewatering through the vertical flushing pipe:
   $1.5 * Qd = C * A * (h_b + f_{flush})^{0.5}$: $A = \pi * d21^{2/4}$: C=2.76 for L=<6m
   $d_{21} = (6 * Qd / (\pi * C * (h_b + f_{flush})^{0.5})^{0.5}$ @ full
   $d_{22} = (4 * Qd / (\pi * C * (f_{flush})^{0.5})^{0.5}$ @ empty

3. Design diameter: Maximum of above (d1, d21,d22)

6.4.3 Spillway at intake

hovertop = 50% of (FB – spillway crest height above NWL)
$Ls1 = Qf/C/h_{overtop}^{1.5}$: for downstream obstruction and constant h overtop.
$Ls2 = 2 * Abs(Qf-Qd)/C/ h_{overtop}^{1.5})$ for no downstream obstruction and average h overtop.
$Ls3 = Qf/C/(2 * h_{overtop} - 0.05)^{1.5}$: for downstream obstruction and constant h overtop (100%-0.05).

6.4.4 Gate

Lifting force F(kg)=W buoyant + 1000*m*Asub*hcg
Gate opening dh=h1-h2
dh<2/3*h1 :=> Pressure flow (as a gate): $Q = C * L * (H1^{1.5} - H2^{1.5})$
dh=>2/3*h1 :=> Open flow (as a spillway): $Q = C * L * H1^{1.5}$
Enter the maximum gate opening in the lowest gate opening cell and press the Calculate Gate Rating Curve button for computing rating curve.

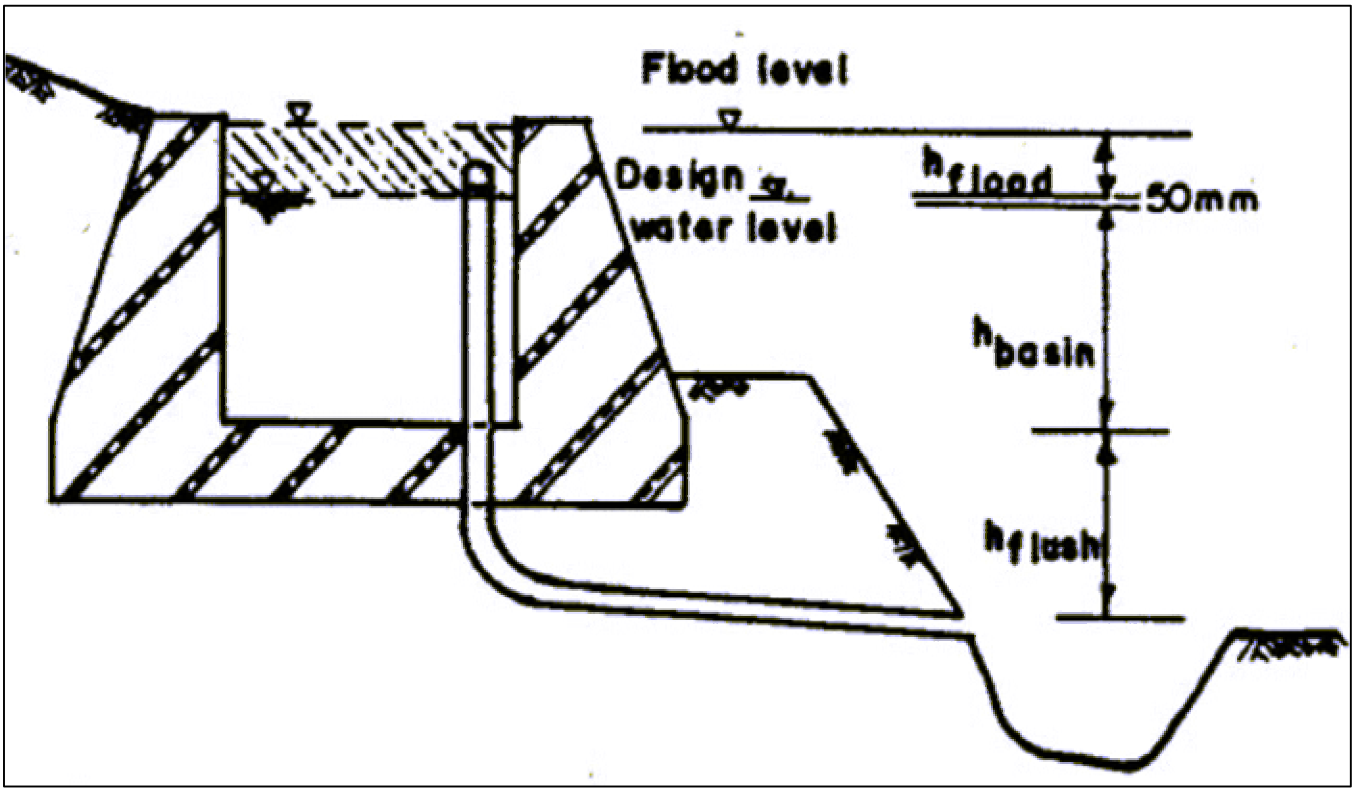


Figure 6.3: Flushing pipe details

Settling Basin Design

Spreadsheet developed by Mr. Pushpa Chitrakar, Engineering Advisor, SHPP/GTZ

Referances: 2,4, 6,9,12,13,15,16	Date	09-Nov-2005	$\eta = 1 - e^{-\left(\frac{wA_s}{Q}\right)}$
SMALL HYDROPOWER PROMOTION PROJECT/GTZ	Revision	2005.10	

Project:	**Upper Jogmai, Ilam**	Location:	Jogmai
Developer	Kankaimai Hydropower P Ltd		
Consultant	EPC Consult		
Designed	Pushpa Chitrakar		
Checked	Pushpa Chitrakar		

Q flood	0.000	Sediment swelling factor S =	1.50
Manning's number M ($m^{1/3}/s$) 1/n=	50.000	Volume of sediment storage V (m3) =	15.12
Design discharge Q_{design} (m^3/s) =	0.421	Sediment depth Hs (m) = V/Asi	0.63
Flushing discharge Q_{flush} (m^3/s) =	0.034	Inlet approach conveyance Canal/Pipe =	Canal
Total discharge Q_{basins} (m^3/s) =	0.455	1/Bottom slope of SB Sf (1:50 to 1:20) =	50.00
Particles to settle d (mm) =	0.300	Outlet approach conveyance Canal/Pipe =	Pipe
Trapping efficiency n (%) =	85%	Water level at inlet NWL (m) =	1950.00
water temperature t (°C) =	15	h flush below the base slab (L<6m)	1.70
Fall velocity w at 15 deg C (m/s) =	0.037	Number of basins N	1.00
Sediment concentration Cmax (kg/m3) =	2	Spillway crest height above NWL m	0.05
Flushing Frequency Fl (hours) =	8	Spillway discharge coeff	1.60
Surface area / basin Asi (m2) 85 % =	24.000	Provided Freeboard h fb1 m	0.30
Basin transit velocity Vt (m/s) =	0.241	Discharge coeff for pipe as orifice (2.76 if L <6 m)	2.76
Bulk Sed density G (kg/m3) =	2600	Drawdown discharge % of design discharge	1.00
Discharge per basin Q_{basin} (m^3/s) =	0.455	Water depth of inlet canal hc1 (m) =	0.50
Max section width for hydraulic flushing B (m) =	3.258	Outlet canal width /canal diameter Bc2 (m) =	0.50
Width used B (m) =	2.500	Water depth of outlet canal hc2 (m) =	0.30
Inlet canal width /canal diameter Bc1 (m) =	1.000	Provided Length of the basin Lact (m)=	0.00
Length of basin L (m) (Idel L = 9.6) =	10.000	Pipe does not need a straight approach!	***
Aspect ratio (4<=AR<=10)	4.000	Head over outlet weir h overtop (m) =	0.23
Min. water depth Hi (m) =	0.755	Approach inlet velocity vi1 (m/s) =	0.91
X-sectional area / basin Ai (m^2) =	1.888	Approach outlet velocity vi2 (m/s) =	3.03
Wetted perimeter / basin Pi (m) =	4.010	1/Energy gradient during operation So =	15763.86
Hydraulic radius Ri (m) =	0.471	d 50 during operation (mm) =	0.33
Normal WL @ basin h b m =	1.385	Depth of water during flushing yfi (m) =	0.12
Straight inlet transition length at 1:5 (m) =	3.750	d 50f during flushing (mm) =	49.32
Straight approach canal length (m) =	10.000	Length of an Ideal Basin (m) =	10.00

Spilling of excess water

Vertical Flushing pipe

Diameter for flood d1 m =	0.000	Diameter for load rejection (u/s flood bypass) d1 m =	2 x 0.43

Spillway

Freeboard m	0.300	Spillway length for Qd (under operation)	6.43
Spillway overtopping height h overtop m	0.125	pillway length for Qd (load rejection & u/s flood bypass)	6.43
Spillway length for Qf (flood and non operational)	0.000	illway length for Qd (d/s obstruction & full hovertop-50)	3.18

Combination of vertical flushing pipe and spillway — *Flood and non operational (Qf)*

Vertical flushing pipe diameter d1 m	0.30	Flood discharge passing through vertical pipe	0.000
No of vertical flushing pipe	1.00	Spillway length for the remaining discharge m	1.00
Spillway length used (m)	1.00		

Flood and Under Operation (Qf- Qd)		*Load Rejection (Qd)*	
H overtopping	0.00	H overtopping	0.262
Discharge passing through vertical pipe	0.00	Discharge passing through vertical pipe	0.240
Discharge passing over spillway	0.00	Discharge passing over spillway	0.215

Figure 6.4: Typical example of a settling basin (Settling basin, spilling and flushing).

Flushing of water and sediment

Flushing pipe and orifice diameter

d for incoming flow and draw down m	0.35
d for incoming flow only (empty state) m	0.40
ncoming flow only (empty state & with y flushing) m	0.39

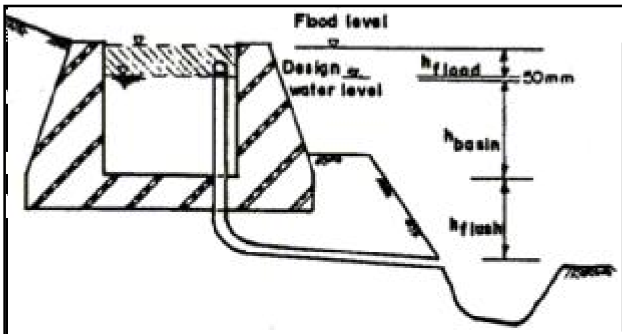
Gate

Buoyance weight of the gate W kgf	300.00
Gate Opening B, (m)	1.00
Gate Opening H (m)	0.50
Submerged area of th gate A m2	0.50
Water surface to cg of submerged area h m	1.11
Coeff of static friction mu	0.90
Lifting force F kgf	799.50
H. of water (H1)	1.36

Calculate Gate Rating Curves

Gate Opening Hg	Relative Gate Openig Hg/H1	Discharge One basin Q
0.000	0.000	0.000
0.033	0.025	0.127
0.067	0.049	0.249
0.100	0.074	0.366
0.133	0.098	0.479
0.167	0.123	0.591
0.200	0.147	0.700
0.233	0.172	0.807
0.267	0.196	0.912
0.300	0.221	1.016
0.333	0.245	1.117
0.367	0.270	1.216
0.400	0.294	1.312
0.433	0.319	1.406
0.467	0.343	1.497
0.500	0.368	1.586

Figure 6.5: Typical example of a settling basin (Gate and rating curve).



Forebay cum settling basin (for one basin only)

Penstock diameter m	0.41
Penstock velocity m/s	3.45
Submergence depth of penstock pipe m	0.91
Height of pipe above the base slab m	0.30
Min. pond depth m	1.62
Effective thickness of penstock mm	3
FS for air vent (5 burried, 10 exposed)	10
Young's modulus of elasticity E N/mm2	200000
Penstock inlet gate (Yes/No)	No
Air vent diameter mm	Nominal

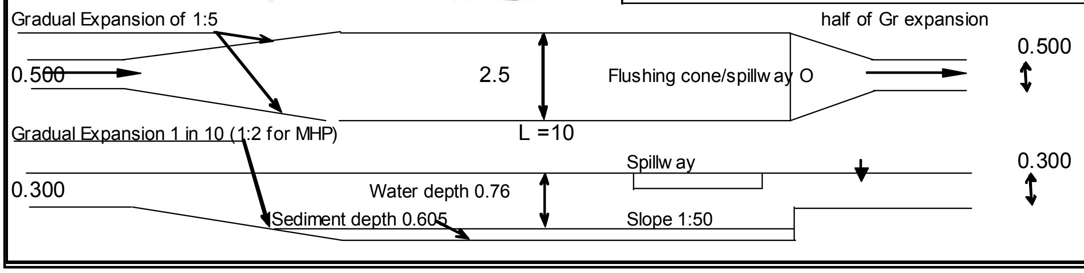


Figure 6.6: Typical example of a settling basin (forebay and dimensioning).

The settling basin calculations presented in Figure 6.6 are briefly described in the following section.

Sizing of settling basin

1. Settling of sediment using:

a. Vetter's equation

Surface area of basin $= -(Q_{total})/w*LN(1-n_{eff})$

Asi $= -(0.455)/.035* LN(1-n_{eff})$

$= 25\ m^2$

Max section with for hydraulic flushing = 4.83*Q^0.5

= 4.83*.455^0.5

= 3.258m

Provided Width B = 2.5m

Length of basin L = Asi/B
= 25/2.5
= 10m, which is 4 times the width hence, satisfies the requirement.

Basin transit velocity vt = 0.44* sqrt(d)
= 0.44*sqrt(0.2)
= 0.241m/s

Water depth Hi = Qi/B/vt
= 0.455/2.5/0.241
= 0.755m

Sediment storage volume assuming 100% trap efficiency (conservative side)
V = (Q_{total})*(Flushing intensity in sec)*Concentration max in kg/Bulk Sed. Density in kg/m^3/Sed Swelling factor
= (Q_{total})*(FI*3600)*Cmax/G*S
= 0.455*(8*3600)*2/2.6*1.5
= 15.12m^3

Sediment depth Hs = V/Asi
= 15.12/25
= 0.6m

b. Ideal settling equation

Length of an Ideal Basin= Maximum of (4xB and Q/B/w)
= MAX(4*2.5, 0.455/2.5/0.035)
= MAX(10, 5.2)
= 10 m

2. Spilling of excess flow due to load rejection: A combination of a 0.3m diameter vertical pipe and spillway of 1.0m length is used.

H overtopping = h ot =(Q1/(1.9*PI()*n1*d1+Cd*Ls))^(2/3)
= (0.455/(1.9*pi()*1*.3+1.6*1))^(2/3)
= 0.262 m

Q pipe = 1.9*PI()*n1*d1*h ot ^1.5
= 1.9*pi()*1*.3*0.262^1.5
= 0.240 m^3/s

Q spillway = Cd*Ls*h ot ^1.5
= 1.6*1*0.262^1.5
= 0.215 m^3/s

3. Flushing of deposited sediment through the flushing pipe: The pipe diameter will be the biggest of :

a. For incoming flow and draw down:
D1 = (Qflushing%*4*Qi/(PI()*Cd*SQRT(h NWL+h flush)))^0.5
= (100%*4*0.455/(pi()**2.76*SQRT(1.36+1.7)))^0.5
= 0.35m

b. For incoming flow only:
D2 = (4*Qi/(PI()*Cd*SQRT(h flush)))^0.5
= (4*0.455/(pi()**2.76*SQRT(1.7)))^0.5
= 0.4m

In the second case the depth of water during flushing yfi may be added to h flush for higher precision. This is not considered here. The recommended minimum diameter of the flushing pipe diameter is 0.4 m.

The gate curve in the example presented in Figure 6.6 includes the gate dimensions, forces and the rating curve. The rating curve of the gate versus different gate opening can be computed by entering allowable gate opening at the lowest input cell and clicking “Calculate Gate Rating Curve” button.

The last part the spreadsheet can be used if the considered basin is a settling basin cum forebay. The basic penstock inlet geometry is computed in this section.

7 PENSTOCK AND POWER CALCULATIONS

7.1 GENERAL

A penstock pipe conveys water from free flow state (at a settling basin or a forebay) to pressure flow state to powerhouse and converts the potential energy of the flow at the settling basin or forebay to kinetic energy at the turbine.

7.2 AEPC MGSP/ESAP GUIDELINES AND STANDARDS

1. Material: Mild steel (exposed and buried) and HDPE (buried) pipes should be used as penstocks pipes.
2. For exposed (i.e., above ground) mild steel penstock alignment, a minimum clearance of 300 mm between the pipe and the ground should be provided for maintenance and to minimise corrosion effects.
3. HDPE pipes should be buried to a minimum depth of 1 m. Similarly, if mild steel penstock pipes have to be buried, a minimum of 1 m burial depth should be maintained and corrosion protection measures such as high quality bituminous/epoxy paints should be applied. Due to higher risks of leakage, flange connected penstocks are not recommended to be buried.
4. The recommended initial trail internal diameter (D) can be calculated as:

   $D = 41 \times Q^{0.38}$ mm

   Where, Q = Design flow in l/s
5. Total penstock headloss should be limited to 10% of the penstock gross head.
6. Anchor / Thrust block at every horizontal and vertical bends and for every 30m of straight pipe stretch.
7. Expansion joints should be placed immediately downstream of every anchor block for exposed mild steel penstock.
8. In stead of providing an expansion joint immediately upstream of turbine, a mechanical coupling is recommended for ease of maintenance and lesser force distribution to the turbine casing.

7.3 PROGRAM BRIEFING AND EXAMPLE

7.3.1 Program Briefing

The design procedure of a penstock is similar to that of a headrace pipes. In this spreadsheet, the penstock is checked against surge / water hammer head propagated due to various closures of the system. Sudden closure of one jet is considered as the critical surge.

Both the installed capacities based on the AEPC criteria and actual cumulative efficiency of the electro-mechanical are presented.

Since a provision of maximum of ten bends is generally sufficient for a typical micro hydropower scheme, head losses due to ten bends only are incorporated. However, users can add any cumulative values if there are more than ten bends or other losses due to turbulence in the “K others” cells.

A fine trashrack is always recommended upstream of penstock inlet. Therefore, a trashrack calculation is included with the minimum submergence criteria by Gordon and AEPC criteria. AEPC criterion of 150% of the velocity head is enough for micro hydropower project up to 100kW.

User specific factor of safety and ultimate tensile strength for mild steel penstock are allowed in the spreadsheet.

The friction factor calculation is based on the iteration procedures described in the Layman's Guidebook on How to Develop a Small Hydro Site by European Small Hydropower Association (ESHA).

Design and installation criteria of expansion joints are presented at the end of the spreadsheet.

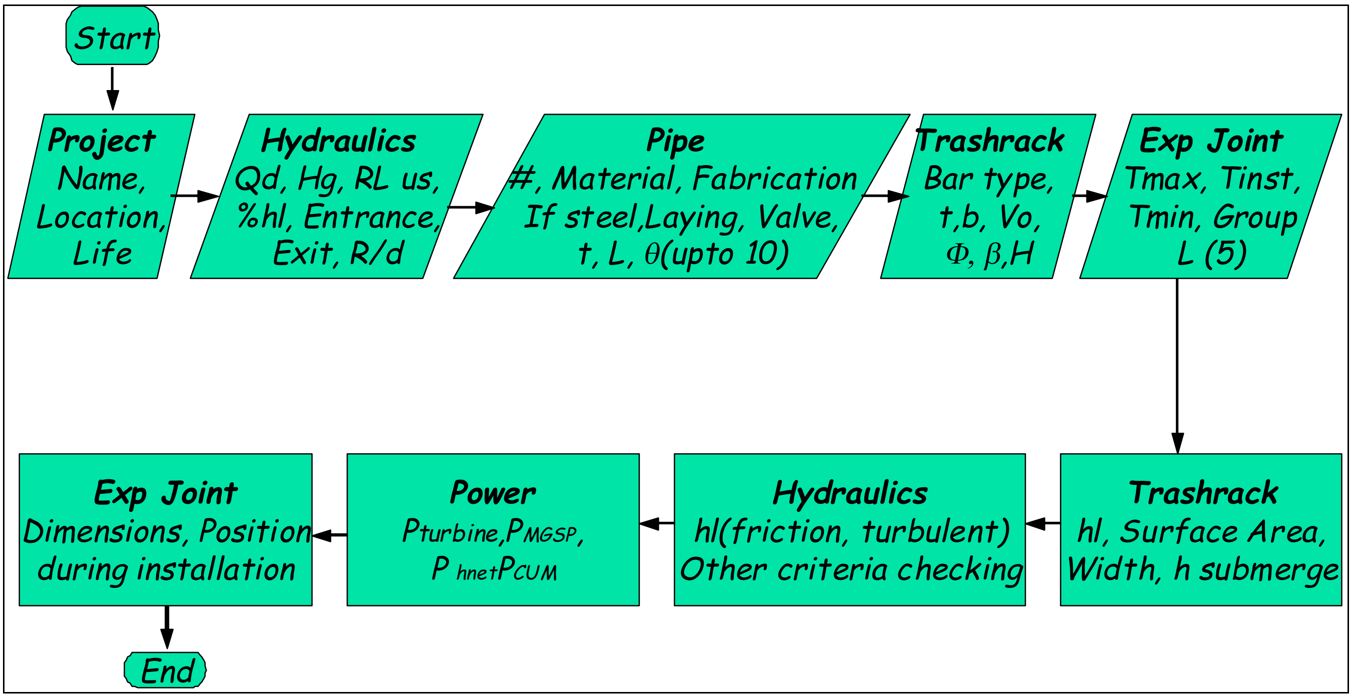


Figure 7.1: Flow diagram of penstock design

7.3.2 Typical example of a penstock pipe

Figure 7.1 presents calculation procedures applied in the example presented in Figures 7.2 and 7.3. For the given head of 180m and discharge of 450 l/s, three units of two-nozzle Pelton turbines are selected. Since trashrack and pipe hydraulics are similar to headrace pipe presented earlier, the detailed calculations are not presented in this section. The steel pipe thickness, expansion joints and power calculations are presented in this section. It is assumed that the valve closing is of slow type. The minimum factor of safety for penstock is chosen to be 2.5.

Pipe thickness:

It is worth noting that in reality the diameter of penstock pipe is optimized by calculating marginal costs and benefit method. In this method, the incremental benefit of annual energy by increasing the pipe diameters and corresponding increase of costs are plotted. The intersecting point represents the cost of optimum diameter. Alternatively, net present values of these cash/cost flow can be calculated and the net present value (NPV) of marginal benefit from energy gain should be higher than that of the marginal cost of that diameter.

Let's consider 4mm thick 300mm diameter pipe, the wave velocity

$$a = \frac{1440}{\sqrt{1+\left(\dfrac{2.1 x 10^9 x d}{E xt}\right)}} = \frac{1440}{\sqrt{1+\left(\dfrac{2.1 x 10^9 x 0.300}{200 x 10^9 x \dfrac{6}{1000}}\right)}} = 1071.454 \, m/s$$

h_{surge} = a * V/(g*njet)
= 1071.454*2.83/(9.81*6)

= 51.484m

h_{total} = h_{gross} + h_{surge}
= 180+51.484
= 231.484 m

$t_{effective}$ = t/(welding factor*rolling) – thickness for corrosion taken as Life span/10
= 6/(1.1*1.2) – 1.0
= 3.55mm

Factor of safety (allowable FS = 3.0)

$$S.F. = \frac{t_{effective}\ x\ S}{5\ x\ h_{total}\ x 10^3\ x\ d} = \frac{(3.55/1000)\ x\ 410x10^6}{5\ x\ 231.484\ x\ 10^3\ x\ 0.450}$$

= 2.79 which does not exceed the allowable FS of 2.5, hence OK. This factor of safety should be used for thinner penstock.

PENSTOCK AND POWER CALCULATIONS

Spreadsheet developed by Mr. Pushpa Chitrakar, Engineering Advisor, SHPP/GTZ
Referances:2,4, 5,6,12,13,15,16 Date 10-Nov-2005
SMALL HYDROPOWER PROMOTION PROJECT/GTZ Revision 2005.10

Project:	Jhankre mini-hydropower	Location:	Barand, Sertung VDC 2, Dhading
Developer	Himal Power Limited		
Consultant	BPC Hydroconsult		
Designed	Pushpa Chitrakar		
Checked	Pushpa Chitrakar		

INPUT

General:			
Project:	Jogmai I		
Location:	Ilam	Economic life (years)	10
Hydraulics:			
Diversion flow Qd (m3/s)	0.450	WL @ forebay or U/S Invert Level (m)	1213.90
Flow in each pipe Qi (m3/s)	0.450	% head allowable headloss hlt (m)	16.00%
Gross head (from forebay) Hg (m)	180.00	Cumulative known efficiency (g,t,tr,others)	79.38%
Power:			
Turbine type (CROSSFLOW/PELTON)	Pelton	Valves (Sperical/Gate/Butterfly)	Butterfly
No of total jets (nj)	6	Taper (Yes/No)	No
Direct Coupling (Yes/No)	Yes	Exit (Yes/No)	No
Closure time T sec	30.00	Non standard ult. tensile strength (UTS) N/mm2	0
Number of units	3		
Penstock pipe:			
Pipe Material (STEEL/HDPE/PVC)	Steel	Safety factor for lower pipes (0 for default)	2.5
Welded / Flat rolled if steel	Welded	Entrance Type	Sharp cornered
Rolled if steel	Rolled	Entrance with gate and air-vent (Yes/No)	No
Type if steel (UNGRADED/IS)	IS	Bending radius (r/d) (1/2/3/5/1.5)	1.5
Burried or exposed	Exposed	Bending angle 05	22
No of pipes	1.00	Bending angle 06	14.00
Bending angle 01(degrees)	2.00	Bending angle 07	0.00
Bending angle 02	11.00	Bending angle 08	0.00
Bending angle 03	4.00	Bending angle 09	0.00
Bending angle 04	11.00	Bending angle 10	0.00
Penstock diameter d=>d estd, d act (mm)	418 / 450	Pipe thickness t=>t min, t act (mm)	3.0 / 6.0
Pipe Length L (m)	550.000	Roughness coefficient (ks)	0.060

Trashrack

k	t	b	Vo	ϕ	β	Q	H
Flat	6.00	20.00	1.00	71.56	0.00	0.450	0.70

Expansion Joints

Tmax (deg)	T installation	Tmin	1st Pipe length(m)	2nd Pipe L (m)	3rd Pipe L (m)	4th Pipe L (m)	5th Pipe L (m)
40	20	4	10.00	15.00	20.00	25.00	30.00

Figure 7.2: Input required for penstock and power calculations

OUTPUT

Trashrack

hf	hb	H coeff	H	S	B	Min Submergence	CGL=1.5v^2/2g
0.0233	0.0000	0.4572	0.0233	2.0555	2.79	1.84	0.61

Turbulent loss coefficients K Total 2.06

K inlet	0.50	K bend 05	0.24	K bend 10	0.00
K bend 01	0.18	K bend 06	0.22	K valve	0.30
K bend 02	0.21	K bend 07	0.00	K taper	0.00
K bend 03	0.19	K bend 08	0.00	K exit	0.00
K bend 04	0.21	K bend 09	0.00	K others	0.00

Hydraulics

Pipe Area A (m^2)	0.159	U/S Invert Level (mAOD)	1213.90
Hydraulic Radius R (m)	0.11	D/S Invert Level (mAOD)	1033.90
Velocity V (m/s)	2.83	Is HLtot < HL available	OKAY
Pipe Roughness ks (mm)	0.060	Friction Losses hf (m)	6.87
Relative Roughness ks/d	1.333E-04	Fitting Losses hfit (m)	0.84
Reynolds Number Re = d V /Vk	1116427	Trashracks and intake loss (m)	0.02
Type of Flow	Turbulent	Total Head Loss htot individual (m)	7.73
Friction Factor f	0.0138	% of H.Loss of individual pipe	4.3% Ok

Factor of Safety

Young's modulus of elasticity E N/mm²		200000	Ultimate tensile strength (UTS) N/mm2	410
Thickness		6.000	H total for one jet closure of Pelton(m)	**231.48**
Diameter (mm)		450.000	t effective (mm)	3.55
Net Head (m)		172.268	Minimum t effictive for negative pressure (mm)	4.71
Wave Velocity a (m/s)		1071.454	Comment on thickness	NA, No gate
Critical time Tc (sec) *2 = Closing time T		1.03 Ok	Safety Factor (S)	2.79
K if crossflow turbine Kcf		0.00000	Check on Safety Factor	Ok
Hsurge for one jet closure of Pelton(m)		51.484	Air vent diameter d vent (mm)	67.45
Hsurge for instanteneous closure of all unit closure of Pelton (m)		308.907	H total capacity of the specified pipe (m)	258.42
Lengths (max & actual) of the specified pipe (m)	613.998	550.000	H static capacity of the specified pipe (m)	206.94

Power

Turbine efficiency as per MGSP	75.00%	Electrical Power as per MGSP GL (kW)	397.31
Available shaft power(kW)	570.36	Electrical Power based on Hnet (kW)	456.29
Reqd.'Turbine Capacity (+10%) (kW)	627.39	Power for known cumulative eff (kW)	603.67

Expansion Joints (mm) Coeff of linear expansion /deg C 1.2E-05

EJ number	1	2	2	4	5
dL theoretical	4	6	9	11	13
dL recommended	9	13	17	22	26
dL for expansion	5	7	10	12	14
dL for contraction	4	6	8	10	12

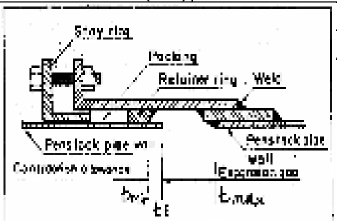


Figure 7.3: Output of penstock and power calculation spreadsheet.

Based on the American Society of Mechanical Engineers (ASME) formula, the allowable thickness is 3.00 mm. Therefore, optimum penstock thickness can vary from 3mm to 6mm. The summary of the penstock thickness corresponding to static head is presented in Table 7.1.

Table 7.1: Summary of penstock thickness and corresponding static head

Penstock thickness (mm)	Static Head (m)
3	40
4	86
5	132
6	180

8 TURBINE SELECTION

8.1 GENERAL

A turbine converts potential energy of water to rotational mechanical energy. Cross-flow and Pelton turbines are the most commonly used turbines in Nepali micro hydropower plants. The size and type of turbine for a particular site depends on the net head and the design flow. Pelton turbines are suitable where the ratio of head to flow is high whereas Cross-flow turbines are suitable for high flow and low head schemes. It should be noted that for certain head and flow ranges, both Pelton (multi-jet) and Cross-flow turbines may be appropriate. In such cases, the designer should consult with manufacturer and make a decision based on availability, efficiency and costs. On a horizontal shaft Pelton turbine the maximum number of jets should be limited to 3 for ease of manufacturing. The number of jets can be higher for vertical shaft Pelton turbines. However, these require higher precision work in mounting the generator vertically on the turbine shaft and furthermore, in case of varying rotational speeds (RPM of the turbine and the generator), the belt drive arrangements (including those for mechanically coupled end uses) will be difficult.

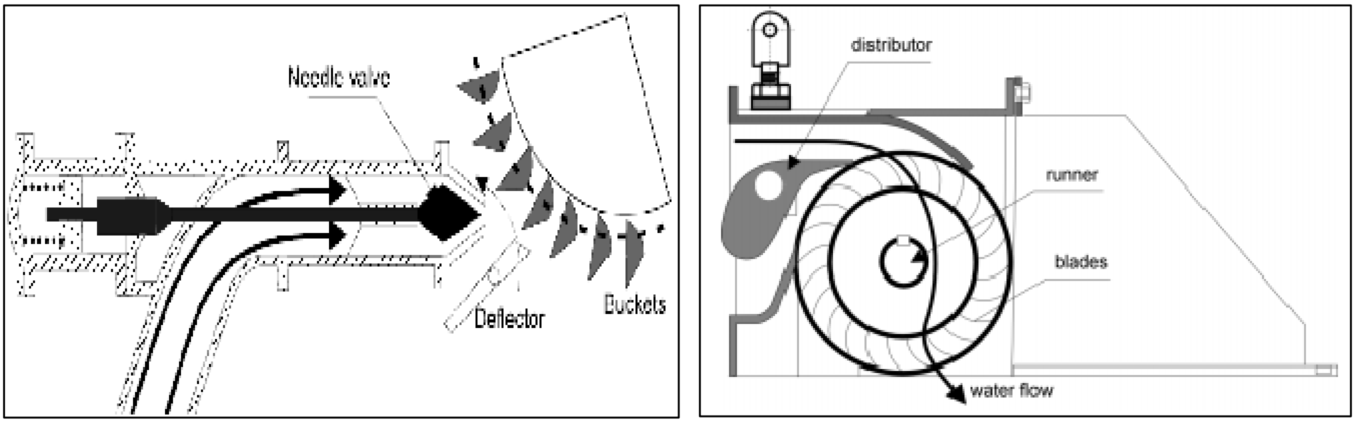


Figure 8.1: A Pelton and a Crossflow Turbines

8.2 AEPC MGSP/ESAP GUIDELINES AND STANDARDS

The recommended net heads for maximum rotational speed (rpm) and efficiencies for different turbines and turbine specifications are presented in Table 8.1.

Table 8.1: Turbine specifications

Type	Net head (m)	Max RPM	Efficiency (n_t)
Pelton	More than 10m	400 to 1500	70 - 75%
T12 Crossflow	up to 50m	900	60 - 78%
T15 Crossflow	up to 80m	1500	60 - 78%

The type of turbine can be determined by its specific speed given by the following equation:

Sp Speed (no gear) n_s = Turbine rpm*$\sqrt{}$(1.4*P_{kW}/$N_{turbines}$)/$Hn^{5/4}$

Sp Speed (gear) n_{sg} = Sp Speed (no gear)* Turbine rpm / Generator rpm

The only unknown in the above equation is the turbine rotational speed ($N_{turbines}$). This depends on the RPM of generators and drive systems (e.g., direct or belt drive). The specific speed of a multi-jet Pelton turbine can be computed by multiplying n_s by the square root of number of jets. Because of higher efficiency both in overall and part load, preference should be given to Pelton turbines. If n_s exceeds the range given in Table 8.2, multiple units should be used.

Table 8.2: Turbine type vs. n_s

Turbine types	n_s Ranges
Single Jet Pelton	10 – 30
Double Jet Pelton	30 – 40
Three Jet Pelton	40 – 50
Cross flow	20 – 80

8.3 PROGRAM BRIEFING AND EXAMPLE

With a typical example, the “Turbine” spreadsheet is presented in Figure 8.2. The specific speeds (n_s) with (gear ratio of 1:2) and without gear are calculated as:

Sp Speed (no gear) n_s = Turbine rpm*$\sqrt{}$(1.4*P_{kW}/$N_{turbines}$)/$Hn^{5/4}$
= 750*SQRT(1.4*67.89/1)/58^(5/4)
= 46 (Turgo/Crossflow/2-jet Pelton is suitable)

Sp Speed (gear) n_{sg} = Sp Speed (no gear)* Turbine rpm / Generator rpm
= 46*1/2
= 23 (Single jet Pelton/Crossflow is suitable)

Specific speed of multi-jet Pelton turbines is computed by multiplying the specific speed of runner by the square root of the number of the jets. The calculations show that for the given parameters in the context of micro hydro plants in Nepal, either a gearless Crossflow turbine or a Pelton/Crossflow with a gear ratio of 1:2 is recommended.

Turbine Selection			
Spreadsheet developed by Mr. Pushpa Chitrakar, Engineering Advisor, SHPP/GTZ			gtz SHPP
Referances: 6,7,8,12,13	Date	10-Nov-2005	
SMALL HYDROPOWER PROMOTION	Revision	2005.10	
Project	Upper Jogmai, Ilam		
Developer	Kankaimai Hydropower P Ltd		
Consultant	EPC Consult		
Designed	Pushpa Chitrakar		
Checked	Pushpa Chitrakar		
Input			
Discharge (l/s)	150	Gear ratio at turbine	1
Gross head (m)	69	Gear ratio at generator	2
Hydraulic losses	15.94%	No of turbines/generators	1
Max turbine output kW	67.89	Total number of jets if Pelton n	2
Turbine rpm	750	Specified turbine	Pelton
Cd	0.96	Cu	0.46
Output			
Net head m	58.001	Generator with gearing rpm	1500
No Gearing		**With Gearing**	
Sp speed of runner rpm (no gearing)	46	Sp speed of turbine	23
Pelton (12-30) => (Ns 17-42)	**	Pelton (12-30) => (Ns 17-42)	Pelton
Turgo (Ns 20-70) => (Ns 28-99)	Turgo	Turgo (Ns 20-70) => (Ns 28-99)	**
Crossflow (Ns 20-80)	Crossflow	Crossflow (Ns 20-80)	Crossflow
Fracis (Ns 80-400)	**	Fracis (Ns 80-400)	**
Propeller or Kaplan (Ns 340-1000)	**	Propeller or Kaplan (Ns 340-1000)	**

Figure 8.2: A Typical turbine example.

9 ELECTRICAL EQUIPMENT SELECTION

9.1 GENERAL

A generator converts mechanical energy to electrical energy. There are two types of generators; namely, synchronous and induction (asynchronous). Generally, induction generators are inexpensive and appropriate for Nepali micro-hydro schemes up to 15kW. For micro-hydro schemes ranging from 10kW to 100kW, synchronous generators are technically and economically more attractive. Both synchronous and asynchronous generators are available in single and three phases.

Load controllers are generally used as the governing system in Nepali micro hydro schemes. An Electronic Load Controller (ELC) is used for controlling power output of a synchronous generator. To control an induction generator, an Induction Generator Controller (IGC) is used.

9.2 SELECTION OF GENERATOR SIZE AND TYPE

Selection of generator size mainly depends up on the loads of a proposed site. Selection of generator type depends on the size of the selected generator, nature of the proposed loads and financial costs and benefits of the scheme. As stated earlier, a generator type can be either synchronous or induction of either single or three phase. Some of the main features of all types of generator are outlined in the following sections:

9.2.1 Single Phase versus Three Phase System

Advantages of a Three - Phase System

- Considerable saving of conductor and machine costs.
- Cheaper above 5 kW.
- Less weight by size ratio.

Advantage of a Single – Phase System

- Simple wiring.
- Cheaper ELC.
- Problem due to unbalanced load is not present.

9.2.2 Induction versus Synchronous Generators

Induction Generators

Advantages of Induction Generators:

- Easily availability
- Cheap, rugged and simple in construction
- Minimum Maintenance

Drawbacks of Induction Generators:

- Problem supplying large inductive loads.
- Less durability of capacitor bank.
- Poor voltage regulation compared to synchronous generators.

Synchronous Generators

Advantages of Synchronous Generators:

- High quality electrical output.
- Higher efficiency.
- Can start larger motors.

Drawbacks of Synchronous Generators:

- The cost is higher than induction generator for small sizes.
- Higher losses due to unbalanced load.

9.3 AEPC MGSP/ESAP GUIDELINES AND STANDARDS

Based on the major features, general guidelines for selection of phase and type of generator are prepared and summarized in Table 9.1.

Table 9.1: Selection of Generator Type

Size of scheme	Up to 10 kW	10 to 15 kW	More than 15 kW
Generator	Synchronous/Induction	Synchronous/Induction	Synchronous
Phase	Single or Three Phase	Three Phase	Three Phase

Maximum ambient temperature, powerhouse altitude, electronic load controller correction factor and power factor of the proposed loads are the major factors affecting the size of a generator. De-rating coefficients to allow for these factors are presented in the Table 9.2.

Table 9.2: Generator rating factors

Max. Ambient temperature in ^{o}C =>	20	25	30	35	40	45	50	55
Temperature Factor (A)	1.10	1.08	1.06	1.03	1.00	0.96	0.92	0.88

Altitudes	1000	1250	1500	1750	2000	2250	2500	2750	3000	3250	3500	3750	4000	4250	4500
Altitude Factor (B)	1.00	0.98	0.96	0.945	0.93	0.915	0.90	0.88	0.86	0.845	0.83	0.815	0.8	0.785	0.77

ELC Correction Factor (C)	0.83

Power Factor (D)	For light bulb loads (inductive) only	1.0
	For mixed loads of tube lights and other inductive loads	0.8

9.3.1 Sizing and RPM of a Synchronous Generator:

The steps for selecting the size of a synchronous generator are as follows:

1 Power factor of 0.8.

2 The size of synchronous generator (kVA):

$$\text{Generator (kVA)} = 1.3 * \frac{\text{Installed Capacity in kW}}{A \times B \times C \times D}$$

Where, A, B, C and D are correction factors from Table 9.2, and 1.3 is the 30% overrating factor (recommended) to allow for:

i) Unexpected higher power from turbine.

ii) Handling of starting current if large motors (> 10% of generator size) are supplied from the generator.

iii) The generator running at full load when using an ELC.

3 The synchronous rotational speed per minute:

$$Rotational\ speed(N)(rpm) = \frac{120f}{P}$$

Where,

f = frequency of the system in Hertz (Hz) (50 Hz in Asia and Europe)

P = number of poles of the generator (2, 4, 6, etc., in pairs). P for Nepali micro-hydropower schemes is generally 4 so that the rotational speed is 1500 RPM.

9.3.2 Sizing and RPM of an Induction Generator:

The steps for selecting the size of an induction generator are as follows:

1 The size of an induction generator (kW):

$$\text{Induction Generator (kW)} = 1.3 * \frac{\text{Installed Capacity in kW}}{\text{A x B}}$$

It is worth noting that an induction generator is basically a motor in nature. Similar to motor rating, the rating of an induction generato should be in kW. Therefore, ELC factor (C) and the power factor (D) corrections are not applicable for an induction generator. Other factors are applied similar to a sychronous generator. Generator voltage and current ratings should not exceed 80% of the electrical motor rating.

2 The rotational speed of an induction generator:

$$Rotational\ speed(Ni)(RPM) = \frac{120f}{P}(1+s)$$

Where,
P and f are the same as for synchronous generator and

s is the slip of the generator, $s = \frac{Ns - Nr}{Ns}$

Where,

N_s is the synchronous speed, i.e. $Ns(RPM) = \frac{120f}{P}$

Nr is the rated rotor speed of the induction motor and Ni always exceeds Ns while acting as a generator.

9.4 PROGRAM BRIEFING AND EXAMPLES

9.4.1 Program Briefing

In addition to calculating electrical parameters stated above, following electrical parameters are added to the presented “Electrical” spreadsheet:

1 Computation of excitation capacitance for an induction generator.

2 Sizing of electrical load controller (ELC) or induction generator controller (IGC) (equal to the installed capacity).

3 Sizing of ballast (20% higher than the installed capacity). In case the installed capacity exceeds or equal to 50kW, the ballast capacity of ELC-Extension is calculated as:

   Ballast capacity of ELC extension (kW) = 60% * 1.2 * Pe (electrical power)

   Fixed load = 40% * Pe (electrical power)

4 Sizing of MCCB/MCB.

5 Sizing of power cables.

1. **Sizing of excitation capacitance of an Induction Generator**

   Excitation capacitance for Delta connection C (цF) = 1/(2*pi()*f*Xc*η_m)

   $$\text{Or, } C(\text{цF}) = \frac{1000 * Pe * \sin(\cos^{-1}(\text{power factor}))}{3 * V^2 * pf * 2 * pi() * f * \eta_m}$$

   Where,

   Xc (Ω) = V / I_m
   V (V) = Rated Voltage of the motor (V) (phase to phase voltage, 380/400/415)
   I_m (A) = Magnetizing Current = I rated at full load current (A) * sin ($\cos^{-1}$ (power factor))
   I rated at full load current = Rated power (kW) * 1000/(V*pf)
   η_m = rated efficiency of motor at full load
   For star connected capacitors, the excitation capacitance is three times that for the Delta connection.

2. **Sizing of MCCB/MCB (A) = 1.25*Pe * 1000/(V*pf)**

   Where,

   1.25 = overrating factor by 25%.
   Pe (kW)= Installed capacity
   V (V) = Rated phase to neutral Voltage (V) (V*√3 for 3-phase)
   pf = power factor if induction generator is used

3. **Sizing of power cable (A) = 1.7*I**

   Where,

   1.70 = overrating factor by 70%.
   I (A) = Current = Generator size/(V *pf if induction generator is used)
   V (V) = Rated phase to neutral Voltage (V) (V*√3 for 3-phase)
   pf = power factor

9.4.2 Typical example of a 3-phase 60kW synchronous generator

Electrical component calculations for an example of a three-phase 60kW synchronous generator at an altitude of 1500m are presented in Figure 9.1. The detailed step-by-step calculations are:

The size of synchronous generator:

$$\text{Generator kVA} = 1.3 * \frac{\text{Installed Capacity in kW}}{A \times B \times C \times D}$$

= 1.3*60.04/(0.96*0.96*0.83*0.8)
= 127.70 kVA

The higher size available in the market of 45kVA is used.

$$Rotational\ speed(N) = \frac{120f}{P} RPM$$

=120*50/4
= 1500 rpm

Since Pe > 50kW, the ballast capacity of ELC extension (kW) = 60% * 1.2 * Pe + 40% * Pe
= 0.6*1.2*60.04 + 0.4*60.04
= 67.24 kW

Selection of Electrical Equipment

Spreadsheet developed by Mr. Pushpa Chitrakar, Engineering Advisor, SHPP/GTZ

Referances: 6,7,8,12,13	Date	11-Nov-2005	
SMALL HYDROPOWER PROMOTION I	Revision	2005.10	
Project	Upper Jogmai, Ilam		
Developer	Kankaimai Hydropower P Ltd		
Consultant	EPC Consult		
Designed	Pushpa Chitrakar		
Checked	Pushpa Chitrakar		

INPUT

Discharge (m^3/s)	0.204	Power factor	0.8
Gross head (m)	60.000	Safety factor of generator	1.3
Overall plant efficiency (%)	50%	Phase	3-phase
Temperature (^oC)	45	Type of Generator	Synchronous
Altitude (m)	1500	Over rating factor of MCCB	1.25
ELC correction factor	0.83	Over rating factor of cable	1.5
Frequency of the system (Hz)	50	No. of poles	4
Capacity of used generator (kVA)	0	Rated rotor speed if induction generator N (rpm)	
	Delta		

OUTPUT

Pe Electrical output (active power) (kW	**60.04**	Ok	
Generator			
Temp.factor	0.96	Altitude factor	0.96
Capacity (kVA)	**127.70**	**Actual available capacity (kVA)**	140.00
Synchronous rotational speed Ns (rpm)	1500		
ELC capacity (kW)	60.04	**Calculated Ballast capacity 1.2*Pe (kW)**	72.04
		Ballast capacity of ELC-Extention (kW)	67.24
Rated Voltage (V)	400	**I_{rated} for Cable & MCCB (A) at Generator side**	202.08
Rating of MCCB (A)	108.32	**Calculated size of MCCB (A)**	**135.40**
Cable			
Rating (A)	303.12	Size of 4-core cupper armoured cables	**185**

Figure 9.1: Electrical components of a 20kW 3-phase synchronous generator.

I_{rated} for Cable & MCCB at Generator side = 1000/ V_{rated} * Generator size /1.732
= 1000 / 400*140/1.732
= 202.08 Amp

Calculated size MCCB/MCB (A) = 1.25*Pe * 1000/(V*pf)
= 1.25*60.04*1000/(400*1.732*0.8)
= 135.40 Amp

Power cable inside the powerhouse

Rating current = $1.5*I_{rated}$
= 1.5*202.08
= 303.12 Amp

For this current a 4-core copper armoured cable of ASCR 185mm^2 is chosen.

9.4.3 Typical example of a single phase 20kW induction generator

Figure 9.2 present electrical equipment sizing of the previous project with a single phase induction generator with a rotor speed of 1450rpm. Since the electrical output is more than 10kW, a reminder error is flagged in the adjacent cell. The electrical components presented in Figure 9.2 are computed as:

The size of the asynchronous generator:

$$\text{Generator kW} = 1.3*\frac{\text{Installed Capacity in kW}}{A \times B}$$

= 1.3*20/(0.96*0.96)
= 28.25 kW

The higher size available in the market of 30kW is used.

$$Rotational\ speed(N) = \frac{120f}{P}$$

=120*50/4
= 1500 rpm

Rotational speed of a generator = Ns*(1+(Ns-N)/Ns)
= 1500*(1+(1500-1450)/1500)
= 1550 rpm

Excitation capacitance

$$C\ (\mu F) = \frac{1000*Pe*\sin(\cos^{-1}(\text{power factor}))}{3*V^2*pf*2*pi()*f*\eta_m}$$

$$C\ (\mu F) = \frac{1000*20*\sin(\cos^{-1}(0.8))}{3*400^2*0.8*2*pi()*50*0.89}$$

= 123.16 цF

I_{rated} for Cable & MCCB at Generator side = 1000/ V_{rated} * Generator size /pf
= 1000 / 220*30/0.8
= 170.45 Amp

MCCB/MCB (A) = 1.25*Pe * 1000/(V)
= 1.25*20*1000/(220)
= 142.05 Amp

Power cable inside the powerhouse

Rating current = $1.5*I_{rated}$
= 1.5*170.45
= 255.68 Amp

For this current a 2-core copper armoured cable of ASCR 185mm^2 is chosen.

Selection of Electrical Equipment			
Spreadsheet developed by Mr. Pushpa Chitrakar, Engineering Advisor, SHPP/GTZ			
Referances: 6,7,8,12,13	Date	11-Nov-2005	
SMALL HYDROPOWER PROMOTION I	Revision	2005.10	
Project	Upper Jogmai, Ilam		
Developer	Kankaimai Hydropower P Ltd		
Consultant	EPC Consult		
Designed	Pushpa Chitrakar		
Checked	Pushpa Chitrakar		
INPUT			
Discharge (m^3/s)	0.08	Power factor	0.8
Gross head (m)	50.968	Safety factor of generator	1.3
Overall plant efficiency (%)	50%	Phase	1-phase
Temperature (°C)	45	Type of Generator	Induction
Altitude (m)	1500	Over rating factor of MCCB	1.25
ELC correction factor	0.83	Over rating factor of cable	1.5
Frequency of the system (Hz)	50	No. of poles	4
Capacity of used generator (kW)	0	Rated rotor speed if induction generator N (rpm)	1450
Capacitor configuration	Delta	Efficiency of motor at full load	89%
OUTPUT			
Pe Electrical output (active power) (kW	**20.00**	**Use of 3-phase generator is mandatory**	
Generator			
Temp.factor	0.96	Altitude factor	0.96
Capacity (kW)	**28.25**	**Actual available capacity (kW)**	30.00
Synchronous rotational speed Ns (rpm)	1500	Rotational speed of the generator (rpm)	1550
IGC capacity (kW)	20.00	**Calculated Ballast capacity 1.2*Pe (kW)**	24.00
		Excitation Capacitance (micro F)	123.16
Rated Voltage (V)	220	**I_{rated} for Cable & MCCB (A) at Generator side**	170.45
Rating of MCCB (A)	113.64	**Calculated size of MCCB (A)**	**142.04**
Cable			
Rating (A)	255.68	Size of 2-core cupper armoured cables	**150**

Figure 9.2: Electrical components of a 20kW 1-phase induction generator.

10 TRANSMISSION AND DISTRIBUTION

10.1 INTRODUCTION AND DEFINITIONS

Power generated at a powerhouse is evacuated to load centres with the help of transmission and distribution lines. According to the Nepal Standards, 400/230V is used for distribution system whereas 400/11000V is used for transmission system. Use of these standard voltages is recommended so that the power can be easily synchronised and evacuated to grid in future.

10.2 AEPC MGSP/ESAP GUIDELINES AND STANDARDS

AEPC MGSP/ESAP has formulated following guidelines regarding micro-hydropower transmission and distribution systems:

1 Cable configuration and poles: Buried or suspended on wooden or steel or concrete poles.

2 Permissible Voltage drop: 10% of nominal value.

3 Conductor: Aluminum conductor steel reinforced (ACSR) or Arial Bundled Cable (ABC)

4 The ASCR specifications are presented in Table 10.1.

Table 10.1: ASCR specifications

ACSR Code number	Type of ACSR	Resistance Ohm/km	Current rating max Amps	Equivalent Copper area mm^2	Inductive Reactance Ohm/km	Sp. Weight (kg/km)	Sp. Cost (Rs/km)
1	Squirrel	1.374	76	13	0.355	80	13000
2	Gopher	1.098	85	16	0.349	106	14500
3	Weasel	0.9116	95	20	0.345	128	15500
4	Rabbit	0.5449	135	30	0.335	214	25750
5	Otter	0.3434	185	50	0.328		
6	Dog	0.2745	205	65	0.315	394	52000

10.3 PROGRAM BRIEFING AND EXAMPLES

10.3.1 Program Briefing

1 The presented spreadsheet is designed to calculated transmission parameters for three phase 11kV and 400V and single phase 230V transmission and distribution lines.

2 Balanced load is considered, i.e., neutral conductor does not carry any current.

3 With a power factor of 0.8, the rated current and voltage drop are calculated as:

Table 10.2: Rated current and voltage drop calculation

Phase	Current (A)	Voltage drop (dV)
3-phase	Power*1000/(1.732*V* power factor)	1.732*IA*Z*Lkm
1-phase	Power*1000/(V*power factor)	2*IA*Z*Lkm

4 Impedance (Z) = √(Resistance^2+Reactance^2).

5 Voltage at node (Vi)

Phase	Voltage at node (Vi)
Single to single phase or 3 to 3 phase	Vprevious - dV
Three to single phase	Vprevious/1.732 - dV

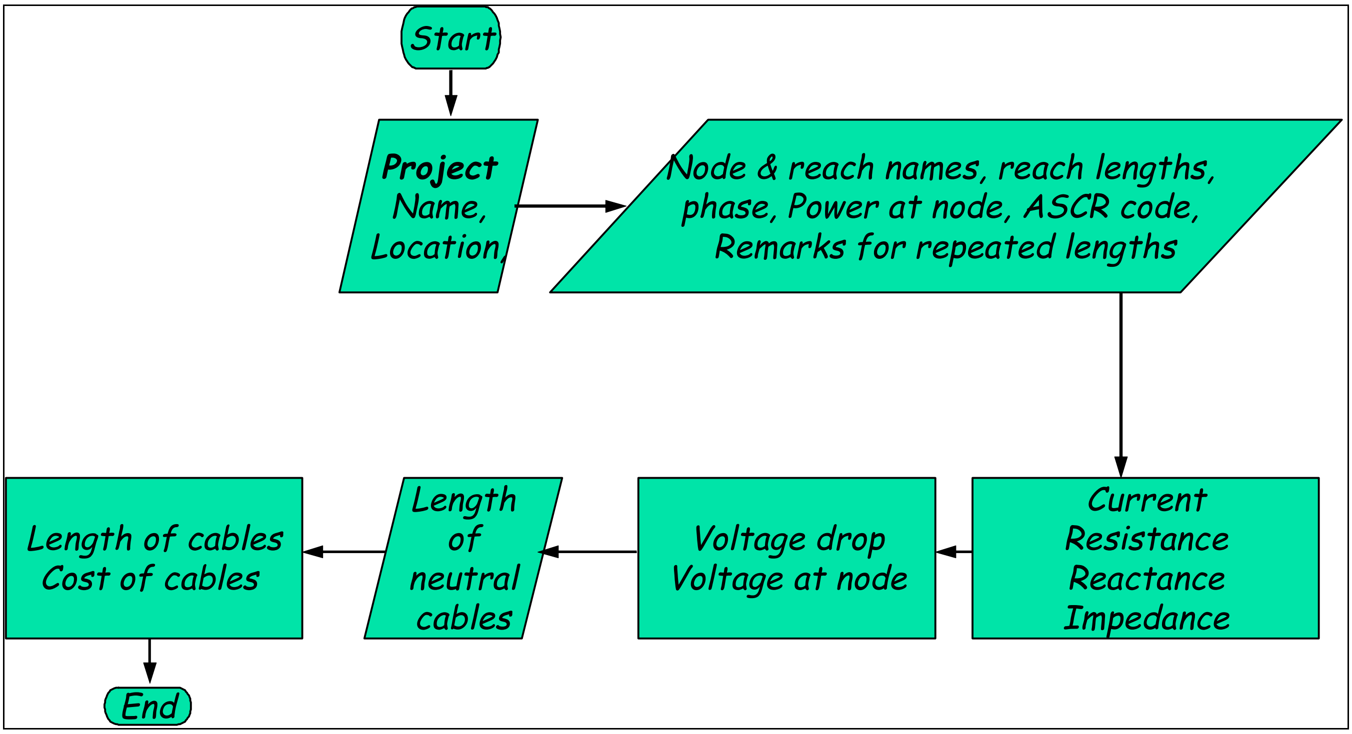


Figure 10.1: Flow chart of transmission and distribution line computation.

The grid and load presented in Figure 10.2 are used for the calculations presented in Figure 10.3.

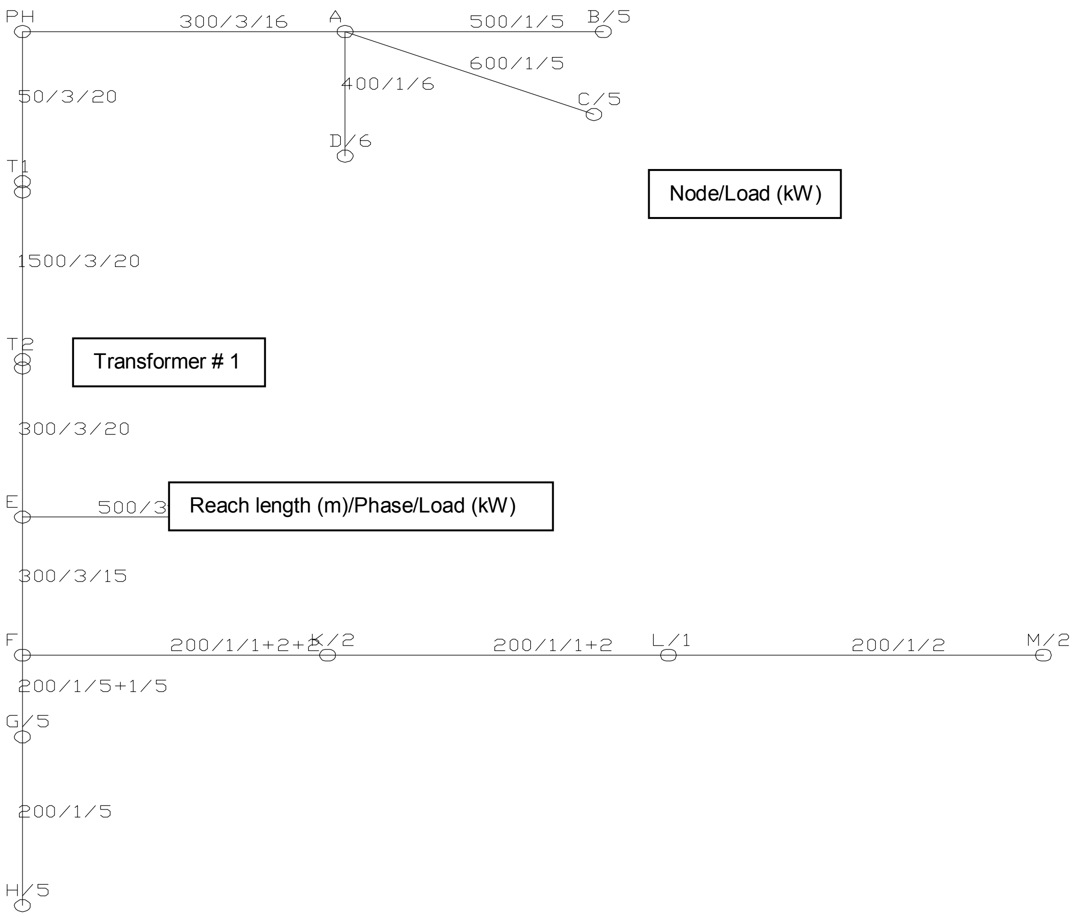


Figure 10.2: Transmission line and load used for the example.

Transmission and Distribution System:

Spreadsheet developed by Mr. Pushpa Chitrakar, Engineering Advisor, SHPP/GTZ

Referances:2,4, 6,12,13,15,16 Date 11-Nov-2005

SMALL HYDROPOWER PROMOTION PROJECT/GTZ Revision 2005.10

Project: Upper Jogmai, Ilam

Developer Kankaimai Hydropower P Ltd

Consultant EPC Consult

Designed Pushpa Chitrakar

Checked Pushpa Chitrakar

SHPP

Name of the project: **Upper Jogmai, Ilam**

Node name		Reach name	Reach Length (km)	Phase 1,3,11	Power at next node (kW)	ACSR type	Vrated @ node & Current (A)	Intermediate Calculation: V @ prev node (V)	Intermediate Calculation: Rated Voltage d/s prev node (V)
PH-A-B-C-D				3			400.00	400.00	400.00
PH	A	PHA	0.450	3	16	Dog	28.87	390.60	400.00
A	B	AB	0.660	1	5	Rabbit	27.71	390.60	225.51
	C	AC	0.090	1	5	Rabbit	30.92	390.60	225.51
	D	AD	0.090	1	6	Rabbit	33.80	390.60	225.51
PH-T1				3			400.00	400.00	400.00
PH	T1	PHT1	0.050	3	20	Otter	36.08	400.00	400.00
T1-T2				11			11000.00	11000.00	11000.00
T1	T2	T1 T2	1.500	11	20	Squirrel	1.31	11000.00	11000.00
T2-E				3			400.00	400.00	400.00
T2	E	T2 E	0.300	3	20	Dog	36.08	400.00	400.00
E-J (r)				1			226.44	226.44	226.44
T2	J	T2 J	0.300	1	20	Dog	110.41	226.44	226.44
E-H (y)				1			226.44	226.44	226.44
E	F	EF	0.300	1	6	Otter	33.12	217.04	226.44
F	H	FH	0.400	1	5	Otter	28.80	217.04	217.04
E-G (b)				1			226.44	226.44	226.44
E	F	E F	0.300	1	7	Rabbit	38.64	211.64	226.44
F	G	FG	0.200	1	5	Rabbit	29.53	211.64	211.64
E-M (r)				1			226.44	226.44	226.44
E	F	EF	0.300	1	1	Squirrel	5.52	221.84	226.44
F	M	FM	0.600	1	1	Squirrel	5.63	221.84	221.84
F-K (y)				1			217.04	217.04	217.04
F	K	F K	0.180	1	2	Squirrel	11.52	217.04	217.04
F-L(b)				1			211.64	211.64	211.64
F	L	F L	0.180	1	1	Squirrel	5.91	211.64	211.64

Total length of cables (km)			7.02	0.00	10.00	2.68	1.55	2.85
Length of neutral cables (km)					10			
Cost of cables(Rs.)		517720.00						
Reach Voltage drop (V)	Volt at node branch (V)	% voltag drop	Squirrel	Gopher	Weasel	Rabbiit	Otter	Dog
0.00	400.00		0.00	0.00	0.00	0.00	0.00	0.00
9.40	390.60	2.35	0.00	0.00	0.00	0.00	0.00	1.35
23.40	202.11	14.47	0.00	0.00	0.00	1.32	0.00	0.00
3.60	221.91	3.52	0.00	0.00	0.00	0.18	0.00	0.00
3.90	221.61	3.65	0.00	0.00	0.00	0.18	0.00	0.00
0.00	400.00		0.00	0.00	0.00	0.00	0.00	0.00
1.50	398.50	0.38	0.00	0.00	0.00	0.00	0.15	0.00
0.00	11000.00		0.00	0.00	0.00	0.00	0.00	0.00
4.70	10995.30	0.04	4.50	0.00	0.00	0.00	0.00	0.00
0.00	400.00		0.00	0.00	0.00	0.00	0.00	0.00
7.80	392.20	1.95	0.00	0.00	0.00	0.00	0.00	0.90
0.00	226.44		0.00	0.00	0.00	0.00	0.00	0.00
27.70	198.74	13.59	0.00	0.00	0.00	0.00	0.00	0.60
0.00	226.44		0.00	0.00	0.00	0.00	0.00	0.00
9.40	217.04	5.64	0.00	0.00	0.00	0.00	0.60	0.00
10.90	206.14	16.01	0.00	0.00	0.00	0.00	0.80	0.00
0.00	226.44		0.00	0.00	0.00	0.00	0.00	0.00
14.80	211.64	7.98	0.00	0.00	0.00	0.60	0.00	0.00
7.60	204.04	19.27	0.00	0.00	0.00	0.40	0.00	0.00
0.00	226.44		0.00	0.00	0.00	0.00	0.00	0.00
4.60	221.84	3.55	0.60	0.00	0.00	0.00	0.00	0.00
9.40	212.44	11.19	1.20	0.00	0.00	0.00	0.00	0.00
0.00	217.04		0.00	0.00	0.00	0.00	0.00	0.00
5.80	211.24	8.16	0.36	0.00	0.00	0.00	0.00	0.00
0.00	211.64		0.00	0.00	0.00	0.00	0.00	0.00
3.00	208.64	9.29	0.36	0.00	0.00	0.00	0.00	0.00

Figure 10.3: Typical example of a low voltage transmission line.

11 LOADS AND BENEFITS

11.1 GENERAL

BY optimising the use of available energy by allocating it in different time slots, benefit from a micro hydro scheme can be maximized. Based on the AEPC MGSP/ESAP guidelines, a spreadsheet on loads and benefits is presented for concerned stakeholders to arrive to the most optimum pre-construction decision.

11.2 AEPC MGSP/ESAP GUIDELINES AND STANDARDS

1. Average subscription wattage should not exceed 120W per household.
2. Minimum of 10% productive end use is mandatory.
3. Multipurpose scheme is preferable.

11.3 PROGRAM BRIEFING AND EXAMPLE

11.3.1 Program Briefing

A flow chart of loads and benefits analyses used in the spreadsheet is presented in Figure 11.1. Based on this flow chart, an example is presented in the in Figure 11.2. The main features and assumptions are:

1. For the first three years of operation, one set of domestic and five different end uses can be defined in five different time slots in the 24-hour load duration curve.
2. Probable business load after three years of operation can defined based on the AEPC requirements.
3. Annual available energy, annual load, productive end use load factor and annual total income are calculated and subsequently used in the financial analyses.
4. A load duration chart for the first three years of operation is presented at the end of the spreadsheet. This chart is very helpful in planning and allocating different loads so that the benefits are maximized.

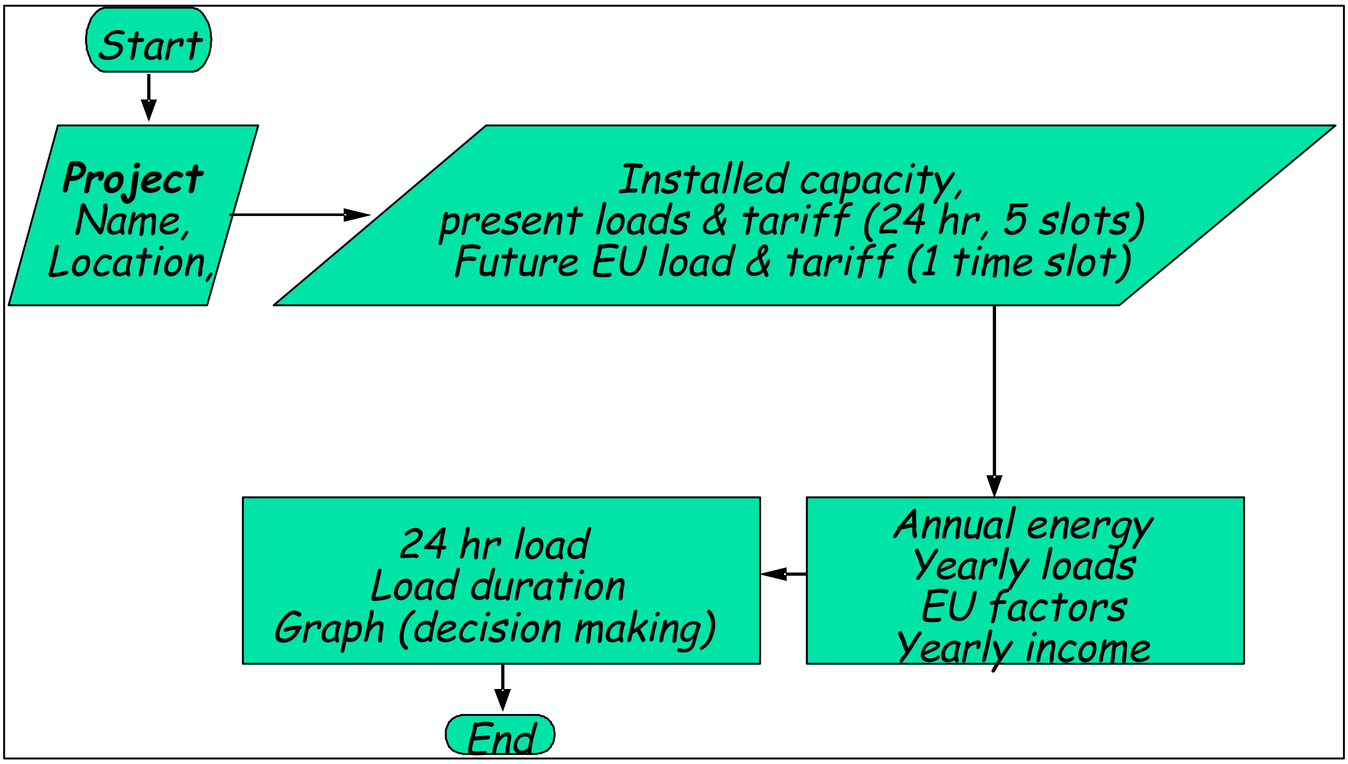


Figure 11.1: Flow chart of the load and benefits calculation spreadsheet.

LOADS AND BENEFITS

Spreadsheet developed by Mr. Pushpa Chitrakar, Engineering Advisor, SHPP/GTZ

Referances: 1,2,3,4, 6,12,13,15,16 Date 11-Nov-2005

SMALL HYDROPOWER PROMOTION PROJECT/GTZ Revision 2005.10

Project:	**Gaddi Gad Khola**	Location:	Ladagada VDC, Doti
Developer	Gaddi Gad Khola MHP		
Consultant	Perinial		
Designed	Pushpa Chitrakar		
Checked	Pushpa Chitrakar		

INPUT

General

Power Output (kW)	96.1
Name of the Source	Gaddi Gad Khola
Beneficiary HH (nos.)	471
Plant's operating days	330

Domestic lighting					
Average subscription/household (W/HH)			85		
System loss	10%				
time	0	5	8	18	20
load	91.08	0	0	91.1	0

Loads (kWh or W/m)	**Operating**	**Tariff (Rs)**
Domestic	330	1.00
Agro-processing	330	6.00
Bakery	320	6.00
Saw Mill	300	5.00
Herbs Processing	180	5.50
Load 5	330	
Load 6	330	

Probable Business Load Expected after 3 years	Operating d/y	Tariff (Rs)	Load	From (hr)	To (hr)
Metal Workshop	330	6.00	10	12	16
Photo Studio	320	6.00	1	8	20
Dairy Processing	320	6.00	8	8	18
Cold Store	310	6.00	6	8	18
Load 5					
Load 6					

Proposed end uses and operting hours

time (hr)	0	4	12	16	22
Agro-processing	0	0	22.5	0	0
time (hr)	0	8	14	18	22
Bakery	0	9	0	0	0
time (hr)	0	3	16	18	22
Saw Mill	0	0	10	0	0
time (hr)	0	3	12	17	22
Herbs Processing	0	0	25	0	0
time (hr)	0	6	8	15	22
Load 5	15	0	0	0	0
time (hr)	0	3	5	10	22
Load 6	12	0	0	0	0

Daily Energy Demand (Dd) kWh	1053
Yearly Energy Demand (Dd) kWh	384199
Average Load Factor	50.71%

OUTPUT

Summary

Annual Available kWh	761112	
	First 3 years	**After 3 years**
Yearly load (kWh)	117060	147680
Productive end use load factor (%)	15.38	19.40
Annual total (domestic + end uses) Income (Rs)	916,050	1,099,770

End Use	Load (kW)	Operation Period Hours/day	Days/year	Yearly Load kWh	LF (%)	**Annual Income (Rs)**
Domestic Lighting	44.0385	14.4782406	330	210408	27.64	**480,420**
Existing/Committed Business Load						
Agro-processing	22.5	4	330	29700	3.90	178200
Bakery	9	6	320	17280	2.27	103680
Saw Mill	10	2	300	6000	0.79	30000
Herbs Processing	25	5	180	22500	2.96	123750
Load 5	15	6	330	29700	3.90	0
Load 6	12	3	330	11880	1.56	0
Total				**117060**	**15.38**	**435,630**
Total Annual Income from sales of electricity						**916,050**
Probable Business Load after 3 years						
Metal Workshop	10	4	330	13200	1.73	79200
Photo Studio	1	12	320	3840	0.50	23040
Dairy Processing	8	10	320	25600	3.36	153600
Cold Store	6	10	310	18600	2.44	111600
Load 5	0	0	0	0	0.00	0
Load 6	0	0	0	0	0.00	0
Total additional annual income after 3 years				61240	8.05	**183,720**
Productive End Use (%)	19.40					

Figure 11.2: An example of load and benefits calculation.

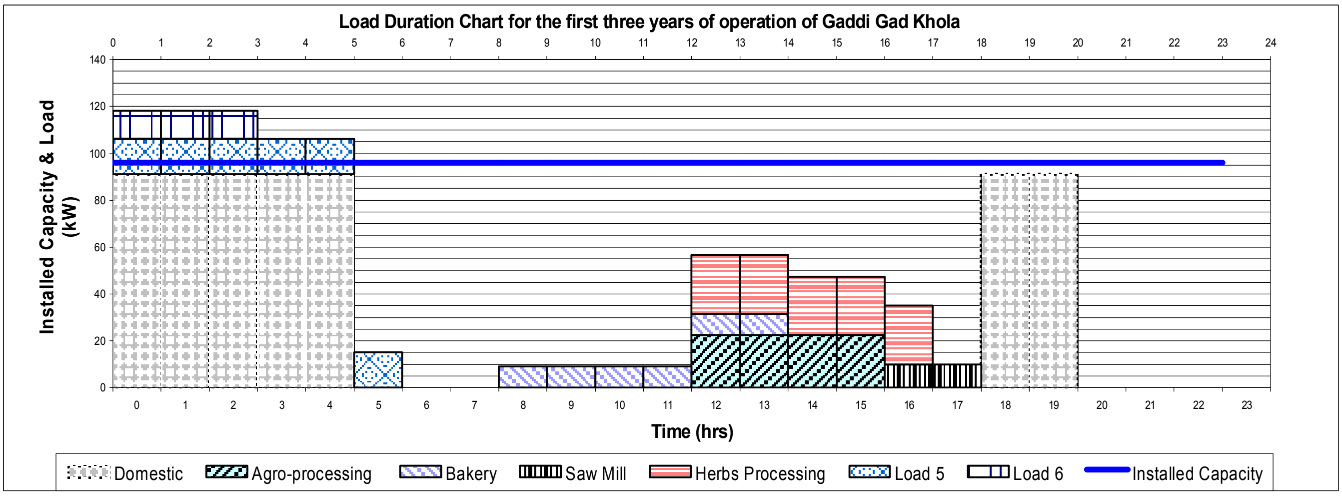


Figure 11.3: Load duration curve

It can be seen from the load duration curve presented in Figure 11.3 that the scheme is mainly dominated by domestic load. Other end uses can be incorporated within 05 to 16 hours. In case the scheme has to share water with other existing water utilities such as irrigation system, this can be arranged during the non-operating hours or during partial load period. This load duration curve can also be used to maximize benefits even at lower tariff during such hours.

12 COSTING AND FINANCIAL ANALYSES

12.1 INTRODUCTION AND DEFINITIONS

As per the guidelines and standards set aside by AEPC, this spreadsheet tests financial viability of a micro-hydro scheme.

12.2 AEPC MGSP/ESAP GUIDELINES AND STANDARDS

1. 15 years as the economic life span of the project for calculating financial parameters.
2. Total cost of the project including subsidy should be limited to

Table 12.1: Per kilowatt subsidy and cost ceiling as per AEPC

Walking distance	Subsidy	Ceiling
less than 2 days walking distance	70000	150000
2-5 days walking distance	78750	158750
more than 5 days walking distance	91500	171500

3. Net present value of equity investment at a discount rate of 4% should be positive.

12.3 PROGRAM BRIEFING AND EXAMPLE

12.3.1 Program Briefing

The spreadsheet presented takes the total costs, financing of the project and annual cost as inputs to calculate the financial parameters such as the net present value, cost per kilowatt, etc. The flow chart on which the spreadsheet is based is presented in Figure 12.1. Annual cash flows for the stated planning horizon is presented and used to calculate different financial parameters.

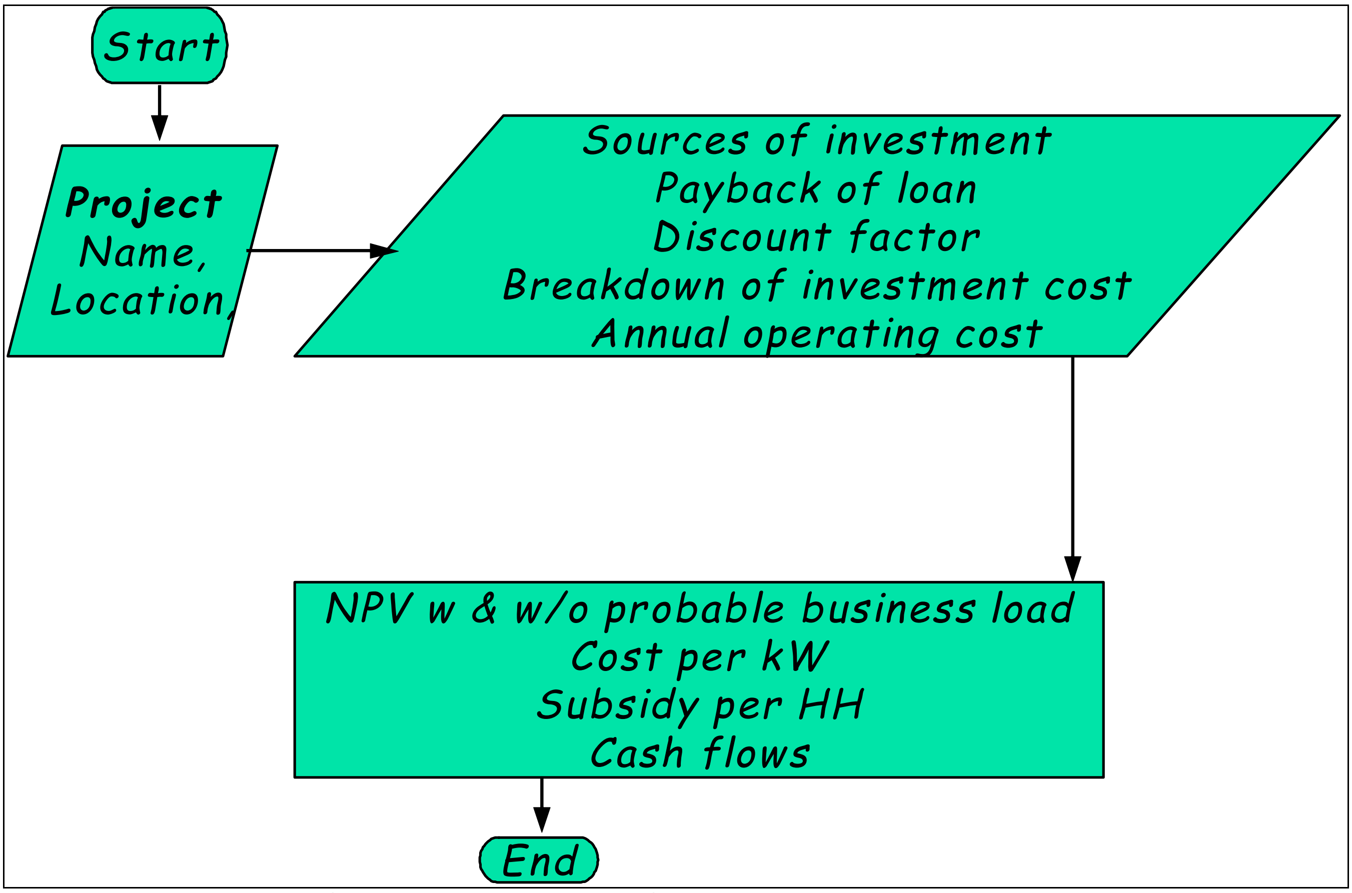


Figure 12.1: Flow chart for Project costing and financial analyses.

12.3.2 Typical example of costing and financial analyses

A typical example of costing and financial analyses of a micro-hydro scheme based on projected cash flow is presented in Figure 12.2.

Project Costing and Financial Analyses

Spreadsheet developed by Mr. Pushpa Chitrakar, Engineering Advisor, SHPP/GTZ

Referances: 1,2,3,4, 6,7,8,12,13	Date	12-Nov-2005	
SMALL HYDROPOWER PROMOTION PROJECT/GTZ	Revision	2005.10	SHPP

Project	Mai Khola
Developer	Kankaimai Hydropower P Ltd
Consultant	EPC Consult
Designed	Pushpa Chitrakar
Checked	Pushpa Chitrakar

INPUT

Project size (kW):	96.10					
Total Project Cost (Rs.)	**12,734,865**					
more than 5 days walking distance	al subsidy	Bank loan	Other loan	Cash equity	Kind equity	Others
91500 Rs/kW x 96.1	8793150	1,890,044		1,200,000	851,671	0
Interest rate (%)		3%				
Payback period (yr)		7				
Plant life (yr)	15					
Discount Rate (%)	4%					

				O & M (Rs)	**305,004**
Investment Cost (Rs)	**8,516,715**			Salary	114000
Mechanical components	999,040	Installation	232,500	Spares	0
Electrical component	2,061,717	Commissioning	0	Maintenance	171,000
Civil component	1,363,497	VAT	623,611	Office expenses	
Spare parts & tools	57,550	Contingencies	0	Miscellaneous	20,004
Transport.	3,178,800	Others		Others	

Cost Summary

Project cost (Rs)	12,734,865
Annual Operation, Maintenance and other Cost	305,004
Annual Income without probable business loads	916050
Annual Income with probable business loads (R	1099770
Annual installment for Bank loan	303364
Annual installment for other loan	NA
NPV on equity without probable business load (	3,627,922
NPV equity with probable business load (Rs)+ve	5,101,797
Cost/Kw=>>Ok	132,517
Subsidy/HH	18,669

NPV Based on Different Project Costs

NPV	Probable Business Load	
	Without	With
Total cost	-3,407,381	-1,933,506
Subsidy	5,047,571	6,521,446
Equity	3,627,922	5,101,797

Annual Cash Flows

Year	Equity	O & M costs	Loan repayment	Without Probable Business Loads		With Probable Business Loads	
				Income	Cash flow	Income	Cash flow
0	1,200,000				-1,200,000		-1,200,000
1		305,004	303,364	916,050	307,682	916,050	307,682
2		305,004	303,364	916,050	307,682	916,050	307,682
3		305,004	303,364	916,050	307,682	916,050	307,682
4		305,004	303,364	916,050	307,682	1,099,770	491,402
5		305,004	303,364	916,050	307,682	1,099,770	491,402
6		305,004	303,364	916,050	307,682	1,099,770	491,402
7		305,004	303,364	916,050	307,682	1,099,770	491,402
8		305,004	0	916,050	611,046	1,099,770	794,766
9		305,004	0	916,050	611,046	1,099,770	794,766
10		305,004	0	916,050	611,046	1,099,770	794,766
11		305,004	0	916,050	611,046	1,099,770	794,766
12		305,004	0	916,050	611,046	1,099,770	794,766
13		305,004	0	916,050	611,046	1,099,770	794,766
14		305,004	0	916,050	611,046	1,099,770	794,766
15		305,004	0	916,050	611,046	1,099,770	794,766

Figure 12.2: A typical example of project costing and financial analyses.

13 UTILITIES

13.1 INTRODUCTION

In this spreadsheet minor tools for independent minor calculations are presented. These tools are specially helpful in case minor quick and handy independent computations are required. Some of the presented tools are:

13.1.1 Uniform depth of a rectangular or trapezoidal canal

Calculation of uniform depths of rectangular and trapezoidal sections is an iterative process. Manning's equation is used for calculating uniform depth. VBA for Excel is used for this iterative process. A typical calculation is presented in Figure 13.1.

Uniform Depth of a Trapezoidal Canal (Y-m)

Design Discharge (l/s):	200.000
1/Mannings Coeff (M):	65.0000
1/Canal Slope (S):	50
Width of Canal (b-m):	0.500
Unlined firm/gravelyl/clay/side hill c/s in average loam cut (z m)	1
Uniform Depth (Y-m)	**0.150**

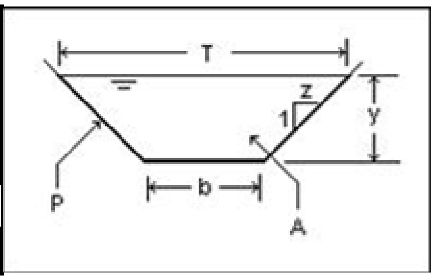


Figure 13.1: A typical example of uniform depth calculation of a trapezoidal section

13.1.2 Payment of loan for different periods such as monthly, quarterly and yearly.

The tool presented in Figure 13.2 is useful for calculating equal instalment payback for a given loan at a specific interest rate and terms. Three modes namely monthly, quarterly and yearly payments are available in this tool.

Payment of a loan

Loan amount:	1,800,000
Interest rate (APR):	6.00%
Monthly payments and No	12
Monthly Payment	**154,919.57**

Figure 13.2: A typical example EMI calculation

13.1.3 Power calculations

This tool is useful for calculating power based on AEPC guidelines for subsidy criteria and actual power based on known cumulative efficiency. A typical example is presented in Figure 13.3 below:

Power MGSP-ESAP (Pe-kW)

Discharge (l/s):	160
Cumulative efficiency(n%)	65.00%
Head (H-m)	27.50
Actual Power (Pact-kW)	**28.06**
Power MGSP-ESAP (Pe-kW)	**21.58**

Figure 13.3: A typical example of power calculation

13.1.4 Spillway sizing.

The spillway sizing tool is useful for calculating spillway lengths for different spillway shapes with different downstream conditions (downstream obstructed or free). As presented in Figure 13.4, this tool calculates actual spillway length required for critical conditions of load rejection and off-take flood.

Spillway Lengths (m)

Flood discharge (l/s):	540
Design discharge (l/s):	126
Overtopping height (ho) mm:	150
Spillway discharge coeff	2.1
L spillway min for Qf m & full height	**4.43**
Length of spillway Ls1 for Qf m & half height	**9.60**

Figure 13.4: A typical example of spillway sizing

13.1.5 Voltage drops of transmission line.

This tool calculates voltage drop, percentage voltage drop and voltage at a lower end of a transmission line segment for a given power. A typical example is presented in Figure 13.5.

Voltage Drop

Reach length (km)	7.000
Voltage at 1st node (V)	11,000
Power (kW)	190
ASCR type	Squirrel
Phase at 1st node (1/2/11(for 11kV or above)	11
Phase at 2nd node (1/2/11(for 11kV or above)	11
Current (A)	**12.47**
Impedence Ohm/km	**1.3803**
Voltage at 2nd node (kV) 208.6V ,1.9%	**10,791.40**

Figure 13.5: A typical example of transmission line calculation

13.1.6 Pipe friction factor.

This tool is quite useful for calculating friction factor. Manual friction factor calculation involves a long and tedious process and can be erroneous. The tool presented in Figure 13.6 also calculates head losses in metres and percentage and net head for given inputs.

Friction Factor (f) & Net head

Discharge (m3/s)	0.160
Gross head (m)	20
Pipe roughness ks (mm)	0.060
Pipe diameter (m)	260.00
Pipe Length (m)	140
Turbulent headloss factor (K)	1.50
Friction factor f	**0.0153**
Net Head (m), hl=4.52m 22.59%	**15.48**

Figure 13.6: A typical example of pipe friction calculation

14 REFERENCES

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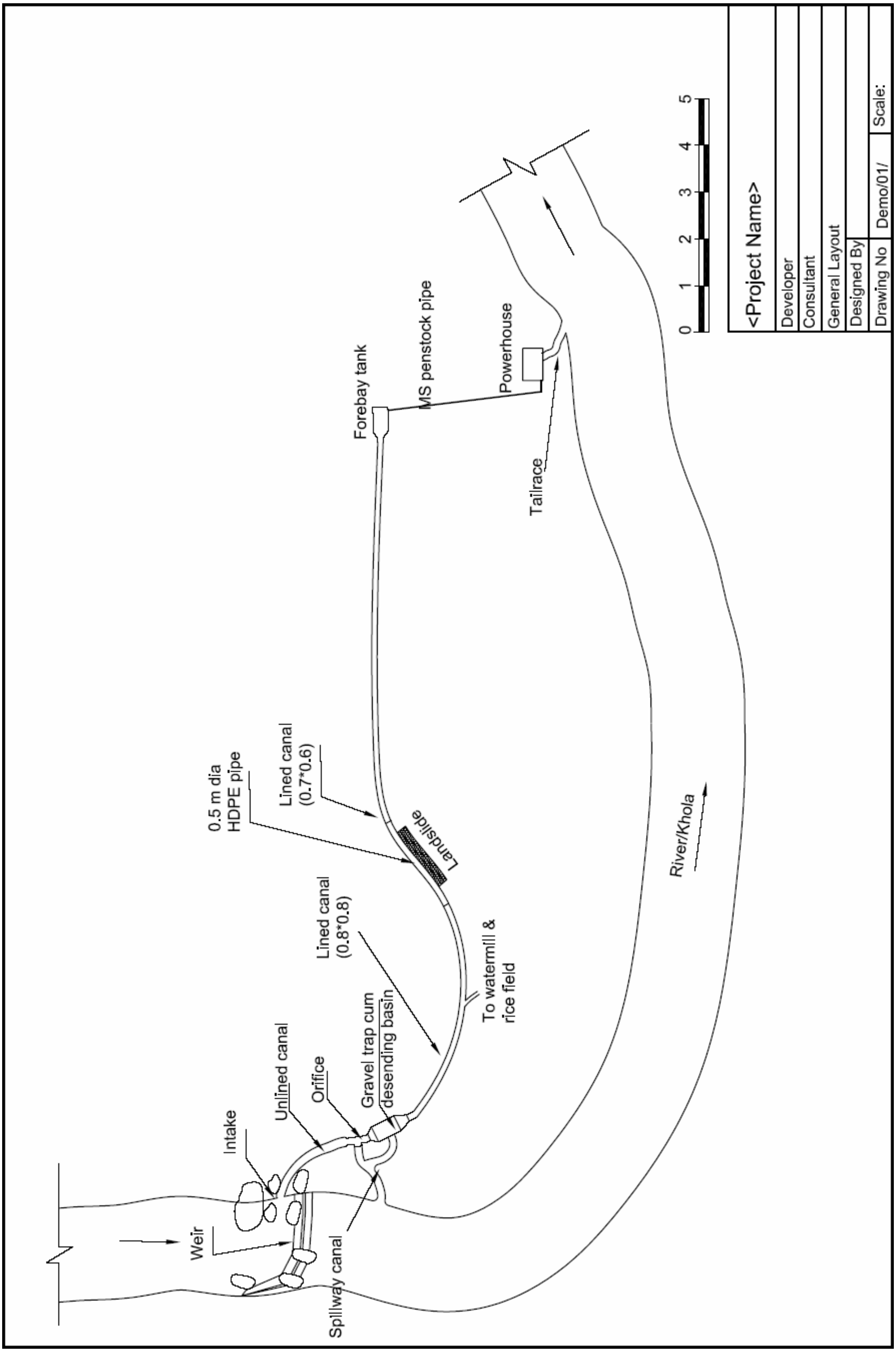
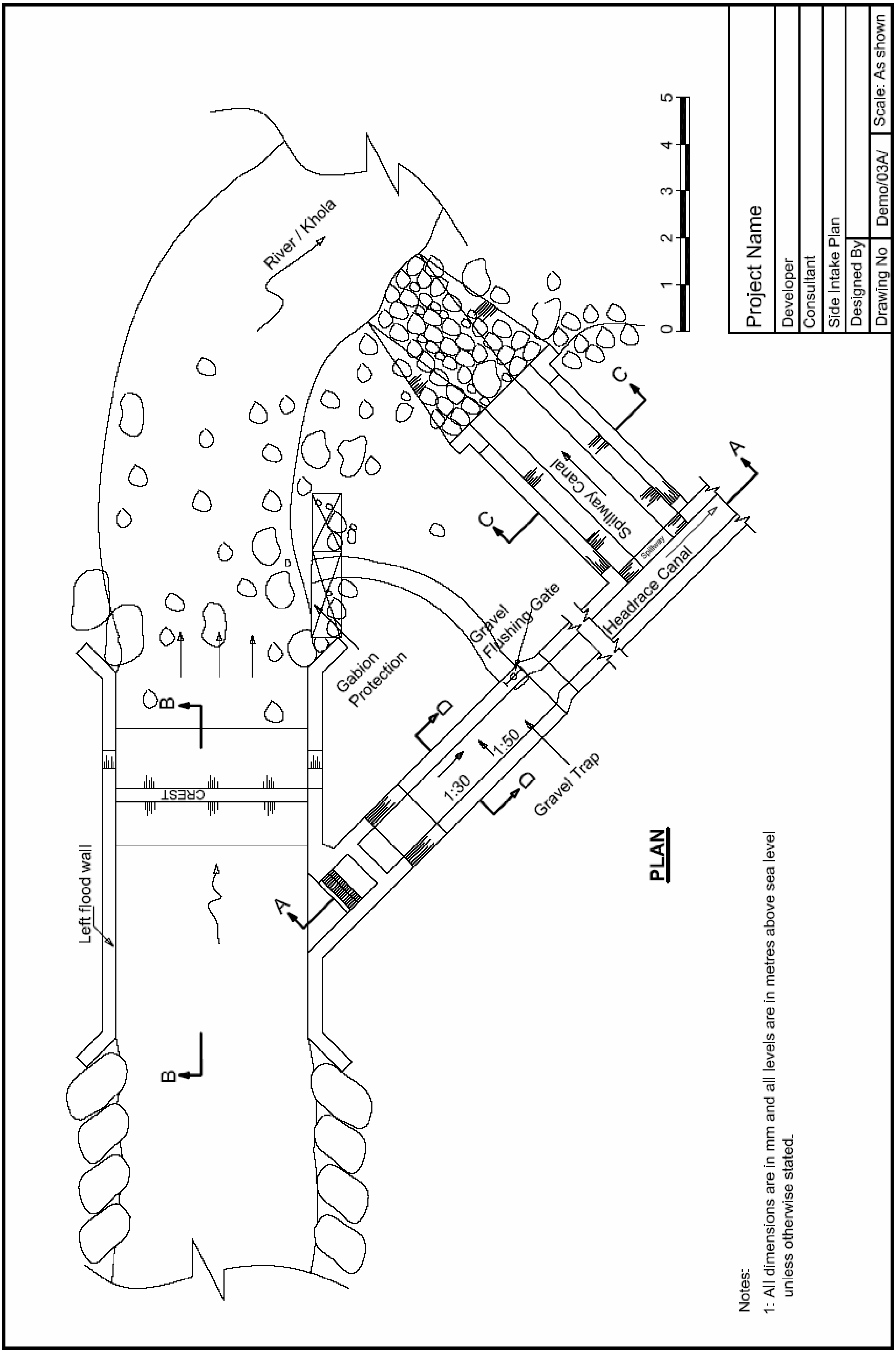
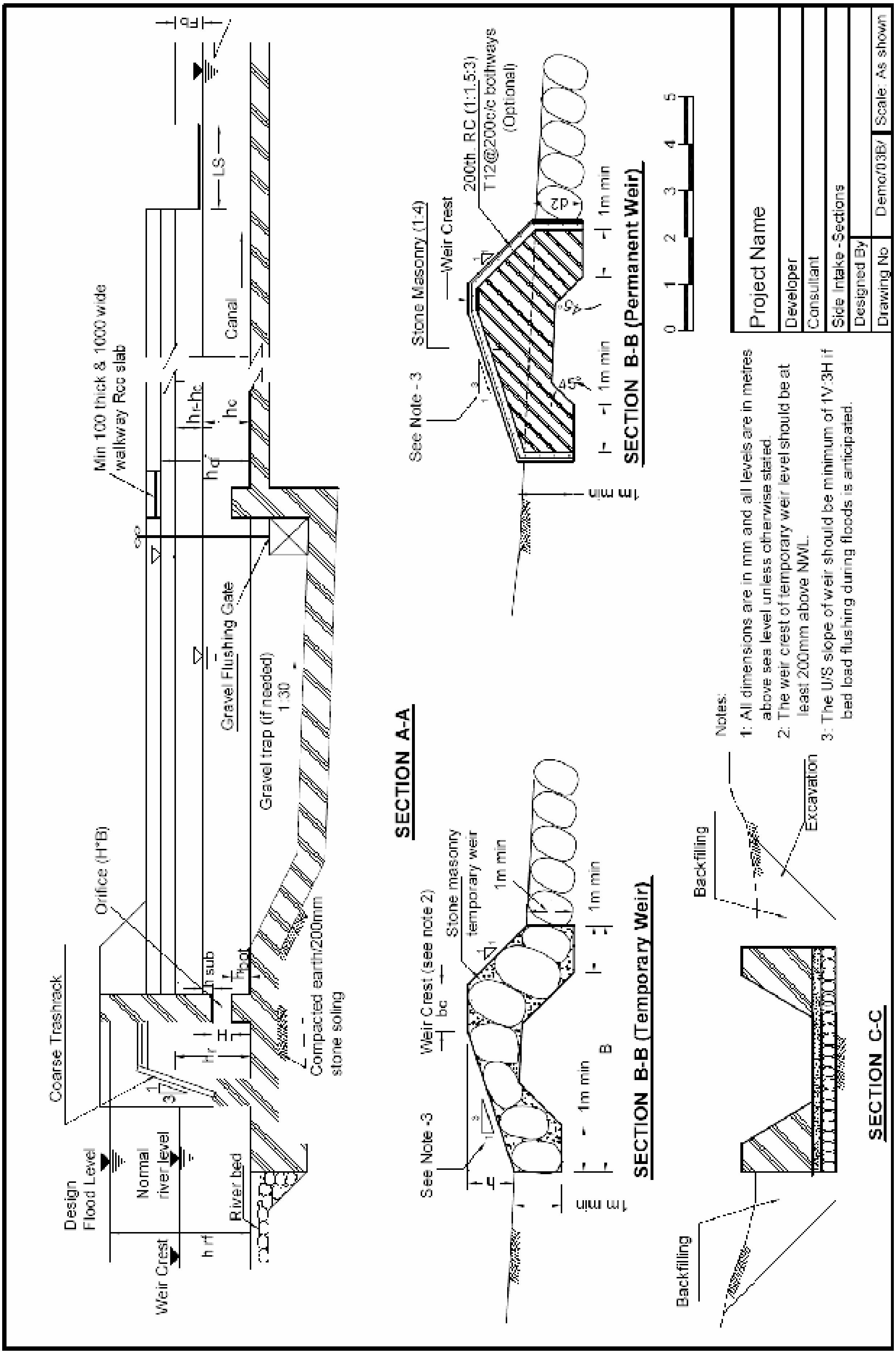
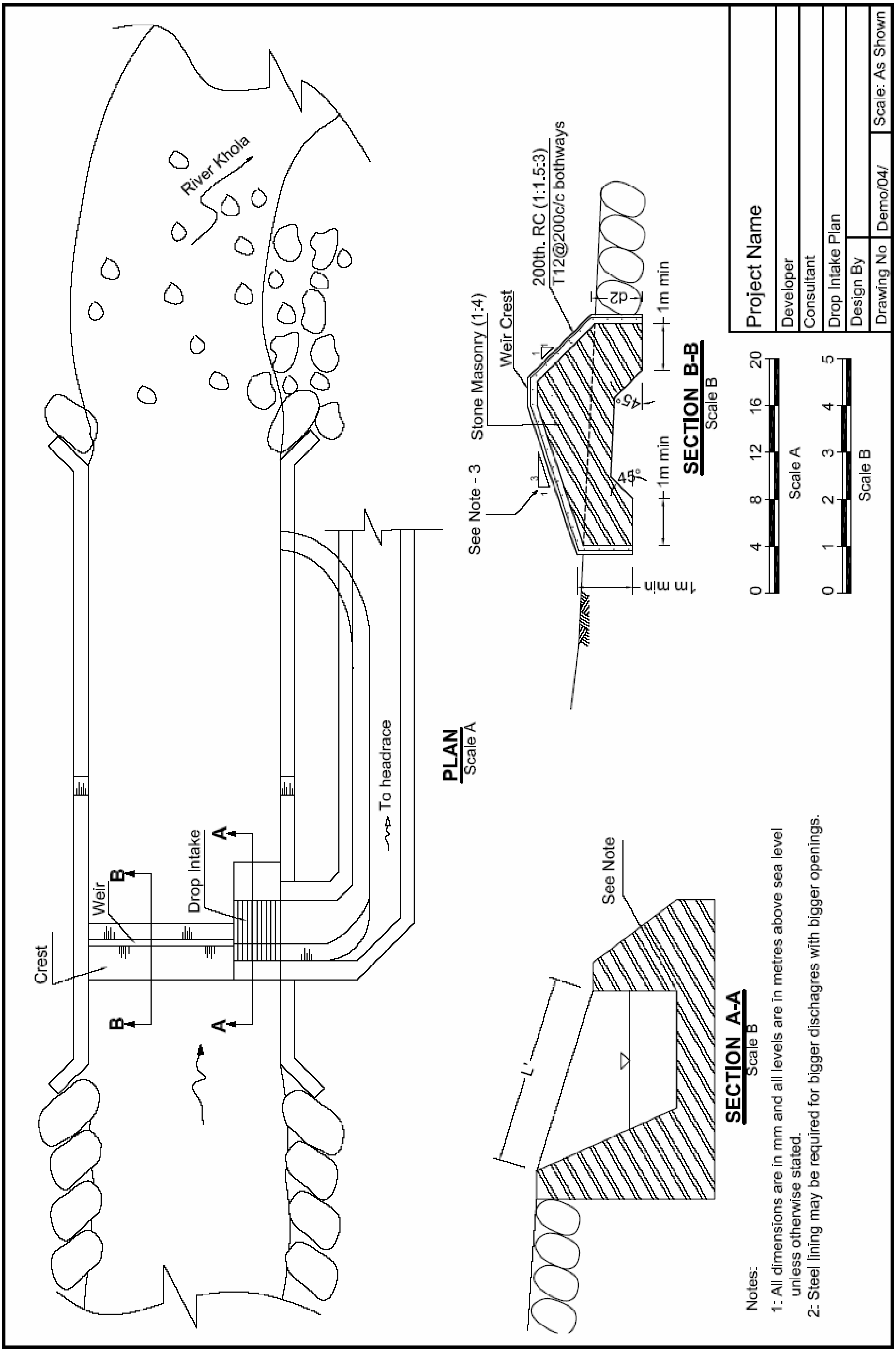
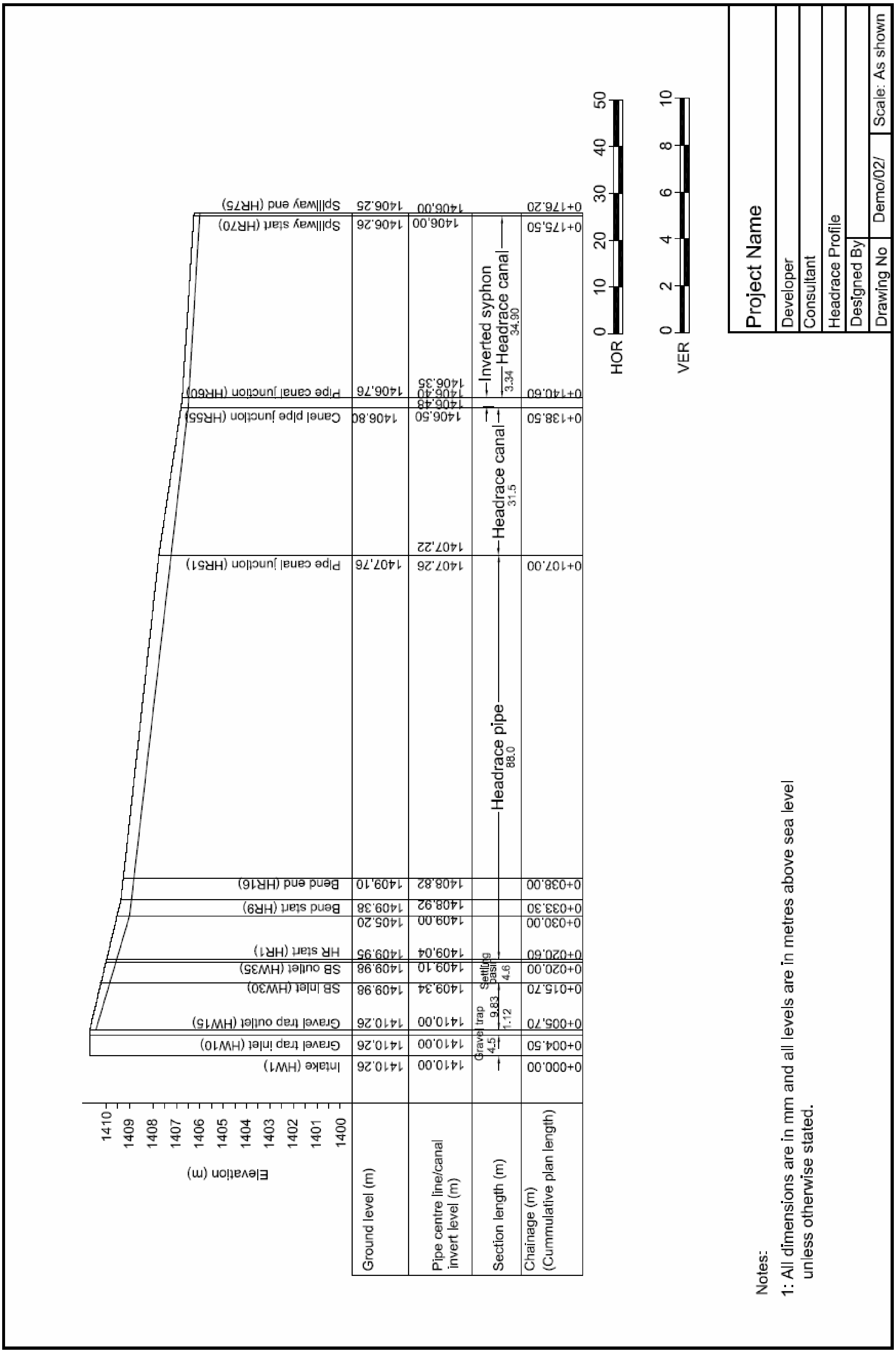
APPENDICES

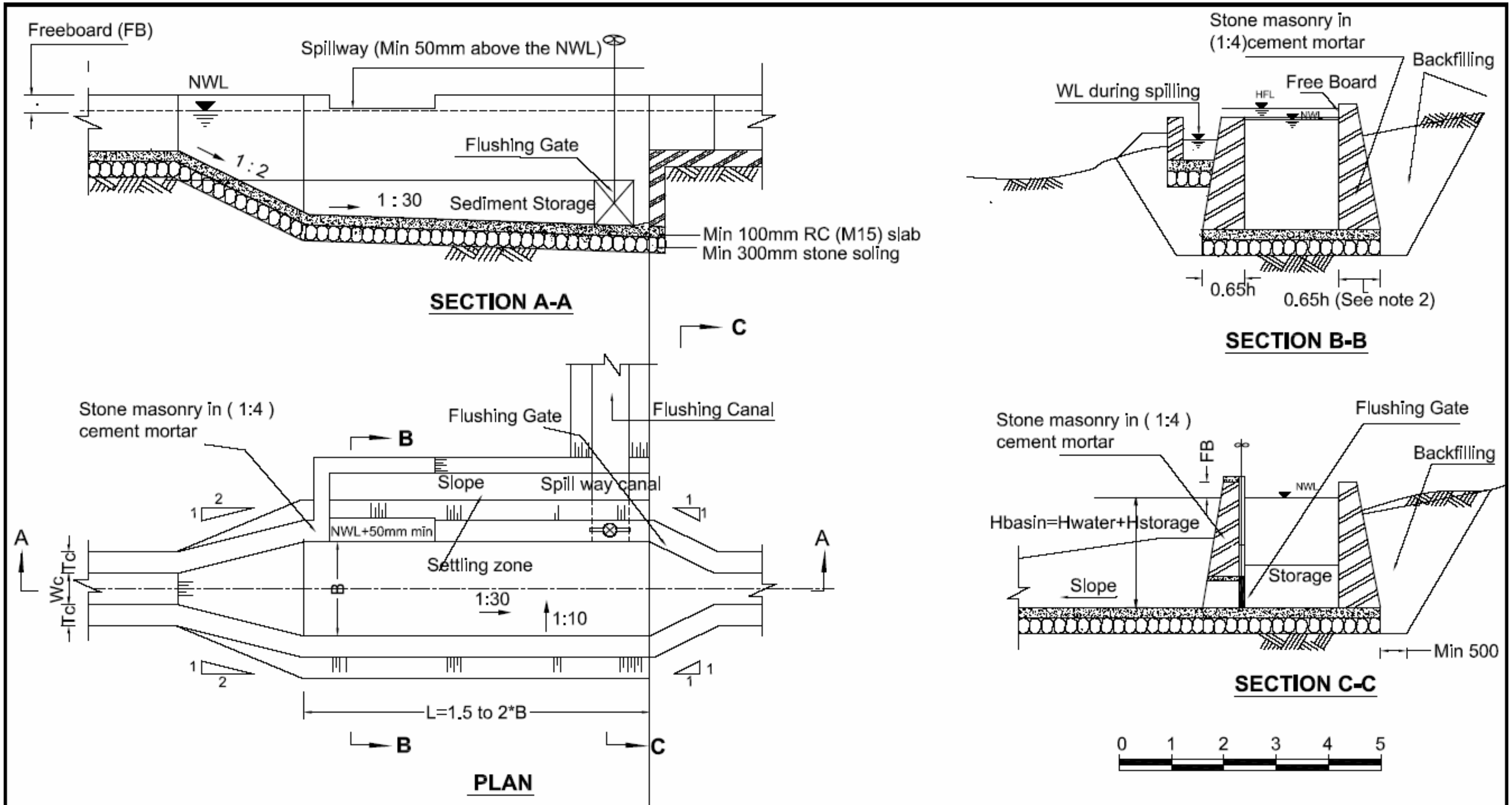

Weir
Spillway canal
Intake
Unlined canal
Orifice
Gravel trap cum desending basin
Lined canal (0.8*0.8)
To watermill & rice field
0.5 m dia HDPE pipe
Landslide
Lined canal (0.7*0.6)
Forebay tank
MS penstock pipe
Powerhouse
Tailrace
River/Khola
0 1 2 3 4 5
<Project Name>
Developer
Consultant
General Layout
Designed By
Drawing No Demo/01/
Scale:


River / Khola
Gabion Protection
Gravel Flushing Gate
Spillway Canal
Spillway
Headrace Canal
Gravel Trap
1:30
1:50
CREST
Left flood wall
A
B
C
D
PLAN
0 1 2 3 4 5
Project Name
Developer
Consultant
Side Intake Plan
Designed By
Drawing No
Demo/03A/
Scale: As shown
Notes:
1: All dimensions are in mm and all levels are in metres above sea level unless otherwise stated.


Design Flood Level
Weir Crest
Normal river level
River bed
h rf
Coarse Trashrack
Orifice (H*B)
h sub
h bot
H
Hr
Compacted earth/200mm stone soling
Gravel trap (if needed)
1:30
Gravel Flushing Gate
Min 100 thick & 1000 wide walkway Rcc slab
hd
hr-hc
hc
Canal
LS
Fb
SECTION A-A
See Note -3
Weir Crest (see note 2)
bc
Stone masonry temporary weir
1m min
B
SECTION B-B (Temporary Weir)
Stone Masonry (1:4)
Weir Crest
200th. RC (1:1.5:3) T12@200c/c bothways (Optional)
See Note - 3
45°
d2
SECTION B-B (Permanent Weir)
Backfilling
Excavation
SECTION C-C
Notes:
1: All dimensions are in mm and all levels are in metres above sea level unless otherwise stated.
2: The weir crest of temporary weir level should be at least 200mm above NWL.
3: The U/S slope of weir should be minimum of 1V:3H if bed load flushing during floods is anticipated.
0 1 2 3 4 5
Project Name
Developer
Consultant
Side Intake -Sections
Designed By
Drawing No
Demo/03B/
Scale: As shown


River Khola
Crest
Weir
B
B
Drop Intake
A
A
To headrace
PLAN
Scale A
See Note - 3
Stone Masonry (1:4)
Weir Crest
200th. RC (1:1.5:3)
T12@200c/c bothways
d2
1m min
1m min
1m min
45°
45°
SECTION B-B
Scale B
See Note
L'
SECTION A-A
Scale B
Notes:
1: All dimensions are in mm and all levels are in metres above sea level unless otherwise stated.
2: Steel lining may be required for bigger dischagres with bigger openings.
0 4 8 12 16 20
Scale A
0 1 2 3 4 5
Scale B
Project Name
Developer
Consultant
Drop Intake Plan
Design By
Drawing No
Demo/04/
Scale: As Shown


Elevation (m)
1410
1409
1408
1407
1406
1405
1404
1403
1402
1401
1400
Ground level (m)
Pipe centre line/canal invert level (m)
Section length (m)
Chainage (m) (Cummulative plan length)
Intake (HW1)
Gravel trap inlet (HW10)
Gravel trap outlet (HW15)
SB inlet (HW30)
SB outlet (HW35)
HR start (HR1)
Bend start (HR9)
Bend end (HR16)
Pipe canal junction (HR51)
Canal pipe junction (HR55)
Pipe canal junction (HR60)
Spillway start (HR70)
Spillway end (HR75)
Gravel trap
Settling basin
Headrace pipe
Headrace canal
Inverted syphon
HOR
VER
Notes:
1: All dimensions are in mm and all levels are in metres above sea level unless otherwise stated.
Project Name
Developer
Consultant
Headrace Profile
Designed By
Drawing No
Demo/02/
Scale: As shown

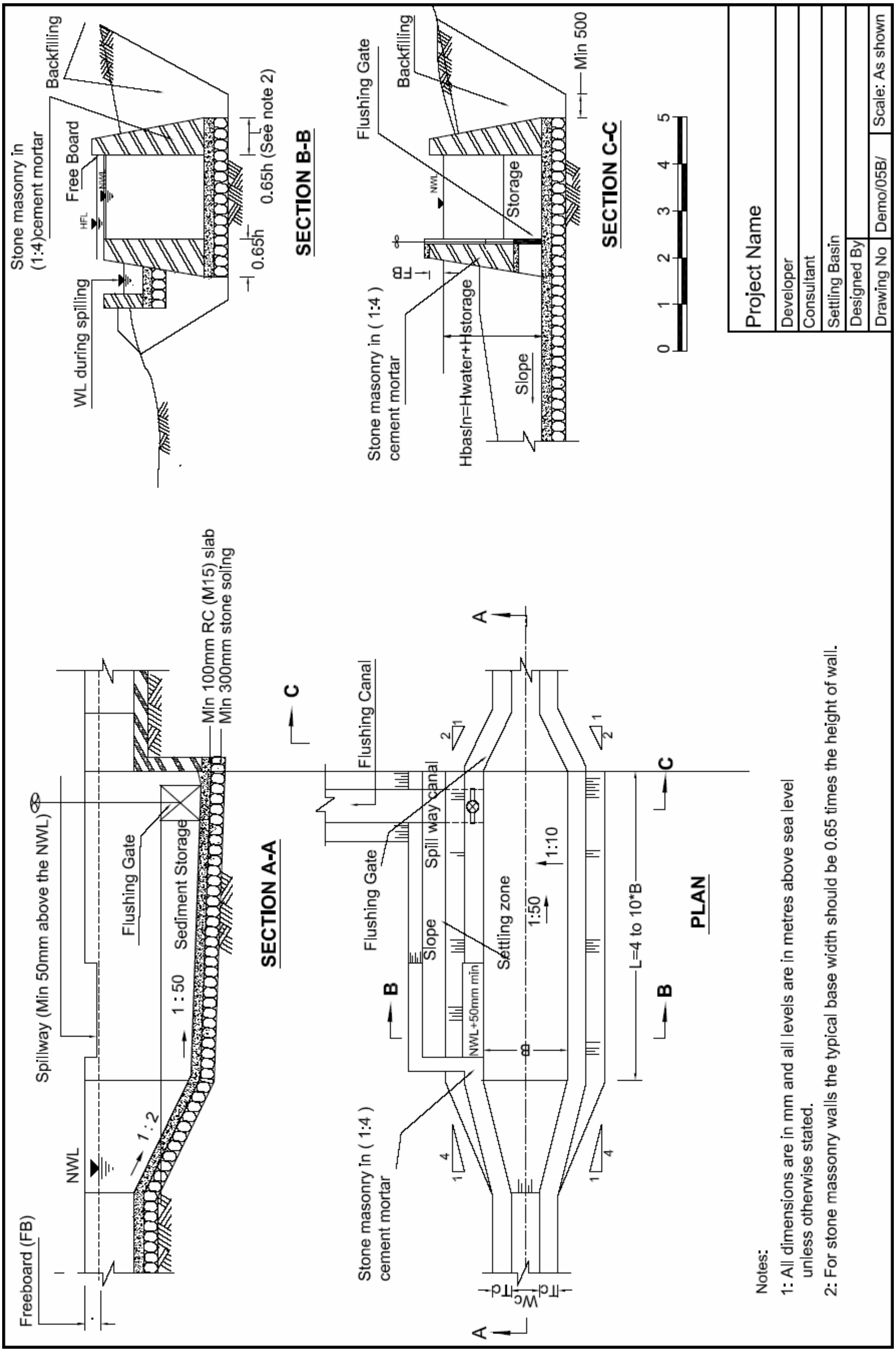


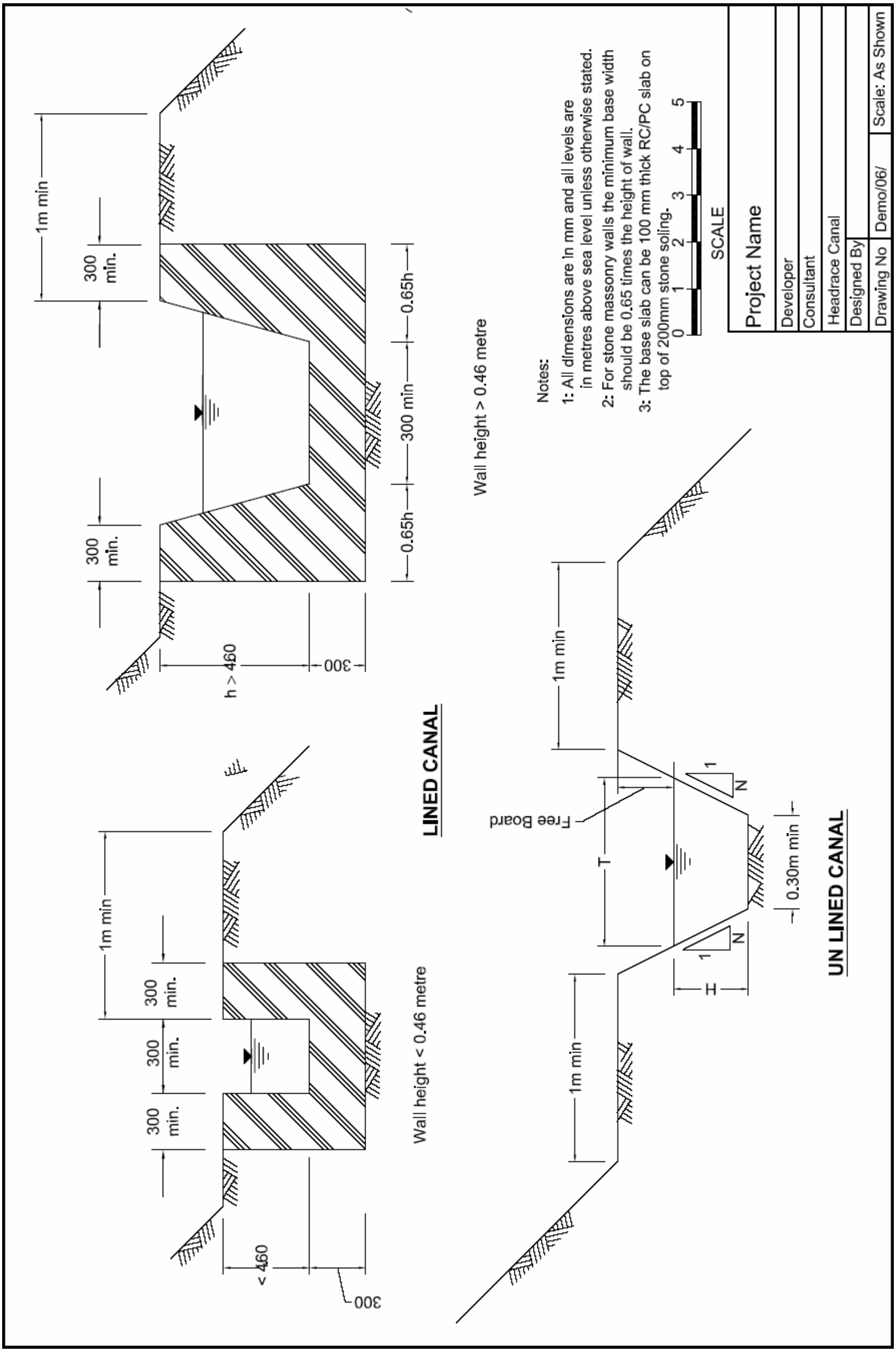
Notes:

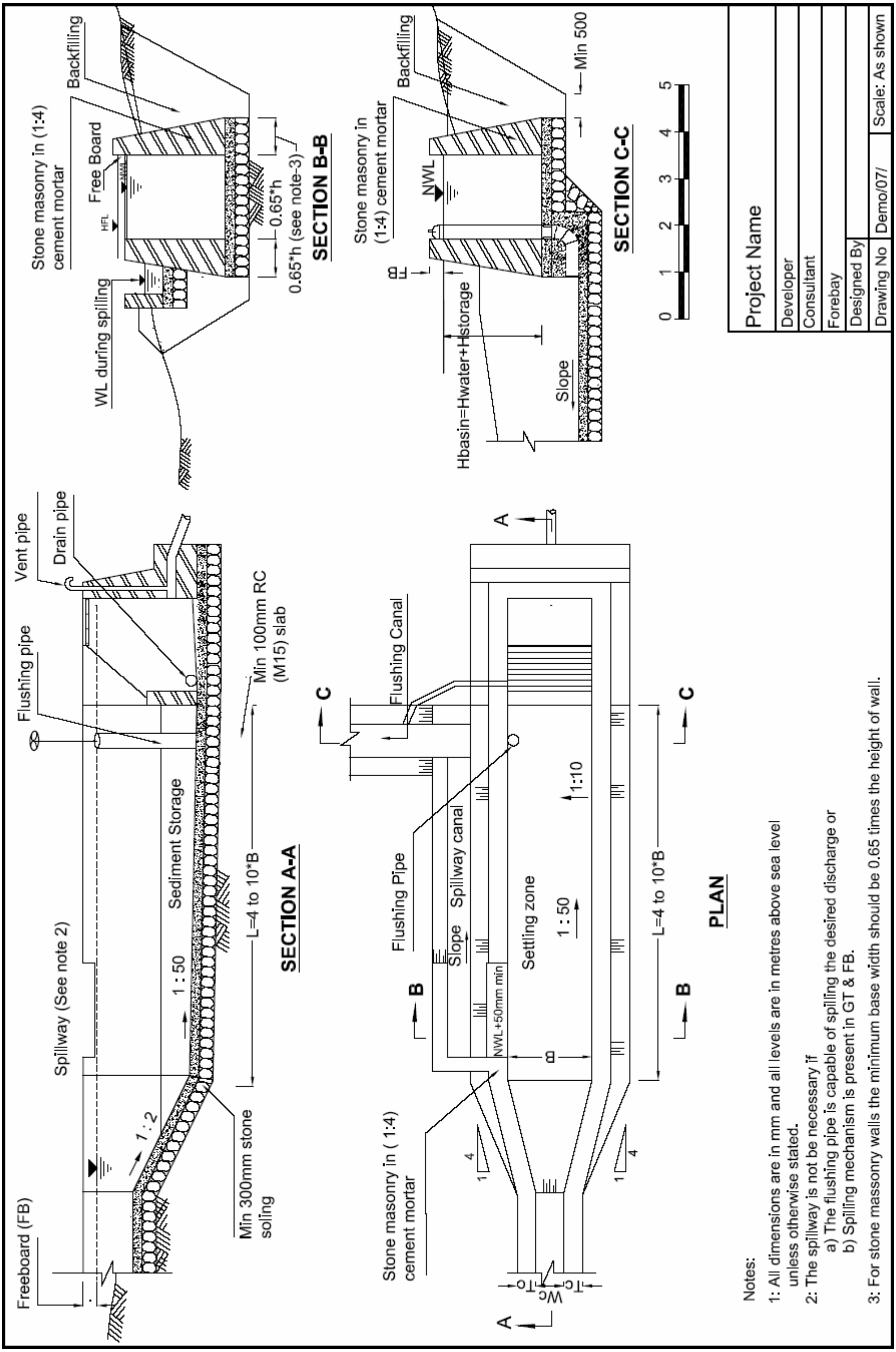
1: All dimensions are in mm and all levels are in metres above sea level unless otherwise stated.

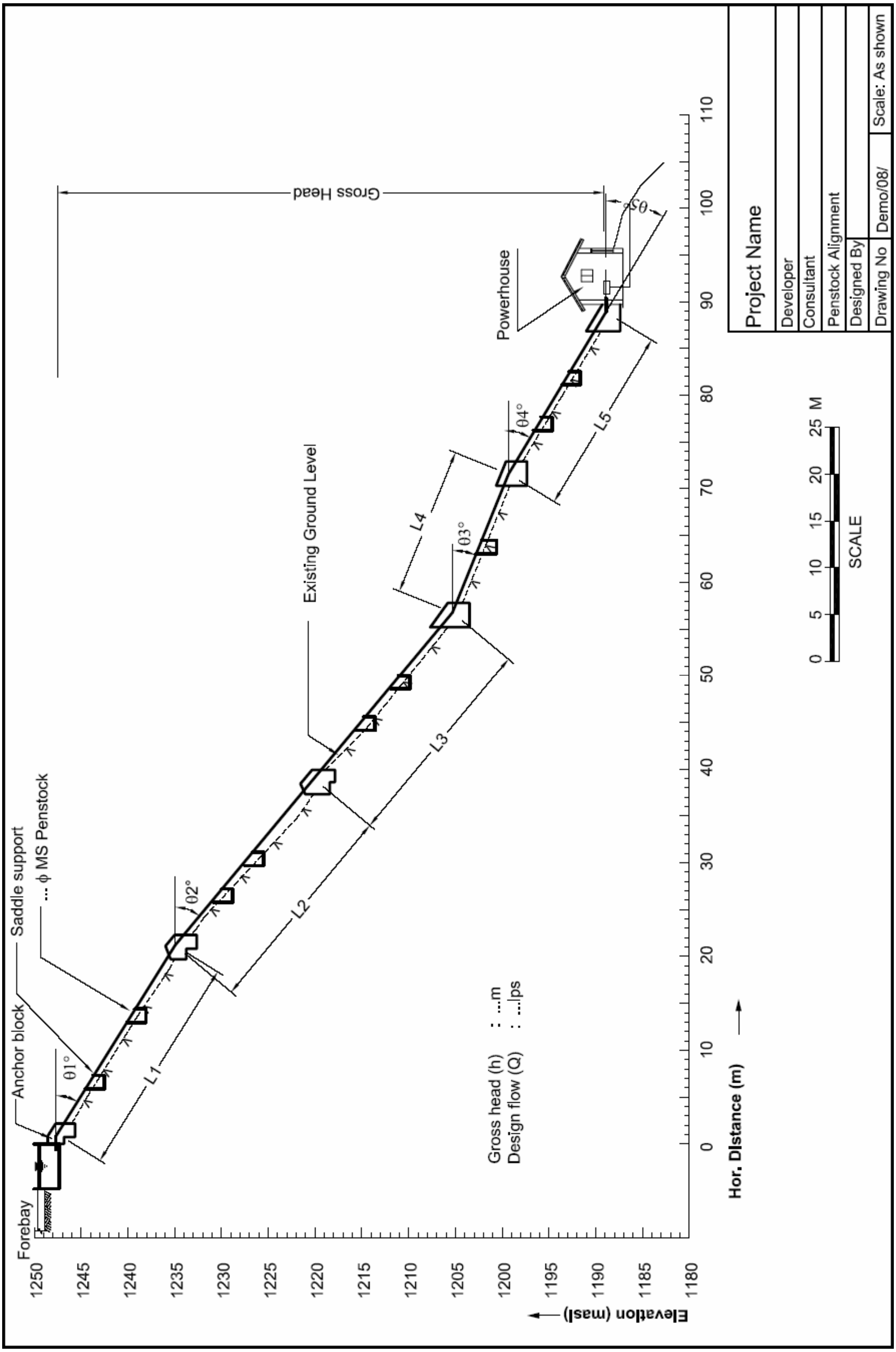
2: For stone massonry walls the typical base width should be 0.65 times the height of wall.

Project Name		
Developer		
Consultant		
Gravel Trap		
Designed By		
Drawing No	Demo/05A/	Scale: As shown

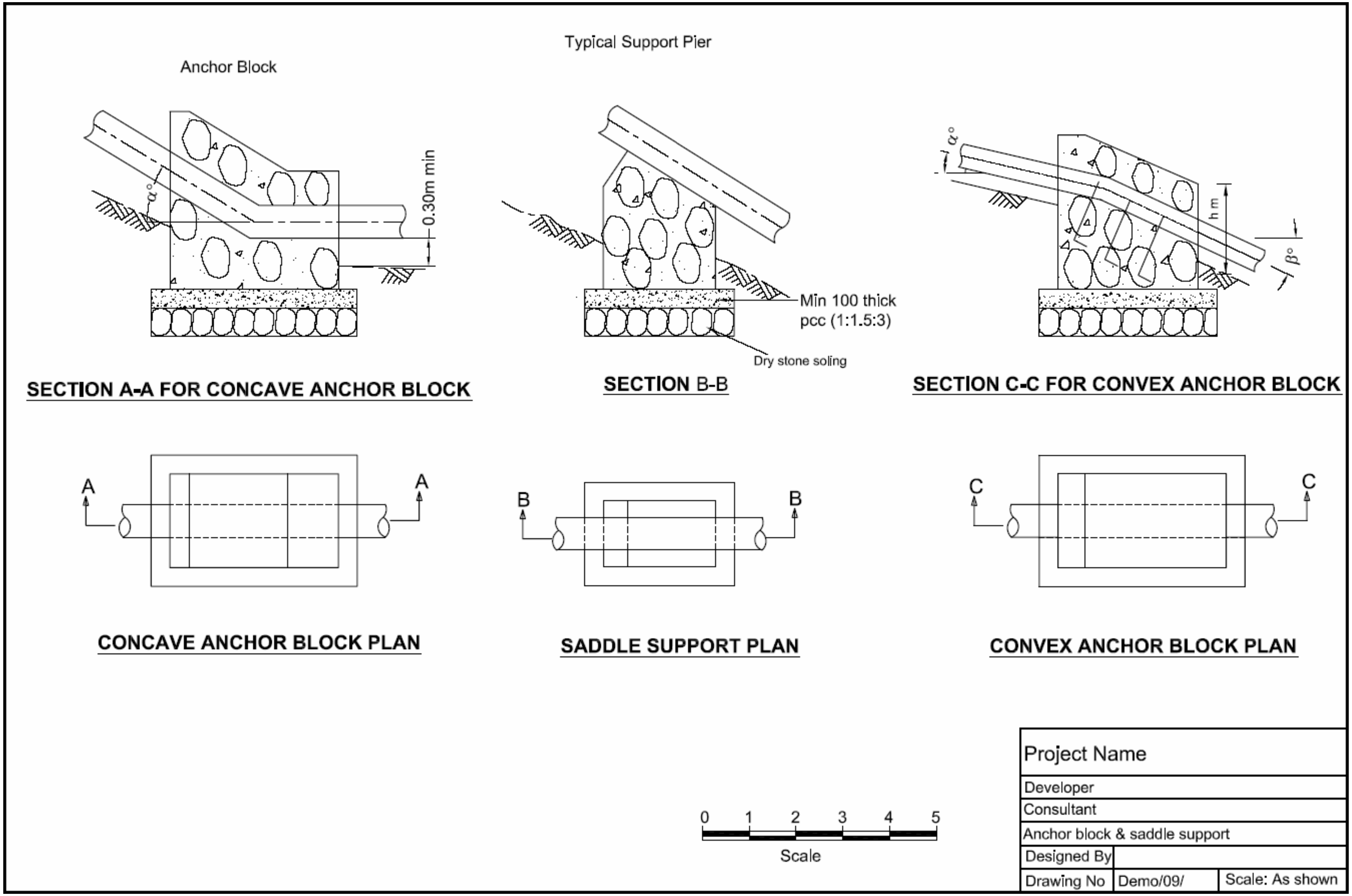

Freeboard (FB)
NWL
1 : 2
1 : 50
Spillway (Min 50mm above the NWL)
Flushing Gate
Sediment Storage
Min 100mm RC (M15) slab
Min 300mm stone soling
SECTION A-A
Stone masonry in (1:4) cement mortar
Flushing Gate
Slope
Spill way canal
Flushing Canal
NWL+50mm min
Settling zone
1:50
1:10
B
L=4 to 10*B
PLAN
A
B
C
Wc
Td
WL during spilling
Stone masonry in (1:4)cement mortar
HFL
NWL
Free Board
Backfilling
0.65h
0.65h (See note 2)
SECTION B-B
Stone masonry in (1:4) cement mortar
Hbasin=Hwater+Hstorage
FB
Slope
Storage
Flushing Gate
Backfilling
Min 500
SECTION C-C
0 1 2 3 4 5
Project Name
Developer
Consultant
Settling Basin
Designed By
Drawing No Demo/05B/
Scale: As shown
Notes:
1: All dimensions are in mm and all levels are in metres above sea level unless otherwise stated.
2: For stone massonry walls the typical base width should be 0.65 times the height of wall.

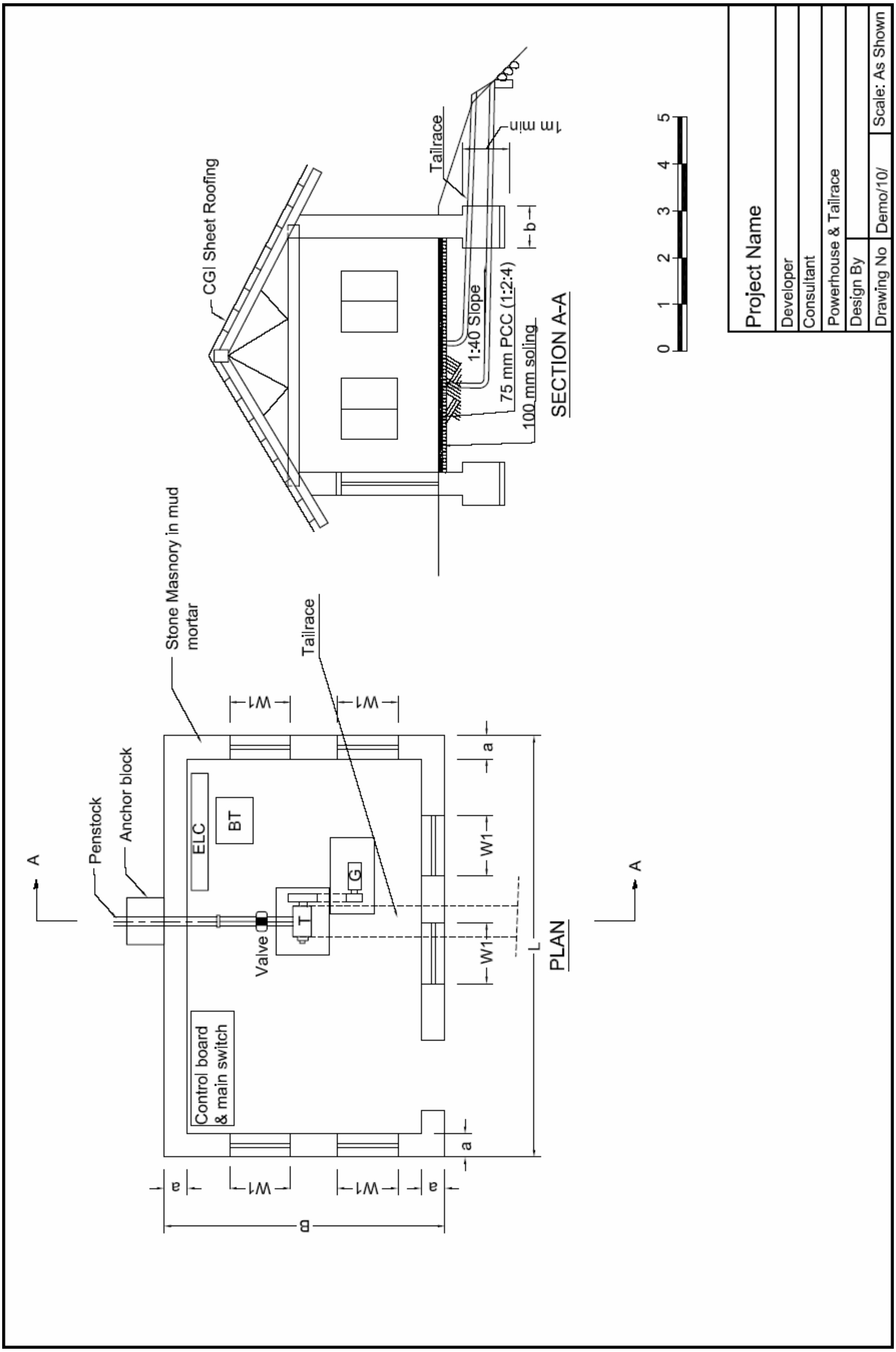

LINED CANAL
Wall height < 0.46 metre
300 min.
300 min.
300 min.
1m min
< 460
300
Wall height > 0.46 metre
h > 460
300
0.65h
300 min
0.65h
300 min.
300 min.
1m min
UN LINED CANAL
Free Board
T
1
N
H
0.30m min
1m min
1m min
Notes:
1: All dimensions are in mm and all levels are in metres above sea level unless otherwise stated.
2: For stone massonry walls the minimum base width should be 0.65 times the height of wall.
3: The base slab can be 100 mm thick RC/PC slab on top of 200mm stone soling.
0 1 2 3 4 5
SCALE
Project Name
Developer
Consultant
Headrace Canal
Designed By
Drawing No Demo/06/
Scale: As Shown

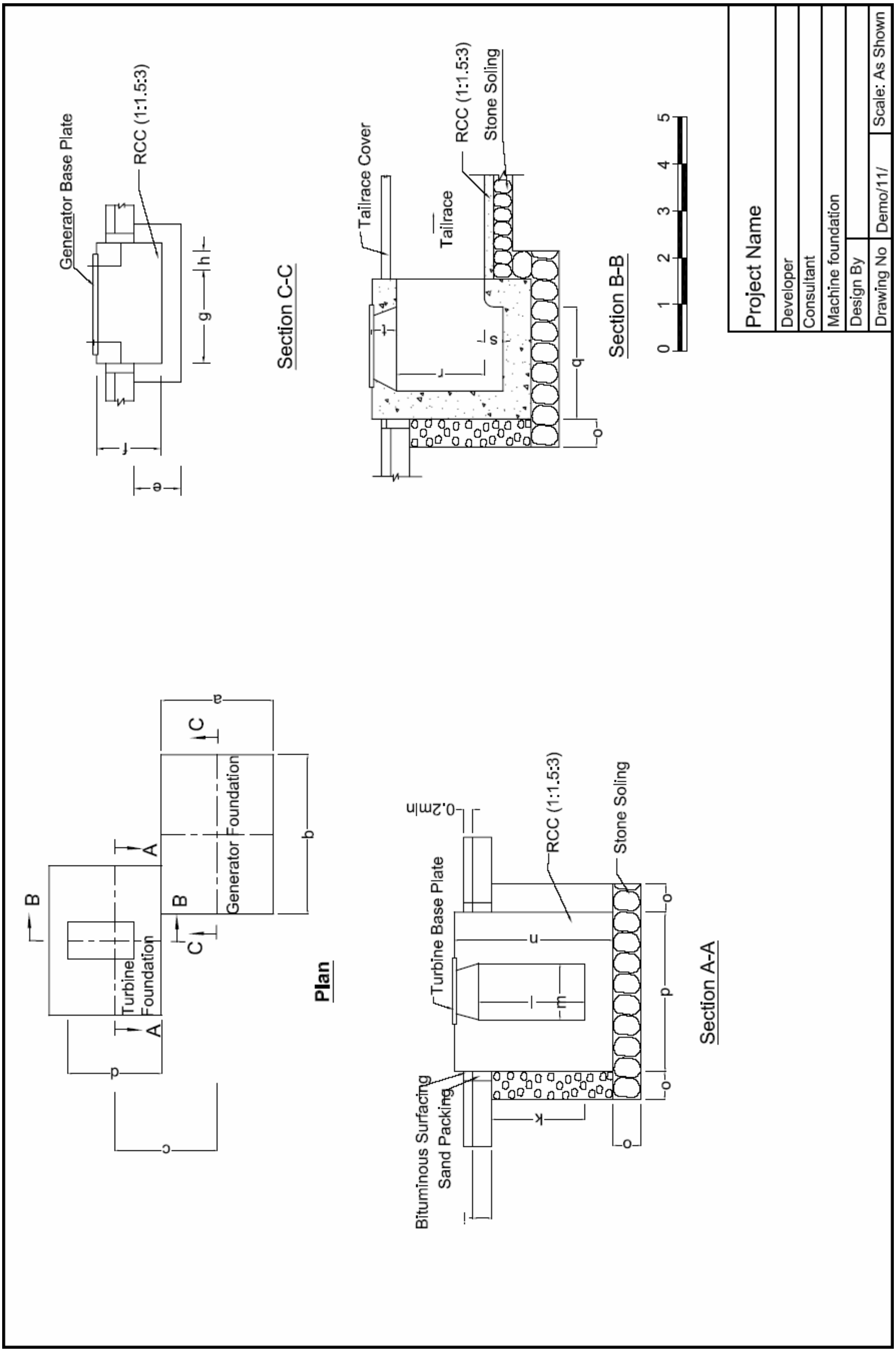

Stone masonry in (1:4) cement mortar
Backfilling
Free Board
HFL
NWL
WL during spilling
0.65*h
0.65*h (see note-3)
SECTION B-B
Stone masonry in (1:4) cement mortar
Backfilling
Min 500
NWL
FB
Hbasin=Hwater+Hstorage
Slope
SECTION C-C
0 1 2 3 4 5
Project Name
Developer
Consultant
Forebay
Designed By
Drawing No Demo/07/
Scale: As shown
Vent pipe
Drain pipe
Flushing pipe
Min 100mm RC (M15) slab
Sediment Storage
Spillway (See note 2)
1 : 50
1 : 2
L=4 to 10*B
SECTION A-A
Freeboard (FB)
Min 300mm stone soling
C
Flushing Canal
Flushing Pipe
Spillway canal
Slope
Settling zone
1:10
1 : 50
NWL+50mm min
B
L=4 to 10*B
PLAN
Stone masonry in (1:4) cement mortar
4
1
A
Tc
Wc
Notes:
1: All dimensions are in mm and all levels are in metres above sea level unless otherwise stated.
2: The spillway is not be necessary if
a) The flushing pipe is capable of spilling the desired discharge or
b) Spilling mechanism is present in GT & FB.
3: For stone massonry walls the minimum base width should be 0.65 times the height of wall.

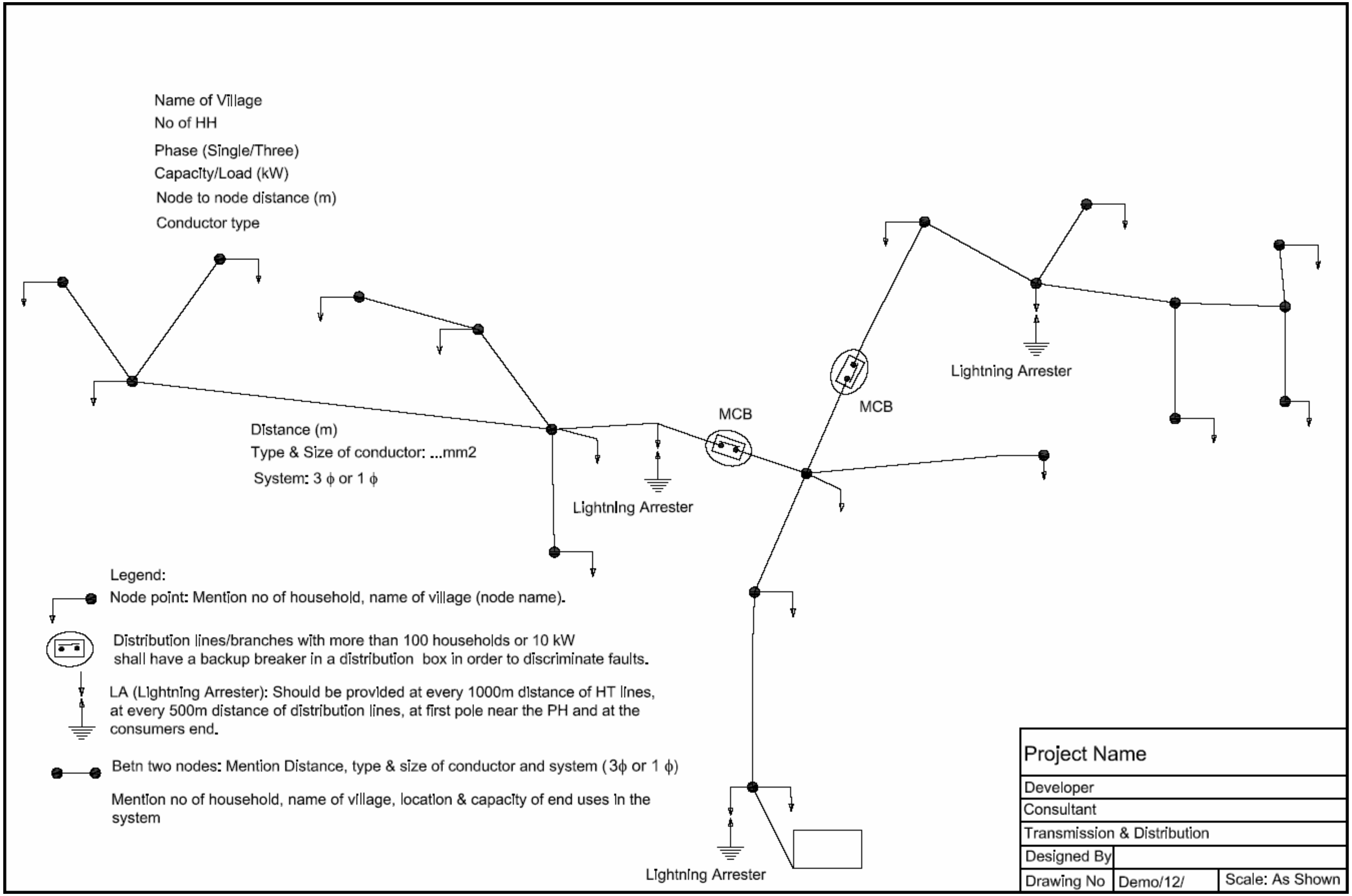


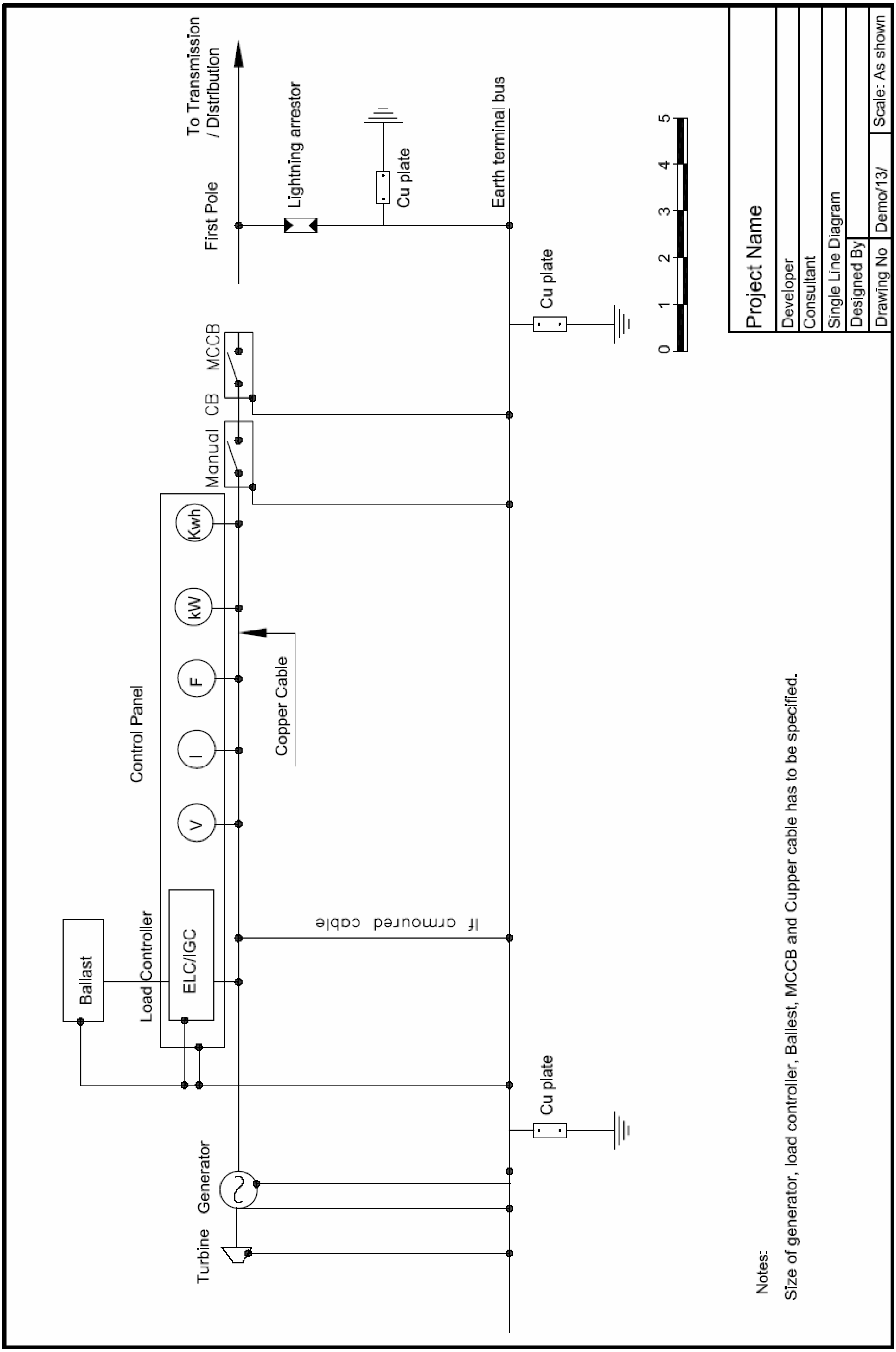
Forebay
Anchor block
Saddle support
... φ MS Penstock
θ1°
θ2°
θ3°
θ4°
θ5°
L1
L2
L3
L4
L5
Existing Ground Level
Powerhouse
Gross Head
Gross head (h) : ...m
Design flow (Q) : ...lps
Elevation (masl)
Hor. Distance (m)
SCALE
0 5 10 15 20 25 M
Project Name
Developer
Consultant
Penstock Alignment
Designed By
Drawing No Demo/08/
Scale: As shown

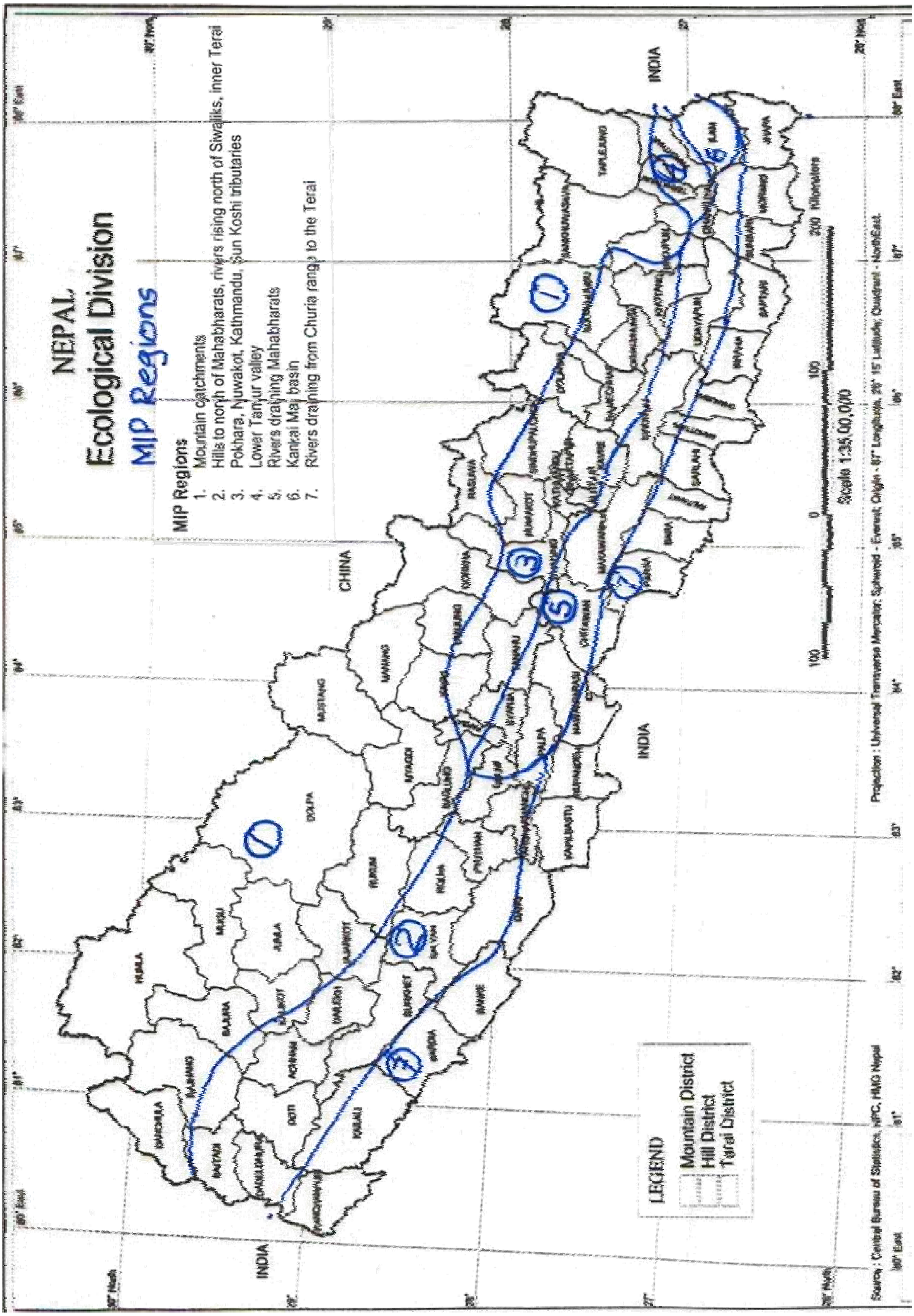

Typical Support Pier
Anchor Block
0.30m min
α°
Min 100 thick
pcc (1:1.5:3)
Dry stone soling
h m
β°
SECTION A-A FOR CONCAVE ANCHOR BLOCK
SECTION B-B
SECTION C-C FOR CONVEX ANCHOR BLOCK
A
B
C
CONCAVE ANCHOR BLOCK PLAN
SADDLE SUPPORT PLAN
CONVEX ANCHOR BLOCK PLAN
0 1 2 3 4 5
Scale
Project Name
Developer
Consultant
Anchor block & saddle support
Designed By
Drawing No
Demo/09/
Scale: As shown

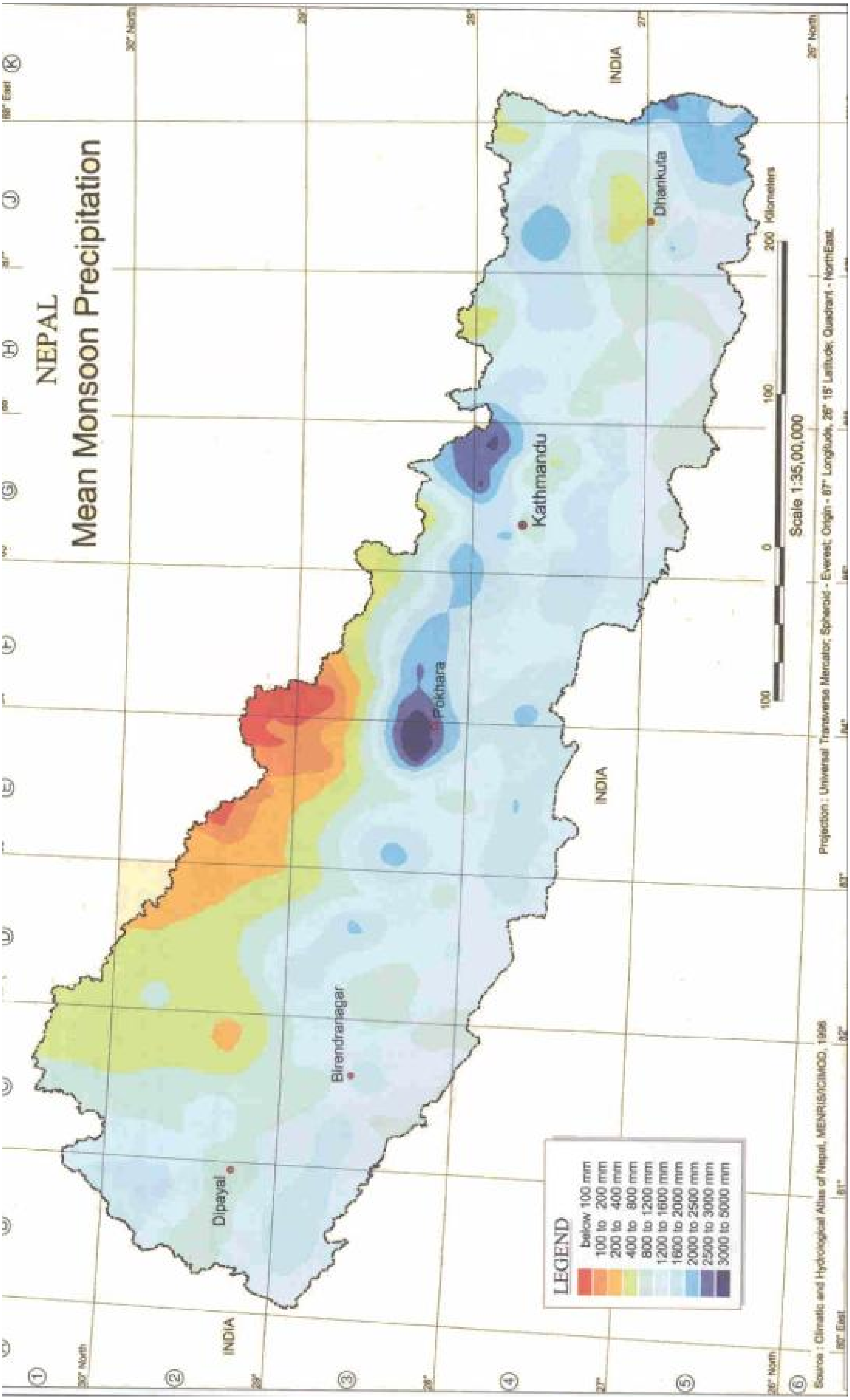

Stone Masnory in mud mortar
Penstock
Anchor block
Tailrace
ELC
BT
G
T
Valve
Control board & main switch
W1
a
L
B
A
PLAN
CGI Sheet Roofing
Tailrace
1m min
b
1:40 Slope
75 mm PCC (1:2:4)
100 mm soling
SECTION A-A
0 1 2 3 4 5
Project Name
Developer
Consultant
Powerhouse & Tailrace
Design By
Drawing No
Demo/10/
Scale: As Shown


Generator Base Plate
RCC (1:1.5:3)
Section C-C
Tailrace Cover
Tailrace
RCC (1:1.5:3)
Stone Soling
Section B-B
0 1 2 3 4 5
Project Name
Developer
Consultant
Machine foundation
Design By
Drawing No
Demo/11/
Scale: As Shown
Turbine Foundation
Generator Foundation
Plan
Turbine Base Plate
RCC (1:1.5:3)
Stone Soling
0.2m
Bituminous Surfacing
Sand Packing
Section A-A


Name of Village
No of HH
Phase (Single/Three)
Capacity/Load (kW)
Node to node distance (m)
Conductor type
Distance (m)
Type & Size of conductor: ...mm2
System: 3 ϕ or 1 ϕ
Lightning Arrester
MCB
MCB
Lightning Arrester
Lightning Arrester
Legend:
Node point: Mention no of household, name of village (node name).
Distribution lines/branches with more than 100 households or 10 kW shall have a backup breaker in a distribution box in order to discriminate faults.
LA (Lightning Arrester): Should be provided at every 1000m distance of HT lines, at every 500m distance of distribution lines, at first pole near the PH and at the consumers end.
Betn two nodes: Mention Distance, type & size of conductor and system (3ϕ or 1 ϕ)
Mention no of household, name of village, location & capacity of end uses in the system
Project Name
Developer
Consultant
Transmission & Distribution
Designed By
Drawing No
Demo/12/
Scale: As Shown


To Transmission
/ Distribution
First Pole
Lightning arrestor
Cu plate
Earth terminal bus
0 1 2 3 4 5
Project Name
Developer
Consultant
Single Line Diagram
Designed By
Drawing No Demo/13/
Scale: As shown
MCCB
Manual CB
Kwh
kW
F
I
V
Control Panel
Copper Cable
Cu plate
Ballast
Load Controller
ELC/IGC
If armoured cable
Cu plate
Turbine Generator
Notes:
Size of generator, load controller, Ballest, MCCB and Cupper cable has to be specified.


NEPAL
Ecological Division
MIP Regions
MIP Regions
1. Mountain catchments
2. Hills to north of Mahabharats, rivers rising north of Siwaliks, inner Terai
3. Pokhara, Nuwakot, Kathmandu, Sun Koshi tributaries
4. Lower Tamur valley
5. Rivers draining Mahabharats
6. Kankai Mai basin
7. Rivers draining from Churia range to the Terai
CHINA
INDIA
INDIA
INDIA
LEGEND
Mountain District
Hill District
Terai District
Scale 1:35,00,000
200 Kilometers

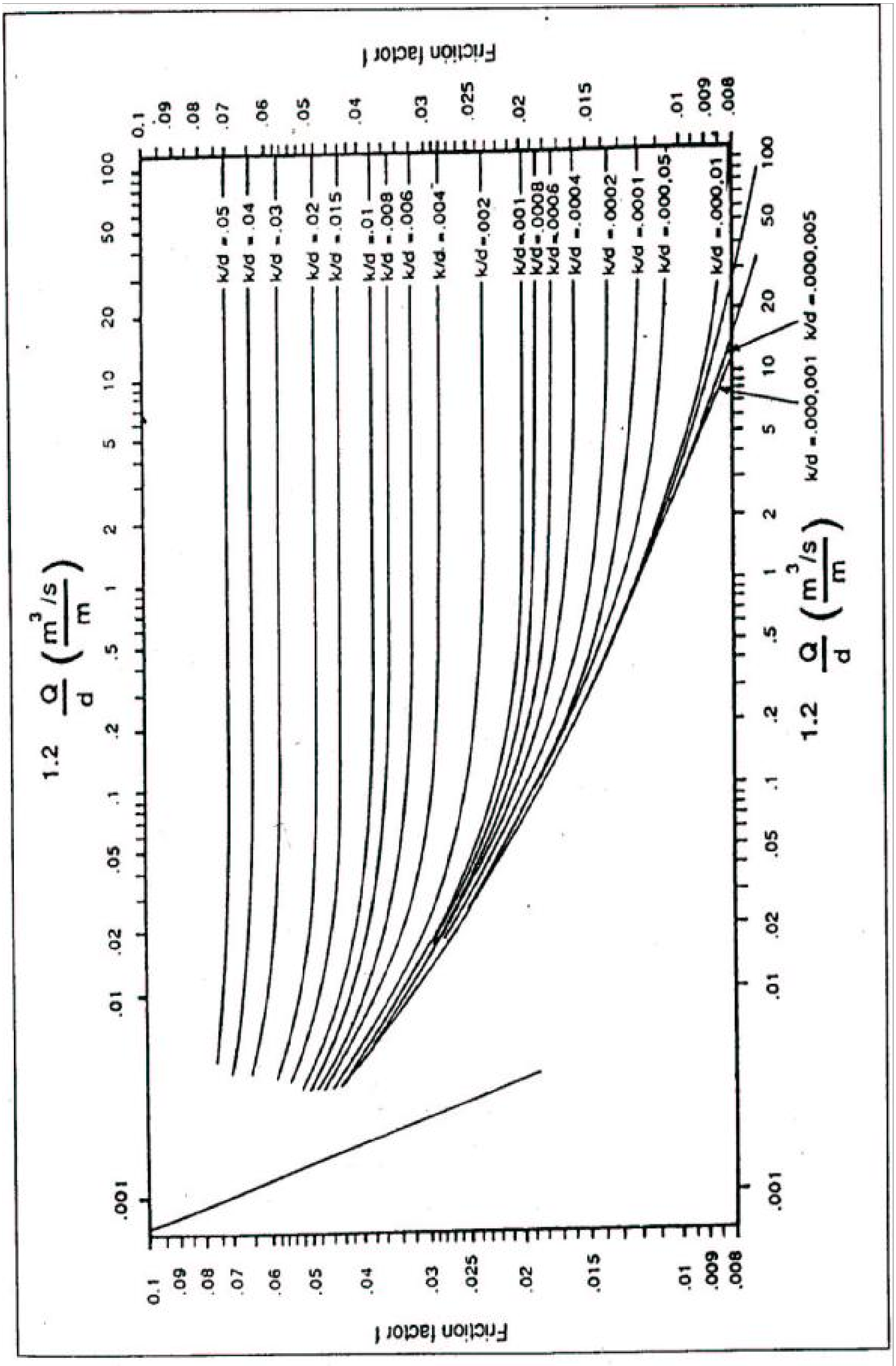

NEPAL
Mean Monsoon Precipitation
LEGEND
below 100 mm
100 to 200 mm
200 to 400 mm
400 to 800 mm
800 to 1200 mm
1200 to 1600 mm
1600 to 2000 mm
2000 to 2500 mm
2500 to 3000 mm
3000 to 5000 mm
Dipayal
Birendranagar
Pokhara
Kathmandu
Dhankuta
INDIA
Scale 1:35,00,000
Kilometers
Source : Climatic and Hydrological Atlas of Nepal, MENRIS/ICIMOD, 1996

Month	**Regions**						
	1	2	3	4	5	6	7
January	2.40	2.24	2.71	2.59	2.42	2.03	3.30
February	1.80	1.70	1.88	1.88	1.82	1.62	2.20
March	1.30	1.33	1.38	1.38	1.36	1.27	1.40
April	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
May	2.60	1.21	1.88	2.19	0.91	2.57	3.50
June	6.00	7.27	3.13	3.75	2.73	6.08	6.00
July	14.50	18.18	13.54	6.89	11.21	24.32	14.00
August	25.00	27.27	25.00	27.27	13.94	33.78	35.00
September	16.50	20.91	20.83	20.91	10.00	27.03	24.00
October	8.00	9.09	10.42	6.89	6.52	6.08	12.00
November	4.10	3.94	5.00	5.00	4.55	3.38	7.50
December	3.10	3.03	3.75	3.44	3.33	2.57	5.00

Roughness values, k mm

Use **'normal condition'** for design purposes

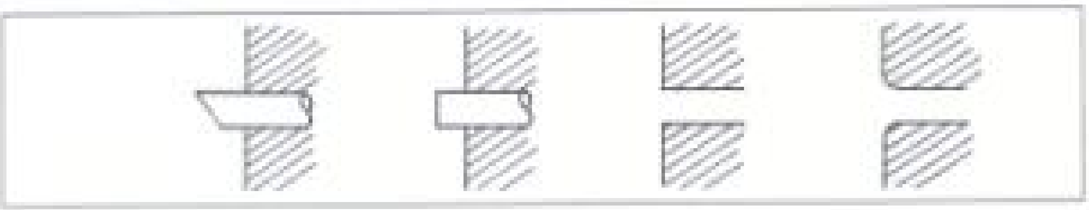
Material		**Age/condition**		
		Good (< 5 years)	Normal (5-15 years)	Poor (>15 years)
Smooth pipes PVC, HDPE, MDPE, Glass fibre		0.003	0.01	0.05
Concrete		0.06	0.15	1.5
Mild steel	- Uncoated	0.01	0.1	0.5
	- Galvanized	0.06	0.15	0.3
Cast iron New		0.15	0.3	0.6
Old	- Slight corrosion	0.6	1.5	3.0
	- Moderate corrosion	1.5	3.0	6.0
	- Severe corrosion	6.0	10.0	20.0



Friction factor f
1.2 Q/d (m^3/s / m)
k/d = .05
k/d = .04
k/d = .03
k/d = .02
k/d = .015
k/d = .01
k/d = .008
k/d = .006
k/d = .004
k/d = .002
k/d = .001
k/d = .0008
k/d = .0006
k/d = .0004
k/d = .0002
k/d = .0001
k/d = .000,05
k/d = .000,01
k/d = .000,005
k/d = .000,001

Head loss coefficient for intakes ($K_{entrance}$)

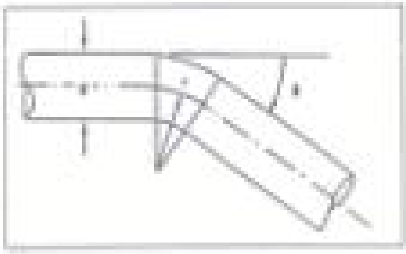
Entrance profile



$K_{entrance}$	1.0	0.8	0.5	0.2

Head loss coefficients for bends (K_{bend})

Bend profile

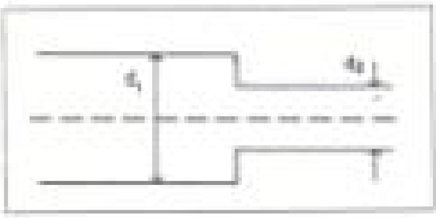


r/d	1	2	3	5	MITRED*
K_{bend} ($\theta = 20°$)	0.20	0.15	0.12	0.10	0.10
K_{bend} ($\theta = 45°$)	0.40	0.30	0.25	0.20	0.22
K_{bend} ($\theta = 90°$)	0.75	0.50	0.40	0.30	0.45

*Mitred bends with r/d = 1.5, maximum 30° per mitred joint

Head loss coefficients for sudden contractions ($K_{contraction}$)

Contraction profile



d_1/d_2	1.0	1.5	2.0	2.5	5.0
$K_{contraction}$	0	0.25	0.35	0.40	0.50

Head loss coefficients for valves (K_{valve})

TYPE OF VALVE	SPHERICAL	GATE	BUTTERFLY
K_{valve}	0	0.1	0.3