Assessment Methods for Small-hydro Projects

IEA Technical Report

IEA Hydropower Agreement

CANADA CHINA FINLAND FRANCE JAPAN NORWAY SPAIN SWEDEN UNITED KINGDOM

OVERVIEW OF THE IEA IMPLEMENTING AGREEMENT FOR HYDROPOWER TECHNOLOGIES AND PROGRAMMES

The Hydropower Implementing Agreement is a collaborative programme among nine countries: Canada, China, Finland, France, Japan, Norway, Spain, Sweden and the United Kingdom. These countries are represented by various organizations including electric utilities, government departments and regulatory organizations, electricity research organizations, and universities. The overall objective is to improve both technical and institutional aspects of the existing hydropower industry, and to increase the future deployment of hydropower in an environmentally and socially responsible manner.

HYDROPOWER

Hydropower is the only renewable energy technology which is presently commercially viable on a large scale. It has four major advantages: it is renewable, it produces negligible amounts of greenhouse gases, it is the least costly way of storing large amounts of electricity, and it can easily adjust the amount of electricity produced to the amount demanded by consumers. Hydropower accounts for about 17 % of global generating capacity, and about 20 % of the energy produced each year.

ACTIVITIES

Four tasks are operational, they are: 1. upgrading of hydropower installations, 2. small scale hydropower, 3. environmental and social impacts of hydropower, and 4. training in hydropower. Most tasks have taken about five years to complete, they started in March 1994 and the results will be available in May 2000. To date, the work and publications of the Agreement have been aimed at professionals in the respective fields.

UPGRADING

The upgrading of existing hydropower installations is by far the lowest cost renewable energy available today. It can sometimes provide additional energy at less than one tenth the cost of a new project. One task force of the Agreement is studying certain technical issues related to upgrading projects.

SMALL SCALE HYDROPOWER

Advances in fully automated hydropower installations and reductions in manufacturing costs have made small scale hydropower increasingly attractive. The small scale hydropower task force will provide supporting information to facilitate the development of new projects.

ENVIRONMENTAL AND SOCIAL ISSUES

For some hydropower projects the environmental and social impacts have been the subject of vigorous debate. There is a need to communicate objective information to the public, so that countries can make good decisions with respect to hydropower projects. The environmental task force will provide such information on possible social and environmental impacts and on mitigation measures.

TRAINING

The availability of well-trained personnel is a key requirement in the hydropower sector. The training task force is concentrating on training in operations and maintenance, and planning of hydro power projects.

THE INTERNATIONAL ENERGY AGENCY – IMPLEMENTING AGREEMENT FOR HYDROPOWER TECHNOLOGIES AND PROGRAMMES

Assessment Methods for Small-hydro Projects

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Guidelines on Methodology for Hydroelectric Turbine Upgrading by Runner Replacement – 1998 (available to non-participants at a cost of US $ 1,000 per copy)

Guidelines on Methodology for the Upgrading of Hydroelectric Generators – to be completed in May 2000.

Guidelines on Methodology for the Upgrading of Hydropower Control Systems – to be completed in 2000.

SMALL SCALE HYDRO POWER TASK FORCE (ANNEX 2)

Small Scale Hydro Assessment Methodologies – to be completed in May 2000 (available to non-participants on request)

Research and Development Priorities for Small Scale Hydro Projects – to be completed in May 2000 (available to non-participants on request)

Financing Options for Small Scale Hydro Projects – to be completed in May 2000 (available to non-participants on request)

Global database on small hydro sites available on the Internet at:
www.small-hydro.com

ENVIRONMENT TASK FORCE (ANNEX 3)

Survey on Positive and Negative Environmental and Social Impacts and the Effects of Mitigation Measures in Hydropower Development – 2000 (available to non-participants on request)

A Comparison of the Environmental Impacts of Hydropower with those of Other Generation Technologies – 2000 (available to non-participants on request)

Legal Frameworks, Licensing Procedures, and Guidelines for Environmental Impact Assessments of Hydropower developments – 2000 (available to non-participants on request)

Hydropower and the Environment: Present Context and Guidelines for Future Action
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Guidelines for the Impact Management of Hydropower and Water Resources Projects – 2000 (available to non-participants on request)

EDUCATION AND TRAINING TASK FORCE (ANNEX 5)

(All of the following reports are available on the Internet at www.annexv.iea.org Some reports may consist of more than one volume.)

Summary of Results of the Survey of Current Education and Training Practices in Operation and Maintenance – 1998 (available to non-participants on request)

Development of Recommendations and Methods for Education and Training in Hydropower Operation and Maintenance - 2000 (available to non-participants on request)

Survey of Current Education and Training Practice in Hydropower Planning – 1998 (available to non-participants on request)

Structuring of Education and Training Programmes in Hydropower Planning, and Recommendations on Teaching Material and Reference Literature - 2000 (available to non-participants on request)

Guidelines for Creation of Digital Lectures – 2000 (available to non-participants on request)

Evaluation of tests – Internet Based Distance Learning – 2000 – (available to non-participants on request)

BROCHURE

A brochure for the general public is available. It is entitled "Hydropower – a Key to Prosperity in the Growing World", and can be found on the Internet (www.usbr.gov/power/data/data.htm) or it can be obtained from the Secretary (address on the inside back cover).

Acknowledgements

The contributions through the provision of software, comment and discussion from all of the institutions and companies mentioned in this report are gratefully acknowledged.

The following reviews of each program are the opinions of the writer and are not necessarily those of the International Energy Agency or other members of the Annex II group of the Hydropower Agreement.

1 Introduction

Small-scale hydro development is often fraught with difficulty. Because it involves diverting water from its natural course in most cases, problems often arise with riparian owners, fisheries, environment agencies, planning departments, licensing authorities, electrical utilities, wildlife protection societies and the general public. All of these have interests to be defended and the developer must expend time and money in preparing arguments and in finding the best solutions to objections. Unfortunately, the developer generally has a small resource and a prospective source of revenue that is inadequate to hire the necessary expertise in engineering and legislation to present his case fairly.

Over the last decade a variety of computer based assessment tools have been developed To address this problem and enable a prospective developer to make an initial assessment of the economic feasibility of a project before spending substantial sums of money. These range from simple first estimates to quite sophisticated programs. Civil engineers and hydrologists with the aid of grants from governments and institutions who wish to encourage renewable energy generation have developed most of these programs. The Kyoto Agreement of 1997 has helped to increase the need for such programs.

The object of these software programs is to find a rapid and reasonably accurate means of predicting the energy output of a particular hydro scheme. These predictions involve establishing the 'head' or vertical distance that water can be dropped, and the incidence, in time and magnitude, of the quantity of water to be used. The first of these is a relatively simple matter of physical measurement together with some hydraulic loss calculations concerning pipe materials and water velocities, etc. The second is much more difficult and it is this part of the problem that is most intractable. There are two main approaches, the flow duration curve (fdc) and the simulated streamflow (ssf) methods. Both methods are used in the programs described in this review.

In the fdc method, catchment characteristics are collected; e.g. area, monthly or annual rainfall, evaporation and soil type. These parameters are then used, through a water balance, to estimate the mean flow of the catchment and to select a typical fdc for the catchment from a range of approximately 30 dimensionless fdcs. This selection is based on a comparison of certain standardised hydrological statistics. With these established a synthesised fdc is drawn, residual flow superimposed and a value of rated discharge selected (by default, the mean flow). The program then suggests the type(s) of turbine to use and automatically calculates the annual energy for the type(s) selected.

The ssf approach, as used in the IMP program, uses recorded discharge data or a simulated run-off record synthesised by time-series analysis using weather data and topography if recored discharge data is missing. Based on this continuous discharge record, energy output may be calculated daily, or hourly if required. Additional benefits of this approach include flood frequency curves (though flood frequency is available from a fdc also) and indications of the time lengths of high and low flow periods. The other features of the fdc method are also available.

Generally there is no clear advantage apparent for either method. However, if a reliable long-term record exists, ideally 10 years, then the IMP method would be the most appropriate. In the absence of such a record, which is usually the case, the question then is whether the inaccuracies of time series simulation based only on weather and topography are greater or lesser than the inaccuracies of selecting an fdc on the basis of mean flow obtained by a water balance and a hydrological statistic (usually Q_{95}) .

For countries with dense networks of meteorological stations and long term statistics, such as the European countries that the HydrA program covers, the HydrA method looks appropriate.

The Canadian RETScreen™, still under development, is an fdc method, which promises to be a valuable addition to the range of available programs. RETScreen™ can be applied internationally, as can IMP. HydrA, on the other hand, applies only to the countries for which it is written as the program contains all of the meteorological data required for analysis.

The French programs Prophete and Peach depend on the transposition of hydrometric data from the nearest catchment areas for which records exist to the particular catchment under study. This data is corrected for area and, therefore, is the most likely source of error. Subsequent procedures tend to be based on the ssf method rather than the fdc method.

Many of the programs, particularly RETScreen™, incorporate costing and financial analysis modules. These are conventional in form, however, for the average user, they are extremely valuable and convenient. PEACH, the only commercially sold program, goes further and offers a design function for the whole project. However, this has not been reviewed as only a demonstration disc was available for this review.

IMP, RETScreen™, HydrA and Prophete are all available free of charge or at nominal cost to cover hardware and supply costs.

2 Report on Assessment of Small Hydro-electric Development at Existing Facilities, US Dept. of Interior. Water and Power Resources service July 1980

The methodology used in this report was to derive a flow-duration curve from observed flow data. It was assumed that the turbo-generator unit was capable of operating under all flow conditions and had constant efficiency over this range. Variation in tail-water levels was not taken into account. Average monthly heads were used to derive power-duration curves. This is a simple appraisal-only method and does not address the problem of the ungauged site.

Useful methods for evaluation of environmental considerations and social impact at small hydro sites are described in the report.

In 1991 a software version of assessment methods was issued by the US Dept. of known as HES. However, as the User Manual states "*The HES is not intended to provide accurate potential development factors for individual sites. It can be used to provide regional or state totals*.--" Energy (US DOE, 1991). The HES does however model local concerns affecting hydropower development when environmental, legal and institutional constraints to development are present.

HES is not a tool for the individual developer but may be valuable to users in the US. Its application elsewhere would be very limited.
Later versions of Hydropower Resource Assessment appeared in December, 1998 (US DOE, 1998)

Further information on these methods is available from: Idaho National Engineering Laboratory, P O Box 1625, Idaho Falls, ID 83415, U.S.A.

3 Civil Engineering Guidelines for Planning and Designing Hydroelectric Developments: ASCE Small Scale Hydro, Vol 4 (1989) USA

This guide describes the hydrologic analysis based on WATSTORE - the U.S.G.S.'s National Water Data Storage and Retrieval system. WATSTORE contains the entire historical record of all active and retired gauging stations in the U.S., together with computer programs and routines which can produce, inter alia, flow duration curves for any part, or all of the record.

If no record exists near to a proposed site, a streamflow record from a nearby gauge may be adjusted by reference to catchment area, topography, soils and precipitation pattern. The method lays emphasis on the need for tail-water rating curves for projects at in-stream dams.

The flow-duration curve method described for the calculation of power and energy is more sophisticated than previous citations and includes consideration of residual flow and minimum turbine flows but still uses average efficiencies for turbine, generator, transformer, etc. over the whole flow range.
The Guide's Chapter 8 (Environmental Mitigation and Facility Design) is a valuable introduction to those writing EIAs.

Available from: American Society of Civil Engineers, Publications Dept, 1801 Alexander Bell Drive, Reston, Virginia 20191-440, U.S.A.

4 Remote Small Hydro Reconnaissance Methodology Vol. 1 (1996), Ottawa Engineering Ltd, Canada

The hydrologic assessment uses a 'flow factor' for ungauged sites which is the ratio of the area of the ungauged catchment to that of a nearby gauged one for which records are available. These records are then multiplied by the flow factor to produce a synthetic record for the ungauged site.

The method does not take soil type or precipitation into account and should therefore only be used for a first approximation.

For further information on this method visit Ottawa Engineering Limited's website at www.ottawaengineering.com

5 IMP (4.0a) Integrated Method for Power Analysis (1999), Charles Howard & Associates Ltd and Natural Resources, Canada.

IMP is a tool for evaluating small scale hydroelectric power sites, developed by Charles Howard & Associates of Vancouver, Canada in association with Natural Resources, Canada.

With IMP, and the relevant meteorological and topographical data, an experienced user can evaluate an ungauged hydro site within about one day of office studies, including a power study, powerhouse and penstock optimisation, fish habitat analysis and development of a flood frequency curve.

IMP is a package of computer programs for small scale hydro projects and for other hydrological applications. It is useful to non-specialists exploring possibilities for small hydro development, for university teaching, and for consulting engineers who need preliminary estimates of flood frequency and energy potential. As would be expected, it is particularly designed for and applicable to Canada.

The software includes tips about hydrologic analysis of ungauged sites. Recorded streamflow data is not essential in that IMP uses topographic and daily weather data which the user inputs to perform flood frequency analysis and to synthesise hourly and daily stream flow and reservoir operations. This data may be acquired from within databases in the program for many sites in N. America or may be input directly by the user. Weighted useable area theory is used to assess stream habitat for fish. This module dealing with fish habitat, is innovative and most useful. The program also contains modules in which proposed power projects are optimised, based on the value of energy and the cost of construction.

Although the program summary describes the program as easy to use, it requires an experienced user to find his way about it. Its use would be greatly enhanced if a clearly written User Manual was available.

To given an impression of the scope and methodology of the program, print-outs of some of the example outputs are included in Appendix 1.

Further information on IMP may be obtained directly from Charles Howard & Associates Ltd, 239 Menzies St, Suite 210, Victoria B.C., V8V 2G6, Canada or www.chal.bc.ca

6 RETScreen™: Pre-feasibility Analysis Software (1999), Natural Resources, Canada: Canmet, Energy Diversification Research Lab.

The RETScreen™ small hydro project is one of a series of renewable energy analysis tools provided by Natural Resources Canada. It may be down-loaded free-of-charge from the Internet (subject to acceptance by the user of a licence agreement) at **http:// retscreen.gc.ca**. It is designed *"to help energy project proponents identify and evaluate, relatively quickly and at low cost, the most viable near-term opportunities for cost-effective RETs project implementation."*

This reviewer has down-loaded and used the small-hydro software. However, in reading the comments which follow it is important to bear in mind that the program is designed for Canadian use, particularly in remote communities and a non-Canadian reviewer is commenting from an international standpoint. However, the latest version of the hydro program within RETScreen™ is designed to be of more universal application.

The version used for this review was RETScreen™ 99-Beta version. This is currently being upgraded to include further financial analysis and foreign currencies to allow its use in different countries. This upgraded hydro program is expected to be released in October 2000 and will be called RETScreen™ 2000.

Down-loading from the Internet

This process is only possible for RETScreen™ 99 or RETScreen™ 2000, for users with Microsoft Excel 97 or higher Once the program is available on the user's hard disk, it is straightforward to use. It is divided into five modules - Energy, Hydrology and Load Calculation, Equipment Data, Cost Analysis and Financial Analysis.

Energy, Hydrology & Load Calculation, Equipment Data

A review of these three modules in the 99-Beta version has prompted the following comments:

- The energy model is presented first, although its logical position would be after Hydrology, Load and Equipment Data.
- The Hydrology analysis offers user-input of residual flow and a specific flow duration curve in both tabular and graphic form. However, it does tell the user the mean flow which he needs to estimate the design turbine flow.
- Hydrology parameters listed include "*Firm flow*" which is "*generally defined as the flow available at least 95% of the time*". This value is recognised internationally as Q_{95}.
- The Equipment Data module offers the user the opportunity to input turbine efficiency v % rated flow for particular turbine types, which is a useful procedure as the default values are optimistic.
- The reference to a turbine manufacture/design coefficient is not understood or explained.

Cost Analysis

Cost analysis is comprehensively treated in a spreadsheet format and is offered on a *formula* basis or by a *direct, user input* means**.** The former is likely to be of greatest applicability in Canada, but is, in any case, of interest for comparison. The only modifications which might be suggested are, firstly, to provide for *pipeline* costs in terms of *metres length* instead of, or as well as *kg*. This could then incorporate costs of trenching and anchor blocks as well as the use of different materials. Secondly *Contingencies* might be quoted in two categories: *Civil engineering 10 - 15 %* and *Mech. and Elec. Engineering 5%*

Financial Analysis

This is a standard spreadsheet which appears particularly appropriate for N. America. However for wider use it might offer as an alternative, in the *Financial Parameters* section

Net annual production	*kWh*
Rate per kWh	*c. (or p etc)*
Gross annual income from electricity sale	*$(etc)*
Embedded generation value	*kW @ $ /kW = $(etc)*
Gross annual income	*$(etc)*

instead of , or in addition to, the three *Avoided costs.*

Notwithstanding the various suggestions made above, the RETScreen™ hydro program is a very impressive one, which will be of great value to hydro developers everywhere as further, more refined versions appear. According to its developers it is already is in use quite widely in N. America and there is no doubt it will become popular internationally as it becomes more widely known. The various spreadsheets , for a typical example, are shown in Appendix 2.

Further information about RETScreen™ may be obtained from the Web site or by mail from CANMET Energy Diversification Research Lab., 1615 Lionel-Boulet PO Box 4800, Varennes, PQ Canada J3X 1S6

7 The PROPHETE method of site evaluation for small hydro stations, BRGM and ADEME, France

The PROPHETE method, which is used in France, allows the evaluation of site potential for small hydro stations. A non-specialist user can estimate potential hydroelectric production anywhere in France, as a function of catchment characteristics and proposed equipment.

Two methods of assessing flows are possible :- a comparison with neighbouring watercourses in the database as a function of catchment area (which is available for the whole country), or an automatic calculation of the flows from a hydrologic model based on basin rainfall and predetermined averaged parameters derived from available detailed studies in eleven Departements.

After the estimation of a series of monthly flows by one of these two methods, the database allows the user to simulate automatically a small hydro station using a prescribed head (which may vary with the flow) and the turbine characteristics (proposed by the computer but which may be changed). It also permits calculation, with annual variation as required, of monthly production and revenues, based on actual selling prices of energy to the EDF grid,- prices which may be altered as required by the user.

A fuller description of the method in both English and French is given in Appendix 3.

Further information on PROPHETE may be obtained from ADEME, 500 Route des Lucioles, Valbonne, France 06560

8 Peach 2.0 Software for investigation and design of small hydro projects, ISL Bureau d'Ingenieurs Conseils, France

This is a sophisticated program designed by the French consulting firm ISL of Paris and Montpelier and is offered for sale. Current prices are quoted at the end of Appendix 4
The program is designed to take a developer through all the necessary procedures in designing, building and commissioning a small hydro scheme and analysing the financial returns which may be expected. To do this the user is led through six distinct steps:

- **Step 1** Site Data Definition,
- **Step 2** Project Creation,
- **Step 3** Project Design,
- **Step 4** Plant Design,
- **Step 5** Economic and Financial Analysis ,
- **Step 6** Report.

This reviewer has only had access to a demonstration version of the progam from which the Appendix 4 has been down-loaded. Accordingly it is not possible to comment on the ease of use nor to suggest modifications or improvements for international use. However, the content of the program as evidenced by the various sections listed below and the figures from the demonstration disc indicate that it is a powerful, though expensive, tool.

Main characteristics
Site, Project and Design parameter set definition
Power curve
Power curve and main results
Construction costs

Bill of quantities	
Cost flows	Yearly cash flow
Economic analysis	Economic analysis graphic results
Financial analysis	Financial analysis graphic results.

*Further information about PEACH may be obtained from ISL,Bureau d`Ingenieurs Conseils, Paris France***.**

9 Hydra Software for the feasibility study of small hydro plants, The European Atlas of Small Hydropower Potential, Institute of Hydrology, UK and the European Small-scale Hydropower Association (ESHA)

The HydrA software

HydrA has been developed to run on IBM compatible PCs within a Microsoft Windows environment. Aimed at hydropower consultants, electricity utilities, environmental agencies and investors, the design principle for the software was that it should be easy to use by those with minimal hydrological knowledge. This is helped by the provision of a man-machine interface (MMI) which allows the user to navigate the software simply by using a mouse to point and click onto a series of pull-down menus or screen-icons.

The software broadly follows procedures laid out in the "Layman's Guidebook on how to develop a small hydro site" (ESHA, 1994). It incorporates regional flow estimation models, which allow a synthetic flow duration curve (fdc) to be derived at any site in the eight European countries, and methods for determining hydropower potential from the fdc. The regional models are derived from a multi-variate regression analysis of long-term river flow data and key catchment characteristics, as described in Gustard et al. (1998). The software is also able to calculate the hydropower potential of sites where gauged river flow data is available.

HydrA comprises four main modules:

Catchment Characteristics Module

This module enables the user to estimate the physical characteristics of the ungauged catchment . A pre-requisite is for the user to enter the upstream catchment boundary for the proposed site as a set of (x,y) co-ordinate pairs. Embedded within the software are 1 km x 1 km grids of average annual rainfall, potential (or actual) evaporation and a standardised low flow statistic (typically the 95 or 90 percentile flow (Q_{95}/Q_{90}). HydrA overlays the user-defined boundary onto the grids to determine a catchment estimate of average annual rainfall, evaporation (potential or actual) and the low flow statistic. The estimates of rainfall and evaporation are used to calculate the mean flow for the site (Gustard et al., 1998).

Flow Regime Estimation module

This module takes mean flow and the low flow statistic (Q_{95} or Q_{90}), calculated in the Catchment Characteristics module, to derive a synthetic flow duration curve for the site. The Q_{95} (or Q_{90}), when standardised by the mean flow, provides a good indication of the hydrological response of a catchment. A high value of Q_{95} relative to the mean flow generally represents a permeable catchment that is characterised by a flat flow duration curve. Conversely, a low value of Q_{95} (relative to the mean flow) would represent an impermeable catchment with a steep flow duration curve (see Figure 2). For a given estimate of Q_{95} (or Q_{90}), HydrA will automatically refer to a set of flow duration type curves and identify an appropriate flow duration curve for the site. The "synthetic" curve characterises the flow regime at the proposed site and is used as the basis for all subsequent hydropower calculations.

Turbine Selection module
Having established a characteristic flow duration curve of the site, the software then determines how much of the water can be used for power generation. First the residual flow must be entered by the user. This is the minimum flow that must be maintained in the river to sustain the ecology and the requirements of downstream consumers. Any flow above this value could be used for generation. However, no turbine is able to operate efficiently in all conditions. Some can only operate upwards from about 40% of their maximum design (rated) flow The larger the rated flow, the larger the cut-off at low flow. Within the software, the rated discharge is provisionally set at the level of the mean flow, although this may be altered by the user. The useable part of the flow duration curve is defined by the residual flow, the rated flow and the minimum turbine flow.

The user is also required to enter the gross (hydraulic) head that is available at the site. Head losses may also be considered by entering an estimate of the nett head as a proportion of the gross head. By default, the nett head is assumed to be 93% of the gross.

The software contains typical operational envelopes and flow v efficiency curves for eight common types of turbines:- Cross flow; Francis Open Flume; Francis Spiral Case; Kaplan; Pelton; Propeller; Semi-Kaplan and Turgo. Given the stated conditions, the software selects the appropriate turbines for the hydropower calculations.

Power Potential Module
This module calculates the hydropower potential of the site. For each selected turbine, average annual energy potential and peak power generation are calculated by combining information from the useable part of the flow duration curve with the flow-efficiency relationship, hydraulic head and the specific weight of water.

The final output from the HydrA software is a single sheet report giving estimates of gross and nett annual average energy output (MWh), maximum power output (kW) and rated capacity (kW) for each of the selected turbines. By comparing the performance of each turbine the user is able to make an informed decision on which turbine is appropriate for the site. The output can be written to a file and, if necessary, used in other external packages for economic assessment.

The user may find the software confusing the first time used, but experienced users can obtain synthetic flow duration curves and estimated annual energy outputs for applicable turbines in very short times.

Although the concepts and methodology on which HydrA is based are sound and the meteorological and geological information within the program for each country is exceptional, the software is not particularly user-friendly. The various modules do not follow each other without prompting. Names are limited to 8 characters and generally inexperienced users become frustrated. Some program upgrading to eliminate these irritations is required.

HydrA would be further improved by allowing the user to modify the various turbine discharge v efficiency curves incorporated in the program, as he can with the flow duration curve selected automatically. Other improvements would allow hydraulic losses to be evaluated by a sub-program for inlet, pipeline and valve losses and possibly the installation of more than one turbine.

Comparison of the RETScreen TM99-Beta and HydrA energy analyses was made for a Scottish catchment where the HydrA derived flow duration curve was entered in RETScreenTM. The standard generic efficiency curves in both programs were left unchanged, although these differ to some extent. Rated flow and residual flows were made the same. The resulting annual energy values were obtained :-

Mean flow 1.90 m^3/s Residual flow 0.27 m^3/s Rated turbine flow 1.63 m^3/s
Gross hydraulic head 65.0 m Net hydraulic head 58.5 m

Appicable Turbines	Gross Annual Av. Ouput MWh	Net Annual Av. Output MWh	Maximum Power Output kW	Rated Capacity kW	Minimum Operational Flow m^3/s
RETScreenTM					
Francis		3092		819.0	
Crossflow		2936		745.0	
Turgo		3125		758.0	
HydrA					
Francis	3270.3	3107			
Crossflow	3072.7	2919	748.3	700.5	0.51
Turgo	3163.1	3005	809.1	728.2	0.43

It may be concluded from this simple test that there is little difference in the energy calculations

10 Conclusions

All these methods, except IMP and possibly Prophete, are based on firstly producing a flow duration curve for a site where flow records are unavailable. Most are designed for particular geographical regions and generally depend on nearby recorded flow values adjusted for variations in catchment area and annual rainfall.

The IMP method used recorded streamflow to calculated energy on a daily (or hourly) basis which is a good solution when a streamflow record of sufficient length is available, but if such a record has to be synthesised for an ungauged site, it is not obviously preferable to the use of a synthesised fdc. If such an fdc is divided into narrow 5% (or less) slices, then the discharge-head combination can be used with turbine/generator efficiencies in a similar way to the streamflow method for each ‘slice’ as is done in HydrA. The difference in energy calculated by both methods is almost certainly within the margins of error in discharge measurement and efficiency estimation. One area where the IMP procedure is preferable is in assessing reservoir operations, where the streamflow record allows reservoir levels to be simulated in time.

There is one other method in use in Canada, the Acres 1994 method, which uses ‘contours’ of Mean Annual Runoff (MAR), and subsequent mathematical curve-forming equations. This is an ingenious solution but it depends on the accuracy of the MAR map. It was not possible to review this method as the program was not available.

Some of the programs go on to tackle the economics of building based on average costs of components used in actual schemes, and these are useful as first order estimates. However, so much depends on the site conditions, access and the proximity of electrical networks, that too much reliance should not be placed on them. The RETScreen ™ program however provides a very good cost estimate template and cost comparison facility which is extremely useful, as are the financial listings which are a great help in making economic analyses.

Where a region has high-quality records of precipitation, evaporation, soil type and topography and adequate surface water run-off records over all or most of the territory, there is probably not much difference in the results produced. However, when there are few actual flow records, the HydrA system can still be used in those European countries for which it has been analysed and established. These are:- U.K., Spain, Portugal, Italy, Ireland, Belgium and Austria.

References

1. *Uniform Criteria for U.S. Hydropower Resource Assessment*: *Hydropower Evaluation Software User`s Manual* : *(Available on 3½ in. diskette)* US Dept of Energy, Idaho Operations Office (Oct 1991)
2. *U.S. Hydropower Resource Assessment Final Report* : US Dept of Energy, Idaho Operations Office (Dec 1998)
3. **Extract from RETSCREEN Executive Summary*
4. Gustard et al *:Developing regional design techniques for estimating hydropower potential. International Symposium on Hydrology of Ungauged Streams in Hilly Regions for Small Hydropower Development, March 9-10 1998, New Delhi,*

11 Appendix I - Integrated Method for Power (IMP)

The following figures have been downloaded from IMP CD 4.0a,

INTEGRATED METHOD FOR POWER ANALYSIS (IMP)

IMP is an easy-to use package of computer programs for small scale hydro projects and for other hydrological applications. It is useful to non-specialists exploring possibilities for small hydro developments, for university teaching, and for consulting engineers who need preliminary estimates of flood frequency and energy potential.

The software includes tips about hydrologic analysis of ungaged sites. Stream flow data are not required. IMP uses topographic and daily weather data to perform flood frequency analysis and to simulate hourly and daily stream flow and reservoir operations. Weighted useable area theory is used to assess stream habitat. Proposed power projects are optimized based on the value of energy and the cost of construction.

COMPONENTS OF IMP

A knowledge based program uses topographic and weather information to **generate flood frequency curves for ungaged sites**.

The watershed model generates a **continuous hourly or daily time series of stream flow** for an ungauged site based on daily precipitation, maximum and minimum temperature and a description of the basin.

The **hydroelectric power simulation program** determines the hourly or daily energy output for a run-of-river or reservoir storage site. It uses recorded stream flow data or the hydrologic time series generated by the watershed model. Sensitivity analysis and economic data provide an estimate of the **optimal installed capacity**.

Fish habitat is assessed by calculation of weighted usable area for selected fish types and cross sections. Simulation with stream flow data provides time series and frequency of weighted useable area vs. discharge.

Graphical tools plot time series and frequency results. Data management tools allow easy input of additional meteorological and stream flow data. IMP operates on a PC in the **Microsoft Windows environment**.

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Victoria Tel: 250-385-0206, Fax: 250-385-7737
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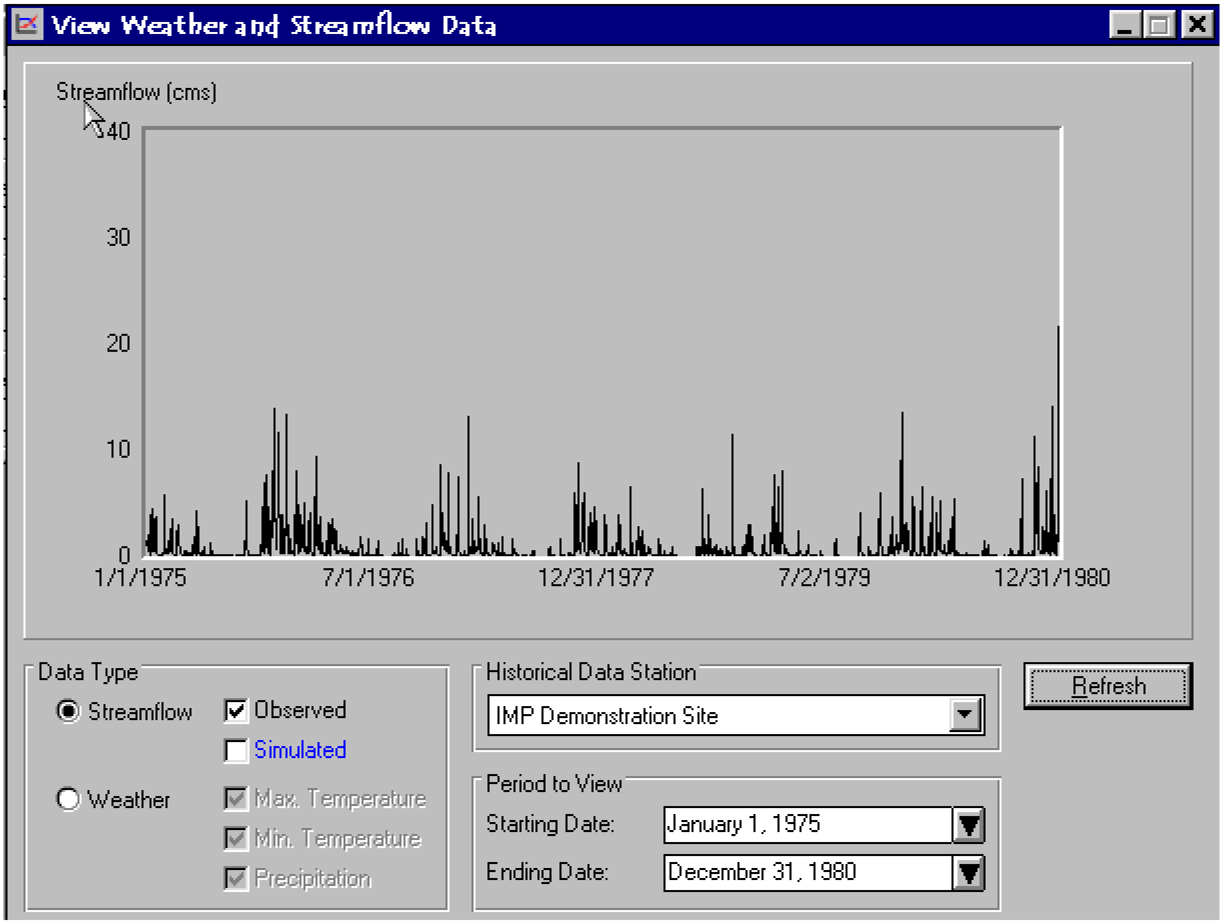
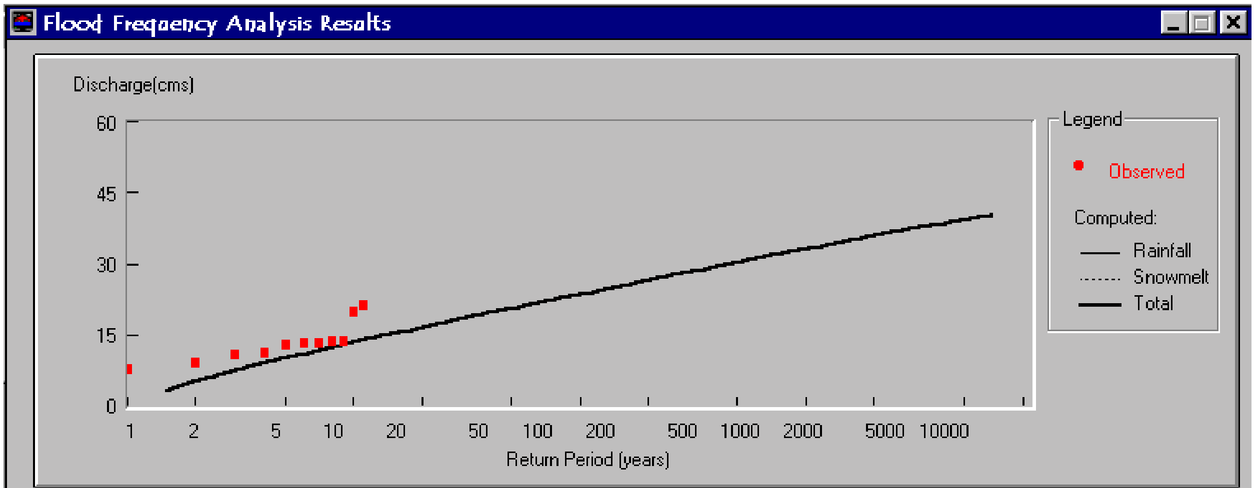
StreamFlow Simulation



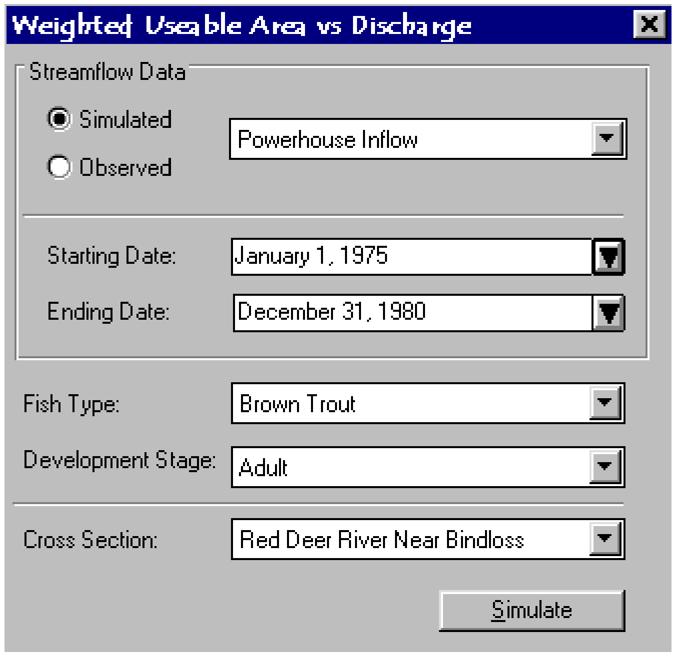
Flood Frequency Simulation



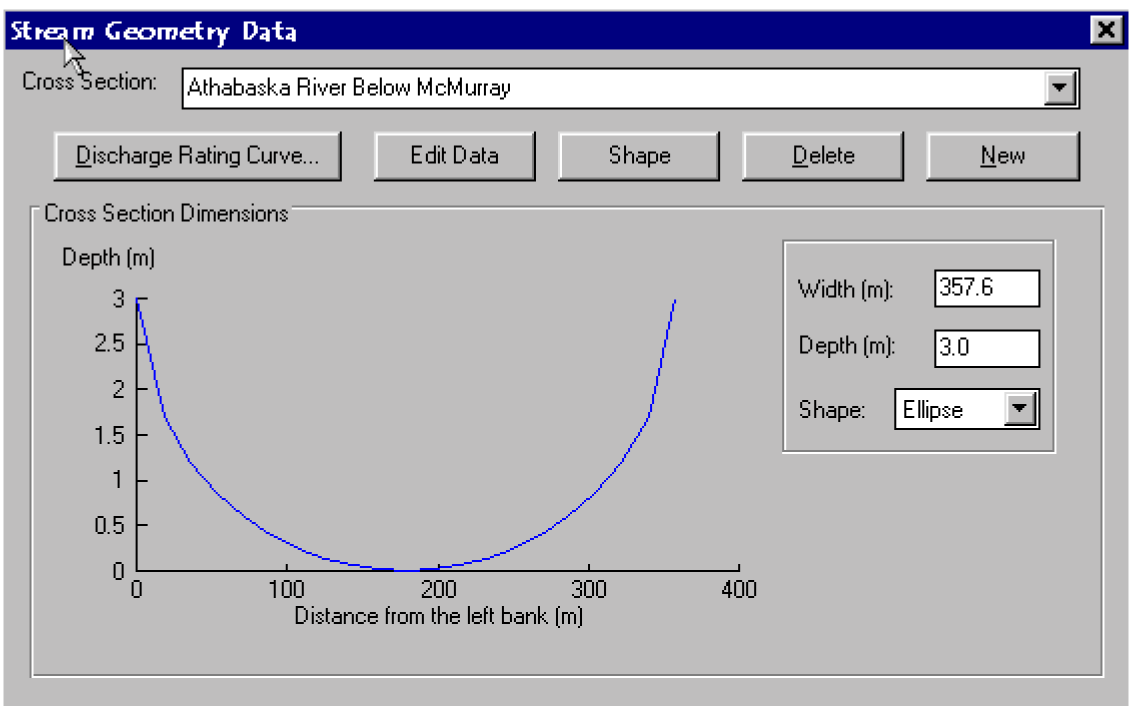
Flood Frequency Table

Intensity (mm/hr)	Concentration Time (hours)	Discharge(cms)	Return Period Rainfall (Years)	Return Period Snowmelt (Years)	Return Period Total (Years)
0.996	24.72	3.15	1:1.50	1:0.00	1:1.50
1.505	20.18	4.77	1:1.87	1:0.00	1:1.87
2.014	17.48	6.38	1:2.45	1:0.00	1:2.45
2.522	15.65	7.99	1:3.30	1:0.00	1:3.30
3.031	14.30	9.60	1:4.53	1:0.00	1:4.53
3.540	13.25	11.21	1:6.32	1:0.00	1:6.32
4.049	12.41	12.82	1:8.91	1:0.00	1:8.91
4.558	11.71	14.43	1:12.7	1:0.00	1:12.7

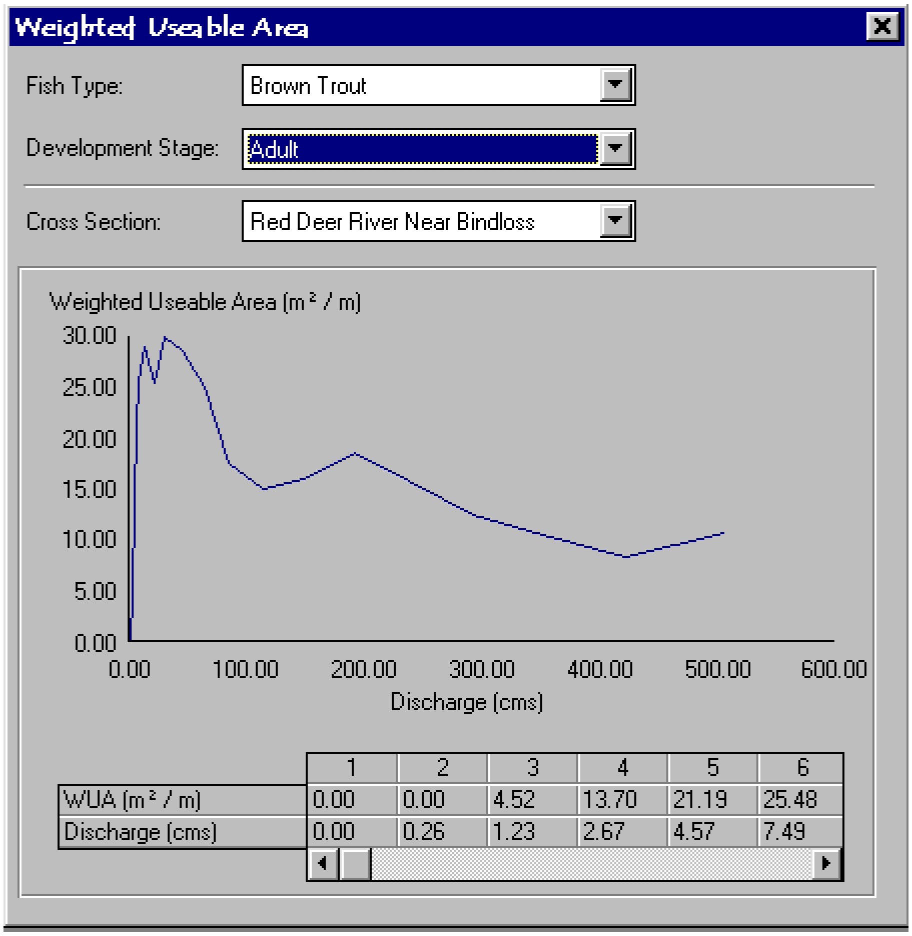
Weighted Usable Area vs. Discharge



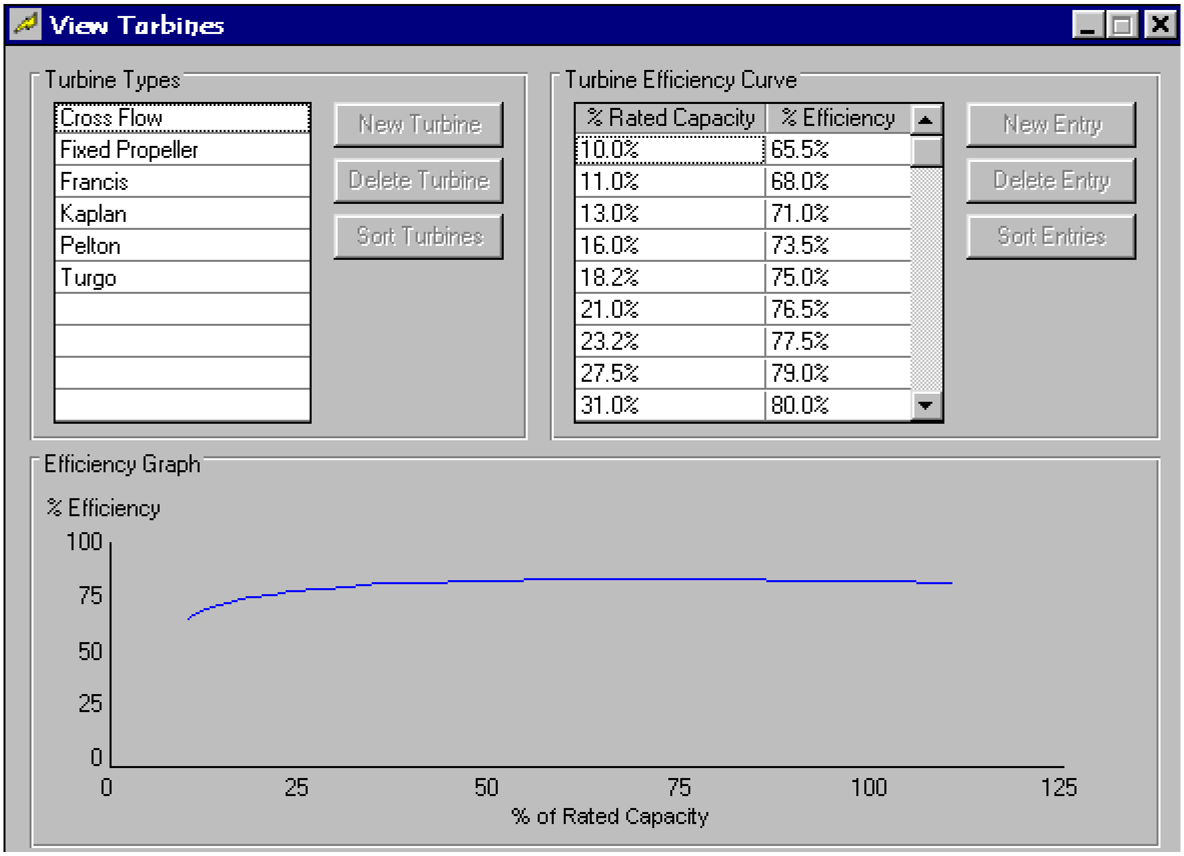
Stream Geometry Data



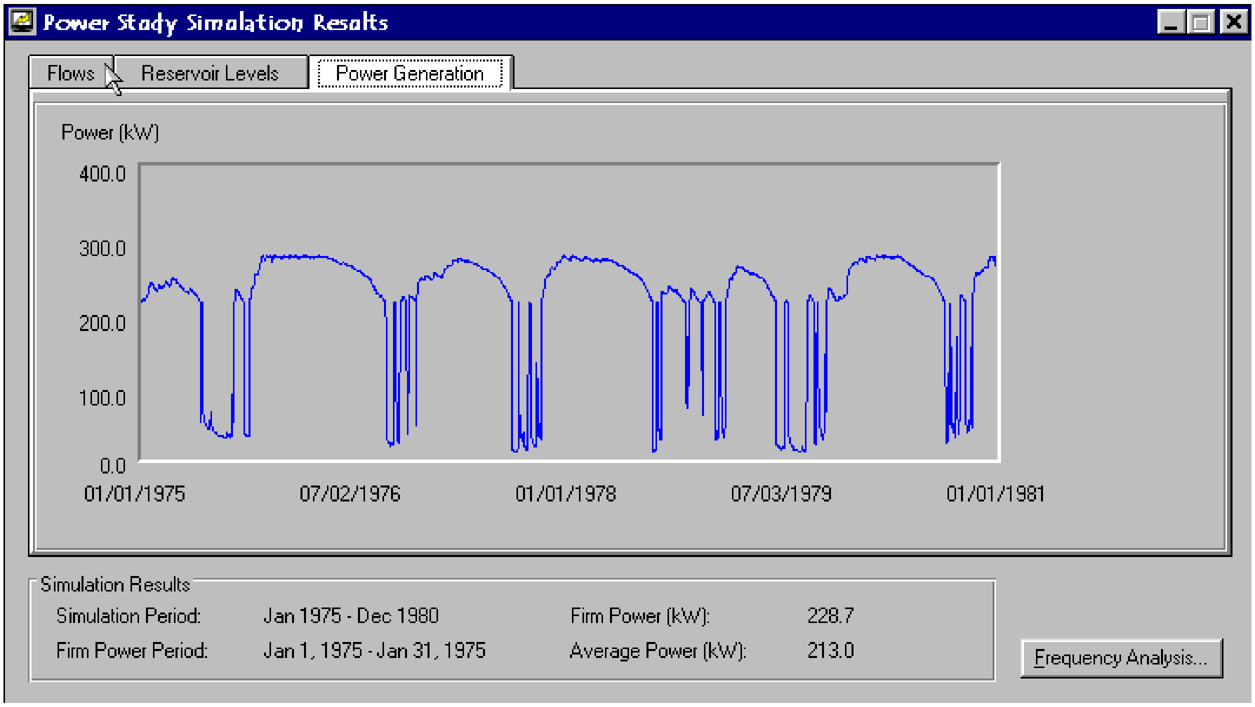
Weighted Usable Area



View Turbines



Power Study Simulation Results



12 Appendix 2 – RETScreen™, Pre-feasibility Analysis Software, Hydro Version 99-Beta

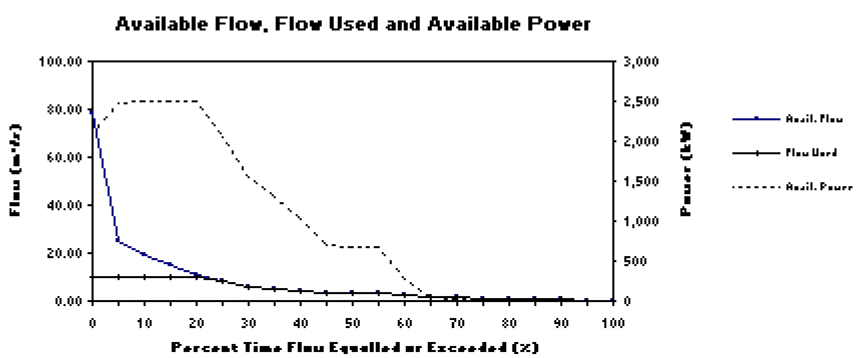
Energy Model

RETScreen™ Energy Model - Small Hydro Project

Site Conditions		Estimate	Notes/Range
Project name		**Example**	-
Project location		**Alberta**	-
Gross head	m	31.6	Measured value
Maximum tailwater effect	m	5	See manual
Residual flow	m³/s	1	*Complete Hydrology & Load sheet*
Firm flow	m³/s	1.40	See *Hydrology & Load* sheet
Peak load (electrical)	kW	**1,146**	See *Hydrology & Load* sheet
Energy demand (electrical)	MWh	**5,065**	See *Hydrology & Load* sheet

System Characteristics		Estimate	Notes/Range
Grid type	-	Isolated-grid	See *Hydrology & Load* sheet
Design flow	m³/s	10	Project specific
Turbine type	-	Francis	*Complete Equipment Data sheet*
Number of turbines	turbine	1	See *Equipment Data* sheet
Turbine efficiency at design flow	%	92.4%	See *Equipment Data* sheet
Maximum hydraulic losses	%	5%	See manual
Generator efficiency	%	95%	93% to 97%
Transformer losses	%	1%	1% to 2%
Parasitic electricity losses	%	2%	1% to 3%
Annual downtime losses	%	5%	2% to 7%

Annual Energy Production		Estimate	Notes/Range
Small hydro plant capacity	kW	2,507	Project specific
	MW	2.507	For user convenience
Small hydro plant firm capacity	kW	0	Project specific
Available flow adjustment factor	-	1.0	See manual
Small hydro plant capacity factor	%	37%	40% to 95%
Renewable energy available	MWh	8,091	Project specific
Renewable energy delivered	MWh	**2,845**	Project specific
	GJ	10240	For user convenience
Excess RE available	MWh	**5,246**	Project specific



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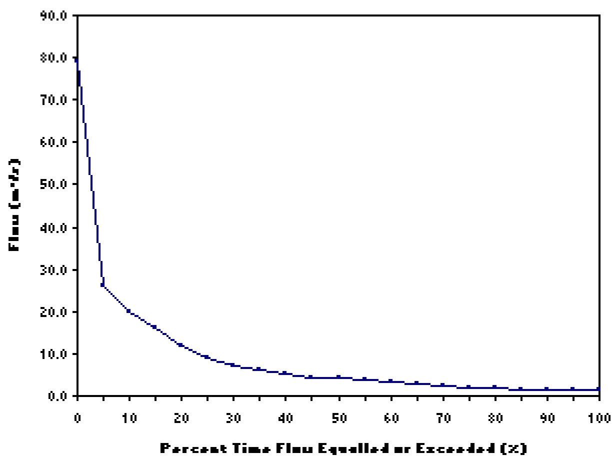
Hydrology & Load

RETScreen™ Hydrology Analysis and Load Calculation - Small Hydro Project

Hydrology Analysis		Estimate	Notes/Range
Project type		Run-of-river	
Hydrology method		User-defined	See manual
Hydrology Parameters			
Residual flow		1	Project specific
Percent time firm flow available	%	95%	90% to 100%
Firm flow	m³/s	1.40	-

Flow-Duration Curve Data

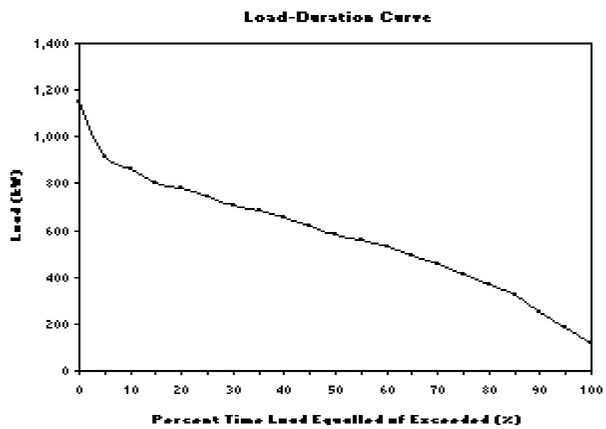
Time (%)	Flow (m³/s)
0%	79.00
5%	26.00
10%	20.00
15%	16.00
20%	12.00
25%	9.00
30%	7.00
35%	6.00
40%	5.00
45%	4.20
50%	4.10
55%	4.00
60%	3.20
65%	2.70
70%	2.50
75%	2.10
80%	1.80
85%	1.60
90%	1.50
95%	1.40
###	1.20



Load Characteristics		Estimate	Notes/Range
Grid type		Isolated-grid	See manual
Load Conditions			
Load duration curve		User-defined	See manual
Peak load (electrical)	kW	1,146	Project specific

Load-Duration Curve Data

Time (%)	Load (kW)
0%	1,146
5%	917
10%	860
15%	802
20%	779
25%	745
30%	711
35%	688
40%	653
45%	619
50%	584
55%	562
60%	527
65%	493
70%	458
75%	413
80%	367
85%	321
90%	252
95%	183
###	115



		Annual	Daily	
Energy demand (electrical)	MWh	5,065	13.9	Project specific
Average load factor	%	50%	50%	Project specific

Return to Energy Model sheet

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Equipment Data

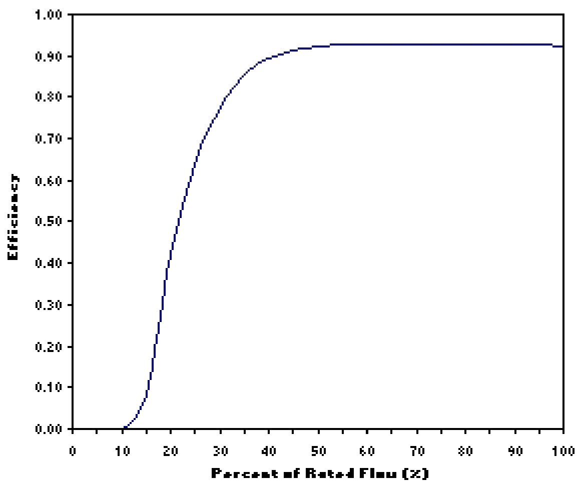
RETScreen™ Equipment Data - Small Hydro Project

Small Hydro Turbine Characteristics		Estimate	Notes/Range
Design flow	m³/s	10	See *Energy Model* sheet
Turbine type	-	Kaplan	*See Product Database*
Turbine efficiency curve data source	-	User-defined	See manual
Number of turbines	turbine	1	See manual
Small hydro turbine manufacture	-	AA	See product database
Small hydro turbine model	-	OO	See product database
Turbine manufacture/design coefficient	-	4.5	2.8 to 6.1; Default = 4.5
Efficiency adjustment	%	0%	Project specific

Turbine Efficiency Curve Data

Flow (%)	Turbine efficien	Turbin es #	Combin ed efficiency
0%	0.00	0	0.00
5%	0.00	1	0.00
10%	0.00	1	0.00
15%	0.08	1	0.08
20%	0.42	1	0.42
25%	0.64	1	0.64
30%	0.78	1	0.78
35%	0.85	1	0.85
40%	0.90	1	0.90
45%	0.92	1	0.92
50%	0.92	1	0.92
55%	0.93	1	0.93
60%	0.93	1	0.93
65%	0.93	1	0.93
70%	0.93	1	0.93
75%	0.93	1	0.93
80%	0.93	1	0.93
85%	0.93	1	0.93
90%	0.93	1	0.93
95%	0.93	1	0.93
100%	0.92	1	0.92

Efficiency Curve - 1 Turbine(s)



Turbine efficiency at design flow	%	92.4%	Turbine type specific

Return to Energy Model sheet

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Cost Analysis

RETScreen™ Cost Analysis - Small Hydro Project

Costing method: Detailed

Initial Costs	Unit	Quantity	Unit Cost	Amount	lative Costs	Quantity Rang	nit Cost Rang
Feasibility Study							
Site investigation	p-d	60	$ 600	$ 36,000	0.40%	10 - 400	$400 - $600
Hydrologic assessment	p-d	25	$ 500	$ 12,500	0.14%	5 - 100	$500 - $700
Environmental assessment	p-d	60	$ 500	$ 30,000	0.33%	Project specific	$400 - $600
Preliminary design	p-d	25	$ 500	$ 12,500	0.14%	10 - 100	$500 - $700
Detailed cost estimate	p-d	20	$ 600	$ 12,000	0.13%	5 - 50	$500 - $700
Report preparation	p-d	10	$ 700	$ 7,000	0.08%	3 - 50	$500 - $700
Project management	p-d	10	$ 700	$ 7,000	0.08%	5 - 50	$500 - $700
Travel and accommodation	p-trip	4	$ 2,500	$ 10,000	0.11%	2 - 10	See manual
Other	-	0	$ -	$ -	0.00%	-	User defined
Credit	-	-1	$ -	$ -	0.00%	-	See manual
Subtotal:				**$ 127,000**	1.42%		
Development							
PPA negotiation	p-d	20	$ 1,000	$ 20,000	0.22%	5 - 200	$700 - $1,500
Permits and approvals	p-d	25	$ 700	$ 17,500	0.20%	5 - 100	$500 - $700
Land rights	site	0	$ -	$ -	0.00%	Project specific	See manual
Land survey	p-d	28	$ 500	$ 14,000	0.16%	20 - 200	$400 - $600
Project financing	p-d	30	$ 1,500	$ 45,000	0.50%	5 - 100	$500 - $1,500
Legal and accounting	p-d	25	$ 1,200	$ 30,000	0.33%	5 - 200	$500 - $1,500
Project management	p-yr	0.2	$ 130,000	$ 26,000	0.29%	0.2 - 2.0	$130K - $180K
Travel and accommodation	p-trip	10	$ 2,500	$ 25,000	0.28%	2 - 10	See manual
Other	-	0	$ -	$ -	0.00%	-	User defined
Credit	-	-1	$ -	$ -	0.00%	-	See manual
Subtotal:				**$ 177,500**	1.98%		
Engineering							
Design and tender documents	p-yr	0.7	$ 130,000	$ 91,000	1.01%	0.6 - 6.0	$130K - $180K
Contracting	p-d	50	$ 700	$ 35,000	0.39%	5 - 200	$500 - $1,500
Construction supervision	p-yr	0.5	$ 130,000	$ 65,000	0.72%	0.2 - 2.0	$130K - $180K
Other	-	0	$ -	$ -	0.00%	-	User defined
Credit	-	-1	$ -	$ -	0.00%	-	See manual
Subtotal:				**$ 191,000**	2.13%		
Renewable Energy (RE) Equipment							
Turbines/generators, controls	kW	2,507	$ 1,700	$ 4,262,197	47.50%	Project specific	$1,000 - $4,000
Equipment installation	%	10%	$ 4,262,197	$ 426,220	4.75%	5% - 45%	Project specific
Transportation	%	10%	$ 4,262,197	$ 426,220	4.75%	1% - 20%	Project specific
Other	-	0	$ -	$ -	0.00%	-	User defined
Credit	-	-1	$ -	$ -	0.00%	-	See manual
Subtotal:				**$5,114,636**	57.01%		

Cost Analysis (cont'd)

Balance of Plant							
Access Road	km	10.0	$ 20,000	$ 200,000	2.23%	Project specific	$20K - $500K
Concrete dam	m³	300	$ 800	$ 240,000	2.67%	Project specific	$400 - $1,600
Timber crib dam	m³	0	$ -	$ -	0.00%	Project specific	$100 - $500
Earthfill dam	m³	0	$ -	$ -	0.00%	Project specific	$30 - $90
Dewatering	%	10%	$ 240,000	$ 24,000	0.27%	5% - 15%	Project specific
Spillway	m³	0	$ -	$ -	0.00%	Project specific	$400 - $1,600
Canal	m³	0	$ 250	$ -	0.00%	Project specific	$20 - $400
Intake	m³	90	$ 1,200	$ 108,000	1.20%	See manual	$400 - $1,600
Tunnel	m³	0	$ -	$ -	0.00%	Project specific	$40 - $150
Pipeline/penstock	kg	10,000	$ 10	$ 100,000	1.11%	Project specific	$5 - $10
Powerhouse civil	m³	180	$ 1,200	$ 216,000	2.41%	Project specific	$400 - $1,600
Fishway	m lift	0.0	$ -	$ -	0.00%	See manual	$4K - $20K
Transmission line and substat	km	10.0	$ 75,000	$ 750,000	8.36%	Project specific	See manual
Transportation	%	8%	$ 1,638,000	$ 131,040	1.46%	See manual	Project specific
Other	-	0	$ -	$ -	0.00%	-	User defined
Credit	-	-1	$ -	$ -	0.00%	-	See manual
Subtotal:				**$ 1,769,040**	19.72%		
Miscellaneous							
Special equipment	project	0	$ -	$ -	0.00%	1	See manual
Contractor's overhead	%	10%	$ 1,769,040	$ 176,904	1.97%	10% - 100%	Project specific
Training	p-d	20	$ 700	$ 14,000	0.16%	5 - 100	$500 - $800
Interest during construction	%	4.0%	$ 7,379,176	$ 295,167	3.29%	3% - 15%	Project specific
Contingencies	%	15%	$ 7,379,176	$ 1,106,876	12.34%	10% - 40%	Project specific
Credit	-	-1	$ -	$ -	0.00%	-	See manual
Subtotal:				**$ 1,592,948**	17.75%		
Initial Costs - Total (Detailed Costing Method)				**$ 8,972,124**	100%		

Annual Costs	**Unit**	**Quantity**	**Unit Cost**	**Amount**	**lative Costs**	**Quantity Rang**	**nit Cost Rang**
O&M							
Land lease	project	1	$ -	$ -	0.0%	Project specific	$0 - $2,000
Property taxes	%	0.0%	$ 8,972,124	$ -	0.0%	0% - 0.6%	Project specific
Water rental	kW	2,507	$ -	$ -	0.0%	Project specific	$0 - $20
Insurance premiums	%	0.40%	$ 8,972,124	$ 35,888	21.3%	0.25% - 1.0%	Project specific
Transmission line maintenanc	%	3.0%	$ 750,000	$ 22,500	13.4%	3% - 6%	Project specific
Spare parts	%	0.50%	$ 8,972,124	$ 44,861	26.6%	0.5% - 1%	Project specific
O&M labour	p-yr	0.75	$ 40,000	$ 30,000	17.8%	0.2 - 1.0	$40K - $80K
Travel and accommodation	p-trip	6	$ 1,000	$ 6,000	3.6%	2 - 10	$500 - $10,000
General and administrative	%	10%	$ 139,249	$ 13,925	8.3%	1% - 20%	Project specific
Other	-	0	$ -	$ -	0.0%	-	User defined
Contingencies	%	10%	$ 153,174	$ 15,317	9.1%	10% - 20%	Project specific
Annual Costs - Total				**$ 168,491**	**100%**		

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Financial Summary

RETScreen™ Financial Summary - Small Hydro Project

Energy Balance

Project name		Example	Peak load	kW	1,146
Renewable energy delivered	MWh	2,845	Energy demand	MWh	5,065
Excess RE available	MWh	5,246	Type of energy displaced	-	Electricity
Firm RE capacity	kW	-			

Financial Parameters

Avoided cost of energy	$/MWh	200.0	Discount rate	%	10.5%
Avoided cost of excess ene	$/MWh	18.0	Debt ratio	%	90.0%
Avoided cost of capacity	$/kW-yr	110.0	Debt interest rate	%	7.5%
Inflation	%	2.5%	Debt term	yr	25
Energy cost escalation rate	%	4.0%	Project life	yr	35

Project Costs and Savings

			Annual Costs		
Initial Costs			O&M	$	168,491
Feasibility study	$	127,000	Fuel/Electricity	$	-
Development	$	177,500	Debt payments (25 years)	$	724,406
Engineering	$	191,000	**Annual Costs - Total**	**$**	**892,897**
RE equipment	$	5,114,636			
Balance of plant	$	1,769,040	Annual Savings (or Income)		
Miscellaneous	$	1,592,948	Energy savings (or income)	$	663,342
Initial Costs - Total	**$**	**8,972,124**	Capacity savings (or income)	$	-
			Annual Savings - Total	**$**	**663,342**

Financial Feasibility

Internal Rate of Return (IRR)	%	10.8%	Project equity	$	897,212
Simple Payback	yr	18.1	Project debt	$	8,074,912
Year-to-positive cash flow	yr	18.3	Debt payments	$/yr	724,406
Net Present Value (NPV)	$	110,839	Debt service coverage	-	0.7
PV of annual costs	$	(8,333,843)	Annual Life Cycle Savings	$	12,003
PV of energy savings	$	9,341,895			
PV of capacity savings	$	-			

Yearly Cash Flows

Year #	Net Flow $	Cumulative $
0	(897,212)	(897,212)
1	(207,233)	(1,104,446)
2	(183,956)	(1,288,402)
3	(159,683)	(1,448,084)
4	(134,372)	(1,582,456)
5	(107,981)	(1,690,437)
6	(80,464)	(1,770,902)
7	(51,776)	(1,822,678)
8	(21,866)	(1,844,544)
9	9,315	(1,835,229)
10	41,820	(1,793,410)
11	75,704	(1,717,706)
12	111,025	(1,606,681)
13	147,841	(1,458,840)
14	186,215	(1,272,626)
15	226,211	(1,046,415)
16	267,896	(778,519)
17	311,340	(467,180)
18	356,615	(110,565)
19	403,798	293,233
20	452,966	746,199
21	504,203	1,250,402
22	557,592	1,807,993
23	613,223	2,421,216
24	671,188	3,092,404
25	731,583	3,823,987
26	1,518,914	5,342,900
27	1,584,473	6,927,373
28	1,652,775	8,580,148
29	1,723,932	10,304,079
30	1,798,061	12,102,140
31	1,875,285	13,977,425
32	1,955,730	15,933,155
33	2,039,529	17,972,683
34	2,126,819	20,099,502
35	2,217,743	22,317,246

Version 98

CEDRL/NRCan

I - Objectives

The PROPHETE database, implemented in 1984 on behalf of the A.F.M.E. and set up on the VAX 1 computer belonging to B.R.G.M. is a very flexible conversational toll enabling the user to:

- prospect the hydraulic or hydroelectric resource of a large number of sites in a region in a very broad way

- make a rapid study of one or several sites that he knows

- analyse a micro power station project by making use of diversified hydrological and technical hypotheses.

The retained time step (monthly) aloows the map of a region or department to be refined very rapidly. On the map for a particular project, taking into account the specific constraintes (hydrological, technical), a specific more detailed study – with a daily time step, for example – can be undertaken, the results of the inquiry on the database only being accurate to within 15%, takning into consideration the time step used.

Depending on his requirements the user will have recouse, to a greater or lesser degree, to the possibilities on offer (calculation of the flows to the site from one or several stations, optimization of the quipment flow), or equally well will use, to a greater or lesser degree, the default options offered and the standard rates for his inquiry on the database.

II – Hydrometric Database

Until October 1986 the reconstruction of the flows to the site were using the monthly data from 1, 904 hydrometric stations representing approximately 22, 000 station-years. The updating of the hydrometric data, has made it possible to include 256 new stations, which is reflected in a database that at present contains 2, 160 hydrometric stations and around 25, 000 station-years.

III – Parameters to be Enetered

<u>The project parameters to be supplied</u> by the user are the height of the fall to be equipped, the reserved flow from the watercourse and the output from the turbine. The calculation of the receipts, if the user so requires, demands in addition the selection of a type of fixed price scale for sales or the purchase of electricity from EDF and the selection of possible auto-consumption of the electricity produced.

IV – Inquiries on the Database

Inquires on the database are performed in two linked stages.

1 - Evaluation of the monthly flows available to the site in m^3/sec
2 – Calculation of the potential output and sales receipts and their variations

The first stage can be carried out in two possible ways:

1. Over the whoile of France constructing the flows to the site with regard to the surfaces of the river basin between the site and a station selected by the user from those nearest it. This method requires a knowledge of the surface area controlled by the site. The use of the surface module allows this surface area to be calculated in every case, except for a site situated in areas controlled by the Agences Artois-Picardie and the Rhone-Mediterranee-Corse.

   For the user's part this module requires him to enter the Lambert co-ordinates for the site. It then owrks out:
   - Firstly, the hydrological sone where the site is to be found (for which it is necessary to have digitized all the contours of the zones)
   - Next, the surface area $S_{AM} + S_{SI}$. This module haas been updated under a contract between the A.F.M.E. and the Compagnie Francaise de Geothermie.

2. Over 4 test regions, constructing the flows to the site from the rains and potential evaporation/transpiration by use of a hydrological model of the rains-flows type. The surface area controlled by the site is then calculated automactically.

   This method gives more stable results, however there is less choice of hydrometric reference stations.

   The test regions: Brittany, Vienne-Haute-Vienne-Creuse, Loire-Haute-Loire-Puy-de-Dome and Var-Alpes-Maritimes have been processed within the framework of further contracts.

The user will have previously been able to consult the directory of river falls in order to select the site which interestes him. This directory at present only cover the department of Brittany and those of the Vienne, Haute-Vienne and Creusse.

V – Results Obtained

The results obtained are displayed on the screen of the terminal and depending on the selection made by the user cover:

- either *the evaluation of the flows to the site*: characteristics of the station used in the evaluation of the flows: median monthly flows, dry and wet quintiles and monthly flows for all the years captured.
- Or *the calculation of the hydroelectric production and sales receipts:* median production, dry and wet quintiles, possible optimization of the flow equipment and the corresponding production.

If the user wishes, the same elements can be obtained for the receipts as for production, with the possibility of maximizing them – optimization of the equipment flow. All these results can equally well be presented on a listing.

VI – Conculsion

This database offers the advantage of a very high speed and ease of use. Furthermore, it allows the variability of the resouyrce from year to year to be taken into consideration, a necessary element for the correct dimensioing of micro power stations.

References

- ”Inventory of potential sites for micro power stations
  PROPHETE database
  - Acquisition of the databases
  - Study of two pilot regions – Creation of the inquiry software package”

  BRGM report nos. 85 SGN 461 EAU and 85 SGN 470 EAU

- ”Inventory of potential sites for micro power stations
  PROPHETE database
  - Updating of the databases
  - Study of the third pilot regions (puy-de-Dome, Loire, Haute-Loire)”

  BRGM report nos. 85 SGN 517 EAU

13 Appendix 4 - PEACH 2.0, Analyse préliminaire des aménagements hydroélectriques

Start a PEACH Study

Starting Peach, the main windows are displayed with a void layout bar.
Before starting the PEACH study, you might change the PEACH options, especially the active language.
You are assumed to be working with the already defined START1 database. If not, you should start by creating a new database.
A Peach study starts with database selection.
Once a database has been selected, the active project is displayed by the layout bar.
The next step is to create a new site.
Once this operationhas been performed, the layout bar displays the new site. The *Parameters* and the *Project* boxes remain void.

You might then proceed with Step 1

Step 1 – Site Data Definition

Site data correspond to: one or several *Flow duration curves*, one or several *Valley descriptions*, a *Unit cost* list.
These data are specific to a *Site* and therefore to every project of this site.
First define a Flow Duration Curve. This curve should refer to the site hydrology at intake; it will be used to compute the project power curves. You might define several FDCs; the FDC selection for a specific project is made in Step 2 (Design parameters definition).
You might then create on or several Valley descriptions. Teo valley descriptions are usally used in a project:

- the weir valley cross-section (in case your project includes a weir) will be used for weir design;
- the plant downstream cross-section allows to account for a variable downstream water level; in case you choose to limit you to a conctant D/S water level, the cross-section is redundant.

You can aalso define several valley decriptions; the valley descriptions relevant to a specific porjects are selected in Step 2.
Finally, there is a Unit Cost list. Several lists might be defined.
With the completion of Step 1, the site you have created in fully defined. The site data can be modified or completed at any time.
You might now proceed with Step 2: the project definition (Step 2)

Step 2 – Project Creation

The project creation consists of two sub-steps. The first is Design parameter definition; the second is Project definition as a complex of basic structures.
The first sub-step is then Design parameters defintion. The Design parameters are independent of the project itself: a project might be designed according to various *Design parameter sets*. For more details, the user is refered to PEACH's database organisation layout.
Once a *Design parameter set* has been defined, the layout bar is updated and displays the new set. Before any project is considered, a first site potential estimate is provided by the power curve.
The second sub-step defines the project. Defining a project means putting tyogether its basci structures.
All stucuture requested for the project design are then operative. You might proceed with Step 3: project design (Step 3).

Step 3 – Project Design

The project design involves design of each one of the structures it comprises. Stuctures are designed according to the current design parameter set.
The *Project layout* window allows a permanent project overview during the design process. Clicking on the corresponding icon from the project ;ayput window starts the structure design.
To start the project design. Choose layout from Project menu.
To access the structure design dialog boxes, click on the *Structures* tabsheet. The structures are designed from upsteam to downstream. The stucture desin always follows the same procedure.
Special attention is given to the plant design, which is described in Step 4

Step 4 – Plant Design

The plant design includes selection of equipment and civil strucutres design. Both outdoor and underground plant can be selected.
To start the plant design, click the plant icon form the project *Layout* dialog box.
The first sub-step is equipment selection according to the site conditions. A turbine selection assistant helps select this equipment.
Once turbines have been selected, the plant structure can be designed on a pre-feasibility level.
With the plant designed, the entire project design is completed. The next step is economic and finacial analysis (Step 5).

Step 5 – Economic and Financial Analysis

The economic and finacial analysis consists of five sub-steps
The first sub-step is power-curve update.
Then proceed with project synopsis that puts together the project design results (costs, head losses).
The third step is equivalent thermal plant definition.
The economic analysis is performed through a comparison between the hydro project and the equivalent thermal plant.
The finacial analysis analysis allows to take into account the electricity sale terms and consider the possibilities for financing.
The PEACH project study is then complete. The lasstep is report edition (Step 6).

Step 6 – Report Edition

Two types of results can be reported, edited and printed out;

- interim results, especially the structure layouts and graphs (power curve, flow duration curve, etc.) and
- a final report.

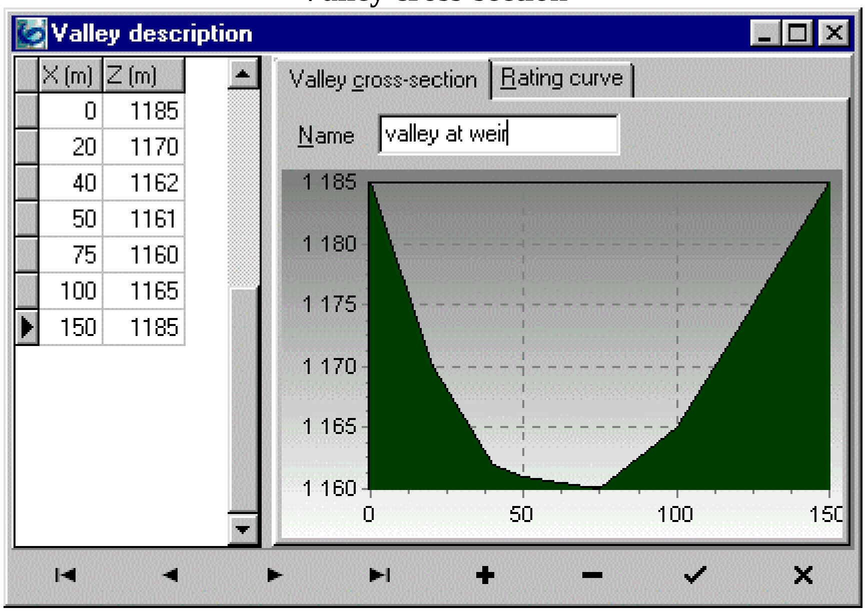
The final report can be customized.

Valley description

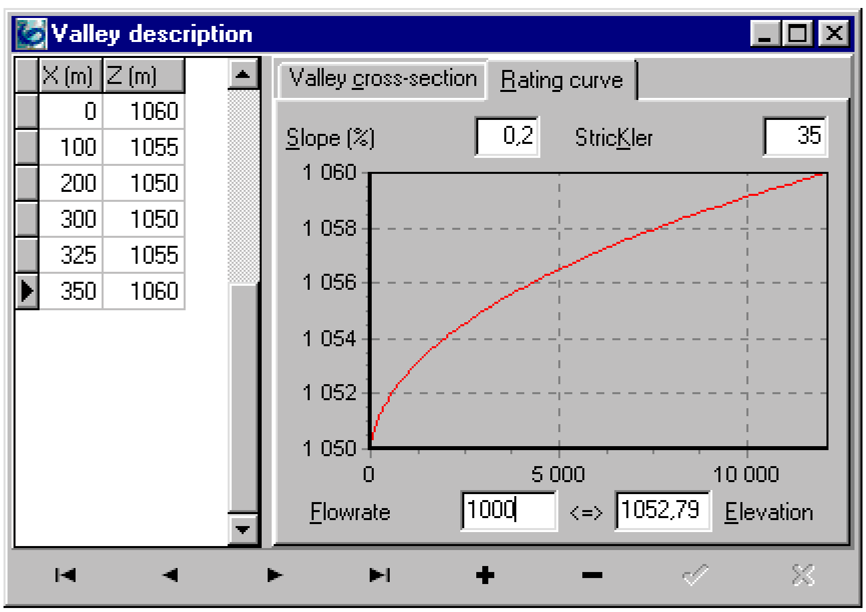
Valley description includes :

- valley cross-sections
- hydraulic parameters

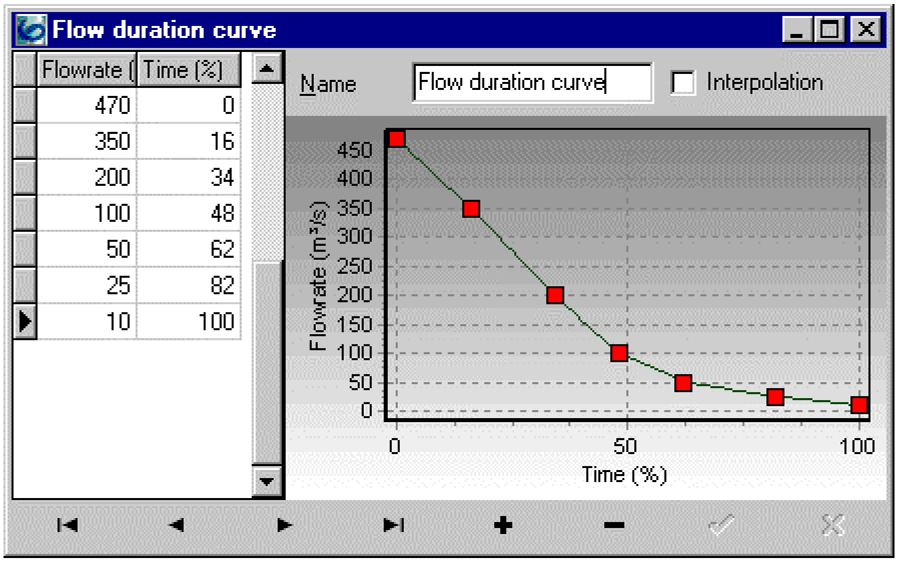
Valley cross-section



Hydraulic parameters



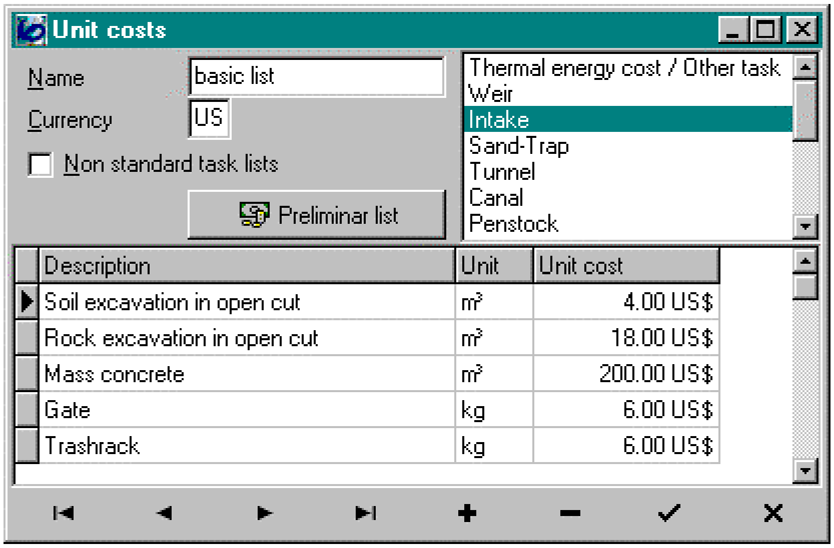
Flow Duration Curve



Unit Costs

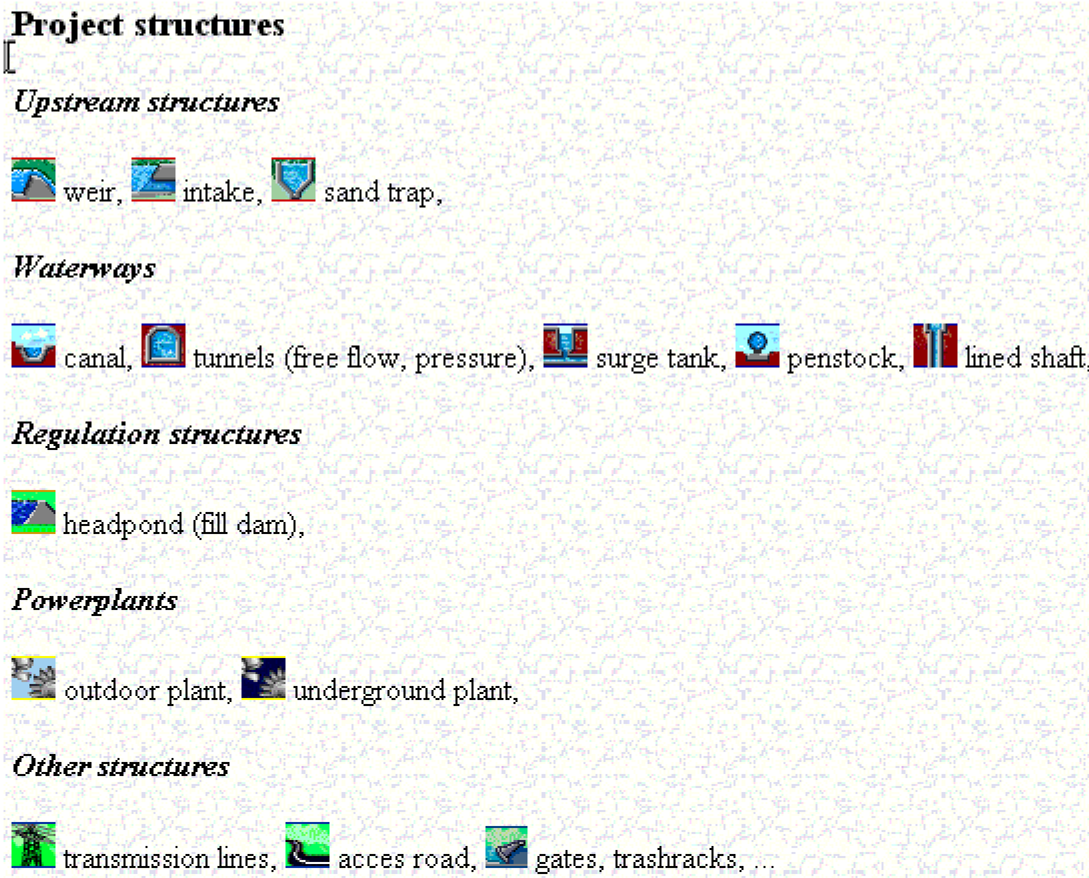
A Unit Costs list is given by the user. This list is used for all project alternatives on a given site.
Two definition levels are provided :

- a unique list for all structures,
- a structure specific list, taking into account the component specific conditions (for instance, different concrete costs for intake and powerplant).



Project definition

Project definition consists of gathering basic structures.



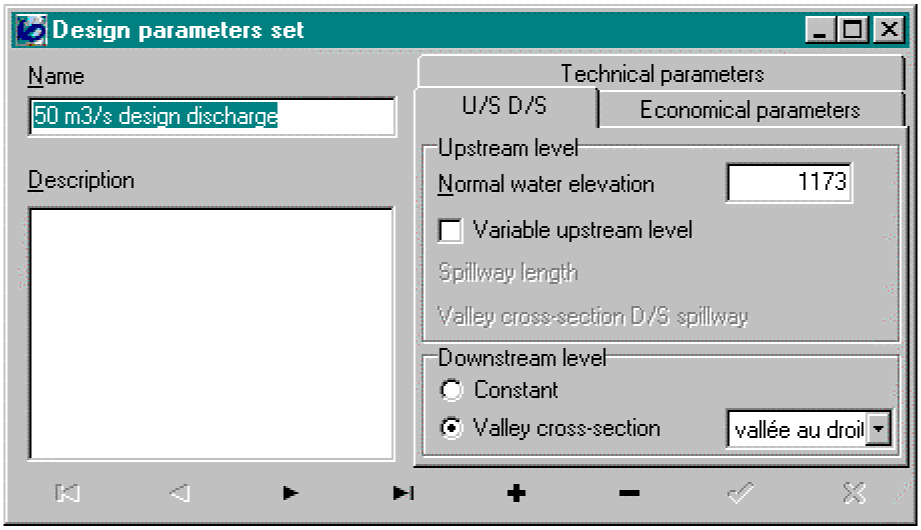
Structure design

Design parameters

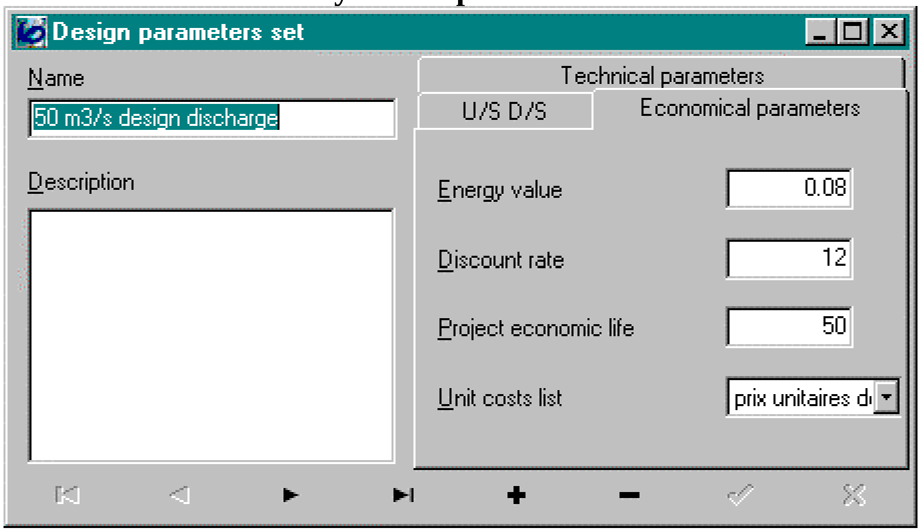
Design parameters are defined in a specific dialogbox and include technical, hydraulic and economical data. These parameters will be used for designing each project component :

- hydraulic computations,
- economic structure optimization (tunnels and penstocks diameter),
- equipment selection,
- ...

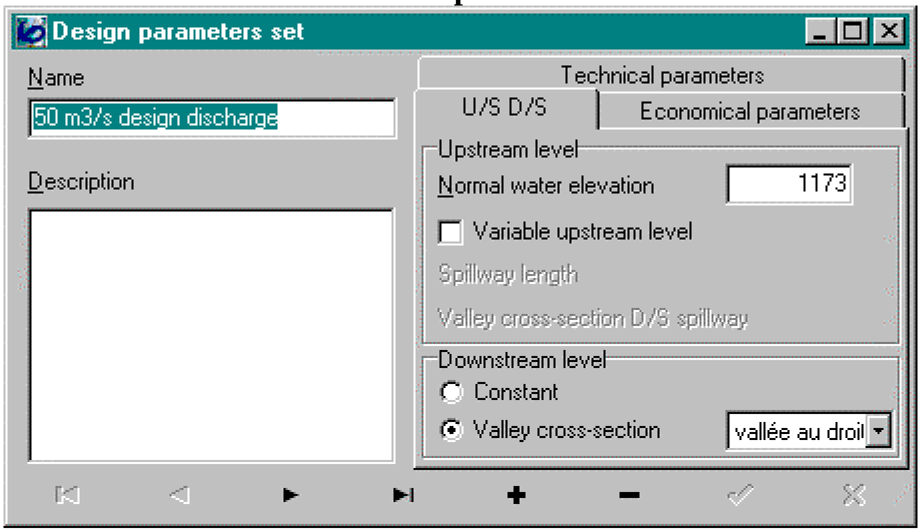
Technical datas



Hydraulic parameters



Economic parameters



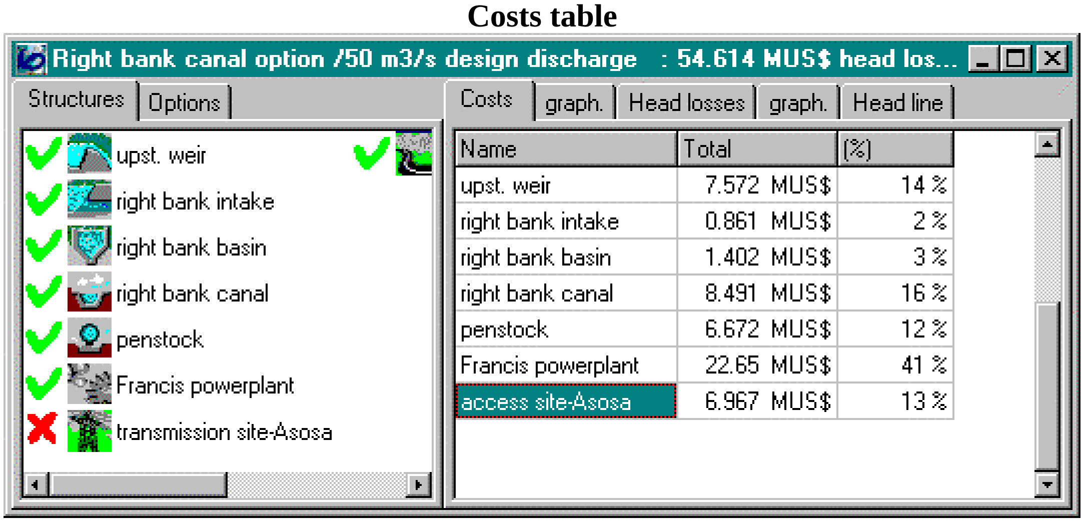
Project layout

The Project Layout window provides a permanent overview on the project during the design process :

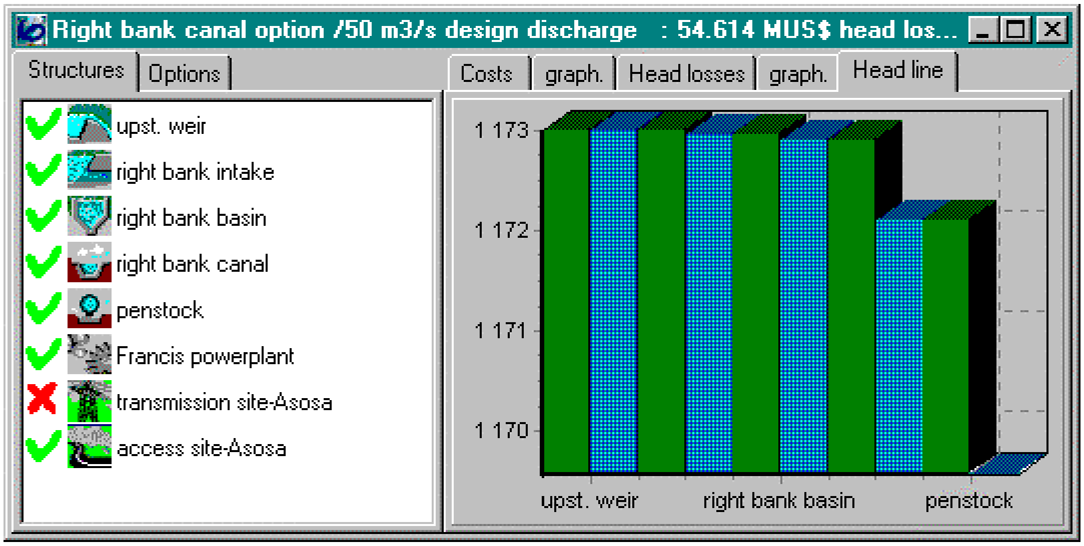
- structure status (designed or not),
- structure costs,
- head losses.

The left part of the window shows each project component. A green or red mark indicates whether the structure is fully designed or not. A check of the head line continuity is made at this stage.
The right part of the window gives the main design results.

Costs table



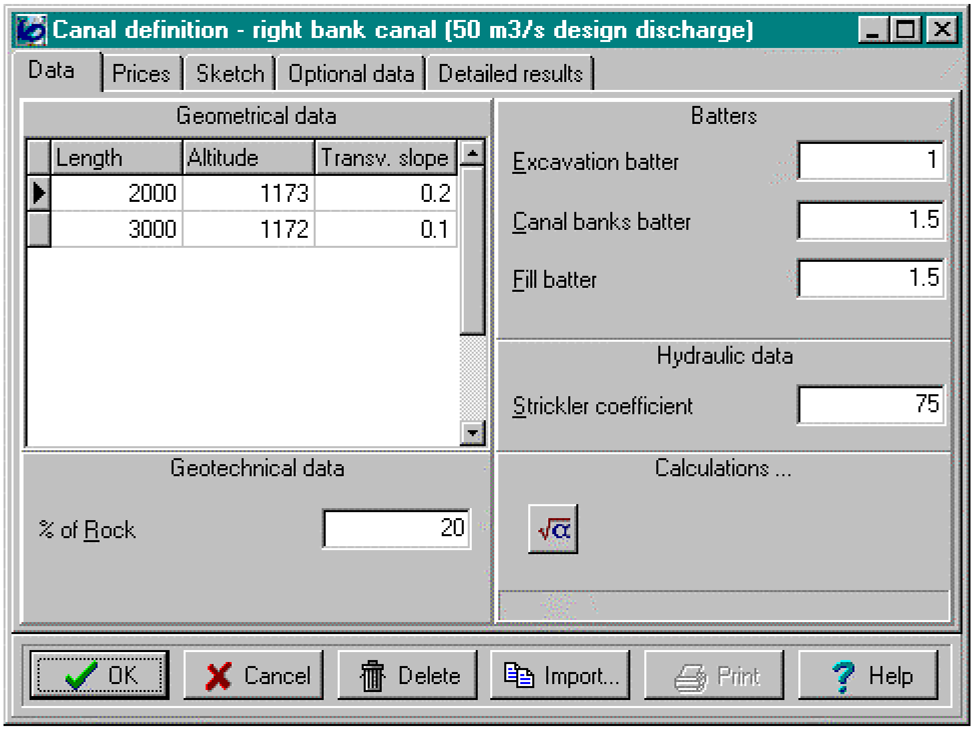
Head line



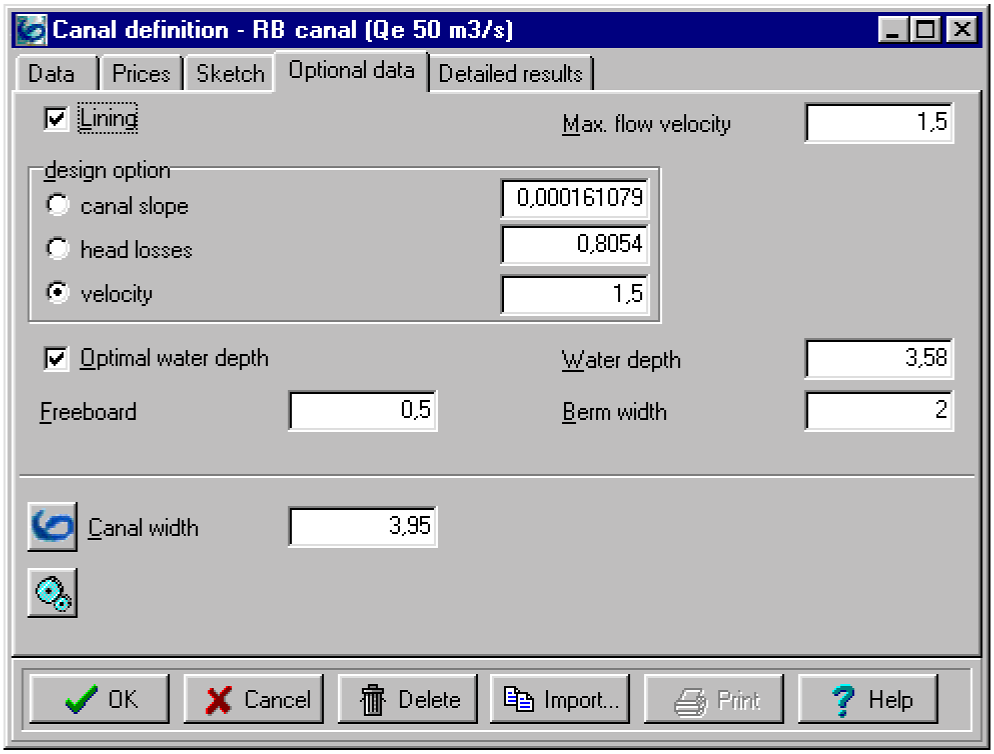
Canal design

[Basic data](#), [Costs](#), [Sketch](#), [Options](#), [Results](#)

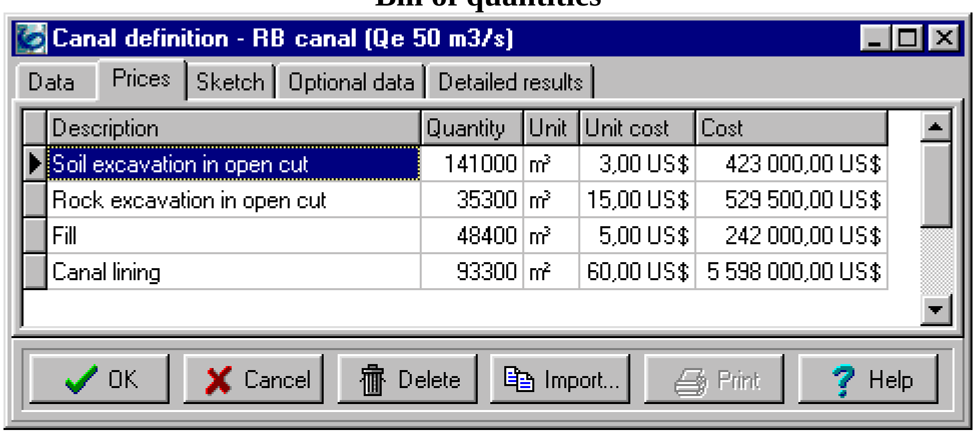
Basic data



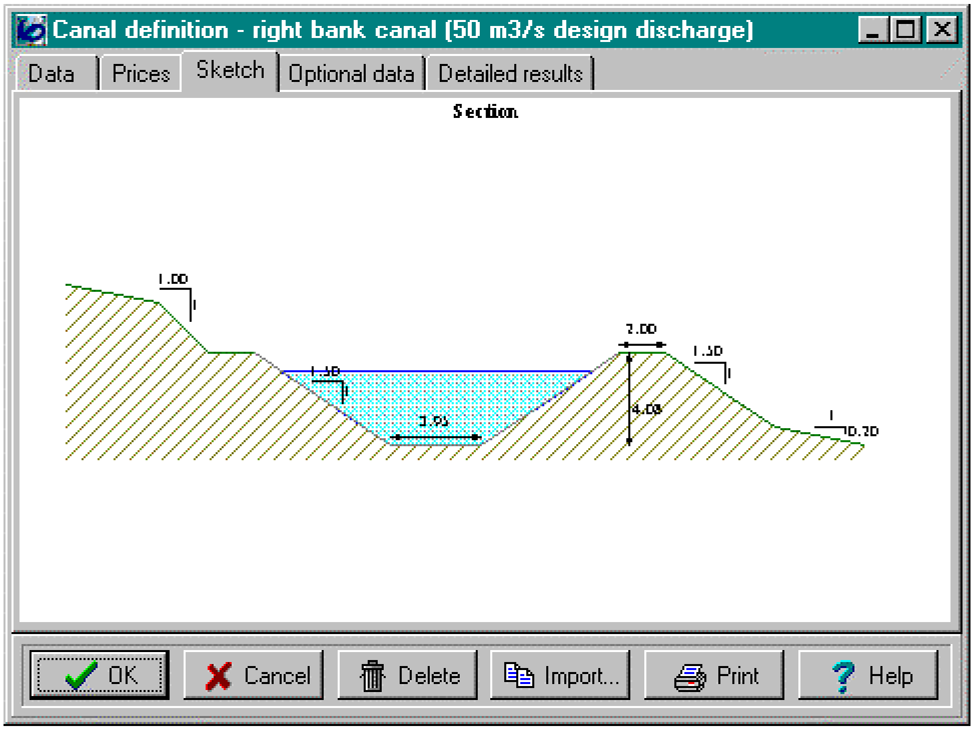
Options



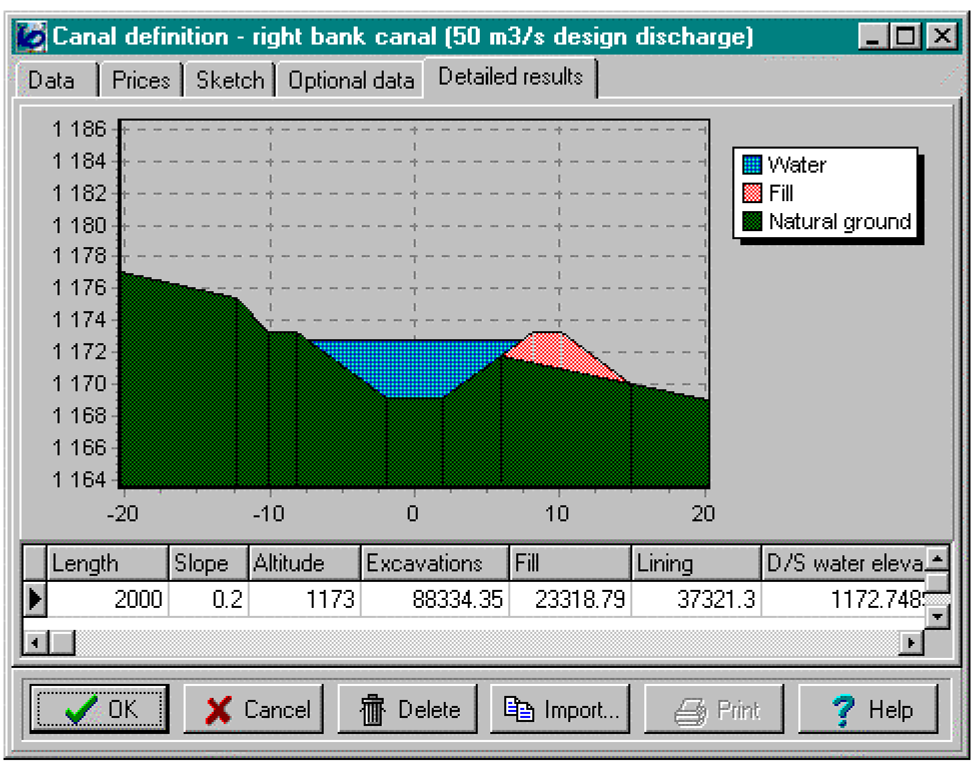
Bill of quantities



Sketch



Results



Powerplant design

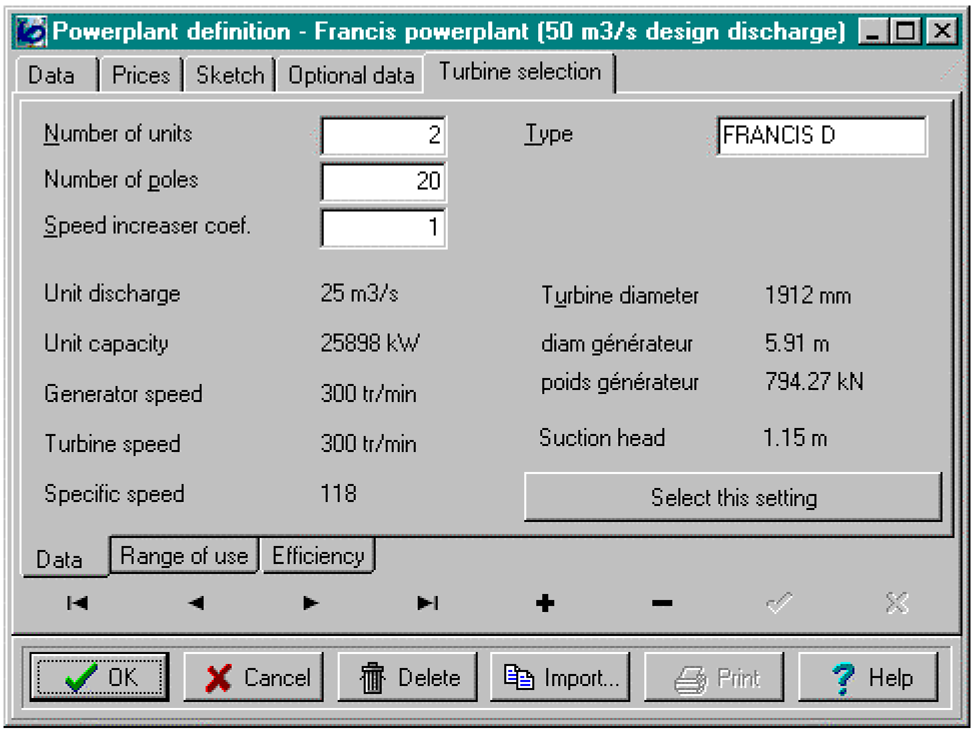
Equipment definition

An on-line assistant helps the user to define and select suitable electromechanical equipment sets :

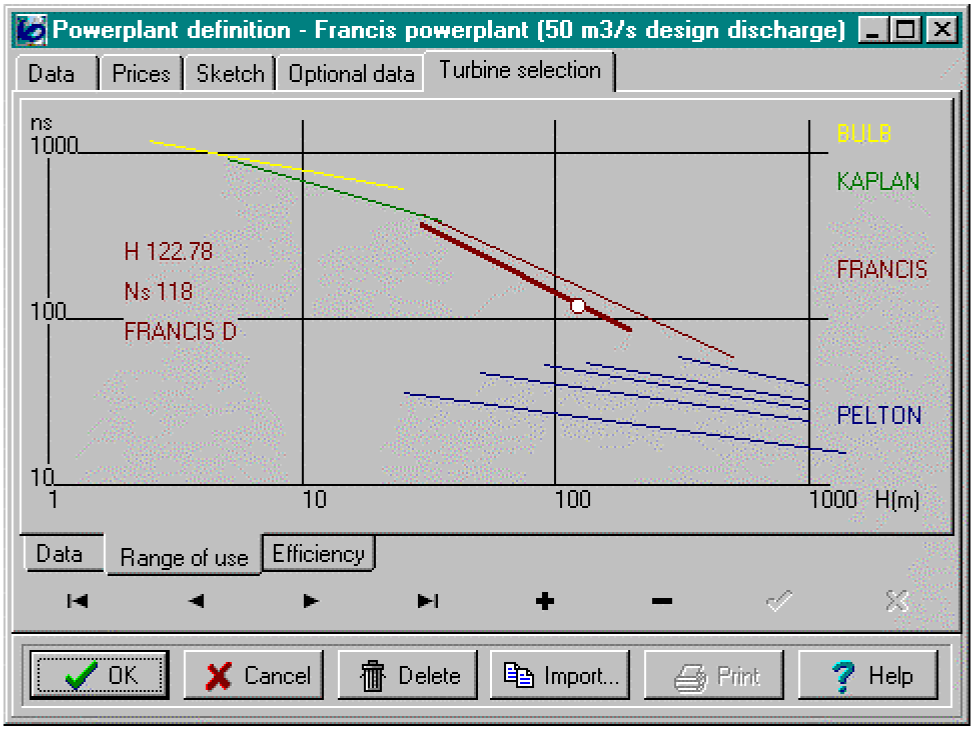
- turbine type,
- number of units,
- specific speed (number of poles, speed increaser).

Peach allows to check the equipment range of use and gives efficiency and production curves.

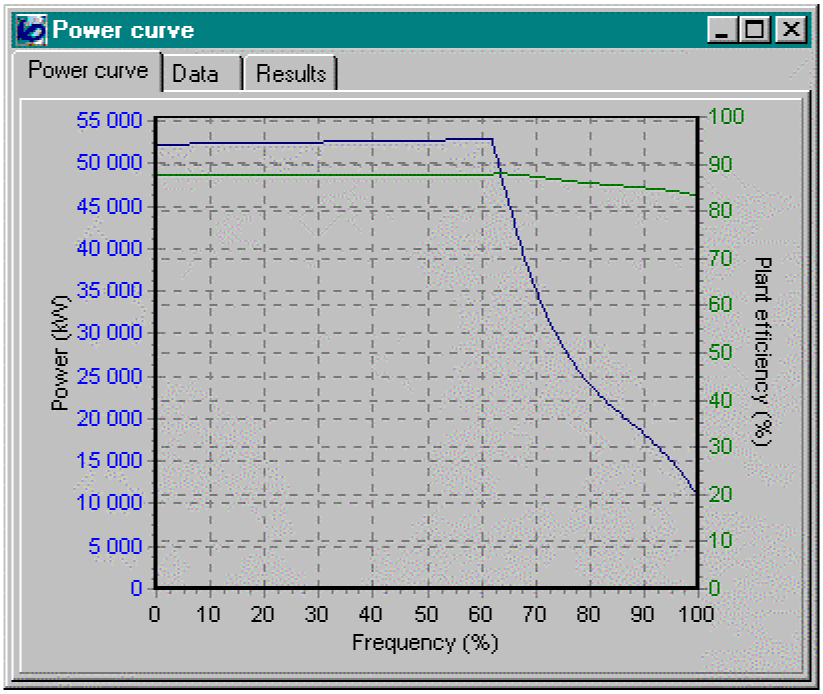
Turbine selection



Range of use

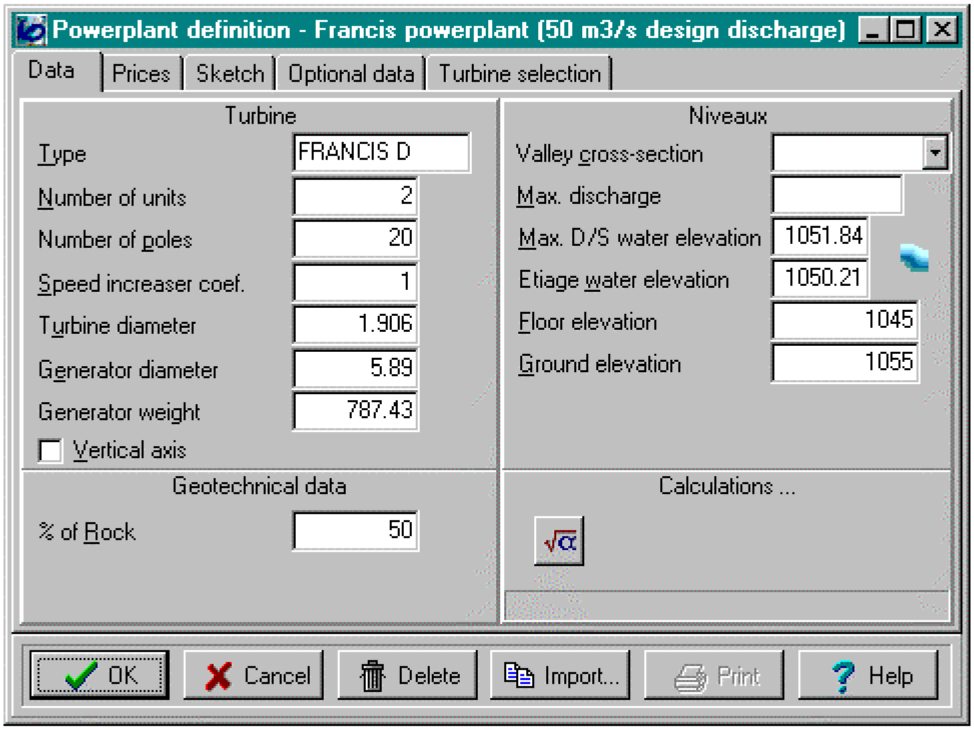


Plant efficiency and power curve

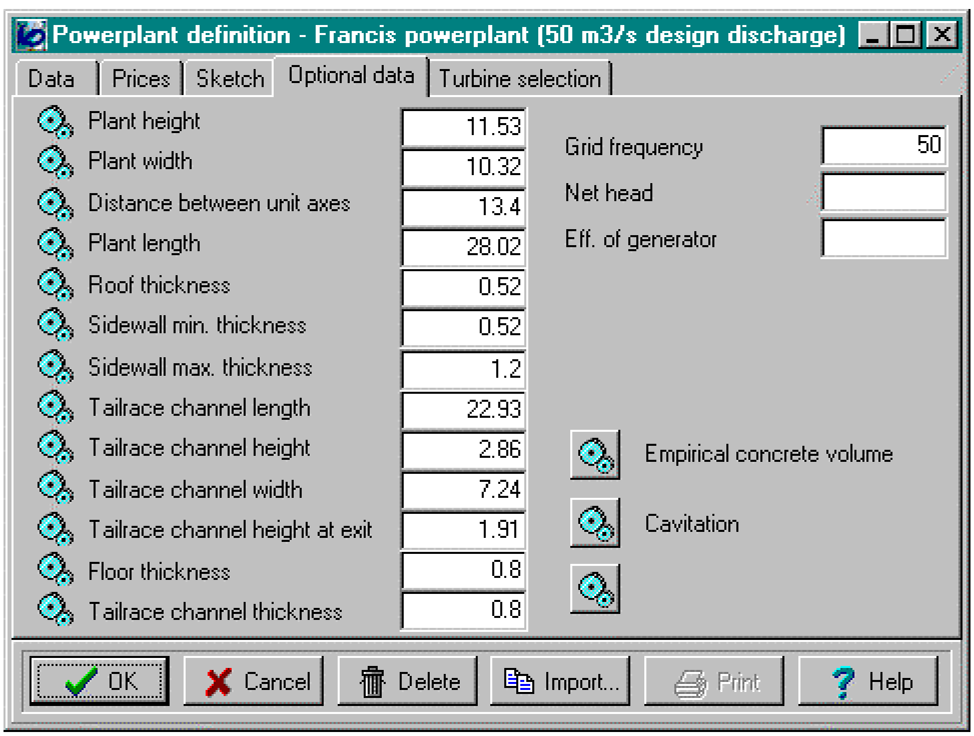


Plant structural design

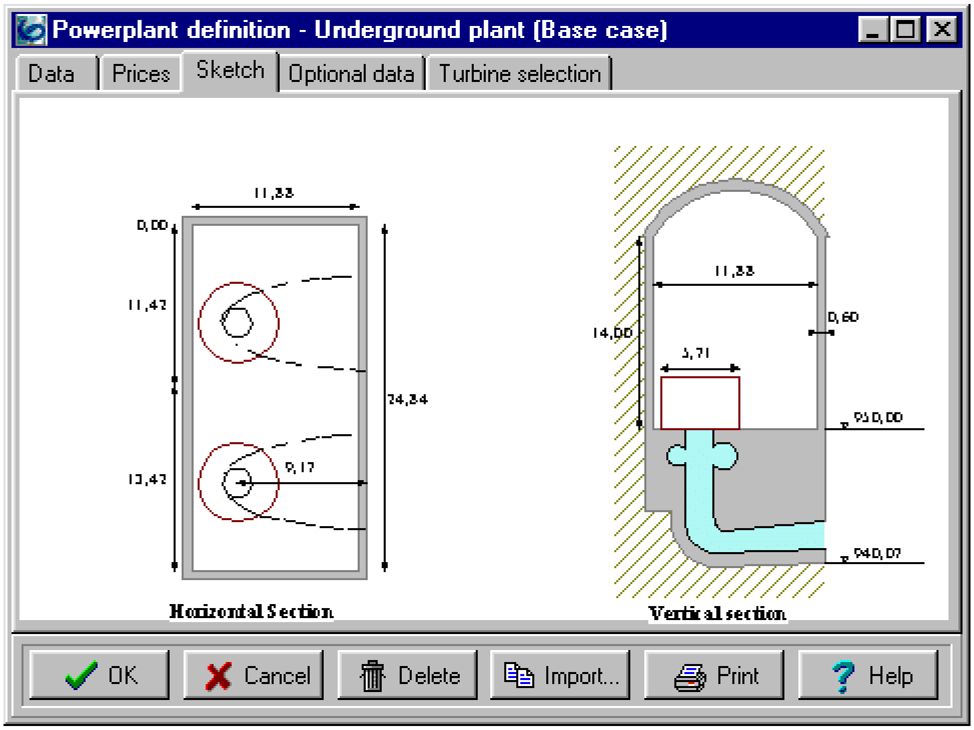
Basic data



Options



Sketch



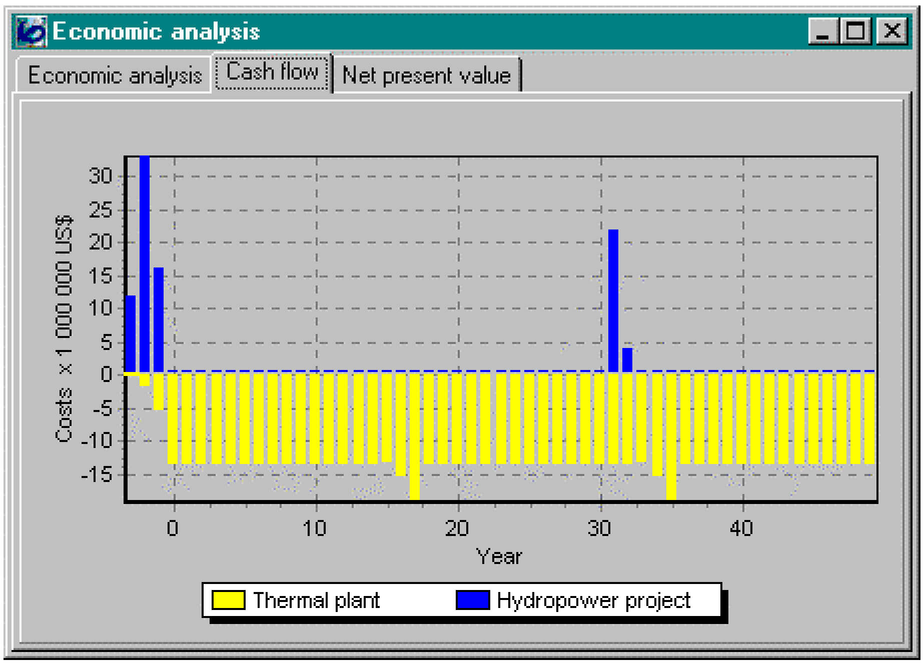
Powerplant definition - Underground plant (Base case)
Data
Prices
Sketch
Optional data
Turbine selection
Horizontal Section
Vertical section
OK
Cancel
Delete
Import...
Print
Help

Economic analysis

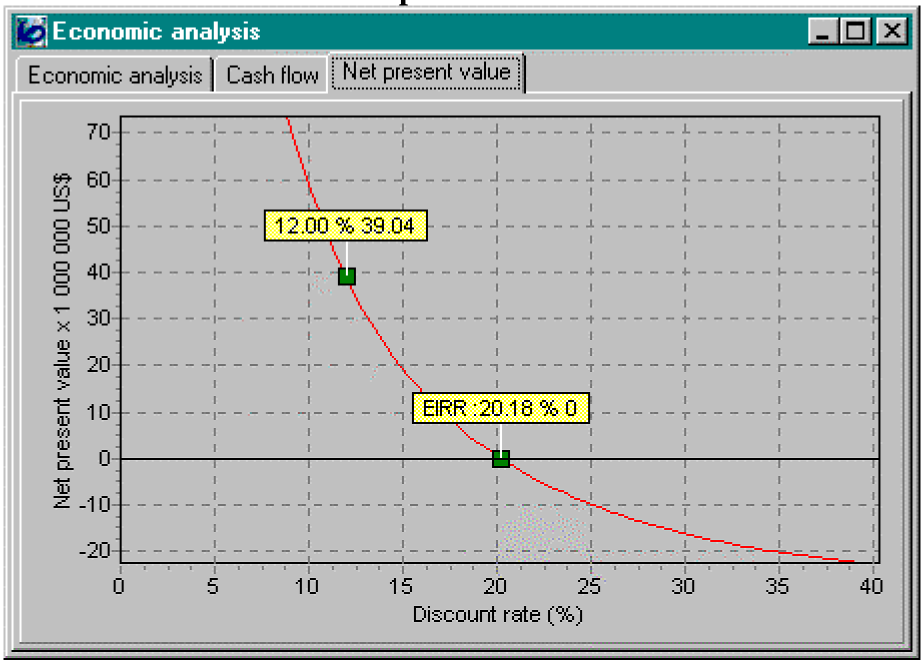
This analysis compares the hydropower project with an equivalent thermal plant and computes the Cash-flow diagram and the Net present value curve.
Results of the analysis are :

- internal rate of return,
- net present value,
- energy cost,
- benefit-cost ratio.

Cash-flow



Net present value

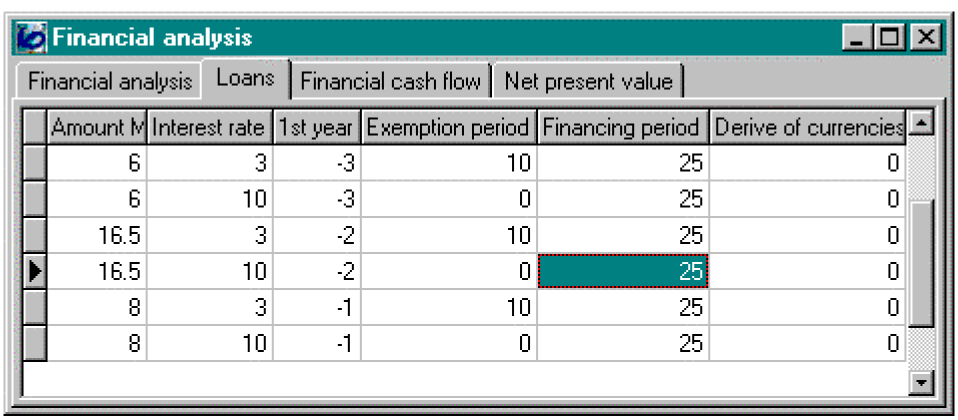


Financial analysis

Financial analysis compares costs and revenue, taking into account loan conditions. Results are given in terms of :

- cash flow diagram,
- internal rate of return,
- net present value,
- benefit cost ratio.

Loans

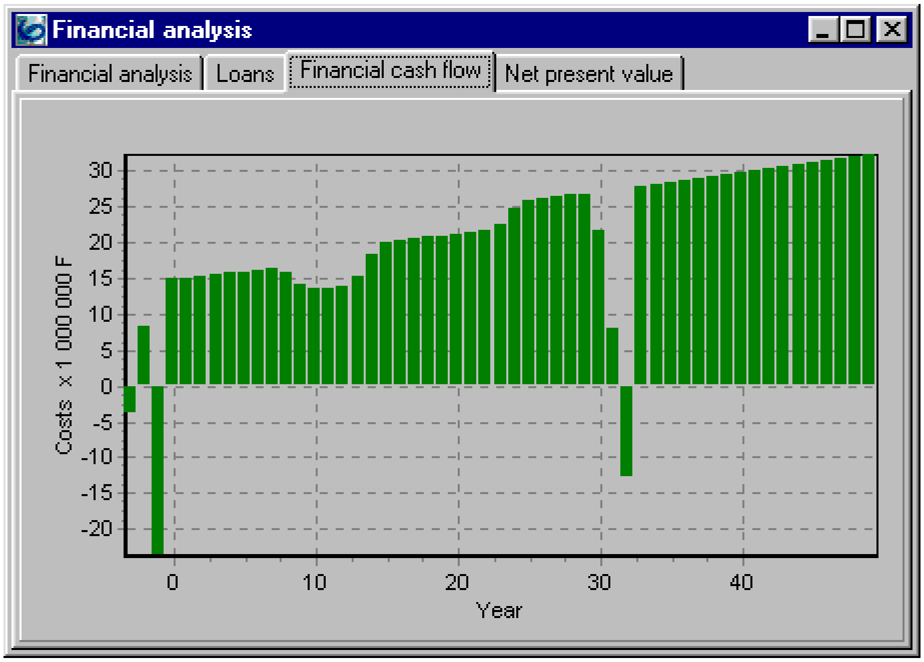


Financial analysis

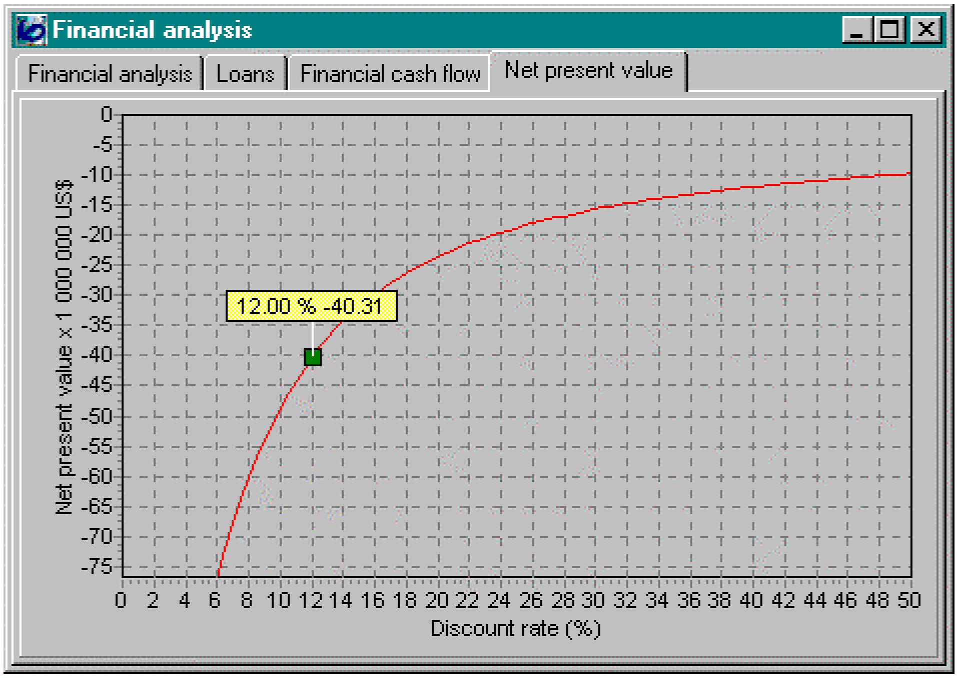
Financial analysis | Loans | Financial cash flow | Net present value

Amount M	Interest rate	1st year	Exemption period	Financing period	Derive of currencies
6	3	-3	10	25	0
6	10	-3	0	25	0
16.5	3	-2	10	25	0
16.5	10	-2	0	25	0
8	3	-1	10	25	0
8	10	-1	0	25	0

Cash-Flow

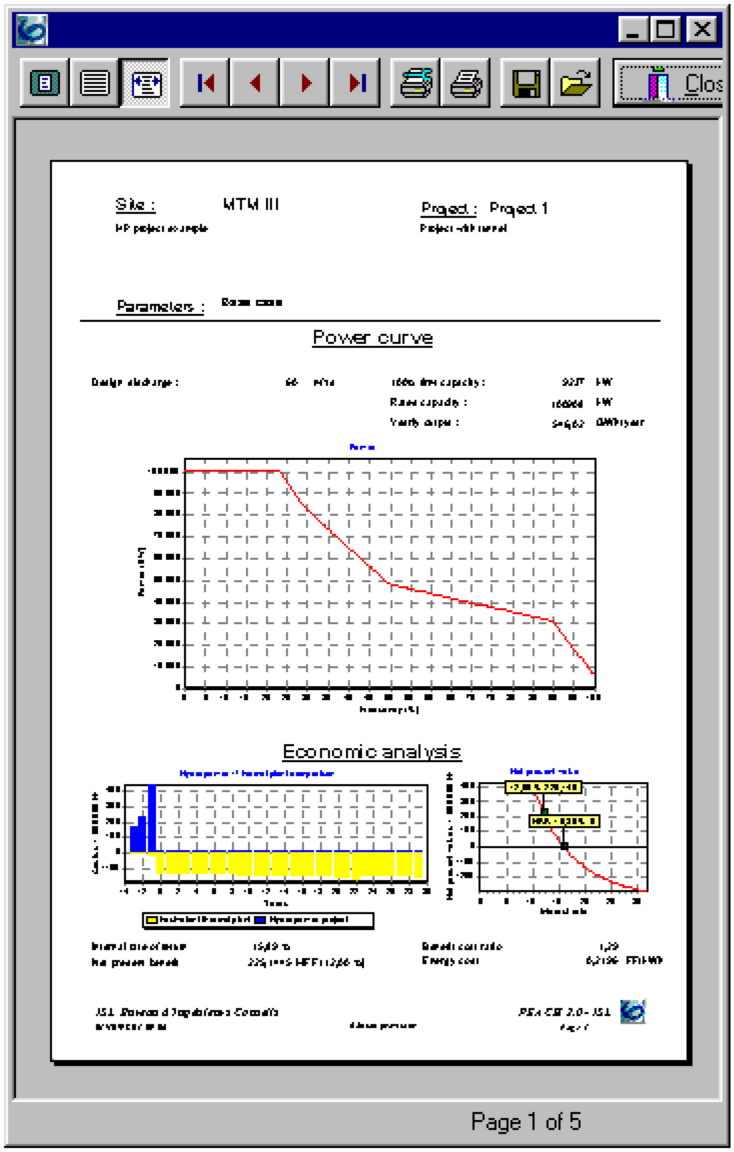


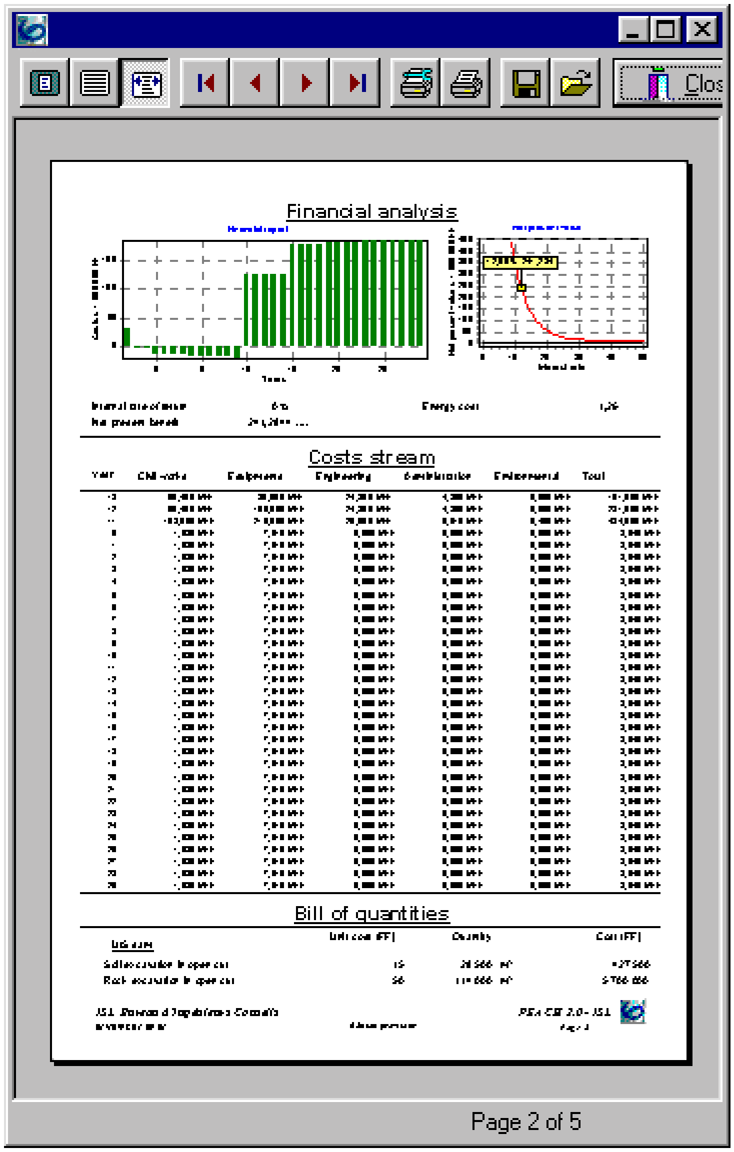
Net present value

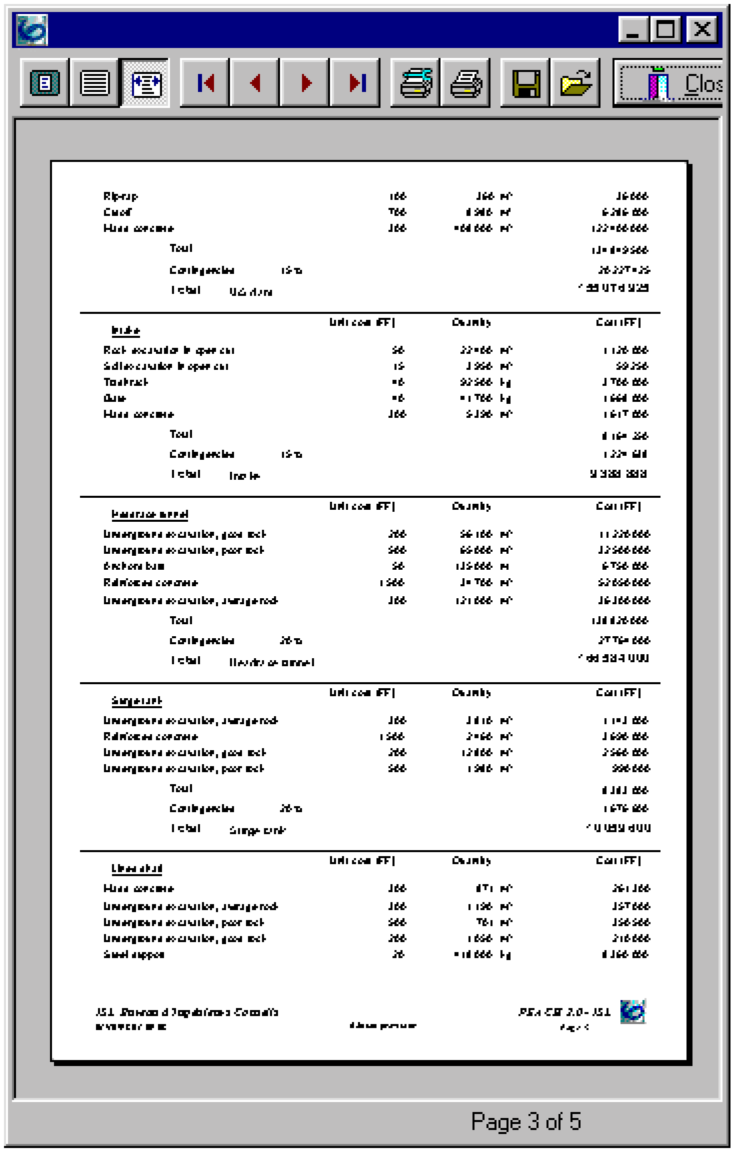


Automatic report edition

Screen copies of report excerpts. All PEACH tables, graphes and sketches might be copied and exported.




Financial analysis
Costs stream
Bill of quantities
Page 2 of 5

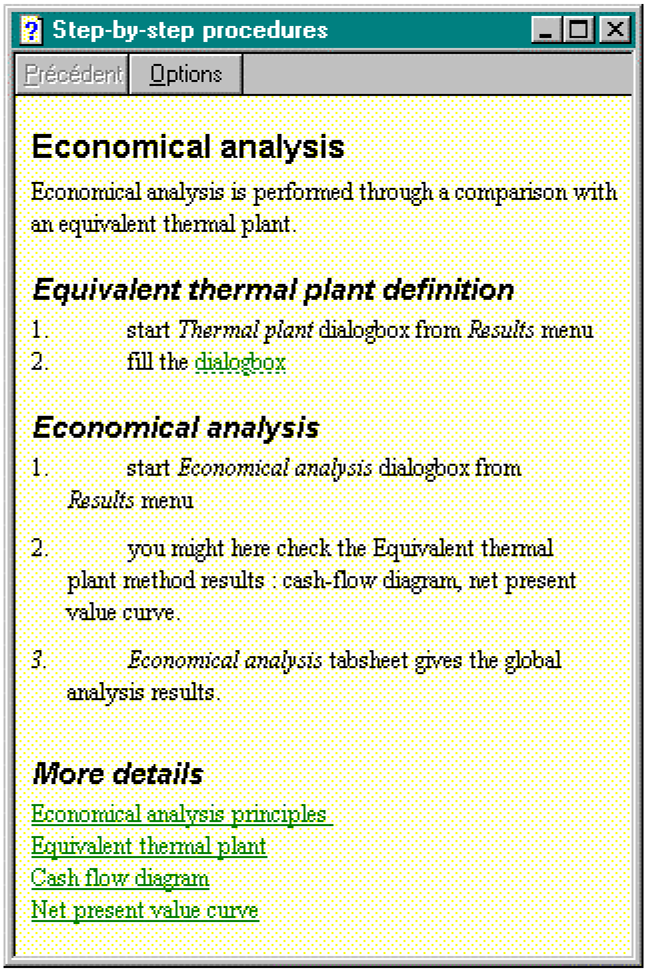

Page 3 of 5

On-line assistance

Peach gives :

- a comprehensive on-line assistance, including technical references,
- step-by-step assistances, which guide the user throughout Peach procedures.

Step-by-step assistant



Peach

Prices

Software license

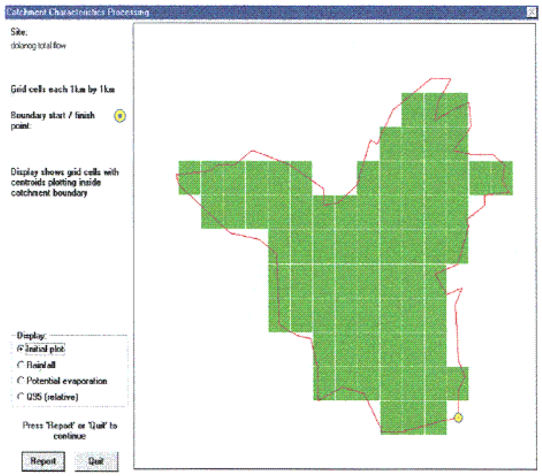
	Price
Company	
1 software license	30 000FRF
2 software licenses	55 000FRF
3 software licenses	75 000FRF
More than 3 licenses	Contact Us
University (1)	
3 software licenses	30 000FRF

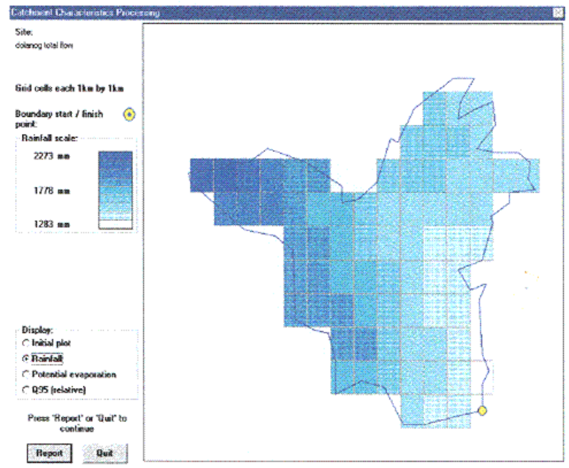
Options

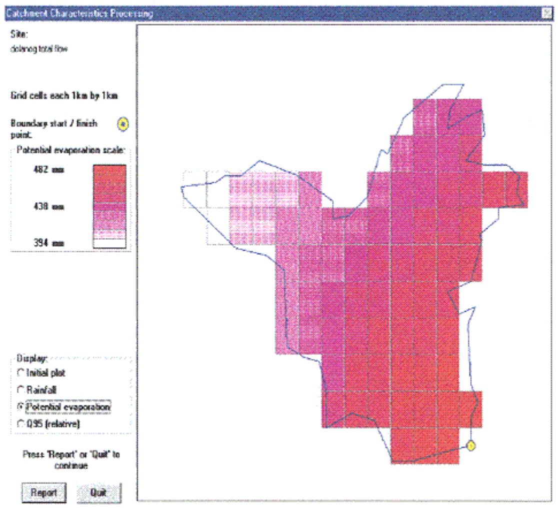
1- Annual maintenance	7 500 FRF
2 – Technical assisitance by email (per year)	6 000 FRF

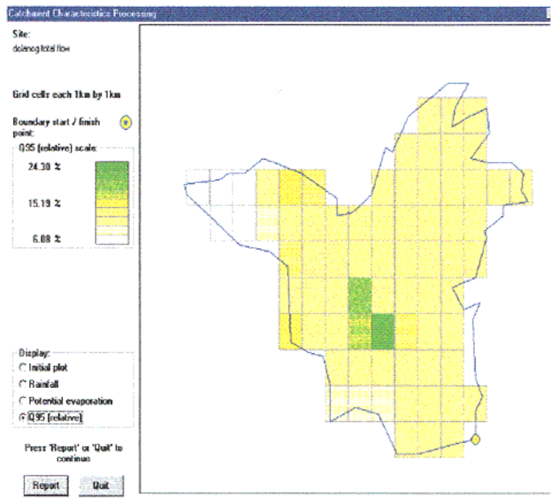
(1) for education only

14 Appendix 5 – Hydra, The European Atlas of Small Hydropower Potential







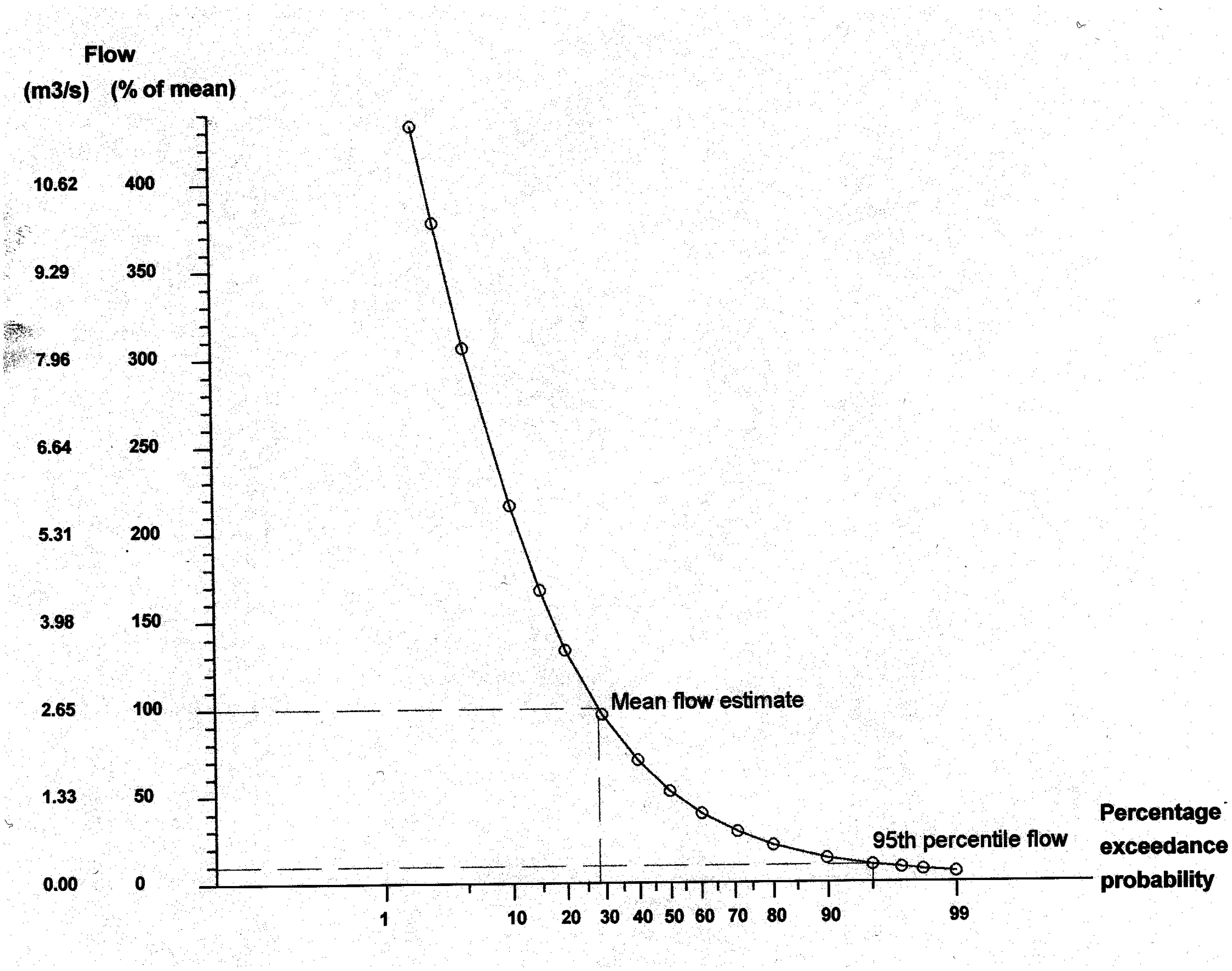


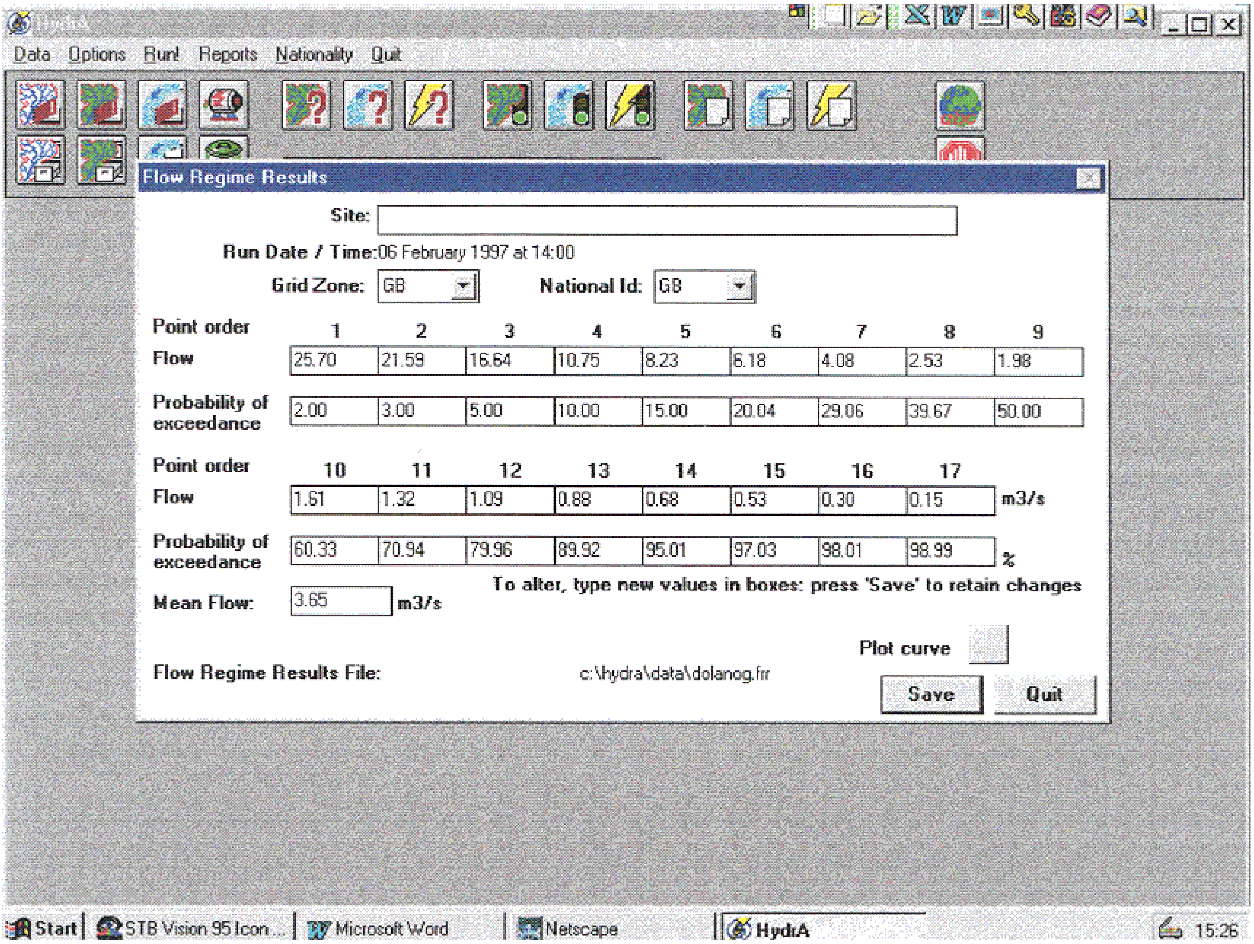
Flow Regime Report
Dolanog total flow

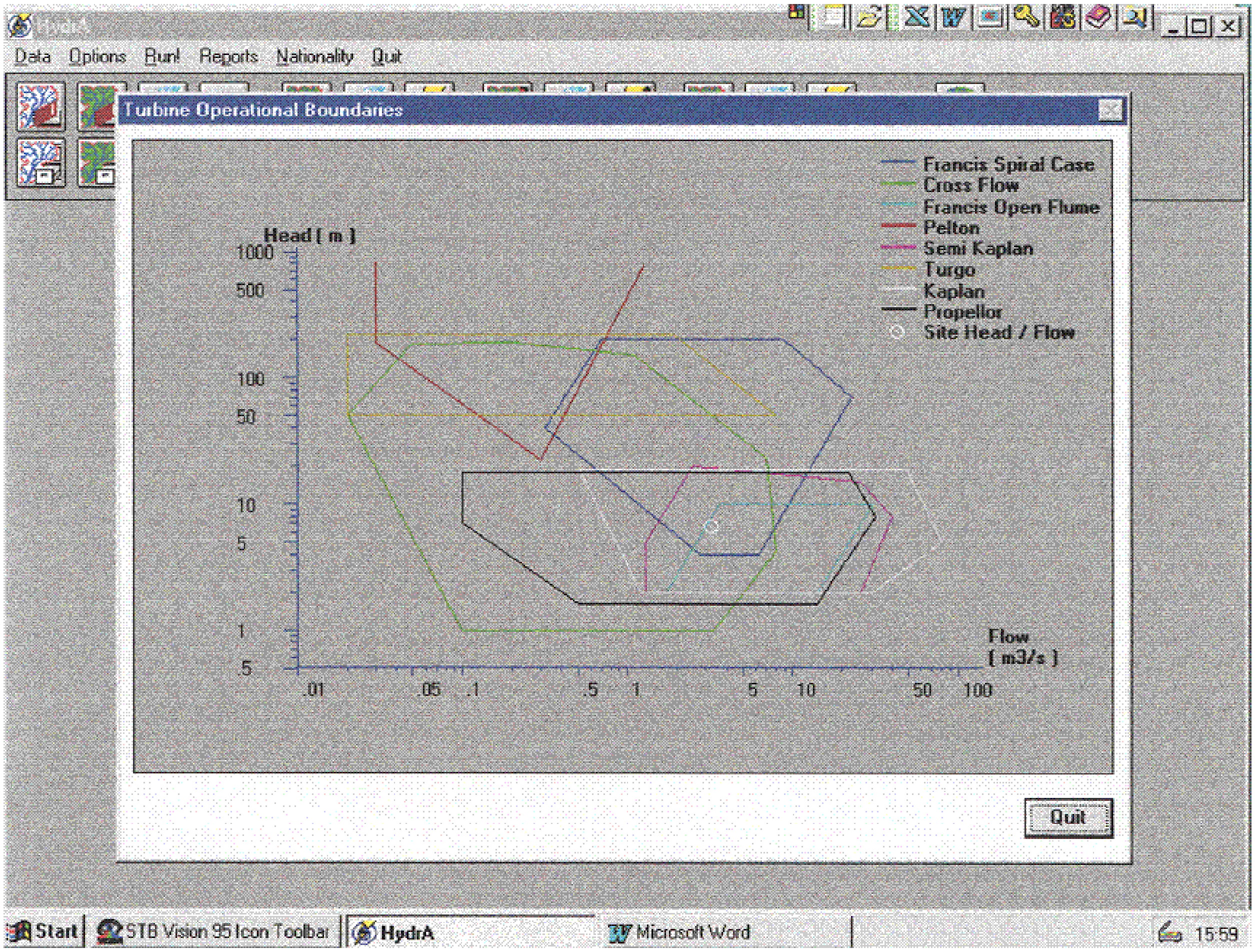
Run date/time	27 February 1997 at 14.44
Catchment Characteristics file:	c:\hydra\data\dolanog.ccf
Catchment Characteristics	
Total Area:	70.7 km^2
Average rainfall	1622.5 mm
Average potential evaporation:	438.5

Flow Regime Results

Q95 (% of mean)	9.8%
Mean flow estimate:	2.65 m^3/s
Q95	0.26 m^3/s




HydrA
Data Options Run! Reports Nationality Quit
Flow Regime Results
Site:
Run Date / Time: 06 February 1997 at 14:00
Grid Zone: GB
National Id: GB
Point order 1 2 3 4 5 6 7 8 9
Flow 25.70 21.59 16.64 10.75 8.23 6.18 4.08 2.53 1.98
Probability of exceedance 2.00 3.00 5.00 10.00 15.00 20.04 29.06 39.67 50.00
Point order 10 11 12 13 14 15 16 17
Flow 1.61 1.32 1.09 0.88 0.68 0.53 0.30 0.15 m3/s
Probability of exceedance 60.33 70.94 79.96 89.92 95.01 97.03 98.01 98.99 %
To alter, type new values in boxes: press 'Save' to retain changes
Mean Flow: 3.65 m3/s
Plot curve
Flow Regime Results File: c:\hydra\data\dolanog.frr
Save
Quit
Start
STB Vision 95 Icon...
Microsoft Word
Netscape
HydrA
15:26


HydrA
Data Options Run! Reports Nationality Quit
Turbine Operational Boundaries
Francis Spiral Case
Cross Flow
Francis Open Flume
Pelton
Semi Kaplan
Turgo
Kaplan
Propellor
Site Head / Flow
Head [m]
1000
500
100
50
10
5
1
.5
Flow
[m3/s]
.01
.05
.1
.5
1
5
10
50
100
Quit
Start
STB Vision 95 Icon Toolbar
HydrA
Microsoft Word
15:59

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