HydroHelp 5

AN EXCEL PROGRAM

DEVELOPED FOR

PRE-FEASIBILITY ASSESSMENT

OF

PUMP-STORAGE HYDROELECTRIC SITES

BY

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HydroHelp 5 for pump-turbine sites.

A continuation of the series of HydroHelp hydro design and cost programs.

A series of programs called HydroHelp has been developed to allow engineers to obtain an initial assessment of a hydro site, with a minimum of site data. All programs use Microsoft Office, Excel 2003 on Windows XP. Some data on charts may be lost if run on older versions of Microsoft Windows. The pump-storage program HydroHelp 5 is unprotected and can be revised by the user. It is a continuation of the HydroHelp series, with the first 4 programs covering HydroHelp 1 for turbine selection, HydroHelp 2 for assessment of Francis turbined sites, HydroHelp 3 for assessment of Impulse turbined sites, and HydroHelp 4 for assessment of Kaplan turbined sites.

The HydroHelp 5 program follows the same format as the HydroHelp 2-4 programs, and guides the user through the pump-turbine site design process, providing the user with prompts in the adjacent "Comment" cell, as to the options available, and the best choice. All the user has to do is hold the cursor over a yellow "Comment" cell, and a box opens to provide detailed instructions on data entry. For this reason, the program does not require a manual. The program is intended for use by relatively inexperienced hydro engineers, by providing an "expert guide" throughout the project design process. The program calculates quantities and costs, based on the data input, for all the required structures and the electro-mechanical equipment, from initial clearing to the substation and transmission line. There is no upper limit on project size. The lower limit is at about 100MW. All cost data has been updated to North American 2008 costs. Equipment prices are based on using European or American equipment.

The HydroHelp program has a large data input sheet where all input data is grouped, comprising a total of 173 items in the program. All data can be derived from maps and a casual site inspection with a GPS position locator, without having to resort to surveys and geotechnical investigations. The end result is a comprehensive pre-feasibility cost assessment with a 3-page detailed cost estimate listing quantities, unit prices and costs. Of course, a detailed site inspection is preferable, and necessary if the preliminary assessment identifies an economic site. The input sheet includes all instructions on data entry. Data entry cells are blue, comment cells are yellow, and red cells on the same line indicate that either iteration is needed or there is a restriction on the data range, where the data must be below or above a number provided in an adjacent cell. For example, the program will calculate the upper surge level in a surge tank, and if the tank is in rock, the level of rock at the tank, must be above the upper surge level. The input sheet starts with options available to the user, as shown in the following –

DATA INPUT SHEET FOR PUMP-TURBINE PROJECT

3	**BAKER PT**	Estimate date --	5-Jan-09
4			
5	**Currency, Canadian $ = 1, USA $ = 2.**	1	
6	**Pump-turbine operating cycle daily (1) or weekly (2).**	1	Comment
7	**Upper reservoir on surface (1) or underground (2)**	1	
8	**Upper reservoir intake structure, yes = 1, no = 0.**	1	Comment
9	**Lower reservoir on surface (1) or underground (2)**	1	Comment
10	**Lower reservoir outlet structure, yes = 1, no = 0.**	1	Comment
11	**Runner diameter limit for umbrella generators, m.**	3.5	Comment
12	**Powerhouse crane capacity limit for single crane, tons.**	350	Comment
13	**Project design standard utility = 1, industrial = 2.**	1	Comment
14			

Other options are also available, such as whether to use a surge tank, the extent of concrete lining in the conduits, or manual optimization of the conduit size. Optimization of unit size and number of units is easily attained, assisted by an energy cost index where the user can immediately see the effect of increasing or decreasing conduit size or number of units. Input starts with basic site data as shown in the following –

14				
15	**Pump-turbine basic data.**		Comment	
16	**Upper reservoir water levels ------------ FSL, m.**	**750.0**	**LSL, m.**	730.0
17	**Lower reservoir water levels, ----------- FSL, m.**	160.0	**LSL, m.**	159.0
18	**Rated powerplant flow, m3/s.**	62.95	Comment	
19	**Number of pump-turbine units in powerplant.**	2	Comment	
20	**Rated turbine head in meters - iterated.**	558.3	Comment	558.3
21	**Tailwater temperature in degrees celcius**	20	Comment	Pump sigma
22	**Required pump runner NPSH meters**	35.66	Comment	0.0766
23	**Specified runner cavitation coefficienct "k"**	0.006	Comment	
24	**Number of runner blades (6, 7, or 8)**	8	Comment	
25	**Runner manufacturing factor "R"**	6.1	Comment	
26	**Plant capacity factor, iterate to = F26**	0.75	Comment	0.75
27				
28	**Operating cycle.**			
29	**Daily peak operating hours on daily cycle.**	8.0	Comment	12.0
30	**Normal +ve waterhammer design for penstock %**	45	Comment	
31	**Allowable negative waterhammer on penstock %**	35	Comment	
32				

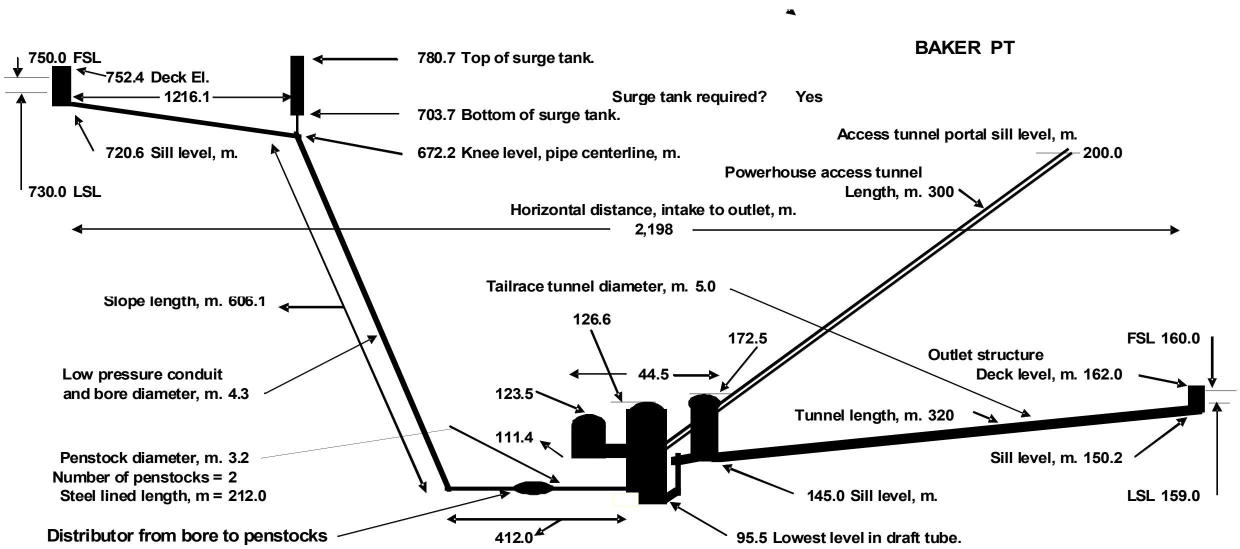
Holding the cursor opens comment cells to assist the user on data entry. For example, the following illustrates the comment from line 19 –

Number of units should be such that pump inlet diameter (Cell G19) is less than about 5m so that runner can be transported to site in one piece. Also, turbine throat diameter must be over about 1.5m (Cell G170) to facilitate 5-axis milling and assembly of runner.

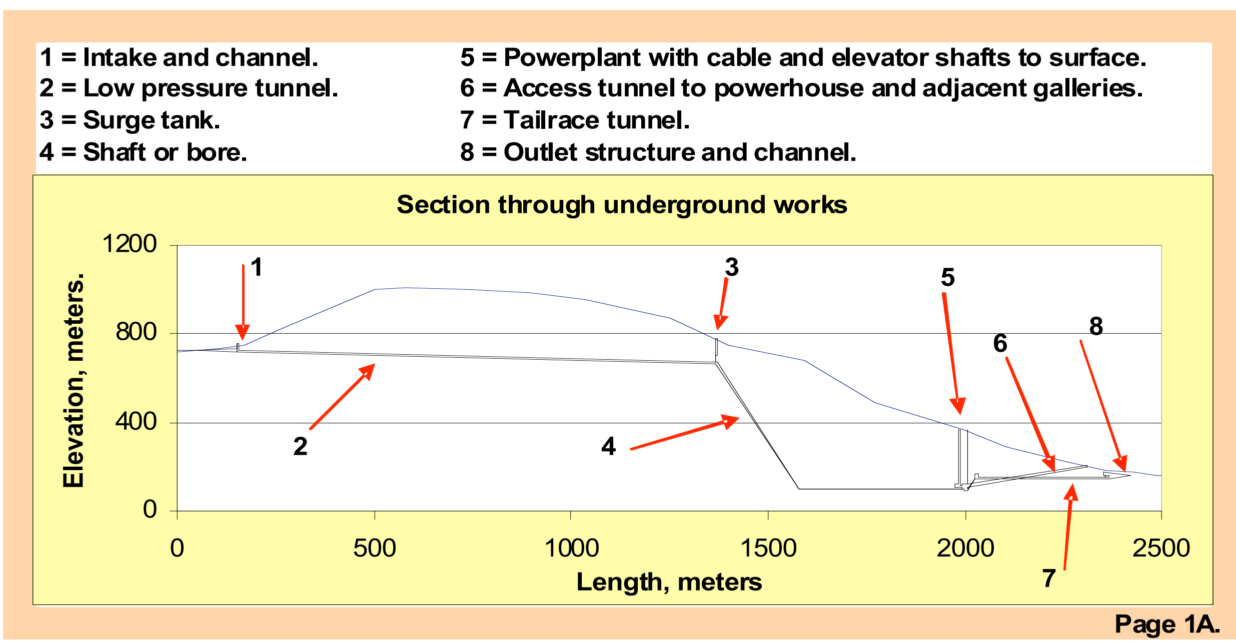
The input sheet also includes detailed instructions on program operation. The following is a typical instruction –

NOTE - FOR PROGRAM TO OPERATE CORRECTLY, NUMERICAL ITERATION OPTION MUST BE ON. Go to Tools, Options, Calculations and check iteration box. Set maximum change to 0.01. Read Cell H190 below first. **Program will crash if negative numbers developed. Always enter the lower reservoir elevation first if above elevation of previous site on program.**

All hydraulic computations are undertaken, such as governor open-close times, surge tank design, and conduit friction losses. Schematics are provided for surge and waterhammer levels, and for a section through the underground work. Also, there is a link to using Google Earth to obtain a profile of the land between the upper and lower reservoirs, and with this data, the program will develop a drawing section, to scale, of the underground excavation work, from intake to discharge structure. The schematic and the Google-site profile are shown in the following illustrations -



Schematic of underground work.

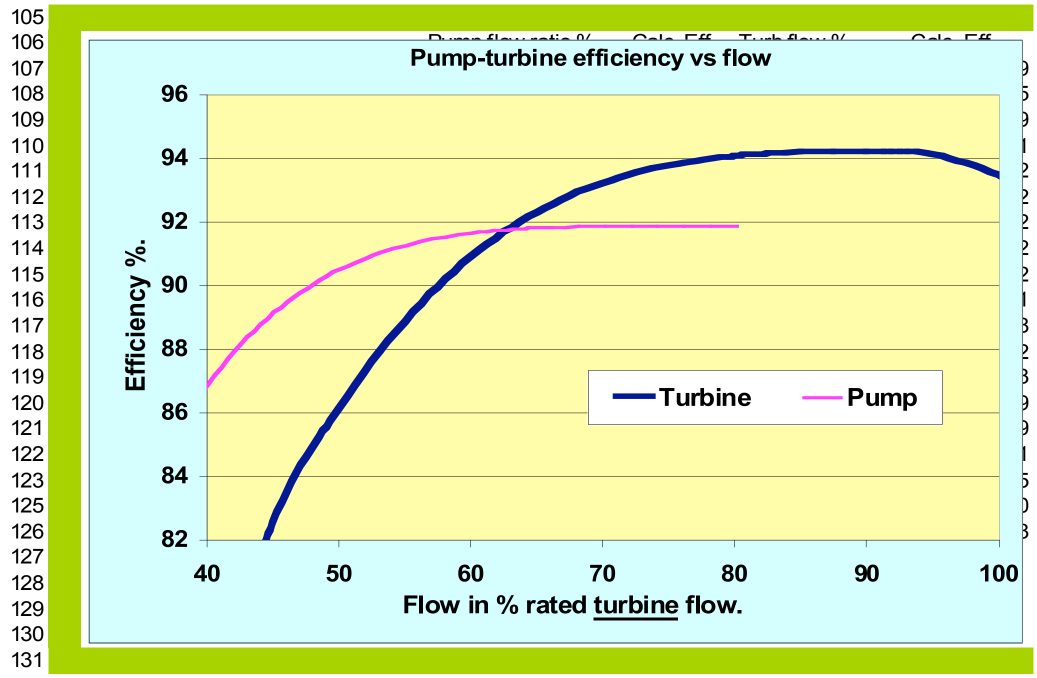


Section through underground work, to scale and developed by the program.

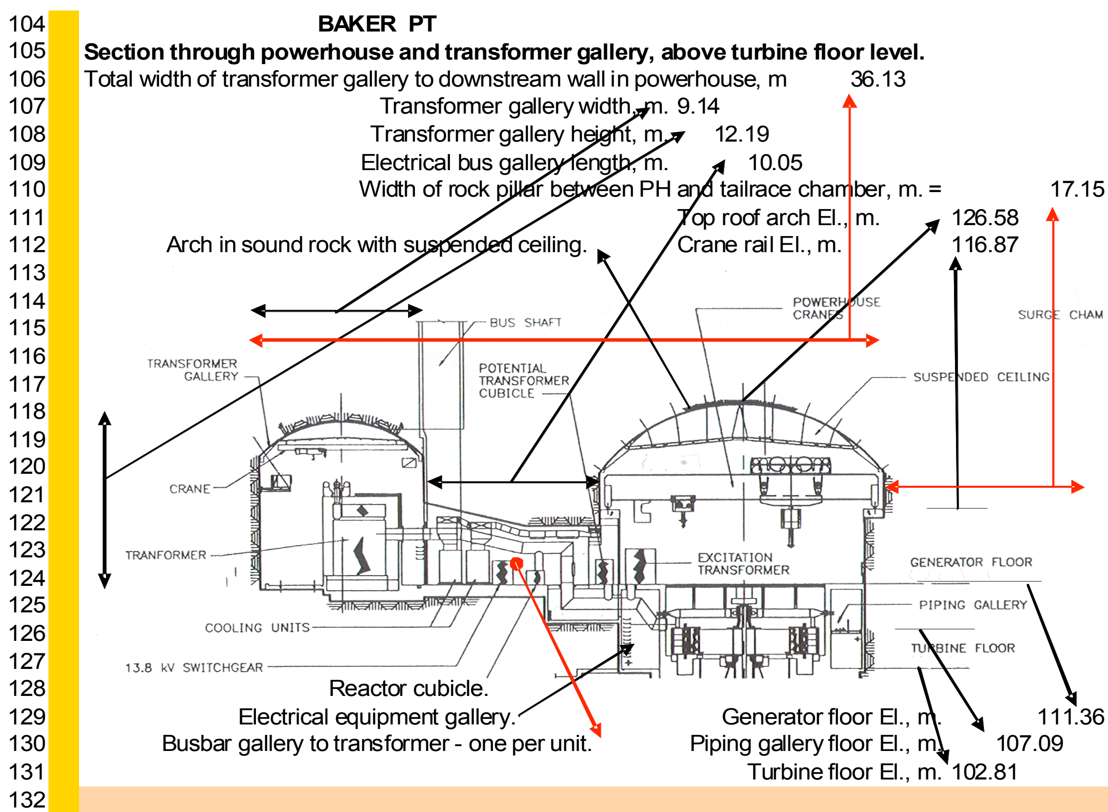
There are two versions of the scaled section, as above, and another to a much larger scale suitable for printing on an 11x17 inch sheet.

With HydroHelp 5 it is very simple to analyze alternatives such as the number of units, dam crest elevations, conduit diameters and so forth to quickly arrive at the preferred development, a task requiring many weeks of intense calculations without the use of the program.

Charts are provided for pump and turbine efficiency as shown in the following -



The program calculates all basic structure dimensions, from reservoir wave heights and the corresponding average rip-rap size on the dam, to the capacity of the powerhouse crane. Sufficient dimensions are shown on typical generic sections of the required structures, to allow a draftsman to produce general drawings for the project, as shown in the following –



Water to wire costs for the generating equipment are developed, along with cost of all ancillary electromechanical equipment, from intake gates to powerplant elevators, as shown in the following tabulation copied from the cost estimate sheet –

82				
83	**Cost of auxiliary mechanical equipment.**			
84	Total cost of intake/outlet stoplog and/or bulkhead gate equipment.			0.933
85	Total cost of intake/outlet gate guides and hoist equipment.			2.053
86	Total cost of draft tube gate guide and hoist equipment.			0.373
87	Total cost of powerhouse crane(s).	Number of cranes =	1	1.386
88	Total cost elevators.			1.471
89	Total powerhouse ancilliary mechanical systems.			1.947
90	**Sub-total cost auxiliary mechanical systems.**			**8.163**
91				
92	**Cost of auxcilliary electrical equipment, summary.**			
93	Underground and surface major transformers 13.8/500kV			5.272
94	500kV insulated cables to surface.			1.239
95	Station service.			0.583
96	Surface switchyard.			5.988
97	Total powerhouse ancilliary HVAC systems.			0.237
98	**Sub-total cost of electrical equipment, except units and valves.**			**13.318**
99				
100	**Cost of W/W generating equipment, TIV, switchgear and controls.**			**68.310**
101				
102	**Total electro-mechanical component cost, millions $ ---------------- >**			**$89.791**
103				

In the cost sheet, the associated program-calculated quantities are shown, along with a suggested unit cost (for North American projects) so that the user can input an appropriate unit cost. The suggested unit cost is based on work quantity, use of union or non-union labor and the site frost days. More frost days and smaller quantity produce higher suggested unit costs. The user has the option of entering other unit costs, as shown in the following extracted from the civil work cost sheet –

	BAKER PT					
	Unit prices used in cost estimate. **Return to this page after completing all data entry to see if unit prices are compatible with quantities shown in column F.**					**Suggested unit cost, based on quantity of work.**
	Work item.			**Unit cost.**	**Estimated quantity.**	
	Earthwork and clearing.			Comment		
10	Clearing, per hectare, $/H			$16,547.20	19.1	**$16,547.20**
11	Unit cost of overburden excavation, m3.			$19.98	56,850	**$19.98**
12	Unit cost of rock excavation, $/m3.			$79.94	23,906	**$79.94**
13	Unit cost of foundation excav in sand or gravel for cutoff, $/m3.			$53.66	27,754	**$53.66**
14	Rock excavation in tunnels, $/m3.			$411.24	165,304	**$411.24**
15	Impervious fill in cofferdams, $/m3.			$0.00	0	**$0.00**
16	Rock fill in cofferdams, $/m3.			$0.00	0	**$0.00**
17	Impervious fill in dams, $/m3.			$40.98	110,976	**$40.98**
18	Filter material in dams, $/m3.			$64.66	64,729	**$64.66**
19	Rock or embankment material in dams, $/m3.			$53.49	314,396	**$53.49**
20	Rock rip-rap, $/m3.	d50 size, m. =	0.24	$166.59	7,046	**$166.59**
21	Sidehill rock excavation for pipeline, $/m3.			$0.00	0	**$0.00**
22	Sidehill overburden excavation for pipeline, $/m3.			$0.00	0	**$0.00**
23	Unit cost of CARPI type liner in reservoirs. $/m2.			$0.00	0	**$0.00**
24						

The program includes a summary sheet suitable for copying into a report, as follows –

HydroHelp - 5 - for PUMP-TURBINES

An Excel + Google program for estimating the cost of a pump-turbine development.

BAKER PT	316 MW	5-Jan-09

Project parameters determined by program.			
Turbine output at rated head and flow, MW.	**161.15**	**Estimated pay-back time not including taxes, years.**	
Powerplant output at rated head and flow, MW.	**316.47**		
Turbine rated net head, m.	**558.25**		
Daily maximum generation MWh.	**2,476**		**38.3**
Corresponding daily power consumption, MWh.	**3,357**		
Overall generating/pumping efficiency factor, %.	**73.8**	# turbines =	**2**
Pump-turbine runner diameters, inlet, m.	**3.044**	Outlet d, m.	**1.418**
Estimated cost, in $M, including interest.	**$501.3**	**$ CAN.**	

Summary of input data for project.			
Headpond full supply level, m. (FSL)	**750.00**	LSL =	**730.00**
Tailpond full supply level, m.	**160.00**	LSL =	**159.00**
Number of water conduits to powerhouse.	**1**		
Total conduit length, intake to draft tube gate or tailrace tunnel outlet, m.			**2,664**

Summary of program output for some parameters.			
Overburden excavation, cubic meters.	**56,850**	Rock Exc.	**23,906**
Rock tunnel excavation, cubic meters.	**165,304**	Conc, m3.	**36,639**
Steel penstock and tunnel liner weight, tonnes.	**960**	Penst. D, m.	**2.229**
Rated turbine flow m3/s.	**31.5**	Pump m3/s	**25.2**
Powerhouse crane capacity, tonnes.	**237**	# cranes =	**1**
Live storage volume, millions of m3.	**1.813**	Stab. Index =	**5.6**
Annual peak turbine energy, MWh.	**631,422**	**Daily cycle**	
Annual off-peak pump energy, MWh.	**855,939**		

Data input and options selected during data input, may vary for each alternative.			
Powerplant generator quality.	**Utility**		**Options for design of all alternatives of powerplant and conduit.**
Surge tank on penstock conduit.	**Yes**		
Surge tank on tailrace conduit.	**Yes**	**By program**	
Turbine equipped with inlet valve.	**Yes**		
Type of draft tube gate hoist.	**Crane**	**By program**	
Generator casing top at repair bay level.	**Yes**		
Conduit optimization option.	**By program**		

Currency, Canadian $ = 1, USA $ = 2.	1	
Pump-turbine operating cycle daily (1) or weekly (2).	1	Comment
Upper reservoir on surface (1) or underground (2)	1	
Lower reservoir on surface (1) or underground (2)	1	Comment
Lower reservoir outlet structure, yes = 1, no = 0.	1	Comment
Upper reservoir intake structure, yes = 1, no = 0.	1	Comment
Runner diameter limit for umbrella generators, m.	3.5	Comment
Powerhouse crane capacity limit for single crane, tons.	350	Comment
Powerhouse design standards utility = 1, industrial = 2.	1	Comment
		Page 1.

And a cost summary, also suitable for adding to a report, as follows –

Ballpark cost by quantities in millions $.		
Clearing at structure sites. Ha.	0.316	
Offices - cost per square meter.	0.300	
Sub-total cost of embankment dam and weir spillway.	33.760	
Sub-total intake/outlet civil work cost.	17.415	
Sub-total underground excavation work cost.	117.292	
Upper low pressure conduit surge tank cost, if required.	2.135	
Sub-total pipelines and penstocks.	14.059	
Total powerhouse civil work cost.	17.422	
Total civil work cost, millions $ -- >		$202.698
Sub-total cost auxiliary mechanical systems.	8.163	
Sub-total cost electrical equipment, except units and valves.	13.318	
Sub-total cost of electrical equip, except units and valves.	68.310	
Total electro-mechanical component cost, millions $ --------------- >		$89.791
Site access and transmission. -- >		$30.702
Feasibility studies and site investigations.	11.670	
Environmental work.	7.352	
Detailed designs and contract documents.	15.145	
Site supervision work.	16.054	
Contingencies on civil and overheads.	70.906	
Contingencies on electromechanical work.	4.490	
Sub-total indirect costs. -- >		$125.617
Total project cost, millions $CAN.	**$449**	
Interest rate, %.	6.0	
Estimated construction time, months.	52	
Interest during construction, $M.		$52.53
Total cost including interest, million $.	**$501**	

For printing the output, there are several options as follows:- (1) Print a one-page executive summary and the cost summary, (2) Print the executive summary and the detailed 3 page cost estimate, or (3) Print a complete input-output.

Experience has indicated that users have their own programs for undertaking a financial analysis. However, to assist the optimization processes within the HydroHelp 5 program, a simple cost per kWh index is included along with an estimated time for capital recovery. With the latter, a final comment on development prospects is shown, ranging from “Too optimistic - check input data” to “Not worth further investigation”. Due to the paucity of cost data on pump-turbine developments, the program has only been tested against two cost estimates for pump-turbine developments prepared by another consultant. The HydroHelp 5 costs were revised to match.
