WOLF1D PKW 2.0 – User manual and tutorial
SE - 06/06/2011

Introduction

The freeware WOLF1D PKW has been developed by the HACH research unit of the University of Liege.

Using the weir geometry, it is able to compute the flow over half a unit of a PKW for a given range of discharge upstream of the structure. The results are

- the water level upstream of the weir depending on the discharge ;
- the distribution of water depth and discharge along both the inlet and the outlet.

Details about the mathematical model, the numerical scheme and the modeling assumptions can be found in dedicated papers by Erpicum S., Machiels O., Archambeau P., Dewals B. and Pirotton M., for instance http://hdl.handle.net/2268/40326 or http://hdl.handle.net/2268/91470. The notation used to name the PKW geometrical parameters is the one proposed by EDF-CIH, LCH-EPFL and ULg-HACH in their naming convention proposal (http://hdl.handle.net/2268/91433).

This document explains, through an example, how to use the solver WOLF1D PKW.exe, version 2.0.

Files

The solver lies in an *.exe* file. It has been written in Fortran and compiled with an Intel Fortran Compiler. Modeling data and results are exchanged with the solver using ASCII text files.

These text files have a generic name "*XX*" and various extensions:

- *XX.par* contains the modeling parameters;
- *XX.top* contains the PKW topography;
- *XX.R* and *XX.R1* contains the modeling results;
- Additional information may be written by the solver in the file *XX.nfo;*
- The file *emplacement.ini* indicates to the solver where the data files are.

In order to facilitate the writing of these text files and to ease the analysis of the results, an Excel file has been created (*PKW.xls*). This file is also useful to summarize in a single place the modeling parameters and results.

The file contains 3 sheets: the sheet "Main" with the PKW unit geometry and hydraulic results for one discharge, the sheet "H-Q" to look at a computed head/discharge curve and compare it with experimental results and the sheets "top" to help in creating the *.top* data file.

Generally, in the Excel file,

- the red values need to be defined by the user (to copy/paste in the text files),
- the black values are the modeling results (copy/paste from the text files),
- the blue values are automatically computed by formula in the Excel file.

How to prepare and run a modeling with WOLF1D PKW?

1) Define the value of the geometrical parameters of the PKW unit you want to test

P_i=.525m

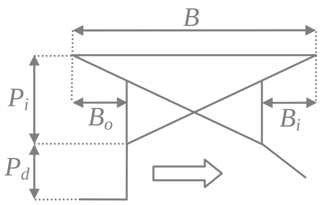
P_d=.2m

B=.63m

B_i= B_o=.185m

W_i= W_o=.18m

T_s=10mm



2) Open the *PKW.xls* file

In the "Main" sheet, define the value of all the cells written en red:

Δx = spatial discretization step → 5 mm

Nb of side wall cells = the number of cells along the sidewall = *(B/Δx)+1* → 127

W_i/2 = half the width of the inlet → 0.09 m

W_o/2 = half the width of the outlet → 0.09 m

K = Manning/Strickler roughness coefficient → 90

(Plastic)

$C_{d,lat}$ = constant discharge coefficient of the sidewall → 0.42

10 mm thick vertical wall, without crest shape (flat crest)

α = momentum exchange coefficient → 1

CFL = constraint on the time step for modeling stability → 0.01

Max nb of time step = maximum number of time step before stop of the modeling (to avoid ad infinitum computing) → 500 000

Depending on the number of cells

Freq = frequency, in time step, to check the computation convergence → 5000

Tol = tolerance to check the computation convergence: relative difference between upstream and downstream discharge, to be verified twice regarding ***Freq*** → 1.D-6

0 to compute until ***Max nb of time step***

Q1 = minimum discharge to model → 0.01

Q2 = maximum discharge to model → 0.1

ΔQ = discharge step to compute H/Q curve in between ***Q1*** and ***Q2*** → 0.005

Hydrologie, Hydrodynamique Appliquée et Constructions Hydrauliques (HACH)
Chemin des Chevreuils, 1 Bât. B52/3 B-4000 Liège 1 (Belgique)
☎ + 32 (04) 366 95 96 🖷 + 32 (04) 366 95 58
hach@ulg.ac.be http://www.hach.ulg.ac.be

Column A = cells number, from 1

Column C = inlet topography, from reservoir bottom at level 0 on cell 1

Column D = outlet topography, including reservoir bottom at level 0 on cell 1

!! In order to avoid the need for downstream boundary conditions, the inlet and the outlet have to be extended downstream of the weir by a steep slope channel (typically 45° slope) on a length equal to B/2.

The PKW unit longitudinal profile is automatically drawn from columns B to D values on the graph on bottom right of the sheet (see Figure 1)

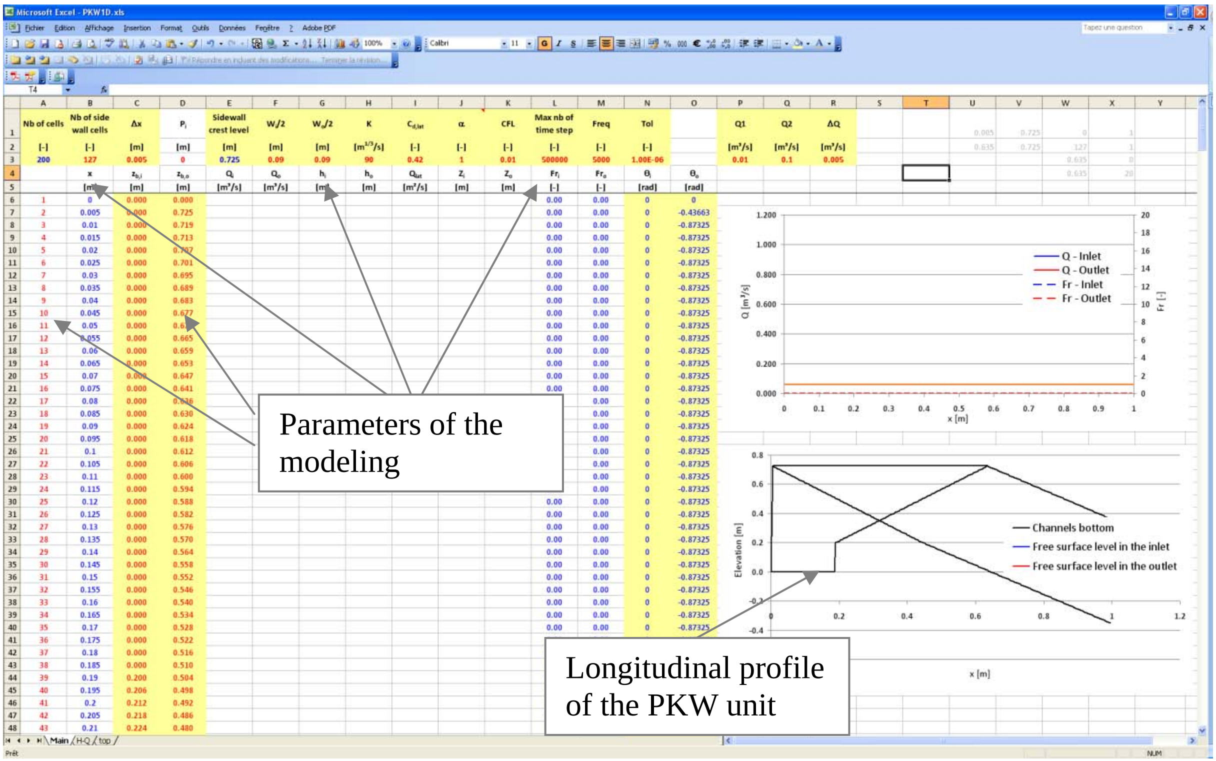


Figure 1 : Excel file completed with the modeling data

3) Create new or fill in existing *.par* and *.top* files

Choose a generic name for your work → test

Create a text file with the generic name and extension *.par* → test.par

Fill in this file with the following parameters on successive lines. An example is given on Figure 2. Parameters value comes from the Excel file.

Nb of cells [-]

Nb of side wall cells [-]

Δx [m]

Sidewall crest level [m]

W_i/2 [m]

W_o/2 [m]

K [$m^{1/3}$/s]

$C_{d,lat}$ [-]

Q [m³/s] = discharge to consider for the modeling (if you want to compute a H/Q curve with ***Q1*** and ***Q2***, this value can be 0)

α [-1, 0 or 1]

CFL [-]

Max nb of time step [-]

Freq [-]

Tol [-]

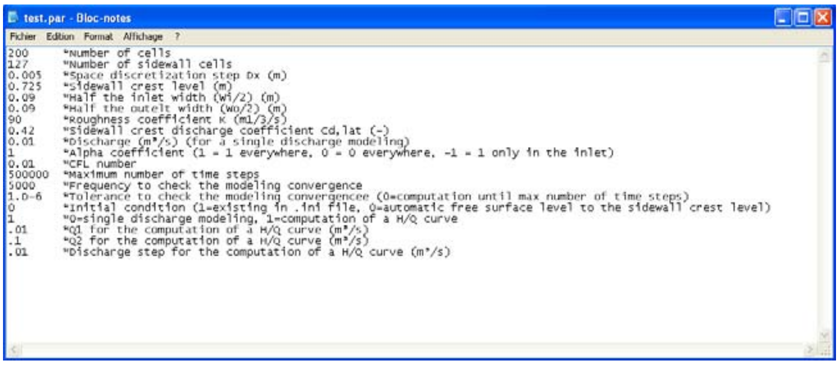
CI [0 or 1] = 1 if you want to give initial hydraulic conditions to the modeling (in an *.ini* text file) or 0 if the solver has to automatically initialize the modeling with a free surface flow at the side wall crest level

H/Q [0 or 1] = 0 if you only want to model the flow of the discharge ***Q*** ; = 1 if you want to compute the H/Q curve from ***Q1*** to ***Q2***

Q1 [m³/s]

Q2 [m³/s]

ΔQ [m³/s]



```
test.par - Bloc-notes
Fichier  Edition  Format  Affichage  ?
200      *Number of cells
127      *Number of sidewall cells
0.005    *Space discretization step Dx (m)
0.725    *Sidewall crest level (m)
0.09     *Half the inlet width (Wi/2) (m)
0.09     *Half the outelt width (Wo/2) (m)
90       *Roughness coefficient K (m1/3/s)
0.42     *Sidewall crest discharge coefficient Cd,lat (-)
0.01     *Discharge (m³/s) (for a single discharge modeling)
1        *Alpha coefficient (1 = 1 everywhere, 0 = 0 everywhere, -1 = 1 only in the inlet)
0.01     *CFL number
500000   *Maximum number of time steps
5000     *Frequency to check the modeling convergence
1.D-6    *Tolerance to check the modeling convergencee (0=computation until max number of time steps)
0        *Initial condition (1=existing in .ini file, 0=automatic free surface level to the sidewall crest level)
1        *0=single discharge modeling, 1=computation of a H/Q curve
.01      *Q1 for the computation of a H/Q curve (m³/s)
.1       *Q2 for the computation of a H/Q curve (m³/s)
.01      *Discharge step for the computation of a H/Q curve (m³/s)
```

Figure 2 : *.par* file completed with modeling data

Create a text file with the generic name and extension *.top* → test.top

Fill in this file by copy/paste the first 4 columns of sheet “top”, containing respectively column C, D, N and O of the sheet “Main”, i.e. the inlet topography, the outlet topography, the inlet axis angle (0) and the outlet axis angle (<>0) (Figure 3).

```
test.top - Bloc-notes
Fichier  Edition  Format  Affichage  ?
0       0       0       0
0       0.725   0       -0.43662716
0       0.719034091     0       -0.87325432
0       0.713068182     0       -0.87325432
0       0.707102273     0       -0.87325432
0       0.701136364     0       -0.87325432
0       0.695170455     0       -0.87325432
0       0.689204545     0       -0.87325432
0       0.683238636     0       -0.87325432
0       0.677272727     0       -0.87325432
0       0.671306818     0       -0.87325432
0       0.665340909     0       -0.87325432
0       0.659375        0       -0.87325432
0       0.653409091     0       -0.87325432
```

Figure 3 : *.top* file completed with modeling data

4) Link the solver with the data file

Create a text file called "*emplacement.ini*" and write in this file, between apostrophes, the pathway to the directory where the data files are stored on your computer, completed by the generic name of your data file:

→ 'D:\PKW Num Model\test' (Figure 4)

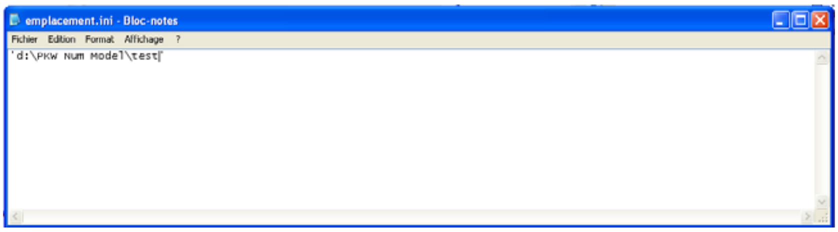


Figure 4 : *emplacement.ini* file

5) Computation of a single discharge

To compute the flow over the PKW for a single discharge, check in the *.par* file if the ***H/Q*** parameter is 0 and if the value of ***Q*** is not 0.

Place the WOLF1D PKW.exe file in the directory of your data file and double click on the *.exe* file. The computation is running… writing in a command line window the evolution of the computed tolerance with frequency ***Freq*** (Figure 5).

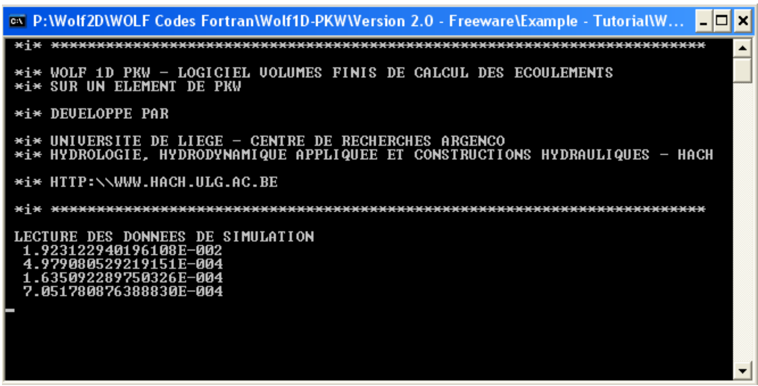


Figure 5 : Computation window

At the end of the computation, the solver indicates the time of simulation in seconds (Figure 6). To close the computation window, just click on "enter".

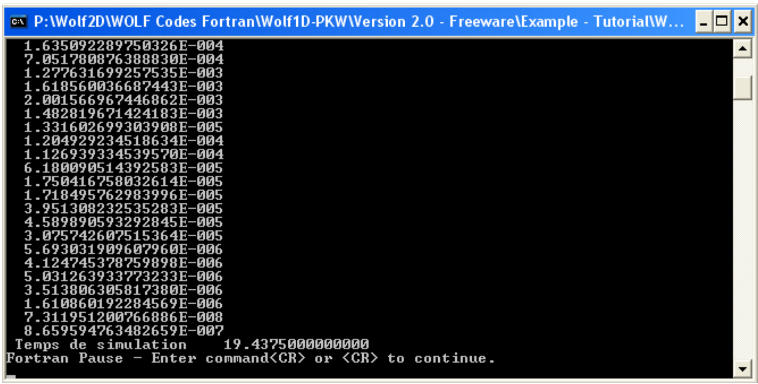
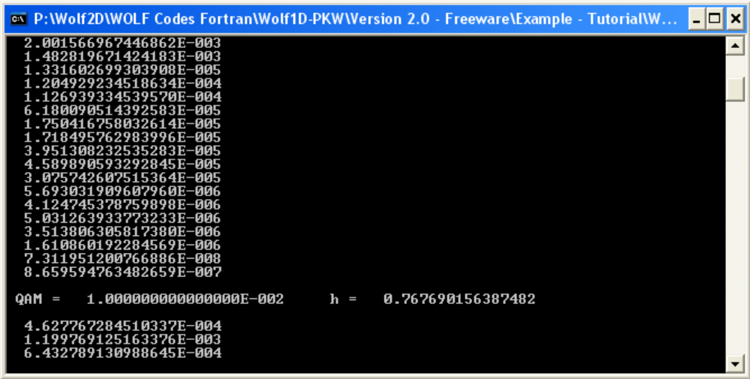


Figure 6 : Computation window at the end of the modeling

6) Computation of a H/Q curve

To compute a H/Q curve, check in the *.par* file if the ***H/Q*** parameter is 1 and if the value of ***Q1, Q2*** and ***ΔQ*** are not 0.

Double click on the *.exe* file. The computation is running… writing in a command line window the evolution of the computed tolerance at frequency ***Freq*** for each discharge successively. When the computation for a discharge is converged, the solver also indicates on the screen the value of the discharge [m³/s] and the corresponding water depth in the reservoir [m] (Figure 7).



```
P:\Wolf2D\WOLF Codes Fortran\Wolf1D-PKW\Version 2.0 - Freeware\Example - Tutorial\W...
 2.001566967446862E-003
 1.482819671424183E-003
 1.331602699303908E-005
 1.204929234518634E-004
 1.126939334539570E-004
 6.180090514392583E-005
 1.750416758032614E-005
 1.718495762983996E-005
 3.951308232535283E-005
 4.589890593292845E-005
 3.075742607515364E-005
 5.693031909607960E-006
 4.124745378759898E-006
 5.031263933773233E-006
 3.513806305817380E-006
 1.610860192284569E-006
 7.311951200766886E-008
 8.659594763482659E-007

QAM =    1.000000000000000E-002      h =    0.767690156387482

 4.627767284510337E-004
 1.199769125163376E-003
 6.432789130988645E-004
```

Figure 7 : Computation window during H/Q curve computation

At the end of the computation, the solver indicates the time of simulation in seconds. To close the computation window, just click on “enter”.

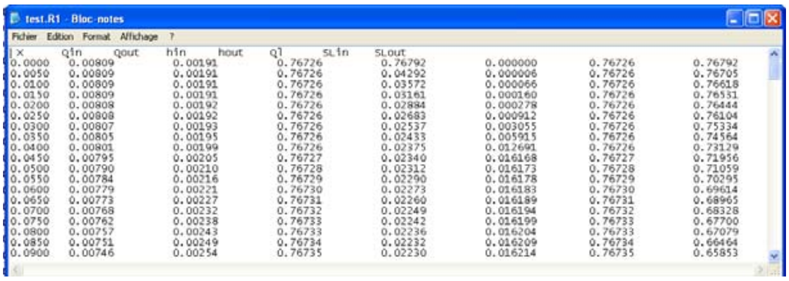
7) To look at the results

The results are stored in the *XX.R* and *XX.R1* text files.

When computing the flow for a single discharge, the 8 columns in *XX.R1* files (Figure 8) gives, for the computation cells numbered in column 1:

- The discharge along the inlet [m³/s] (column 2);
- The discharge along the outlet [m³/s] (column 3);
- The water depth along the inlet [m] (column 4);
- The water depth along the outlet [m] (column 5);
- The lateral discharge [m²/s] (column 6);
- The free surface level along the inlet [m] (column 7);
- The free surface level along the outlet [m] (column 8).

The columns 2 to 8, without the headings, can be copy/paste in the “Main” sheet of the Excel file (columns E to K, from line 6) to visualize these results on the 2 graphs of the Excel file (Figure 9).



test.R1 - Bloc-notes

Fichier Edition Format Affichage ?

x	qin	qout	hin	hout	ql	SLin	SLout
0.0000	0.00809	0.00191	0.76726	0.76792	0.000000	0.76726	0.76792
0.0050	0.00809	0.00191	0.76726	0.04292	0.000006	0.76726	0.76705
0.0100	0.00809	0.00191	0.76726	0.03572	0.000066	0.76726	0.76618
0.0150	0.00809	0.00191	0.76726	0.03161	0.000160	0.76726	0.76531
0.0200	0.00808	0.00192	0.76726	0.02884	0.000278	0.76726	0.76444
0.0250	0.00808	0.00192	0.76726	0.02683	0.000912	0.76726	0.76104
0.0300	0.00807	0.00193	0.76726	0.02537	0.003055	0.76726	0.75334
0.0350	0.00805	0.00195	0.76726	0.02433	0.005915	0.76726	0.74564
0.0400	0.00801	0.00199	0.76726	0.02375	0.012691	0.76726	0.73129
0.0450	0.00795	0.00205	0.76727	0.02340	0.016168	0.76727	0.71956
0.0500	0.00790	0.00210	0.76728	0.02312	0.016173	0.76728	0.71059
0.0550	0.00784	0.00216	0.76729	0.02290	0.016178	0.76729	0.70295
0.0600	0.00779	0.00221	0.76730	0.02273	0.016183	0.76730	0.69614
0.0650	0.00773	0.00227	0.76731	0.02260	0.016189	0.76731	0.68965
0.0700	0.00768	0.00232	0.76732	0.02249	0.016194	0.76732	0.68328
0.0750	0.00762	0.00238	0.76733	0.02242	0.016199	0.76733	0.67700
0.0800	0.00757	0.00243	0.76733	0.02236	0.016204	0.76733	0.67079
0.0850	0.00751	0.00249	0.76734	0.02232	0.016209	0.76734	0.66464
0.0900	0.00746	0.00254	0.76735	0.02230	0.016214	0.76735	0.65853

Figure 8 : *.R1* file with modeling results for one discharge

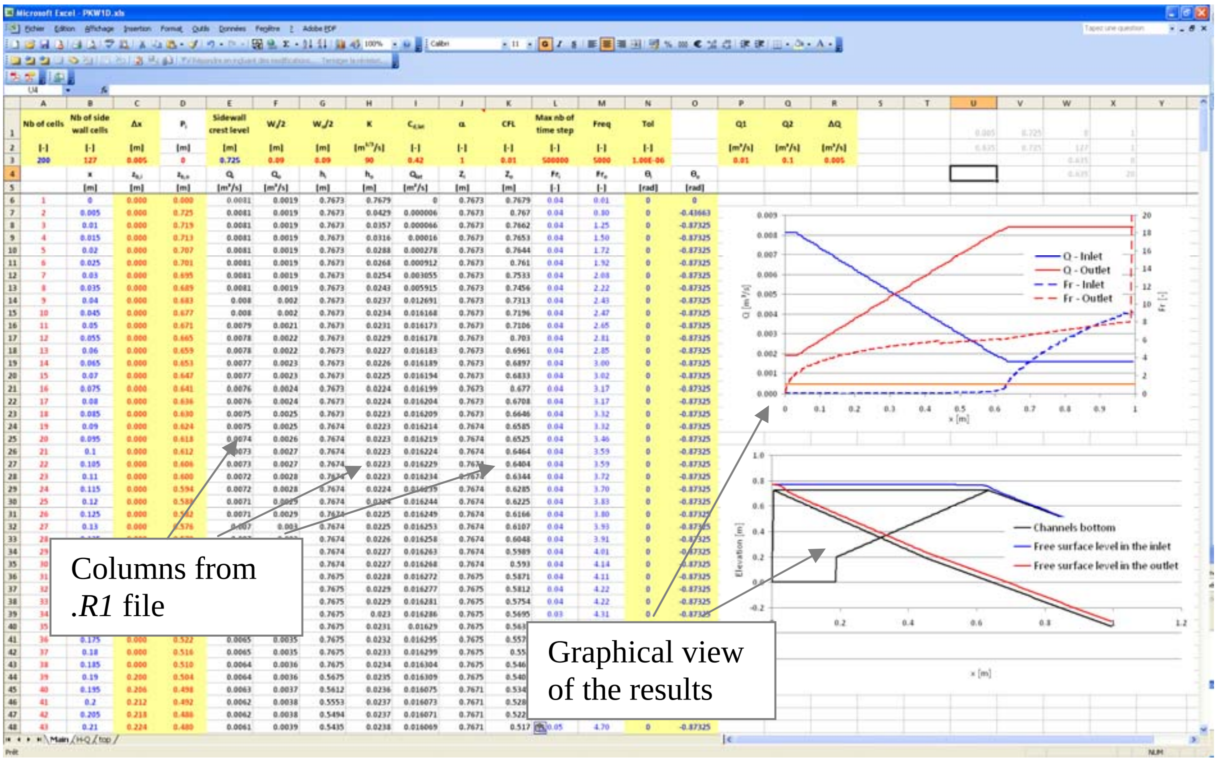
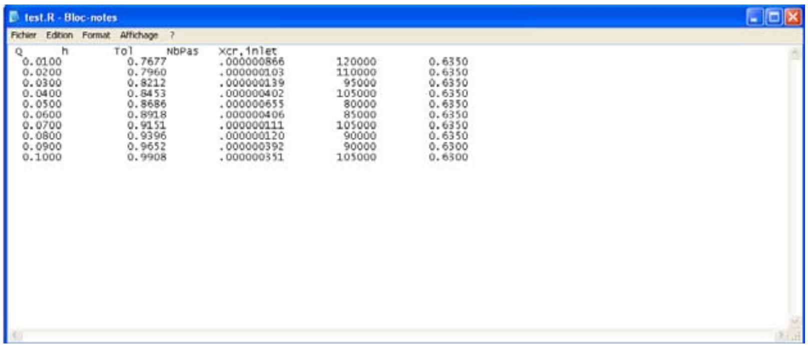


Figure 9 : Excel file completed with the modeling results for one discharge

When computing a H/Q curve, the 5 columns in *XX.R* files (Figure 10) gives, for each point of the curve:

- The discharge [m³/s] (column 1);
- The corresponding water depth in the reservoir [m] (column 2);
- The final tolerance raised for this discharge [-] (column 3);
- The number of time step computed for this discharge [-] (column 4);
- The abscissa of the control section (*Fr=1*) in the inlet [m] (column 5).

The columns 1 to 4, without the headings, can be copy/paste in the "H/Q" sheet of the Excel file (columns A to D, from line 4) to visualize these results on a *H-Q* curve or a $C_{d,w}$-*H/P* curve, and to compare them with experimental data (Figure 11).


test.R - Bloc-notes

Q	h	Tol	NbPas	Xcr,inlet
0.0100	0.7677	.000000866	120000	0.6350
0.0200	0.7960	.000000103	110000	0.6350
0.0300	0.8212	.000000139	95000	0.6350
0.0400	0.8453	.000000402	105000	0.6350
0.0500	0.8686	.000000655	80000	0.6350
0.0600	0.8918	.000000406	85000	0.6350
0.0700	0.9151	.000000111	105000	0.6350
0.0800	0.9396	.000000120	90000	0.6350
0.0900	0.9652	.000000392	90000	0.6300
0.1000	0.9908	.000000351	105000	0.6300

Figure 10 : *.R* file with modeling results (H/Q curve computation)

Hydrologie, Hydrodynamique Appliquée et Constructions Hydrauliques (HACH)
Chemin des Chevreuils, 1 Bât. B52/3 B-4000 Liège 1 (Belgique)
☎ + 32 (04) 366 95 96 + 32 (04) 366 95 58
hach@ulg.ac.be http://www.hach.ulg.ac.be

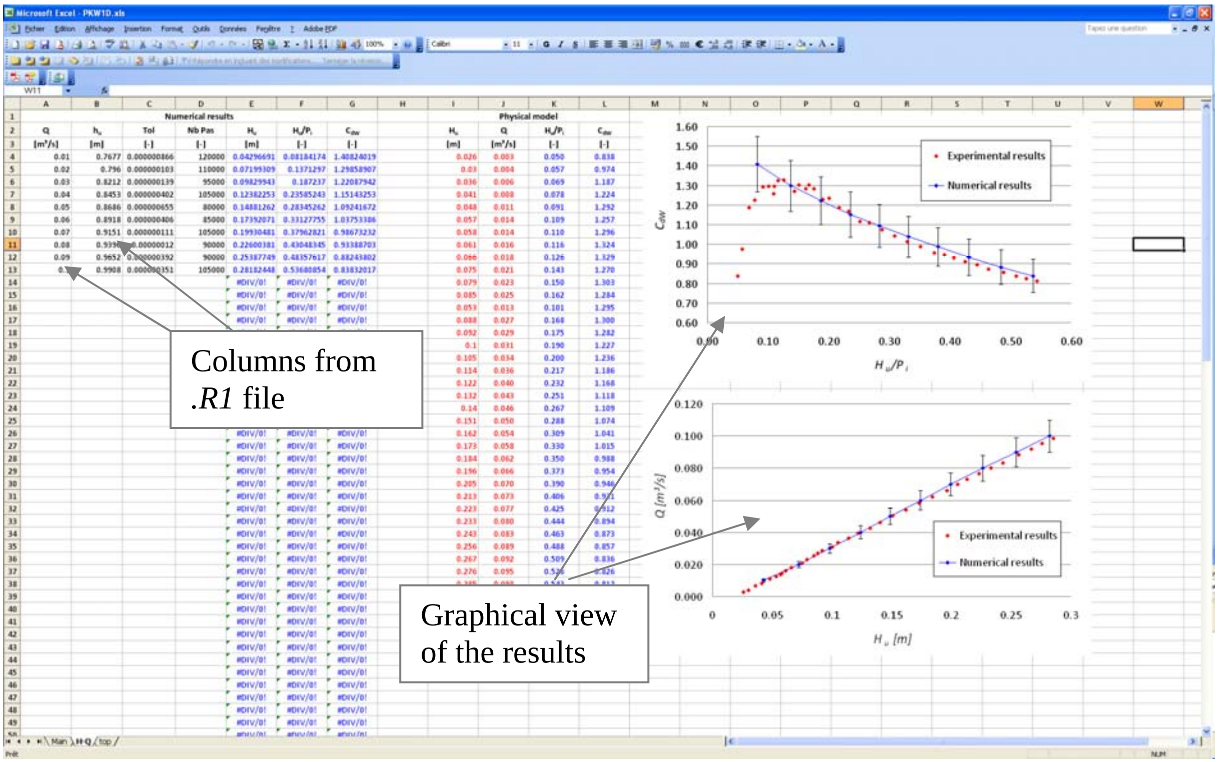


Figure 11 : Excel file completed with the modeling results (H/Q curve computation)

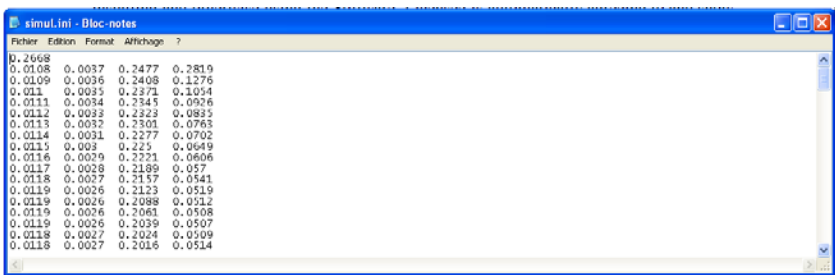
8) To provide an initial condition

In order to accelerate the convergence of a computation or to help the solver to reach a stable solution, it could be interesting to provide a better initial condition to the computation than the one imposed by default (equalization of the free surface level to the crest level).

An initial condition consists in values of discharge and water depth along both the inlet and the outlet. These values can be the computation results obtained for a discharge close to the one we want to compute or for a slightly different geometry (but same number of computation cells).

An initial boundary condition is provided to the solver using a *XX.ini* text file (Figure 12), containing on the first line the reservoir water depth and then 4 columns with respectively

- The discharge along the inlet [m³/s];
- The discharge along the outlet [m³/s];
- The water depth along the inlet [m];
- The water depth along the outlet [m].


simul.ini - Bloc-notes

```
0.2668
0.0108  0.0037  0.2477  0.2819
0.0109  0.0036  0.2408  0.1276
0.011   0.0035  0.2371  0.1054
0.0111  0.0034  0.2345  0.0926
0.0112  0.0033  0.2323  0.0835
0.0113  0.0032  0.2301  0.0763
0.0114  0.0031  0.2277  0.0702
0.0115  0.003   0.225   0.0649
0.0116  0.0029  0.2221  0.0606
0.0117  0.0028  0.2189  0.057
0.0118  0.0027  0.2157  0.0541
0.0119  0.0026  0.2123  0.0519
0.0119  0.0026  0.2088  0.0512
0.0119  0.0026  0.2061  0.0508
0.0119  0.0026  0.2039  0.0507
0.0118  0.0027  0.2024  0.0509
0.0118  0.0027  0.2016  0.0514
```

Figure 12 : *.ini* file completed with an initial condition

Hydrologie, Hydrodynamique Appliquée et Constructions Hydrauliques (HACH)
Chemin des Chevreuils, 1 Bât. B52/3 B-4000 Liège 1 (Belgique)
☎ + 32 (04) 366 95 96 🖷 + 32 (04) 366 95 58
hach@ulg.ac.be http://www.hach.ulg.ac.be

The values to fill in an *.ini* file can be found in the results text files of a previous modeling. The reservoir water depth value is in the *.R* file (second column) and the 4 columns are in the *.R1* file (column 2 to 5).

To use a non default initial condition, parameter ***CI*** has to be set to 1 in the *.par* file.

9) Convergence

The computation is performed on the basis of an evolution along time of the flow in the PKW, considering a constant upstream discharge. The convergence is reach when the downstream discharge is constant and equal to the upstream one (regarding the tolerance ***tol***).

In some cases (very bad initial condition, flow characteristics out the numerical model assumptions), the computation might diverge. This can be seen by following the evolution of the tolerance criterion directly on the solver screen (see for instance Figure 5) or in the results files, looking at the number of time step computed. If the tolerance value written on the solver screen increases with each writing, of if the maximum number of time steps is reach to stop a computation, it is likely that the convergence has not been achieved.

In such a case, for all that the numerical assumption are met, you should try to start from a better initial condition or to decrease the ***CFL*** number value.

Acknowledgement and reference

All written communication of results obtained using the Software shall display the following acknowledgement: *"Results obtained using WOLF 1D PKW software developed by the HACH research unit - Argenco Department - University of Liège"* or other wording to be agreed.

All written communication of results obtained using the Software shall refers to the solver as

HACH (2011). WOLF 1D PKW - 1D numerical model of the flow over a piano key weir, University of Liege, Belgium. http://hdl.handle.net/2268/92290

Help, contact, feedback…

WOLF1D PKW has been developed in the purpose of scientific research. In this scope, we will be happy to help you to overcome the problems you would encounter to apply it, but we can't guarantee you with a full time availability nor success in solving your problem.

On the other hand, we are strongly interested in feedback from your use of the solver, especially if it can help in improving its capacity and then be shared with the scientific community.

Contact mail address is pk-weirs@ulg.ac.be.

Hydrologie, Hydrodynamique Appliquée et Constructions Hydrauliques (HACH)
Chemin des Chevreuils, 1 Bât. B52/3 B-4000 Liège 1 (Belgique)
☎ + 32 (04) 366 95 96 🖷 + 32 (04) 366 95 58
hach@ulg.ac.be http://www.hach.ulg.ac.be