



Faculty of Engineering  
Department of Civil Engineering  
**Hydraulics Section**  
Kasteelpark Arenberg 40  
BE-3001 Leuven, Belgium

tel. +32 16 32 16 58  
fax +32 16 32 19 89  
Patrick.Willems@bwk.kuleuven.be

[www.kuleuven.be/hydr](http://www.kuleuven.be/hydr)

# **WETSPRO: Water Engineering Time Series PROcessing tool**

Manual, version 2.0, 2004

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## WETSPRO: Methodology (Short Reference Manual)

(see also paper in reference)

### Reference:

Willems, P., A time series tool to support the multi-criteria performance evaluation of rainfall-runoff models, Environ. Model. Softw. (2008), doi:10.1016/j.envsoft.2008.09.005

## 1 Subflow filtering

### 1.1 Introduction

A time series of total rainfall-runoff discharges can be splitted into its subflows (such as the overland flow, the subsurface flow or interflow, and the groundwater flow or baseflow) using a numerical digital filter technique. Its physical interpretation is based on the linear reservoir modelling concept, which will be described first.

### 1.2 Linear reservoir modelling concept

In a linear reservoir model (Figure 1), the outflow discharge  $b(t)$  is dependent on the inflow discharge  $q(t)$  by the following equation:

$$b(t) = \exp\left(-\frac{1}{k}\right)b(t-1) + \left(1 - \exp\left(-\frac{1}{k}\right)\right)\left(\frac{q(t-1) + q(t)}{2}\right)$$

Using:

$$\alpha = \exp\left(-\frac{1}{k}\right)$$

this equation can be simplified:

$$b(t) = \alpha b(t-1) + (1 - \alpha)\left(\frac{q(t-1) + q(t)}{2}\right) \quad (1)$$

The single parameter  $k$  of the linear reservoir model is called the 'reservoir constant' or 'recession time'. The unit of  $k$  is equal to the duration  $\Delta t$  of the time step  $[t-1, t]$ .

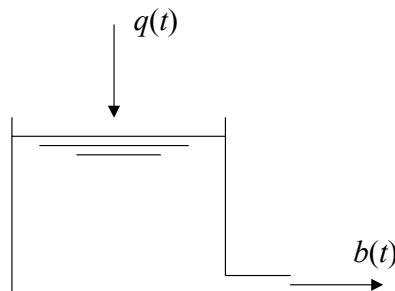


Figure 1. Input and output series of a reservoir model.

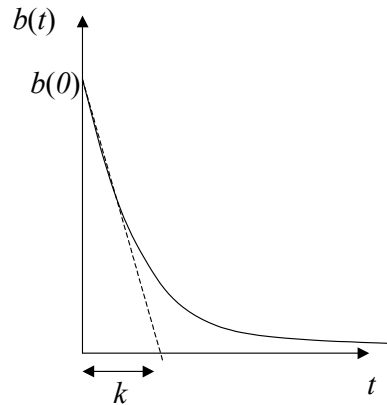
The recession time  $k$  equals the time in which the flow is reduced during dry weather flow periods to a fraction  $\exp(-1) = 0.37$  of its original discharge. Indeed, for periods with zero reservoir inflow ( $q(t)=0$ ), the reservoir outflow decreases in an exponential way:

$$b(t) = \exp\left(-\frac{t}{k}\right)b(t-1) = \alpha b(t-1)$$

When the outflow discharge equals  $b(0)$  at time  $t=0$ , the outflow discharge at time  $t=k$  equals:

$$b(k) = \exp(-1)b(0)$$

The recession time is closely related to the 'concentration time' of the modelled system, which is defined as the time the water needs to flow from the (in time) most remote point of the catchment to the location at which the output variable is considered [Chow et al., 1988]. The larger the system or the more the flow is hampered in the system, the larger the recession time / concentration time and the larger the interval over which the input values can jointly influence the model output.



**Figure 2. Exponential recession of the linear reservoir outflow during periods with zero inflow.**

### 1.3 Recursive digital filter

The linear reservoir model can be seen as a 'lowpass filter'. Equation (1) has the same structure as the recursive lowpass RC filter [Bendat and Piersol, 1971]:

$$b(t) = \alpha b(t-1) + (1-\alpha) q(t)$$

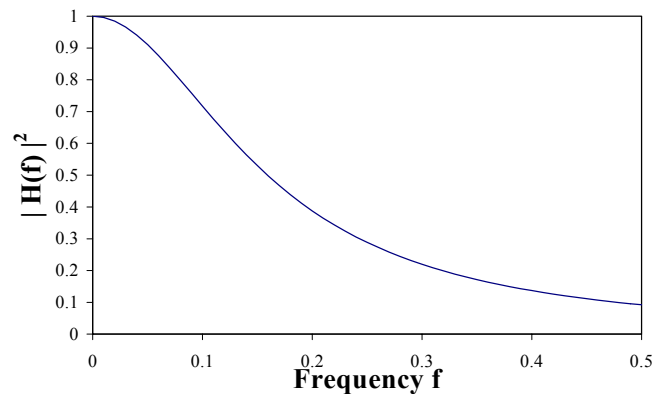
with:

$$\alpha = \exp\left(-\frac{1}{RC}\right)$$

The parameter  $RC$  thus corresponds with the recession time  $k$  of the linear reservoir. The unit of  $RC$  is, as is the case for  $k$ , the duration  $\Delta t$  of the time step  $[t-1, t]$ . The filter has approximately the following characteristic (Figure 3):

$$|H(f)|^2 \approx \frac{1}{1 + (2\pi f RC)^2}$$

with  $H(f)$  the frequency response function ( $f$  denotes the frequency, which has the unit of  $1/\Delta t$ ).



**Figure 3. Characteristic of a linear reservoir model-structure as lowpass filter.**

High frequency noise on the model input (with frequencies much larger than the recession time) is thus filtered out by a linear reservoir model. It is not observed in the model output. This means that this high frequency noise (e.g. caused by measurement errors) will not have any effect on the model output. In this way, information in the model input that is of no relevance for the model output is eliminated. In the same way, high frequency noise on the model output measurements can be filtered out.

Such a filter can also be used to separate a time series of measurements that is build up of different exponentially recessive components (as is the case for rainfall-runoff discharges), into the different components. This can at least be done for the components with clearly different recession times. For each component, with a certain recession time, the other components with clearly higher recession times can be filtered out from the time series. These latter components can thus be considered as the higher frequency components in the filter. By starting with the component with the largest recession time, all components can be filtered in a recursive way. In this filtering, the knowledge can be used that during periods where the higher frequency components are zero ( $f(t) = 0$ ), the time series  $q(t)$  (which equals the component  $b(t)$  to be filtered) should be exponentially recessive:

$$b(t) = \alpha b(t-1)$$

Based on this knowledge, Chapman [1991] has derived the following 'recursive digital filter for exponential recessions':

$$f(t) = af(t-1) + b(q(t) - \alpha q(t-1)) \quad (2)$$

$$b(t) = \alpha b(t-1) + c(1 - \alpha)(f(t-1) + f(t)) \quad (3)$$

with:

$$\alpha = \exp(-1/k)$$

$$a = \frac{3\alpha - 1}{3 - \alpha}$$

$$b = \frac{2}{3 - \alpha}$$

$$c = 0.5$$

where:

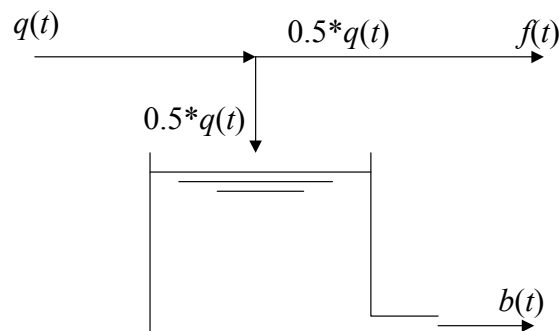
$q(t)$  : the total time series

$b(t)$  : the time series of the filtered component (with recession time  $k$ )

$f(t)$  : the higher frequency components

The similarity between the equations of this 'Chapman-filter' and those of a linear-reservoir model can be directly mentioned. Equation (1) equals the Chapman-filter equation (3) for  $f(t) = q(t)$ . The working principle of the Chapman-filter can thus be explained physically as the routing of the high-frequency components through a linear reservoir, with the reservoir constant  $k$  equal to the recession time of the component being filtered. In this reservoir routing, the routed discharges are considered equal to the filtered component as they have the same qualitative behaviour during recession periods.

As the total time series  $q(t)$  is the sum of the filtered component  $b(t)$  and the higher-frequency components  $f(t)$ , and as the higher-frequency components are routed through the reservoir model to derive the filtered subflow, it can be easily seen that the filtered components and the higher-frequency components have the same (both 50%) cumulative values in the Chapman-filter (Figure 4). This means in rainfall-runoff applications that the rainfall fractions that contribute to the filtered subflow (e.g. baseflow) and the higher frequency subflows (e.g. overland flow and interflow) are assumed identical. This is an important assumption that may not be valid.



**Figure 4. Schematic representation of the working-principle of the Chapman-filter.**

Therefore, a generalization of the filter was developed (Figure 5). The generalization consists of a time-variability in the fraction  $w$  of the cumulative values in the total time series that is related to the filtered component. After introduction of a new filter parameter  $v$ :

$$v = \frac{1-w}{w}$$

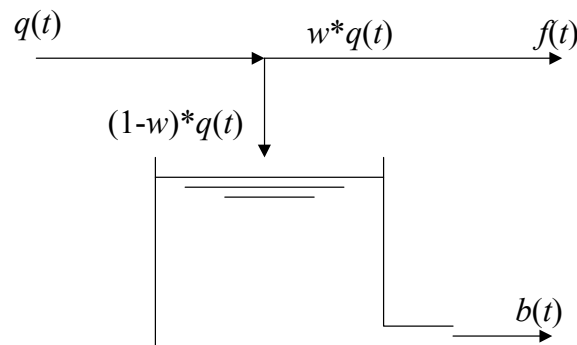
and after adaptation of the filter parameters:

$$a = \frac{(2+v)\alpha - v}{2+v-v\alpha}$$

$$b = \frac{2}{2+v-v\alpha}$$

$$c = 0.5v$$

the filter equations (2) and (3) can still be used in the generalization.



**Figure 5. Generalisation of the Chapman-filter.**

In the Chapman-filter,  $v$  equals 1, as the filtered component contributes for 50% to the cumulative volumes.

The fractions  $w$  are unknown in practical applications. However, their values can be estimated by numerical calibration. In this calibration, the agreement between the total time series and the filtered component is maximized for the recession periods, as the higher-frequency components are diminished to very small values during these periods. Between two such recession periods, the fraction  $w$  varies in time. However, it is impossible to estimate this variability and, therefore, the fractions are taken constant during subperiods that are bounded by the ending times of two successive recession periods. The fraction  $w$  thus is considered a discrete time variable.

#### **1.4 Discharge splitting**

On the basis of the filter, the series of total runoff discharges can be split up into the series of its subcomponents: overland flow, interflow and baseflow. The splitting procedure is based on the clear difference in the order of magnitude of the recession constants of the runoff subflows. The baseflow is first separated from the total rainfall-runoff discharge. Interflow is then separated from the combined discharge of surface runoff and interflow.

The recession constants of the subflows can be calibrated as the average value of the inverse of the slope of the linear path in the recession periods of a  $\ln(q)$  - time graph (see examples in Figure 6 for baseflow and Figure 7 for interflow). When  $s$  is a number of time steps considered during the recession periods, the recession constant can be calculated as follows:

$$\frac{\ln(q(t-s)) - \ln(q(t))}{s} = \frac{1}{k}$$

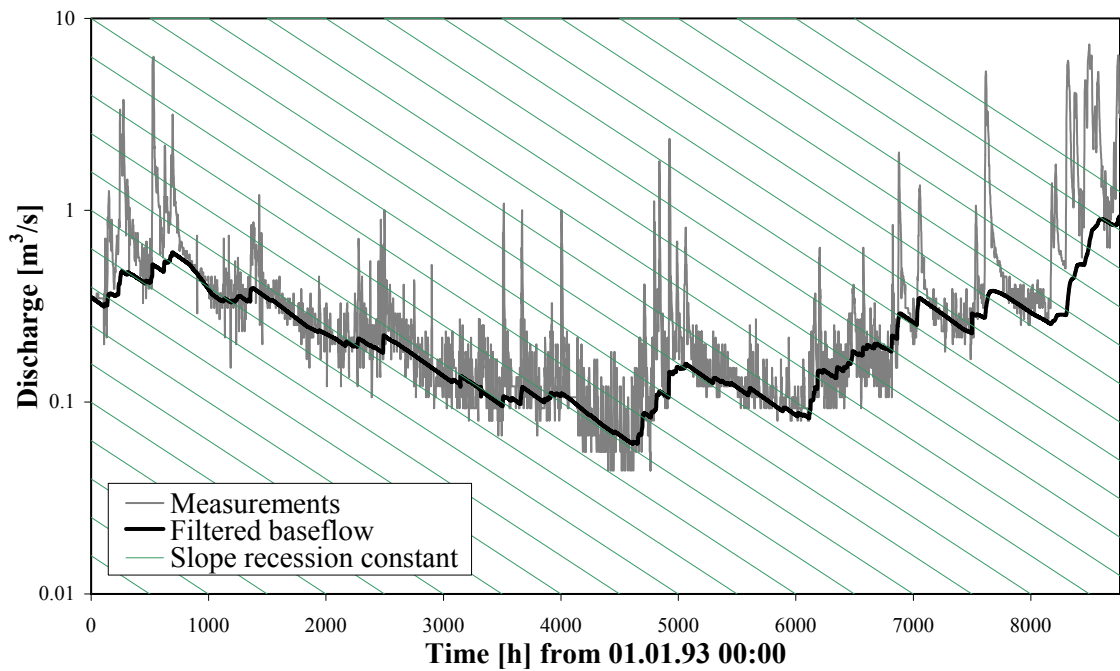


Figure 6. Example of the baseflow filter results; hourly discharge observations Molenbeek River at Erpe-Mere (Belgium).

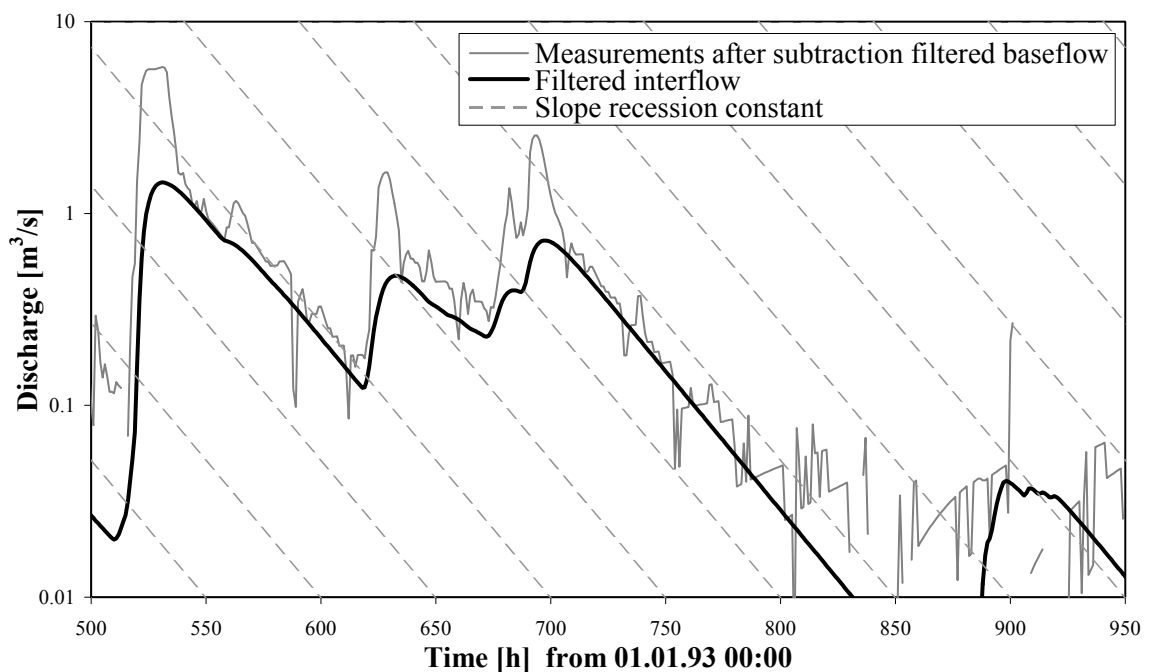


Figure 7. Example of the interflow filter results; hourly discharge observations Molenbeek River at Erpe-Mere (Belgium).



## **1.5      *References***

Bendat, J. S, and Piersol, A. G., 1971. *Random data: analysis and measurement procedures*, Wiley-Interscience, New York.

Chapman, T., 1991. Comment on 'Evaluation of automated techniques for base flow and recession analyses' by R.J.Nathan and T.A.McMahon, *Water Resources Research*, vol. 27, no. 7, 1783-1784.

Chow, V.T., Maidment, D.R., and Mays, L.W., 1988. *Applied hydrology*. McGraw-Hill, New York.

Nathan, R. J., and McMahon, T. A., 1990. Evaluation of automated techniques for base flow and recession analysis, *Water Resources Research*, vol. 26, no. 7, 1465-1473.

## 2 POT selection

### 2.1 Introduction

In water engineering applications, extremes are often analysed for time series. Those extremes have to be extracted first as peak-over-threshold values from the time series in a preliminary study (see descriptive statistics). They can take the form of instantaneous or aggregated values (averaged values in a fixed time duration) or cumulative values in events (e.g. storm volumes). As the extremes in an extreme value analysis have to be independent, an 'independency criterion' has to be used in the extraction.

In river flood applications, for instance, the U.S. Water Resources Council (1976) considers consecutive peak floods as independent if the interevent time exceeds a critical time and if an interevent discharge drops below a critical flow (see also Lang et al. (1999) and Claps & Laio (1999)). Another and more usual approach selects the POT values as the highest discharges in periods where the flow upcrosses a selected threshold. The threshold selection can be based either on physical or statistical considerations, as discussed extensively in Lang et al. (1999). The statistical considerations are based on the independence assumption (test on zero serial correlation; see also section 3.8 in the course). The threshold is usually compared with the total discharge value of the peaks. It can also be applied to the discharge increment relative to the baseflow level preceding each peak event, as was done by Claps and Laio (2003). The latter approach accounts for the fact that rainfall-runoff consists of quick flow and slow flow components, and that both components have strongly different recession times. By this reason, the dependence of subsequent peak discharges depends on the height of the slow flow (the baseflow), and thus on the hydrological season. In the wet seasons, higher soil moisture levels occur in the catchment, and consequently the baseflow is higher and the peak discharges are more dependent for the same peak height. Based on these concepts, some POT selection methods are presented hereafter.

### 2.2 Method based on baseflow

Two successive discharge peaks can be considered largely independent when the smallest discharge in between the two peaks reaches almost the baseflow value. In this way, it can be stated that the overland flow and interflow (or subsurface flow) components are independent, because these 'quick flow' components reach a value close to zero. An example is given in Figure 8.

A peak discharge can be considered independent from the previous one when - for the minimum discharge  $q_{min}$  between the two peaks - the difference of this minimum discharge with the baseflow (or baseflow + interflow) value  $q_{base}$  is smaller than a limited fraction  $f$  of the peak discharge  $q_{max}$  (see also Figure 9):

$$\frac{q_{min} - q_{base}}{q_{max}} < f \quad \text{if } q_{base} < q_{min}$$

When  $q_{base} > q_{min}$ , the minimum discharge can be considered close to the baseflow discharge (the difference is only caused by inaccuracies in the filtering technique) and the discharge peak can be considered independent from the previous one.

A second and last criteria is needed to avoid that small peak heights are selected:

$$q_{max} > q_{lim}$$

### 2.3 **Method based on baseflow + interflow**

The same method can also be applied using baseflow + interflow.

### 2.4 **Method independent on the subflows**

An easier criterion is the use of the 'recession constant' of overland flow or the combined recession constant of overland flow and interflow. During dry weather periods, the discharge of each flow component shows typically an exponential decrease in time. According to the definition of the recession constant of a flow component, the flow component reaches a value lower than 37% of its peak value after a dry weather period longer than the recession constant. To check this criterion, also a rainfall series is needed. It is however also possible to use only the discharge series. Two successive peaks can be considered independent when the time  $p$  between the two peaks is longer than the recession constant  $k$ , and when the minimum discharge in between these two peaks is smaller than a fraction  $f$  of the peak discharge (e.g. smaller than 37%). Using the latter criterion, one can check whether the period is dry enough, without using rainfall data. One more additional criteria is in this case needed to avoid that small peak heights are selected ( $q_{max} > q_{lim}$ ). The method thus has to check the following three criteria (see also Figure 9 for the parameters):

$$p > k$$

$$\frac{q_{min}}{q_{max}} < f$$

$$q_{max} > q_{lim}$$

### 2.5 **References**

USWRC (1976), Guidelines for determining flood flow frequency. United States Water Resources Council, Bull.17, Hydrol. Comm. Washington, DC, 73 p.

Claps, P., and F. Laio (2003), Can continuous streamflow data support flood frequency analysis? An alternative to the partial duration series approach. *Water Resources Research*, 39(8), 1216, doi:10.1029/2002WR001868.

Lang, M., Ouarda, T.B.M.J., and Bobée, B., 1999. Towards operational guidelines for over-threshold modeling. *Journal of Hydrology*, vol. 225, 103-117.

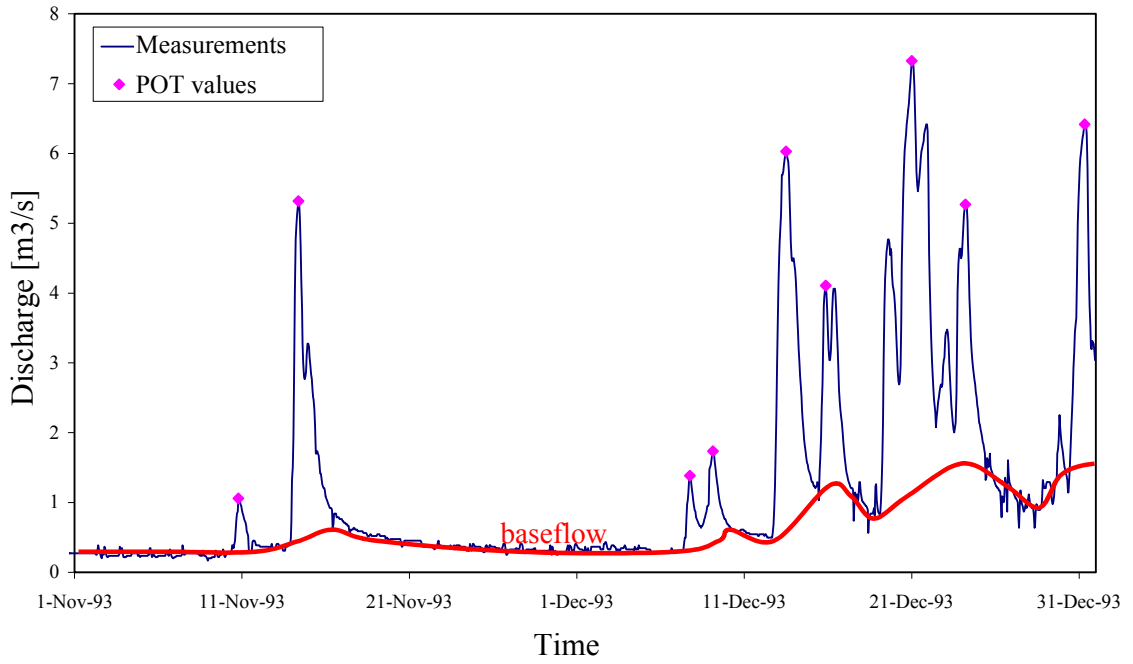


Figure 8. Example of selected POT values, using an independency criterion based on the filtered baseflow; hourly discharge observations Molenbeek River at Erpe-Mere (Belgium).

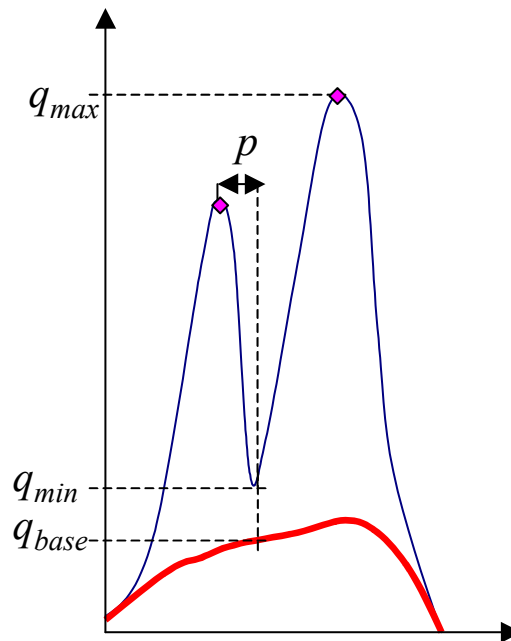


Figure 9. Parameters used in the criteria to select independent POT values.

### **3 Model validation**

#### **3.1 Introduction**

During model calibration, as well as during model evaluation / validation, evaluation of model performance is needed. This is primarily done based on goodness-of-fit statistics. These statistics have the advantage, but also the disadvantage that they largely summarize the goodness-of-fit information only in a few numbers and values. The statistics can be complemented with graphical goodness-of-fit plots. In general, these plots compare observed and modelled values of a flow series (as also used on the basis of the statistics) in a graphical way, and provide the modeller with complete information about the goodness-of-fit. For instance, when a poor goodness-of-fit is concluded, the plots can make clear to the modeller whether this poor performance is caused by the high flow events, the low flow events, the quick flow components and/or the slow flow components, etc. Physical insight of the modeller in the hydrology and related model code then can make clear where focus needs to be given for improving model calibration.

#### **3.2 Model validation plots**

In WETSPRO, evaluation of model performance is supported by means of the following plots:

- modelled versus observed discharge maxima during (nearly independent) quick flow hydrograph periods;
- modelled versus observed discharge minima during (nearly independent) baseflow or slow flow periods;
- cumulative flow volumes;
- high flow extreme value statistics;
- low flow extreme value statistics;
- discharge time series, with and without log-scale for the discharge.

Observed flow series can be compared with model results for 2 different runs. To 2 runs can be obtained from the same model using different parameter sets (for instance to test the improvement in the model performance after parameter change or recalibration; or to test the sensitivity of the model results to specific changes in model parameters; or to compare 2 different models).

The comparison of the discharge time series, with log-scale for the discharge can be used to test the linearity of the subflow recessions (see subflow filtering) and, consequently, the hydrographs' shape.

#### **3.3 Box-Cox transformation**

For the validation plots on discharge maxima and minima, Box-Cox (BC) transformation can be applied to give similar weight to errors at high and low flow conditions (Box and Cox, 1964). The BC transformation is commonly applied in the scope of regression and correlation analyses in an attempt to reach homoscedasticity in the residuals (model errors), and thus for a more unbiased evaluation of the model performance.

The BC-transformation, when applied to a variable  $Y$ , is given by:

$$BC(Y) = \frac{Y^\lambda - 1}{\lambda}$$

where the parameter  $\lambda$  needs to be calibrated to reach approximately the homoscedasticity condition. Its value can range from 0 to 1. The strongest transformation in this range is the logarithmic transformation (equals the BC-transformation for  $\lambda=0$ ). The logarithmic transformation is useful in case the standard deviation of the residuals is shown proportional to the runoff value. In this case, the model has a constant relative error. In most practical cases, neither the absolute error neither the relative error is constant and a BC transformation is needed. Usually, the  $\lambda$  parameter adopts values around 0.25.

### **3.4 Nearly independent hydrograph selection**

For the calculation of the validation plots for maxima, minima and extreme value statistics, independent flow values need to be extracted from the observed (input) and modelled (simulated) flow series. For daily data, it is most often assumed by modellers that the mean daily flow observations can be considered approx. independent. This is, however, often not that case, and certainly not for flow series with a shorter time step (e.g. hourly). During dry periods, the autocorrelation of the flow series is much higher in comparison with wet periods. This is caused by the longer recession constant of the baseflow component in comparison with the quick flow components (overland flow and interflow). Therefore, the prior selection of nearly independent values from the flow series is applied. These are peak values during nearly independent quick flow hydrographs, cumulative volumes during these hydrographs, low flow values during nearly independent baseflow recession periods, etc. The nearly independent quick flow hydrographs are defined as the periods between the flow minima selected in between subsequent POT quick flow extremes (see POT selection). The nearly independent slow flow periods are the periods between subsequent POT slow flow extremes.

After selection of independent values and after the BC transformation, it is feasible to derive homoscedastic and uncorrelated residuals. The mean ( $\bar{E}$ ) and the standard deviation ( $\sigma_E$ ) of these residuals  $E$ , or combined the mean squared error  $MSE$ , can be considered as a goodness-of-fit statistic and can be specified for both maxima and minima:

$$MSE \approx \bar{E}^2 + \sigma_E^2 = (bias)^2 + (st.dev.)^2$$

### **3.5 References**

Box, G. E. P. and D.R. Cox. 1964. An analysis of transformations, *Journal of the Royal Statistical Society*: 211-243, discussion 244-252.

## WETSPRO: Short User's Manual

### Overview of the menu items

|                   |   |
|-------------------|---|
| Clear             | : to clear all the data and results from previous calculations  |
| Input             | : input of the data series<br>(when the input series is longer than the 65536 rows that can be used in Excel, additional columns can be created by means of the control button "Number of data columns")<br>Information on the river name, the station name, the station ID and the unit of the time series is optional and not needed for the calculations.  |
| Subflow filtering | : main sheet for the subflow filtering: input of filter parameters and activation of filter calculations  |
| POT selection     | : main sheet for the POT selection: input of parameters and activation of POT selection calculations  |
| Model validation  | : main sheet for the model validation: input of parameters and calculation of model validation plots  |
| Sheets results    | : selection of sheets with results (either for the subflow filtering (sheet "SFresults"), or the POT selection (sheet "POTresults"), or the model validation (sheet "VALresults"))  |
| Charts results    | : selection of charts with results (either for the subflow filtering (charts "Filter results", "Filter results-BF", "Filter results-IF" and "Filter results-OF"), or the POT selection (chart "POT selection"), or the model validation (charts "validation time series", "validation BF recession", "validation maxima", "validation minima", "validation cumulatives", "validation extremes high" and "validation extremes low")) |
| Support bar       | : switch on some Excel toolbars   |
| About WETSPRO     | : general information about the program + reference to the methodology implemented  |

## Parameters subflow filtering

|                        |  |
|------------------------|--|
| constant term          | : constant discharge flux (will be subtracted from the total discharge before the subflow filtering will be started; the constant discharge term indeed does not show exponential recessions). The value can be assessed based on data on emissions along the river, or empirically based on the "Filter results-BF" plot (it is the discharge below which the exponential recession stops). The unit of this parameter is the same as the unit of the input discharge series. |
| initial flow value     | : initial subflow discharge value to be used for the first time step of the series. The unit of this parameter is the same as the unit of the input discharge series.  |
| number of filter steps | : number of filter steps (1 when only a forward filtering step is followed; 3 when the forward filter step is followed by a backward and a second forward step). The default value is 1. The user has to take into account that a change in the number of filter steps will also require a change in the $w$ parameter value. The $w$ fraction is indeed considered for each filter step.  |
| recession constant     | : recession constant of the subflow (can be estimated based on the sloped lines in the plot "Filter results-..."). The unit of this parameter equals the time length of 1 time step in the input discharge series.   |
| w-parameter filter     | : $w$ parameter of the filter (mean fraction of the total discharge contributing to the quick flow components; the components filtered out). This parameter needs to be adjusted iteratively till the filter results reach the right level. After each change of the value for this parameter, the filter calculation needs to be repeated (by pressing the button "Execute ... filter").  |
| upper cut-off value    | : when the decreasing flank of the overland flow hydrograph decreases below this parameter value, the overland flow hydrograph will be ended (the next smaller discharge peaks will be considered as noise peaks rather than overland flow discharge peaks) as soon as the discharge decreases below the value of the 'lower cut-off value'. The unit of the cut-off values equals the one of the input discharge series.  |
| lower cut-off value    | : see 'upper cut-off value'  |



Graphical parameters:

- distance lines graph : distance between the sloped lines in the plot "Filter results-..." (as number of time steps).
- first time step lines : first time for drawing of the sloped lines (the sloped lines can be shifted to higher time steps by increasing the parameter)
- lowest value lines : lowest discharge value for the sloped lines (the unit equals the one of the input discharge series)
- highest value lines : highest discharge value for the sloped lines (the unit equals the one of the input discharge series)
- lower limit : in case the input discharge series has zero or negative values, these values will be replaced by the 'lower limit' parameter value (this is to avoid that zero or negative values will be plotted in plots with log-scale axis). the unit equals the one of the input discharge series.
- plot data column no. : the number of the input column for which results will be plotted (the subflow filtering needs to be repeated by pressing the button "Execute ... filter" before change in the parameter value will have an effect.
- writing step : the number of time steps in between two values that will be written in the results sheets and in the plots (1 to write/plot all values in the series; 2 to write/plot results every 2 time step; etc.). By increasing the value of this parameter, the filter calculation can be speed up (only useful when WETSPRO is used on an old slow computer). After the calibration of the filter parameters is finished, one last filter calculation is needed using 'writing step' 1.

## Parameters POT selection

- method : select "1" for the method based on baseflow, "2" for the method based on baseflow + interflow, "0" for the method independent on the subflows
- max ratio difference with subflow : parameter  $f$  in the Reference Manual
- independency period : parameter  $k$  in the Reference Manual
- min peak height : parameter  $q_{lim}$  in the Reference Manual

Each time the parameters of the POT selection are modified, the POT selection needs to be carried out again (button "Execute POT selection ...")

Different parameters can be specified to extract independent 'quick flow periods' (nearly independent quick flow hydrographs), and for nearly independent 'slow flow periods'. For the 'quick flow periods' the 3 different methods can be selected. Parameter  $k$  in method 1 or 2 is by preference taken close to the recession constant for interflow (for method 2) or overland flow (for method 1). For the 'slow flow periods', method "0" needs to be selected. In the latter case, the recession constant is taken higher than the recession constant for baseflow.

Graphical parameters:

- lowest value hydrogr. separation lines : lower limit for the lines to show the separation of the time series in 'quick flow periods' in the plot "POT selection". The unit equals the one of the input discharge series.
- highest value hydrogr. separation lines : upper limit for the lines to show the separation of the time series in 'quick flow periods' in the plot "POT selection". The unit equals the one of the input discharge series.

## Parameters model validation

- aggregation series : press “goto series” to go to the results sheets “SFresults2”  
In this sheet, the subflow filter results can be aggregated to a time step larger than the time step of the input series. Select the aggregation level in cell “C4” and press “Aggregate”. The aggregated subflow filter results will be written in the columns E-I. In the current version of the software the aggregated series can contain up to only 65534 values. For comparison with the aggregated flow series, and making use of the POT selection, model results can be input in column J. Additional columns for input of different series of model results (e.g. for comparison of different runs with the same model, or for comparison of results with different models) can be created by means of the control button “no of model results”. Labels to the different model results can be given in column C, row 12 and next. These labels will be used in the different model validation plots.
- Processing of observed series : press “Process” to calculate based on the aggregated input series maxima en minima during quick flow and slow flow hydrograph periods, cumulative volumes, extreme value statistics, etc.
- select model results, run 1;  
select model results, run 2 : select two model results series (based on the numbers used in sheet SFresults2), and press “Process”. The labels of the selected series automatically appear in the cells “E12-13”
- Box-Cox parameters : type the Box-Cox parameters to be used for the model validation plots “validation maxima” and “validation minima”. Press “update” to update the plots after a different Box-Cox parameter is selected.
- Lower limit values : type the lower limit to be used for the validation plot “validation extremes low” to avoid that infinite values are reached after transformation  $1/q$  in case some low flow extremes are equal to zero.
- observed series processed;  
model results, run 1 processed;  
model results, run 2 processed : in the cells “J11-13”, it is indicated which processing steps have been conducted already

## Sheet results

|            |  |
|------------|--|
| SFresults  | : time series of total discharge (after removal of noise peaks by the 'cut-off value' applied to the overland flow), baseflow, interflow and overland flow (for each data column in the input)   |
| POTresults | : list of selected POT values (time step of the POT value counted from the beginning of the data column; the POT value; and the time step at the start of the hydrograph)  |
| VALresults | : lists of results derived for the model validation (quick flow hydrograph maxima (max), slow flow minima (min) and hydrograph volumes, before and after ranking, and before and after BC transformation) for the observed series and the model results run 1 and run 2. The mean and standard deviation of the model residuals for max and min after BC transformation are given in columns Z-AA. |

## Charts results

|                         |  |
|-------------------------|--|
| Filter results          | : results of the filtered baseflow, interflow and overland flow subflows in a plot with a normal scale for the vertical axis   |
| Filter results-BF       | : sloped lines to calibrate the recession constant of baseflow<br>+ result of filtered baseflow in a $\ln(q)$ - time plot  |
| Filter results-IF       | : sloped lines to calibrate the recession constant of interflow<br>+ result of filtered interflow in a $\ln(q)$ - time plot  |
| Filter results-OF       | : sloped lines to calibrate the recession constant of overland flow<br>+ application of cut-off values   |
| POT selection           | : results of the POT-selection   |
| Validation time series  | : comparison of the input series and its baseflow filter results, with the 2 selected model results series   |
| Validation BF recession | : comparison of the input series and its baseflow filter results, with the 2 selected model results series, after $\ln$ -transformation of the vertical discharge axis (to validate the linear baseflow recession slope) |
| Validation maxima       | : scatterplot of observed versus simulated quick flow hydrograph maxima after BC transformation (for the 2 selected model results), together with the mean and the standard deviation of the model residuals             |
| Validation minima       | : scatterplot of observed versus simulated slow flow minima after BC transformation (for the 2 selected model results), together with the mean and the standard deviation of the model residuals                         |

Validation cumulatives

: cumulative hydrograph volumes versus time for the input series and the 2 model results

Validation extremes high

: quick flow hydrograph maxima versus return period for the input series and the 2 model results (for validation of the high flow extreme value distribution)

Validation extremes low

: slow flow minima (after  $1/q$  transformation) versus return period for the input series and the 2 model results (for validation of the low flow extreme value distribution)

## Steps to follow

Baseflow filtering:

- calibrate recession constant baseflow (iteratively changing the recession constant value, and evaluating this value in the Chart "Filter results-BF")
- choose other parameters baseflow filtering
- calculate the baseflow filter results (press "Execute baseflow filter" button; limit the length of the input series to limit the calculation times, or increase the writing step e.g. 3)
- evaluate the baseflow filtering results in the Chart "Filter results-BF"
- repeat iteratively the previous three steps, until results are satisfactory
- make a final calculation of the baseflow filter results, using the complete input series

Idem for interflow filtering, when needed

POT selection:

- choose POT extraction method and the parameters (1 for the method based on baseflow, or 2 for the method based on baseflow + interflow, or 0 for the method independent on the subflows)
- conduct the POT selection (press "Execute POT selection" button)
- evaluate the POT selection results in the chart "POT selection"
- when needed: repeat iteratively the previous three steps, until results are satisfactory

The POT selection can be conducted for the separation of both 'quick flow periods' and 'slow flow periods'.

Model validation:

- aggregate the input series to the time step of the model results, and input the different model results
- select 2 series (runs) of model results and process the series
- evaluate and compare the selected model results based on the different validation plots

Faculty of Engineering  
Department of Civil Engineering  
**Hydraulics Section**  
Kasteelpark Arenberg 40  
BE-3001 Leuven, Belgium



tel. +32 16 32 16 58  
fax +32 16 32 19 89  
Patrick.Willems@bwk.kuleuven.be

[www.kuleuven.be/hydr](http://www.kuleuven.be/hydr)