



Software Package for Water Sciences

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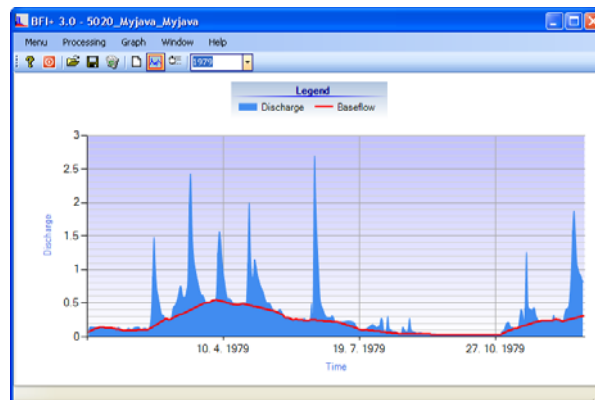
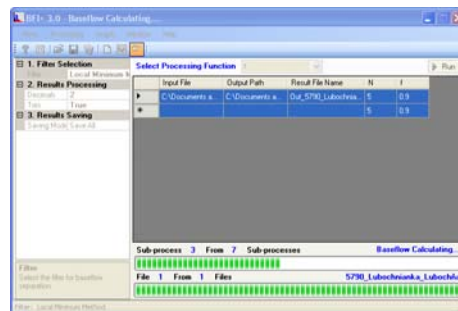
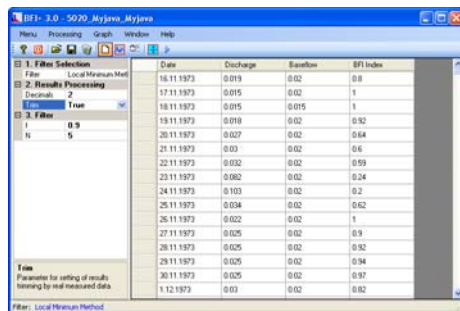
# BFI+ 3.0

## User's Manual

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By Miloš Gregor

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2010

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<b>Product Name: BFI+</b>
<b>Version: 3.0</b>
<b>Build: 9</b>
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## INTRODUCTION

This manual was created for the use of the BFI+ 3.0 module (build 6) of [HydroOffice 2010](#) software. The manual describes the functionality and limitations of module use. After studying, you should be able to use the full functionality of the module.

The module BFI+ 3.0 serves for analysis and separation of baseflow for total catchment discharge. The methodics for module developing is based on Tallaksen & van Lannen (2004) and others listed in reference section.

For the purposes of baseflow separation exist more small and simple tools and programs (e.g. in Tallaksen & van Lannen, 2004 or Sloto & Crouse, 1996). The BFI+ 3.0 program allows the user to choose from eleven methods of baseflow separation and results can be analysed in either a table or graphical form. For the setting of filtration coefficients is possible to use one useful tool for its calibration.

To prepare the input file of time-series values is necessary to study the manual – [How to prepare input data for modules](#). This manual briefly describes the preparation of input data for individual modules. The great advantage of HydroOffice 2010, all modules use the same structure of input data. Therefore, prepared data for one module is possible use than in other modules.

Individual modules of HydroOffice 2010 use the same structure of the graphical user interface, so if you learn to use a one module, than the next transition to other one will be greatly simplified.

I hope that the module you will help in daily work. For further study the use of modules can be used [video-tutorials](#), located on the [HydroOffice website](#). In the case you find a bug in the module, you have an idea for improving it, or any other question, please use the [user forums](#) on the site, so that other users can use the solution to your problems. Also, if you know solution to the problem of another user, do not hesitate to help him. The more you can help me on the forums, the sooner can be issued the upcoming new modules for you.

If you are using the HydroOffice tools, please quote them. If you not know what work you can cite, you can find them on [this site](#). If you quoted something, you can send me a citation to your work and I will add this to [citation page](#) with the reference to your work site.

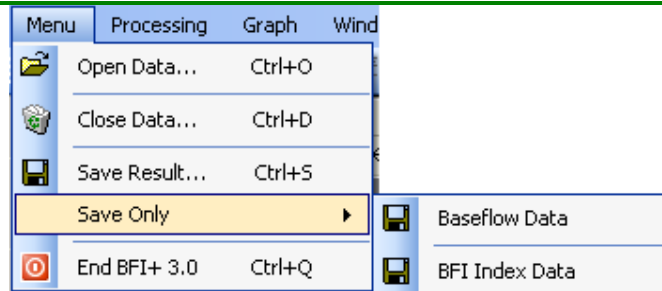
**Miloš Gregor**

(hydrogeologist, HydroOffice developer)

**HydroOffice**

## MAIN FUNCTIONS

The basic features of the program are listed under **Menu** (*fig.1*) or the first buttons in application toolbar. The function **Open Data** serve for import of input data to program. After entering the input file that are data stored in the table (*fig.2*).

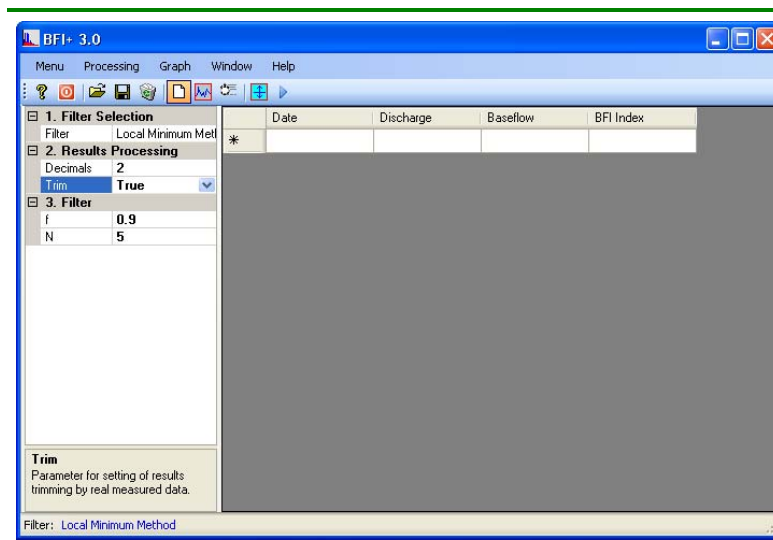


**Fig. 1: Basic commands in BFI+ 3.0 module.**

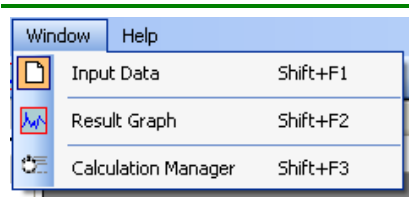
If the input file is formatted correctly, the dates of measurements and values are automatically divided into separate columns. Also at the end of the table should not be more than one blank line. If there are more after their selection and pressing

**Delete** button is possible delete them. Thus prepared data can then be used for further processing. Which will be explained in the next chapter (*fig.3*).

In addition to the described function are in the menu also three other functions. Command **Close Data** serves to complete removal of all data in the application. The command clear the input data table, result data table and chart results. Command **Save Result** serves for saving of calculated results. The forms of results will be presented later. The program allows you to save the results into four types of files (\*.txt, \*.xls, \*.doc and \*.rtf). Due to difficulties and problems of compatibility between different versions of programs (e.g. MS Office), the results are not really saving to selected file formats (e.g. .xls). It's always basically just a text file (.txt) that is automatically opened and processed in an associated program (something like \*.txt.xls). The last command **End** serves to module termination.



**Fig. 2: The main window of BFI+ 3.0 module.**



**Fig. 3: The commands for switching of main windows.**

In the case of results saving is in program possible select one of three saving mode types for calculated results. On the figure 2 is showed empty table of input data and calculated results. This table can be saved by command **Save Result (fig.1)**. If user can save only part of results, that ca use as input file for other module, than can export

the time-series of calculated baseflow or time-series of calculated BFI index (**Save Only – Baseflow Data** or **Save Only – BFI Index Data**).

In main window exist three main parts of application. These parts are possible switching by commands in menu **Window (fig.3)** or in toolbar.

The command **Input Data** serves for showing of input data and result data table. The second command **Result Graph** shows calculated results in the form of graph. The last command **Calculation Manager** can show group of tools for bulk data processing. The options of bulk data processing are introduced in last chapter of this manual.

## **BASEFLOW SEPARATION THEORY**

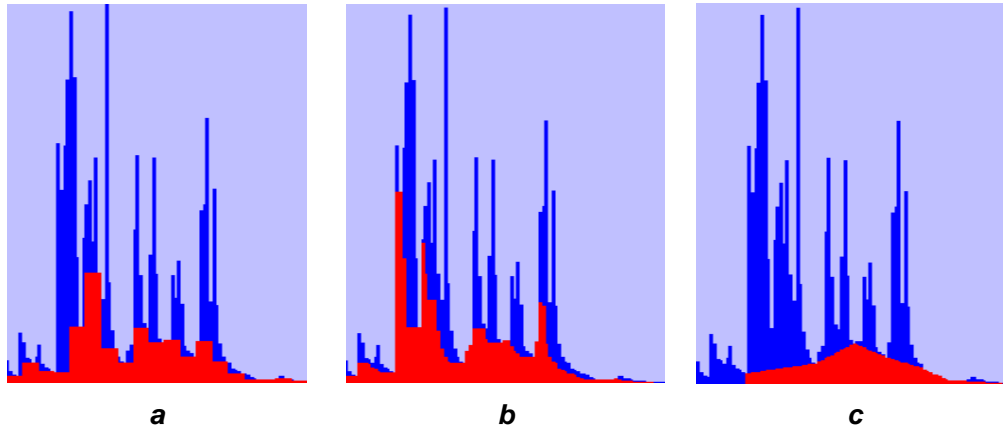
Many hydrograph separation techniques have been applied for identification of the different flow components of the total flow. The components are thought to represent different flow paths in the catchment, each characterised by different flow has traditionally been separated into flow that originates from overland (direct), unsaturated (thoroughflow) and saturated (groundwater) flow. In their review Nathan & McMahon (1990) distinguish between methods for continuous separation of the different components of the flow (Tallaksen & van Lannen, 2004).

Methods for continuous separation generally divide the flow into one quick and one delayed component using an automated time-based separation. The delayed flow component using an automated time-based separation. The delayed flow component is thought to represent the proportion of flow that originates from groundwater and other delayed sources, by Hall (1968) defined as the baseflow,  $Q_b$ . Time-series of base flow have been seen as useful as a measure of the dynamic behaviour of groundwater in a catchment, whereas the baseflow proportion of the total flow has as an index of the catchment's ability to store and release water during dry weather. A high index of baseflow would imply that the catchment has more stable flow regime and is thus able to sustain river flow during extensive dry periods. Base flow indices have performed satisfactorily as a catchment descriptions in many low flow studies because even a rough estimate of storage properties greatly increases the performance of the estimation model (Tallaksen & van Lannen, 2004).

Baseflow indices are generally highly correlated to the hydrological properties of soils and geology and other storage related descriptions like lake percentage. Consequently, information on properties like soil and geology may be used directly to derive an index of storage to be included in the regression model. However, until detailed soil and geology maps are available for larger areas and at the appropriate scale, it is likely that flow-derived indices will be in use (Tallaksen & van Lannen, 2004).

For the baseflow separation was created number of methods. In Sloto & Crouse (1996) was presented three main methods (*fig.4*):

- **Fixed interval method**
- **Sliding interval method**
- **Local minimum method**



**Fig. 4: Example of main baseflow separation methods (a – fixed interval method; b – sliding interval method; c – local minimum method).**

#### **Fixed interval method**

The fixed-interval method assigns the lowest discharge in each interval ( $N$ ) to all days in that interval starting with the first day of the period of record (*fig.4a*). The method can be visualized as moving a bar  $2N^*$  days wide upward until the bar first intersects the hydrograph. The discharge at that point is assigned to all days in the interval. The bar is then moved  $2N^*$  days horizontally, and the process is repeated. The assigned values are then connected to define the base-flow hydrograph (Sloto & Crouse, 1996).

#### **Sliding interval method**

The sliding-interval method finds the lowest discharge in one half the interval minus 1 day [ $0.5(2N^*-1)$  days] before and after the day being considered and assigns it to that day (*fig.4b*). The method can be visualized as moving a bar  $2N^*$  wide upward until it intersects the hydrograph. The discharge at that point is assigned to the median day in the interval. The bar then slides over to the next day, and the process is repeated (Sloto & Crouse, 1996).

#### **Local minimum method**

The local-minimum method checks each day to determine if it is the lowest discharge in one half the interval minus 1 day [ $0.5(2N^*-1)$  days] before and after the day being considered. If it is, then it is a local minimum and is connected by straight lines to adjacent local minimums (*fig.4c*). The base-flow values for each day between local minimums are estimated by linear interpolations. The method can be visualized as connecting the lowest points on the hydrograph with straight lines (Sloto & Crouse, 1996).

## Recursive digital filters

The recursive digital filters are routine tools in signal analysis and processing, are used to remove the high-frequency quickflow signal to derive the low-frequency baseflow signal. Table 1 outlines some of the digital filters that have been applied to smooth hydrographic data.

The BFI+ module in third version includes following methods:

- One parameter algorithm
- Boughton two-parameter algorithm
- IHACRES (three-parameter algorithm)
- BFLOW (Lynie & Hollick algorithm)
- Chapman algorithm
- Furey & Gupta filter
- Eckhardt filter
- EWMA filter

**Tab. 1: Recursive digital filters used in BFI+ 3.0 program.**

Filter name	Filter Equation	Comments
<b>One-parameter algorithm</b> (Chapman & Maxwell, 1996)	$q_{b(i)} = \frac{k}{2-k} q_{b(i-1)} + \frac{1-k}{2-k} q_{(i)}$	$q_{b(i)} \leq q_{(i)}$ Applied as a single pass through the data.
<b>Boughton two-parameter algorithm</b> (Boughton, 1993; Chapman & Maxwell, 1996)	$q_{b(i)} = \frac{k}{1+C} q_{b(i-1)} + \frac{C}{1+C} q_{(i)}$	$q_{b(i)} \leq q_{(i)}$ Applied as a single pass through the data Allows calibration against other baseflow information such as tracers, by adjusting parameter C.
<b>IHACRES three parameter algorithm</b> (Jakeman & Hornbarger, 1993)	$q_{b(i)} = \frac{k}{1+C} q_{b(i-1)} + \frac{C}{1+C} (q_{(i)} + \alpha_q q_{(i-1)})$	Extension of Boughton two-parameter algorithm.
<b>Lynie &amp; Hollick algorithm</b> (Lynie & Hollick 1979; Nathan & McMahon, 1990)	$q_{f(i)} = \alpha q_{f(i-1)} + (q_{(i)} - q_{(i-1)}) \frac{1+\alpha}{2}$	$q_{f(i)} \geq 0$ $\alpha$ value of 0.925 recommended for daily stream data filter recommended to be applied in three passes Baseflow is $q_b = q - q_f$



<b>Chapman algorithm</b> (Chapman, 1991; Mau & Winter, 1997)	$q_{f(i)} = \frac{3\alpha - 1}{3 - \alpha} q_{f(i-1)} + \frac{2}{3 - \alpha} (q_{(i)} - \alpha q_{(i-1)})$	Baseflow is $q_b = q - q_f$
<b>Furey &amp; Gupta filter</b> (Furey & Gupta, 2001)	$q_{f(i)} = (1 - \gamma)q_{b(i-1)} + \gamma \frac{c_3}{c_1} (q_{(i-d-1)} - q_{b(i-d-1)})$	Physically-based filter using mass balance equation for baseflow through a hillside
<b>EWMA filter</b> (Tularam & Ilahee, 2008)	$q_{b(i)} = \alpha q_{(i)} + (1 - \alpha)q_{b(i-1)}$	Exponential Smoothing Method of Base Flow Separation

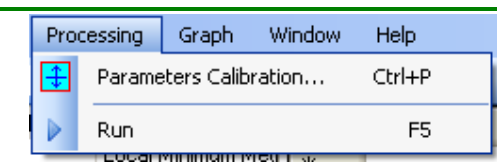
$q_{(i)}$  is the original streamflow for the  $i^{\text{th}}$  sampling instant  
 $q_{b(i)}$  is the filtered baseflow response for the  $i^{\text{th}}$  sampling instant  
 $q_{f(i)}$  is the filtered quickflow for the  $i^{\text{th}}$  sampling instant  
 $q_{(i-1)}$  is the original streamflow for the previous sampling instant to  $i$   
 $q_{b(i-1)}$  is the filtered baseflow response for the previous sampling instant to  $i$   
 $q_{f(i-1)}$  is the filtered quickflow for the previous sampling instant to  $i$   
 $k$  is the filter parameter given by the recession constant  
 $\alpha, \alpha_q$  are filter parameters  
 $C$  is a parameter that allows the shape of the separation to be altered  
 $\gamma, c_1, c_3$  are physically based parameters

The Base Flow Index (BFI) was developed during a low flow study in the UK (Institute of Hydrology, 1980). The index gives the ratio of baseflow to total flow calculated from a hydrograph smoothing and separation procedure using daily discharges. The BFI is thus considered a measure of the river's runoff that derives from stored sources and as a general catchment descriptor it has found many areas of application, including low flow estimation and groundwater recharge assessment. Values of the index range from above 0.9 for permeable catchment with a very stable flow regime to 0.15-0.2 for an impermeable catchment with a flashy flow regime (Tallaksen & van Lannen, 2004).

The BFI is closely related to other low flow indices and is frequently used as a variable for estimating low flow indices at the ungauged site. Relationships between the index and catchment descriptors have been derived for different hydrogeological regimes and used to estimate BFI, and hence flow indices, at the ungauged site (Institute of Hydrology, 1992).

For the further study I recommended studying the papers cited in the text.

## PARAMETERS CALIBRATION

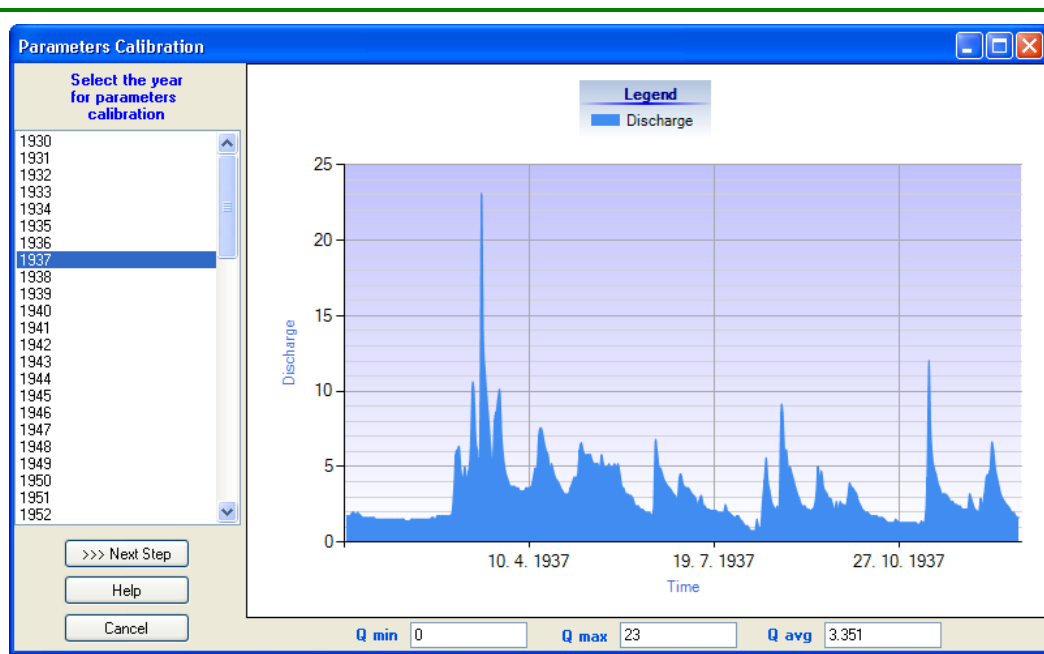


**Fig. 5: Processing commands in BFI+ 3.0 program.**

As is evident from previous chapter, each baseflow separation filter contains several filtration coefficients or parameters. For its calibration or dependency analysis of calculated baseflow from the modification of filter coefficients and

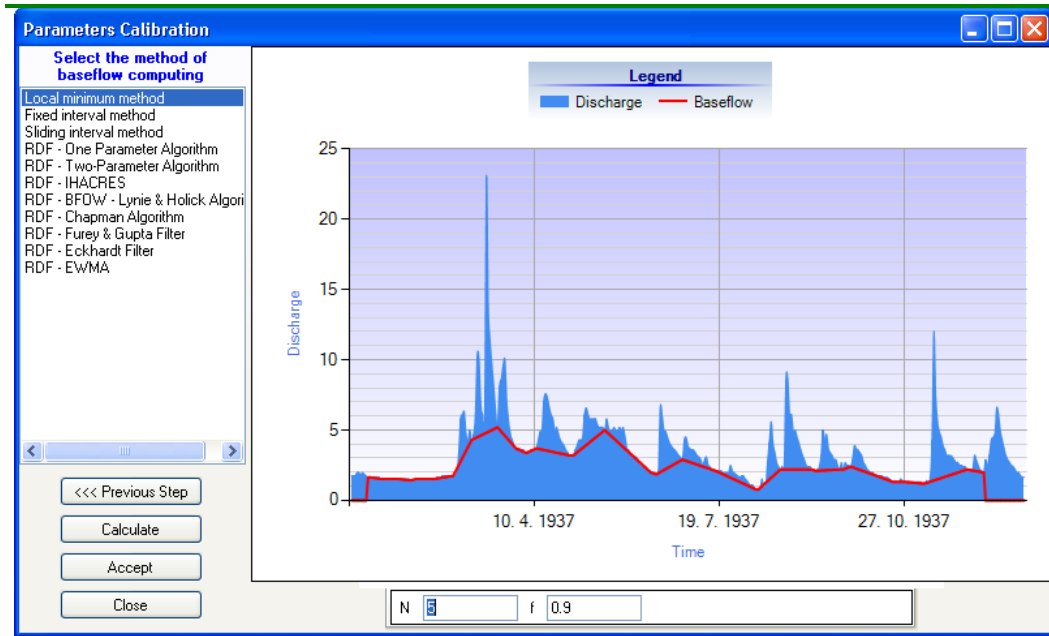
parameters is possible use one useful tool, that can be showed by command in menu **Processing – Parameter Calibration...** (*fig.5*). After its start is showed window like on figure 6.

In the first step user select one year from imported time-series, on which will be analysed the impact of filtration coefficient changes to calculated baseflow. When user select year in listbox on left part of window, the discharge data from this year are automatically drawing in graph and under the graph are calculated minimal, maximal and average values of discharge for selected year. If user have select one year, for the next step of processing can move through button **>>> Next Step**. The window for next step looks like on figure 7.



**Fig. 6: Year selection for filter coefficients and parameters calibration.**

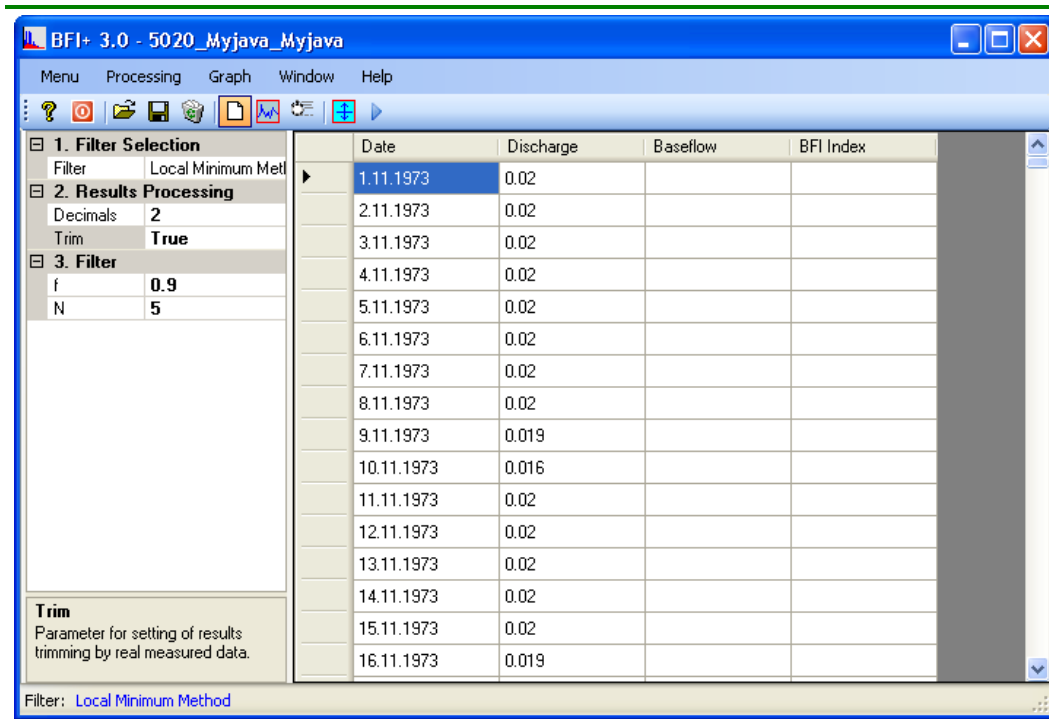
In the second step user select in left listbox one method for baseflow separation. When you change the selected method, the parameters also change below the chart. After its completion and pressing **Calculate** button or pressing **Enter** key is baseflow calculated and displayed in the chart. The great advantage of this tool is that the baseflow is calculated much faster than in main window and that is mainly used in the analysis of changing parameters impact on the calculated results.



**Fig. 7: Filtration coefficients and parameters analysis in selected method.**

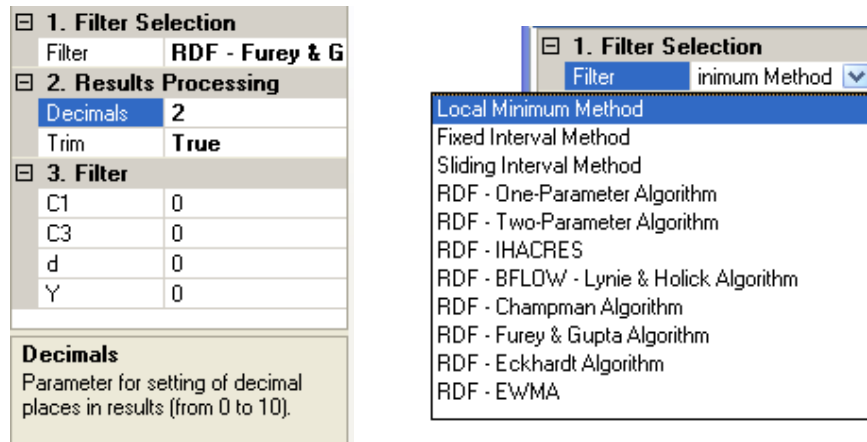
If we want to copy the filter coefficients and parameters from this tool to the main window, click in the **Accept** button (*fig.7*).

## DATA PROCESSING



**Fig. 8: Main window for baseflow calculation.**

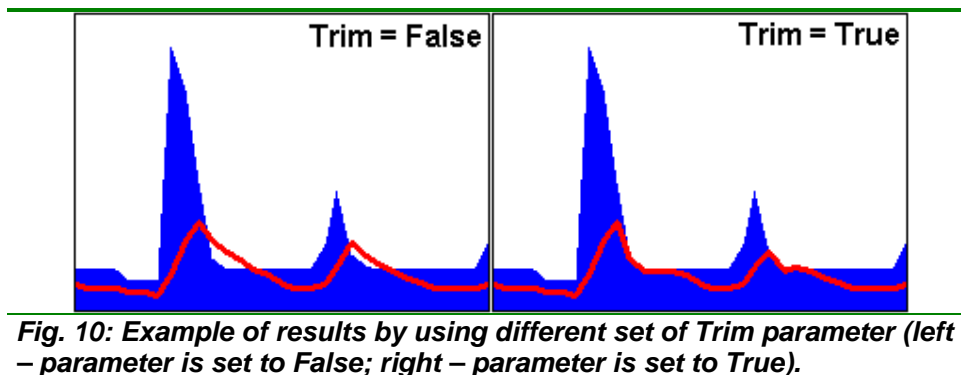
All baseflow calculations and data processing are processed in main window (*fig.8*). The most important for baseflow processing is the property grid on left part of window (*fig.9*).



**Fig. 9: Settings and properties of baseflow separation filter (left – all parameters; right – filter selection).**

The filtration algorithm parameters are grouped in **Filter** and **Filter Selection** section. The left part of picture shows the choices of baseflow separation method. When you change the selected method also changes the **Filter** section. Each of prepared filters has its own coefficients, whose purpose is described in the previous theoretical section and mainly in table of recursive digital filters.

It is also possible to set two other parameters in **Results Processing** section. The first parameter **Decimals** sets the number of decimal places in the calculated results. The last parameter **Trim** is parameter, which determines whether the results can be cut by real data. In some methods, it often happens that the calculated baseflow is higher than the real measured total discharge. Therefore, if user can cut the calculated baseflow by the total discharge must set the **Trim** parameter to **True** (*fig.10*).



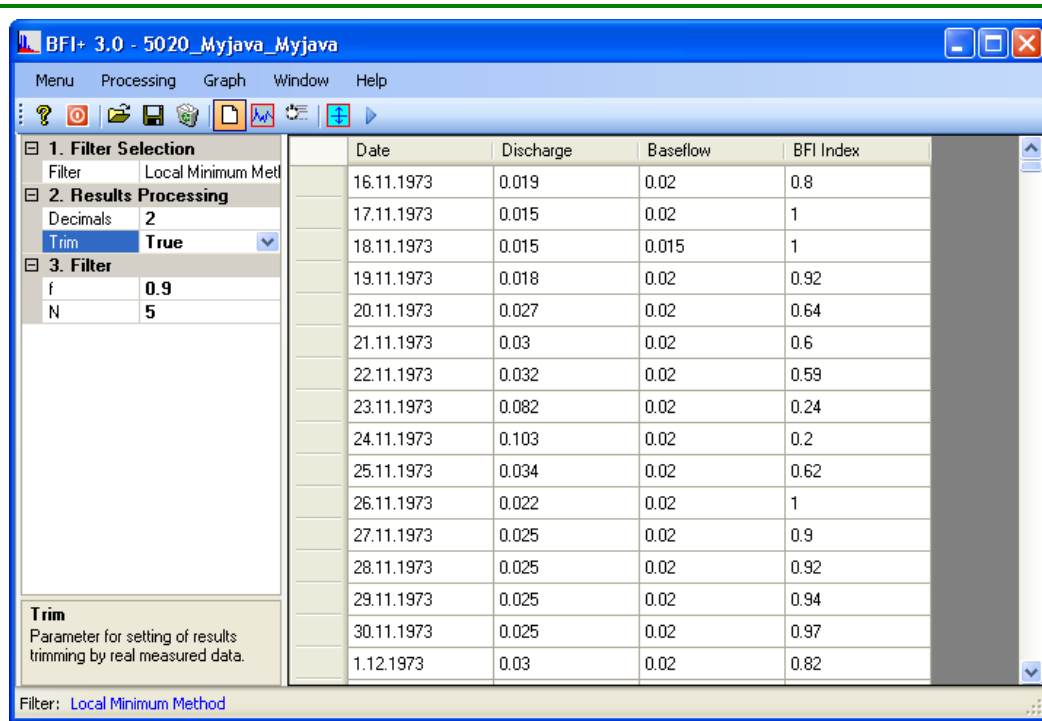
**Fig. 10: Example of results by using different set of Trim parameter (left – parameter is set to False; right – parameter is set to True).**

After setting of all necessary parameters is possible to execute the algorithm for baseflow calculating. Run it using the command in the menu **Processing - Run** (*fig.5*). After running the calculation program calculate

baseflow, crop results by real measured discharge if that the user define (Trim parameter), calculate the baseflow index (**BFI**), round results and draw a chart for the first year in imported time-series.

## TABLE RESULT

All results together with the input data are located in the main window in the table in four columns. The first column defines the discharge measurement date. In module BFI+ 3.0 can be used daily or weekly type of time-series.



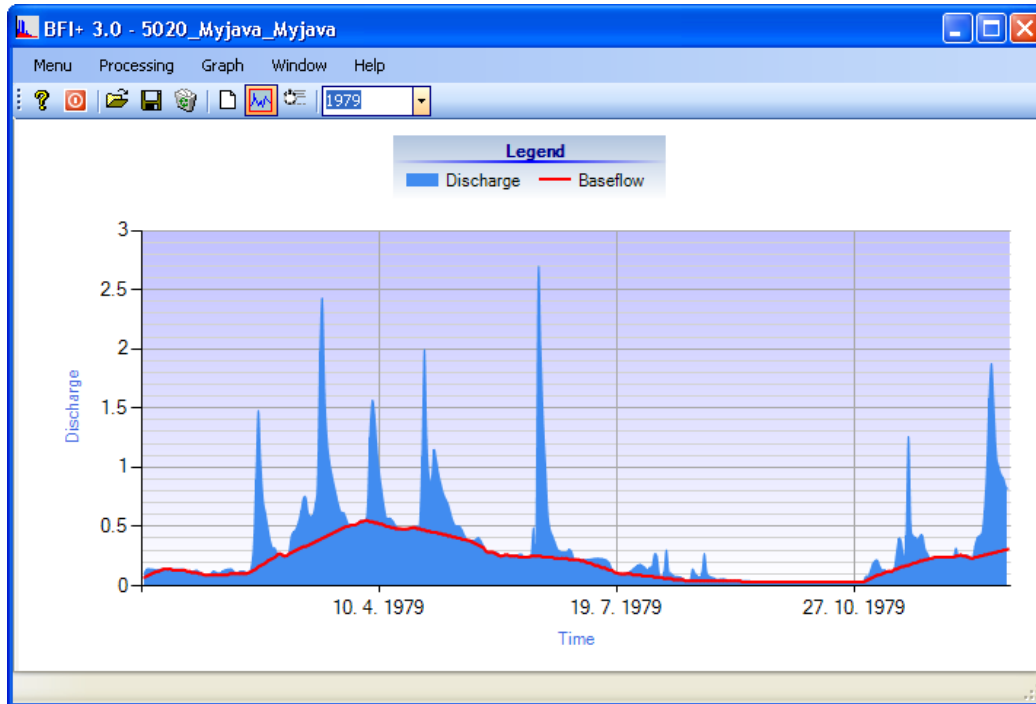
**Fig. 11: The table results in BFI+ module.**

In the second column discharge data are imported. The next column contains the calculated values of baseflow and the last contains the baseflow index (**BFI**).

The values of calculated baseflow and discharge can be visually analysed in predefined chart. These options are presented in the next chapter.

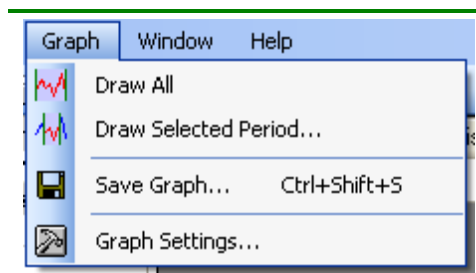
## GRAPH RESULT

After completing of the baseflow computation is always shown the graph of catchment discharge and baseflow in the first year of imported time-series (*fig.12*).



**Fig. 12:** The chart example of baseflow (red line) and total catchment discharge (blue area) in one year.

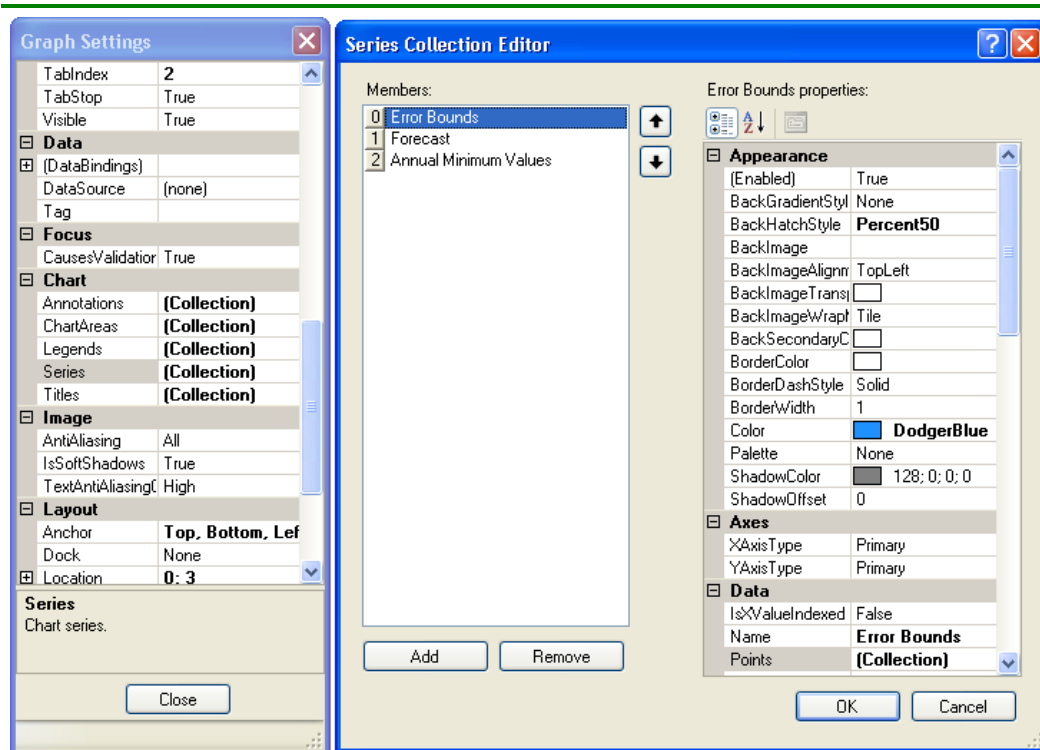
BFI+ 3.0 module contains several graphical tools for results displaying. All are located in menu **Graph** (fig.13).



**Fig. 13:** Tools for graphical processing of calculated results.

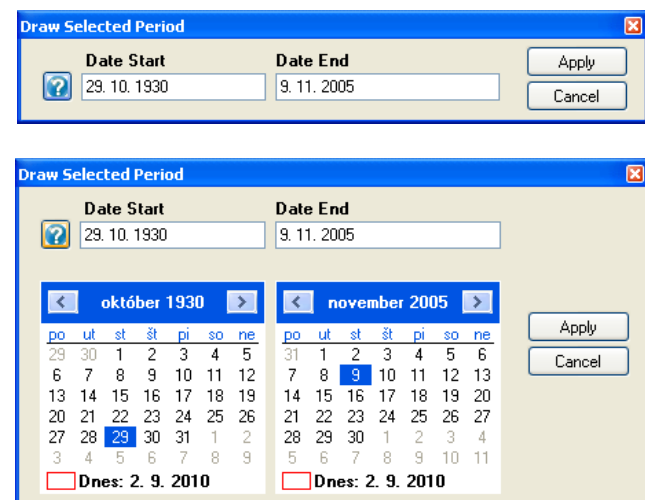
Each displayed chart can be saved using the **Save Graph** command. BFI+ 3.0 module allows user to export generated chart from the program in six graphical formats (\*.bmp, \*.emf, \*.gif, \*.jpeg, \*.png, \*.tiff).

The second function, **Graph Settings**, is for visual adjustments of automatically generated charts. For its adjustments can be showed **Graph Settings** window (fig.14). In it can be set practically everything that is visible in the graph (e.g. legend, lines, chart area, axis, chart titles, etc.).



**Fig. 14: Tools for graph visual adjustments.**

In the chart settings tool can be set up really everything. In addition to the visual settings can be set also the length of displayed data. By use the combo box in toolbar can be displayed in chart selected year (fig.12). With **Draw All** function can be displayed at once all calculated results in one chart.

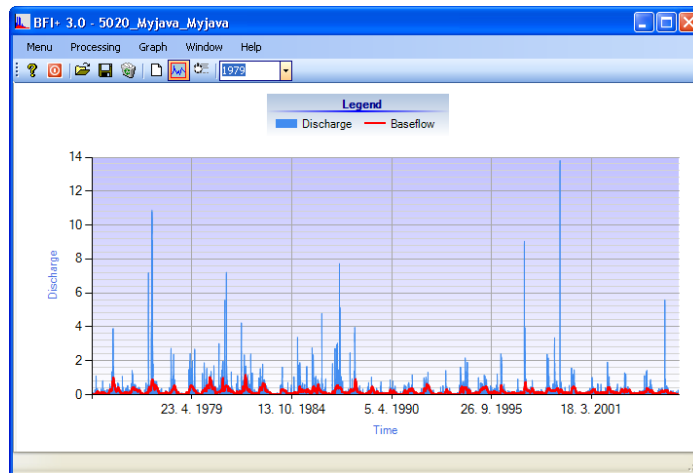
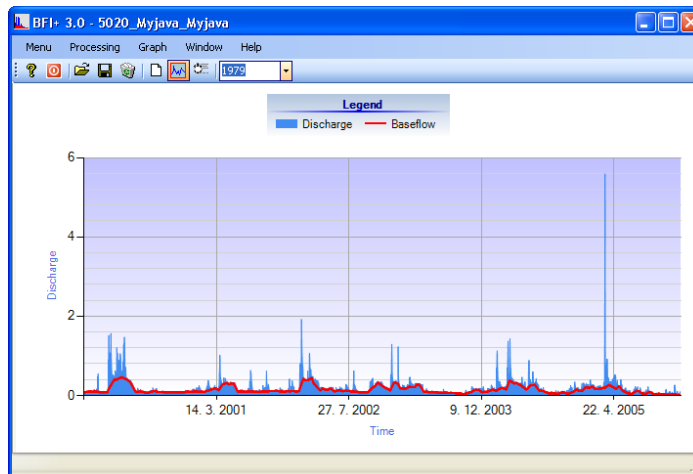
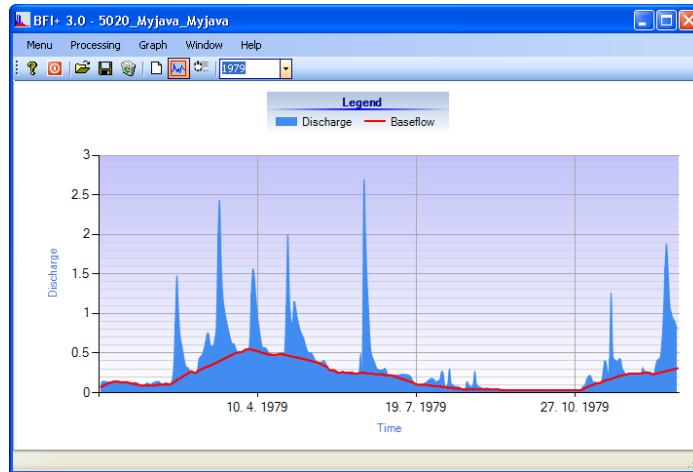


**Fig. 15: Form for data selecting from time-series to drawing in graph.**

Their rendering may take longer time, depending on the capabilities of your graphics card. It is also possible using the **Draw Selected Period...** function to choose the part of calculated results to display in chart by using the form on picture 15.

With two textboxes in form user define the start and end of period for displaying in chart. If user clicks on the button with a question mark, support calendars are shown for the rapid definition dates (fig.15-bottom).

After click on the **Apply** button is selected period rendered in the chart. Examples of the periods rendering with different length are shown on Figure 16.

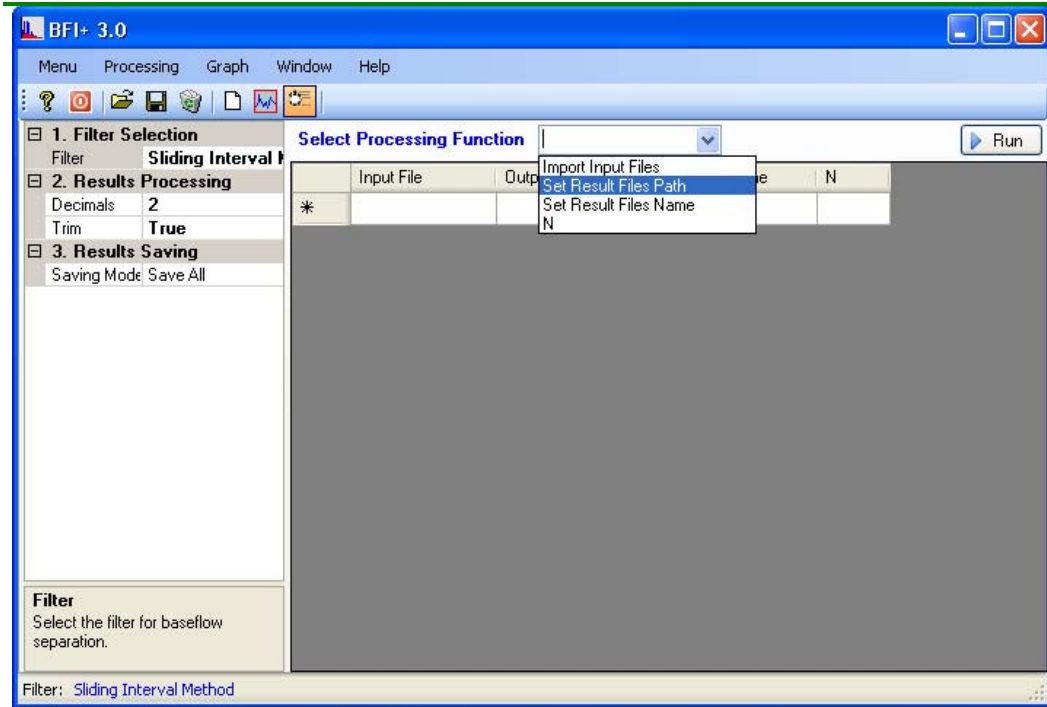


**Fig. 16: The different settings example of period length displayed in chart (top – one year graph; middle – 5-year long graph; bottom – long-term graph).**

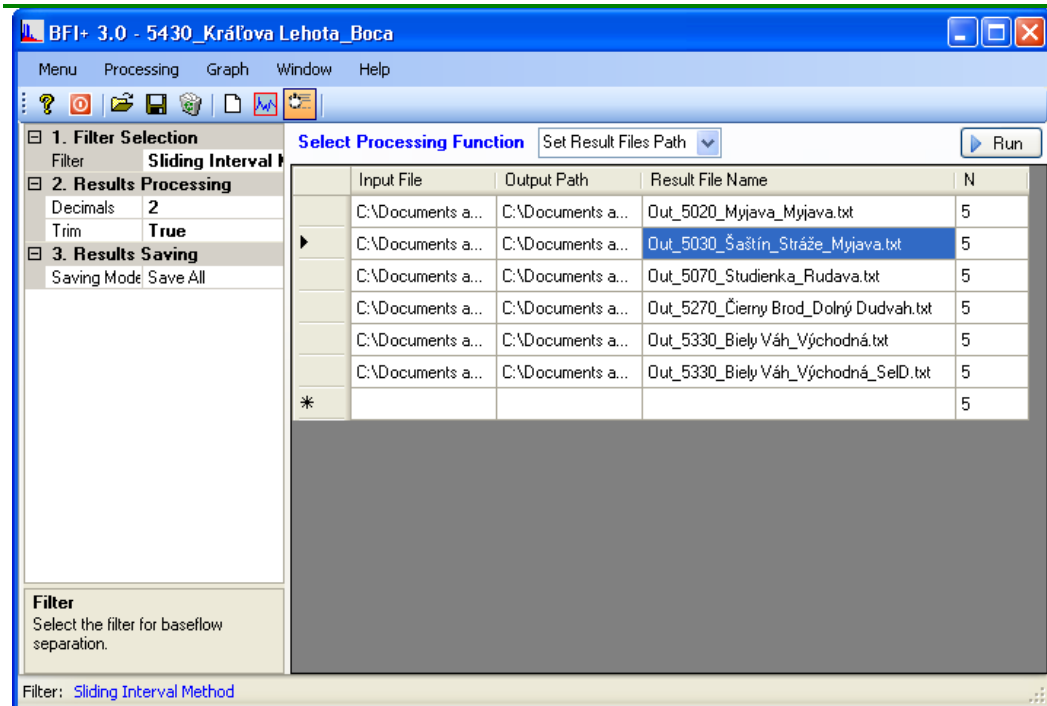


## CALCULATION MANAGER

An important part of the BFI+ module in the third version is calculation manager, used to automatic block data processing. This tool will show command **Window - Calculation Manager** (*fig.17*).



**Fig. 17: Calculation manager tools in main window of BFI+ module.**



**Fig. 18: Ready-made tool for bulk data processing.**

The user in this tool set that, what wants to process, like as the input data, such like as what results the user wants to store, where they want to save, etc. (*fig.18*).

Procedure of setting is as follows:

**1. Set the method for baseflow calculating.**

The method of baseflow calculating set in property grid in the left part of window, under **Filter** section. After entering the structure of the table is automatically redefined.

**2. Setting the results processing.**

In property grid in the section **Results Processing** user defines the number of decimal places for results in property **Decimals**. **Trim** parameter defines whether the baseflow results will be trimmed by the total discharge values (*fig.10*).

**3. Saving settings of calculation results.**

In the **Results Processing** section, user can set the mode of the results storing on disk. As mentioned in the first chapter, user can store the entire table, or may export only the time-series of baseflow or baseflow index (**BFI**).

**4. Setting of parameters in table.**

After setting the basic parameters in property grid, user can set parameters in table. The first column contains information about the position of the input file on disk. These files can be imported multiple into the table using the function **Import Input Files** in combo box above the table or individually and directly in the table, either manually or by using **Open File Dialog** that appears after double click on selected cell in the table (in first column exactly).

After importing the input file, in the second column define the results file path for saving, which is a predefined set to the same location as the input file is located. This can be changed just once for the entire table using function in combo box, or by double-clicks at the selected cells (in the second column exactly).

The third column defines the name and type of file for results storing. When you import the data input file, is automatically generated file name for the results.

The bottom line is that the program takes the input file name and adds the string “**Out\_**” (e.g. for input file name “**Donau\_River.txt**” generate results file name – “**Out\_Donau\_River.txt**”). Like the name, the user can also define the type of file. BFI+ supports four types of files (\*.txt, \*.xls, \*.rtf, \*.doc). The names the output files can also be defined automatically by command in combo box. The user enters a file name and type and program copy to all cells in the column this name, but they are numbered (for example, the name is “**Result.txt**” and program generate in the first row name “**1\_Result.txt**”). It is important that, the each name of result file must be unique, because in other case the results file from one analysis can overwrite the results file from other one.

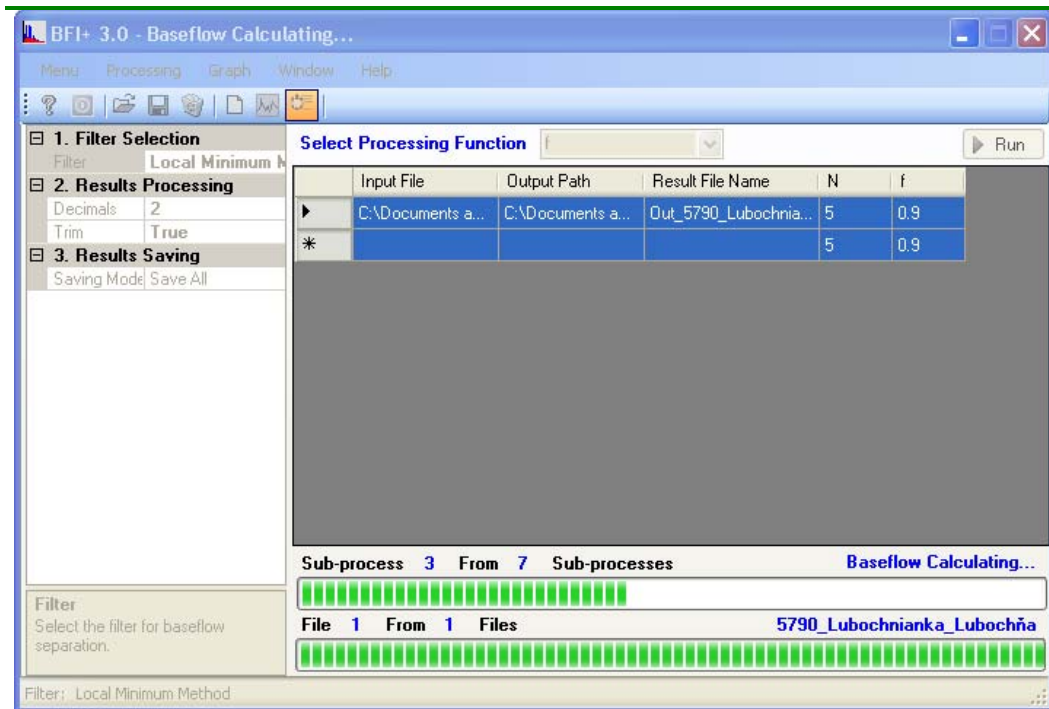
Other columns are generated depending on the chosen method of baseflow calculating. They are set manually in individual cells or can be defined automatically in one column by using commands in combo box.

The resulting table after filing should look like on figure **18**.

**5. Launch bulk data processing.**

If we defined all the parameters in property grid and table, the bulk calculations can be launched by button **Run** in the top right part of the window. After its launch window will appear like as in Figure 19.

The program displays two progress bars, where the bottom shows the number of processed and unprocessed files and the processing status of the current file (processing steps) is showed on top progress bar.



**Fig. 19: The course of computerized calculations of BFI+ module.**

## CONCLUSION

This manual describes the functionality and uses of BFI+ 3.0 module.

The module serves to separation of baseflow from total catchment discharge, where we can use 11 methods of separation. For analysis of the relationship between calculated baseflow and the separation filter coefficients (or parameters) can be used tool for its calibration. In addition, the program contains a sophisticated tool allows bulk processing of data without any interaction from the user. The results can be exported from the program in three forms and we can analyse them in predefined charts.

Application has several features that are detailed described in the text. In case of problems with the module can be use user's forum on the [HydroOffice.org](http://HydroOffice.org) web. To further study of the module functionality can be used [videotutorials](#). Freely can be downloaded in the [Downloads section](#) of web.

If in program absence any function or feature, you can inform me in forum on web. If you find a bug in the program, I will be grateful for the notification. You can inform me about it via [forum](#) or via my [email](#). If you use this module, it would be good to cite it in your work. If you do not know what to quote, on [this page](#) you can find the publications focused to HydroOffice software and its modules. If you quoted something of HydroOffice project, I'll be happy if you inform my and give me a quote to your work. I can add a link

to your site on [this page](#) of HydroOffice web. This can also help you with better placement in search engines.

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