
 **EPA BASINS Technical Note 9**

Web-based HSPF Toolkit to Support Low Impact Development (LID) and Other Urban Stormwater Modeling Applications

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Web-based HSPF Toolkit to Support Low Impact Development (LID) and Other Urban Stormwater Modeling Applications

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The RCHRES module of the Hydrological Simulation Program – FORTRAN (HSPF) is used to simulate various features including hydraulic behavior, sediments, general water quality constituents, and biochemical constituents in free-flowing channel reaches and well-mixed reservoirs. The toolkit described in this technical note is accessible at <http://www.epa.gov/athens/research/modeling/ftable/index.htm> and uses the RCHRES module to simulate how certain structural best management practices (BMPs) such as detention basins (wet ponds, treatment wetlands, etc.) mitigate the impacts of stormwater runoff. This technical note focuses on the use of RCHRES to simulate the impacts of BMPs on flow only. Future notes will explore the simulation of pollutant retention as well. In its current development stage, the tool represents open channels and flow control devices (weirs and orifices). The open channel component has five shape choices; each shape is represented by a depth-area-volume-flow relationship known as hydraulic function table or FTABLE. The open channel's shapes are: circular, parabolic, rectangular, triangular, trapezoidal, and natural. Simulated flow control devices consist of V-notch, sharp-crested (Cipoletti), rectangular, broad-crested weirs, and under-drain and riser pipe orifices. For each channel shape, users have the option of selecting an open channel with or without a flow control device. In many applications, users may select an open channel only, while in other applications, users may select an open channel with one or more flow control devices. Note that HSPF allows a maximum of five flow exits in one FTABLE.

This toolkit enables HSPF users to extend the model's application to urban watersheds with sewer system networks and to areas with flow-modifying BMPs such as detention basins. The toolkit was developed for low impact development (LID) modeling applications. Specifically, the tool simulates BMPs that store stormwater runoff to attenuate flooding and remove pollutants. Presently, the tool is not recommended for simulating infiltration trenches, dry wells or other BMPs that function by enhancing infiltration.

The tool requires some UCI file manipulations, but does not require HSPF code changes. Detailed instructions on how to run the program are given in the tutorials.

Note: The applet was compiled using the Java 1.5. If you cannot see the applet when you open the web page in the browser, go to <http://java.sun.com> and download the latest Java Runtime Engine. The Java Runtime Engine, or (JRE), is under the Java SE category on Sun's website. We recommend that users read the tutorial before using the tool.

1. Web-tool Tutorials

A. Human-made open channels with and without flow control devices

The Web-tool generates FTABLES for five human-made channel shapes and six flow control devices. Generating FTABLES for the human-made shapes and flow control devices are straightforward if these steps are followed.

STEP 1. Select a channel shape (e.g., trapezoidal as shown in Figure 1).

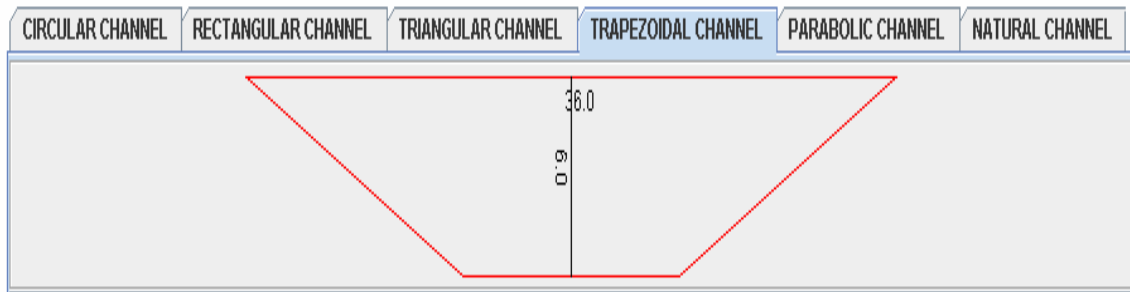


Figure 1. trapezoidal channel shape

STEP 2. After the desired channel shape is selected, users should enter channel geometry data in the input grid (Figure 2). Note that changing one parameter value without adjusting other parameters can change the channel shape and invalidate the FTABLE. Always check the channel shape after it is redrawn following each program execution. No output is generated if the channel shape changes. For example, changing the side slope from 2 to 4 without changing other parameters alters the channel shape from trapezoidal to triangular.

OPEN CHANNEL INPUT DATA	
Maximum Channel Depth (ft):	6.0
Top Channel Width (ft):	36.0
Channel Side Slope (H:V):	2.0
Channel Length (ft):	4000.0
Channel Mannings Value:	0.05
Longitudinal Slope (ft/ft):	0.025

Figure 2. Input grid for a trapezoidal channel

STEP 3. After the desired input data is entered, users should hit “Calculate FTABLE” to generate the FTABLE without a control device (Figure 3). Note that only four columns of the output grid table are populated.

Results Copy Results Calculate FTable

Right click the grid for more options.

depth(ft)	area(acres)	volume(ac-ft)	outflow1(cfs)
0.00	1.10	0.00	0.00
0.10	1.14	0.11	1.24
0.20	1.18	0.23	3.92
0.30	1.21	0.35	7.71
0.40	1.25	0.47	12.48
0.50	1.29	0.60	18.17
0.60	1.32	0.73	24.73
0.70	1.36	0.86	32.13

Figure 3. Generated FTABLE for a trapezoidal channel

STEP 4. Generation of an FTABLE with a control device requires the selection of one or more flow control devices by checking the box next to the desired device. In this example, a riser orifice was selected (Figure 4).

CONTROL STRUCTURES (optional)

Vnotch Weir
 Vertex Angle (deg): 30
 Weir Invert (ft): 5

Sharp Crested Weir (Cipoletti)
 Weir Crest Width (ft): 30
 Weir Invert (ft): 5

Broad Crested Weir
 Weir Crest Width (ft): 30
 Weir Invert (ft): 5

Rectangular Weir
 Weir Crest Width (ft): 30
 Weir Invert (ft): 5

Underdrain Orifice
 Orifice Diameter (ft): 5
 Orifice Height (ft): 2

Riser Orifice
 Orifice Diameter (ft): 5
 Weir Invert (ft): 2

Figure 4. Input grid for flow control devices

STEP 5. After selecting the riser orifice, a new FTABLE with an additional flow column for the flow control device (riserorf) is generated by clicking on “Calculate FTABLE” (Figure 5).

depth(ft)	area(acres)	volume(ac-ft)	riserorf(cfs)
0.30	1.21	0.33	0.0
0.40	1.25	0.47	0.0
0.50	1.29	0.60	0.0
0.60	1.32	0.73	0.0
0.70	1.36	0.86	0.0
0.80	1.40	1.00	0.0
0.90	1.43	1.14	0.0
1.00	1.47	1.29	0.0
1.10	1.51	1.44	0.0

Figure 5. FTABLE generated for a trapezoidal channel

STEP 6. Now that the program has generated an FTABLE with the desired channel and flow control combinations, the next step is to transfer the FTABLE to the HSPF UCI file and to ensure that its format is compatible with that of the UCI file. To transfer the FTABLE to a UCI file, point the mouse any where of the output grid, right click and then select “Copy to UCI file” (see Figure 6).

depth(ft)	area(acres)	volume(ac-ft)	riserorf(cfs)
0.30	1.21	0.33	0.0
0.40	1.25	0.47	0.0
0.50	1.29	0.60	0.0
0.60	1.32	0.73	0.0
0.70	1.36	0.86	0.0
0.80	1.40	1.00	0.0
0.90	1.43	1.14	0.0
1.00	1.47	1.29	0.0
1.10	1.51	1.44	0.0

Figure 6. FTABLE transfer to HSPF UCI file

STEP 7. After clicking on “Copy to UCI FILE,” the program generates an FTABLE that is compatible with the UCI format (Figure 7). To copy the FTABLE to a UCI file, select the entire FTABLE, then press CTRL+C to export the file to a UCI file. For UCI file related guidance, refer to the section on UCI File Manipulations (Step 12).

```

*** TRAPEZOIDAL ***
FTABLE _ID***
rows cols ***
61 4
depth area volume riserorf***
0.0 1.1 0.00 0.00
0.1 1.14 0.11 0.00
0.2 1.18 0.23 0.00
0.3 1.21 0.35 0.00
0.4 1.25 0.47 0.00

```

Figure 7. Exporting FTABLE to HSPF UCI file.

B. Natural channels with and without flow control devices

Presently, BASINS/WinHSPF may use either of two automated methods to generate FTABLEs for a reach cross-section. These are the default and the Alternate FTABLE methods. These automated FTABLE generation methods are intended for use in areas with no surveyed channel cross-section data (x, y). In reaches where surveyed channel cross-section data is available, users can select the natural channel option to generate FTABLEs from surveyed data.

The natural channel option produces channel profiles similar to those obtained with the U.S. Army Corps of Engineers' HECRAS model. Just like the HECRAS program, when entering (x, y) data, the x values must always increase from the left over-bank to the right over-bank (Figure 8). Although the natural channel program is capable of generating FTABLEs for many irregular channel shapes, it may not work for some channel cross-sections. For example, the natural channel program does not work for divided channels or for channels with fewer than six data points. In such cases, users may increase the number of data points for example by interpolation, or choose one of the human-made channel shapes to approximate the natural channel.

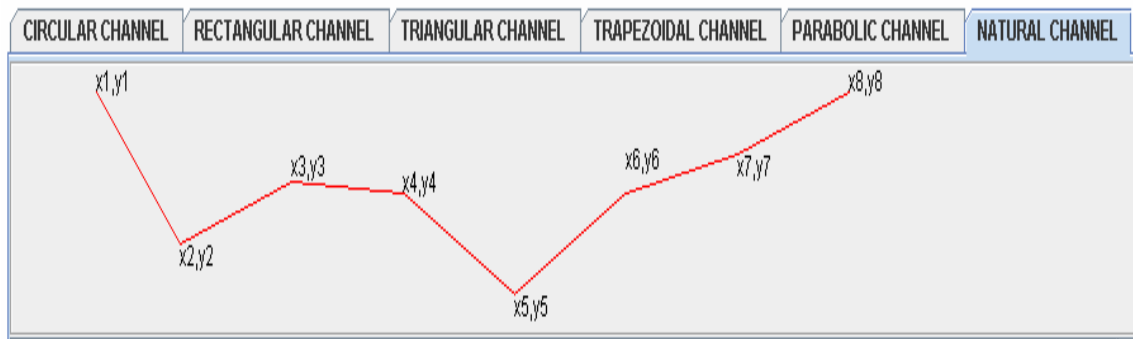


Figure 8. Schematic diagram of a natural channel cross-section

Step 8. To use the natural channel FTABLE option, prepare cross-sectional profile (x, y) data in comma-delimited text format by using a text editor such as Notepad. The user must first populate the left-hand side of the input grid with channel length, Manning's roughness coefficient, longitudinal slope, and height or depth increment. To import (x, y) data for the right hand side of the grid table, point the mouse at the input grid table and then right click to get "Import from CSV file" (Figure 9).

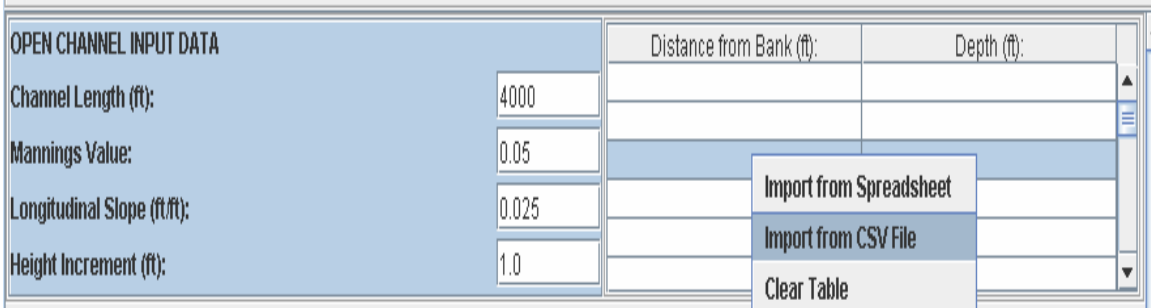


Figure 9. Natural input grid table

STEP 9. Right click on “Import from CSV file” shown in Figure 9 to open an empty Java Applet Window (Figure 10). Go to the input data file containing the (x, y) data (just a notepad not shown here), then select all the (x, y) data then copy it.

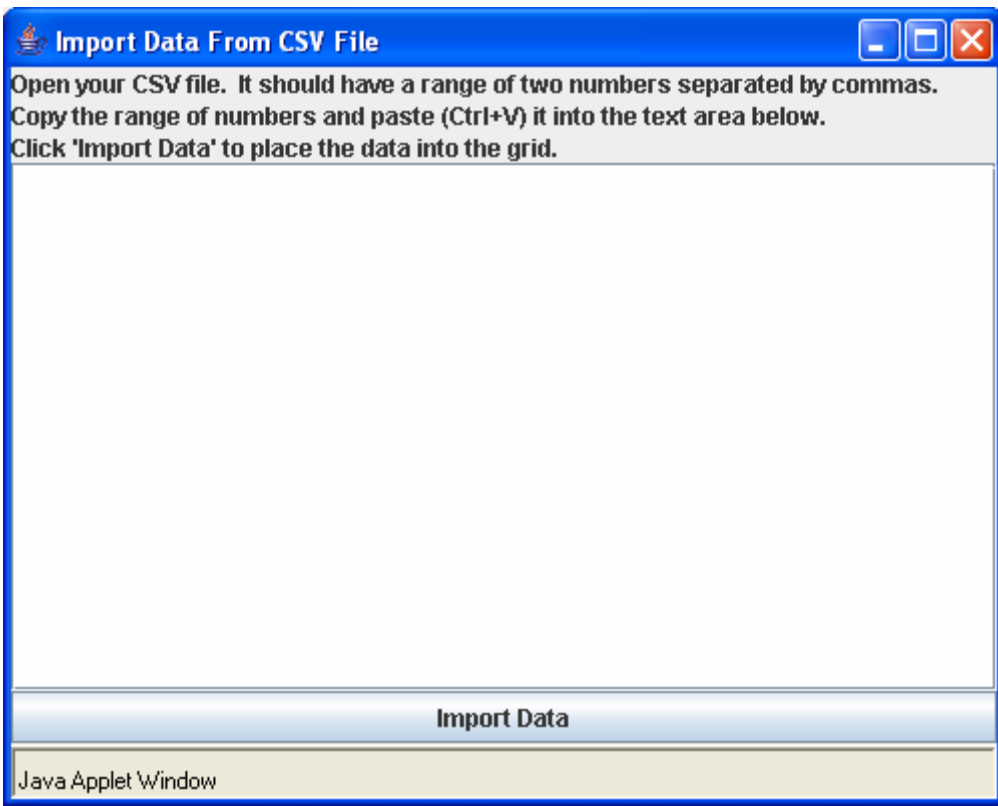


Figure 10. Data import screen

Step 10. The data in the notepad must have the format shown in Figure 11. Go back to the empty Java Applet Window and hit CTRL+V to paste the data into the Applet Window (Figure 11).

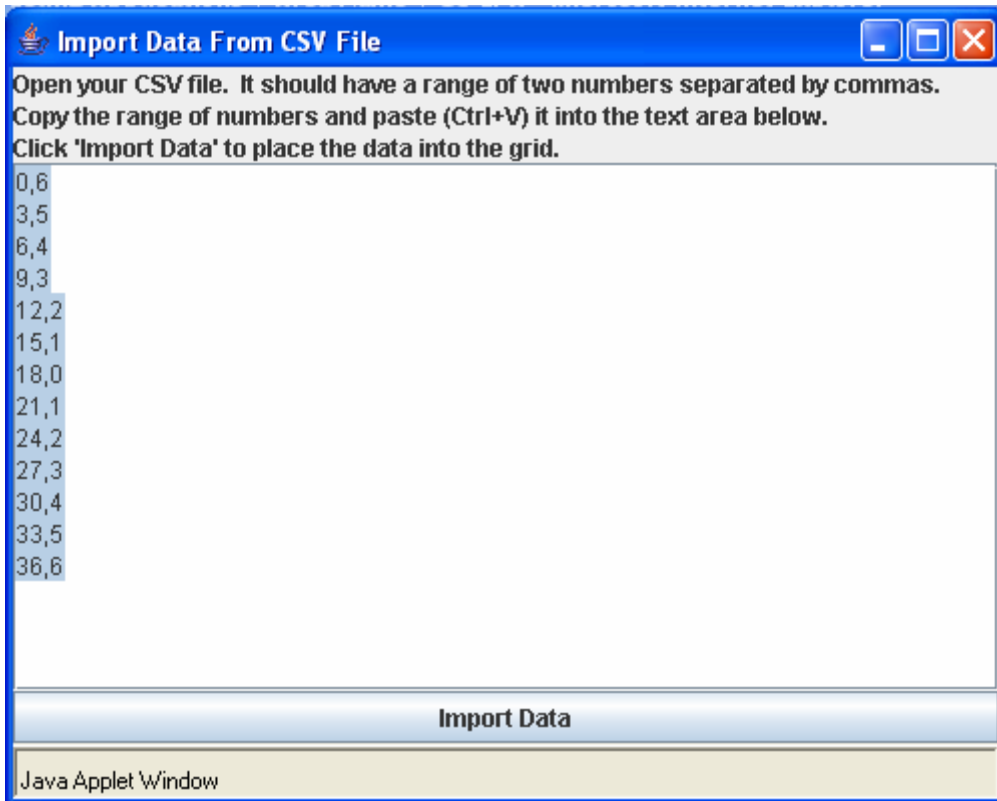



Figure 11. A Java Applet Window data import showing imported (x, y) data.

STEP 11. To transfer the pasted data into the natural channel grid, hit “Import Data” (see the lower side of Figure 11). Make sure that the data is entered into the grid (Figure 12).

OPEN CHANNEL INPUT DATA		Distance from Bank (ft):	Depth (ft):
Channel Length (ft):	4000	0	6
Mannings Value:	0.05	3	5
Longitudinal Slope (ft/ft):	0.025	6	4
Height Increment (ft):	1.0	9	3
		12	2
		15	1

Figure 12. A natural channel showing imported data points

STEP 12. Generate an FTABLE by clicking on . The default height increment is one foot for the natural channel. To refine the resolution of the FTABLE, set the height increment to any number from 0 to 1. The generated FTABLE can be exported to a UCI following the instructions given in Step 7.

Results		Copy Results	
depth(ft)	area(acres)	volume(ac-ft)	outflow1(cfs)
0.00	0.00	0.000	0.00
1.00	0.55	0.275	8.57
2.00	1.10	1.102	54.44
3.00	1.65	2.479	160.52
4.00	2.20	4.408	345.70
5.00	2.75	6.887	626.79
6.00	3.31	9.917	1019.23

Figure 13. FTABLE generated for a natural channel

C. HSPF UCI FILE MANIPULATIONS

STEP 13. To place the generated FTABLE in a UCI file, users must have an HSPF project that has existing FTABLES. It is wise to save a backup copy of the UCI file before making any modifications. Select the UCI file to change in the HSPF project, open it with a text editor, identify the FTABLE to change, and then paste the calculated FTABLE (copied from the Web-tool) above or below the existing FTABLE. Give the new FTABLE the same ID as the FTABLE to be replaced. Make sure to delete or comment out the existing FTABLE.

```

*** TRAPEZOIDAL ***
FTABLE   _ID***
rows cols          ***
61  5
depth    area      volume    outflow1    riserorf ***
0.00     1.1      0.00     0.00        0.00
0.1      1.14     0.11     1.24        0.00
0.2      1.18     0.23     3.92        0.00
0.3      1.21     0.35     7.71        0.00
0.4      1.25     0.47     12.48       0.00
0.5      1.29     0.6      18.17       0.00
0.6      1.32     0.73     24.73       0.00
0.7      1.36     0.86     32.13       0.00
0.8      1.4      1        40.33       0.00
0.9      1.43     1.14     49.34       0.00
1        1.47     1.29     59.13       0.00
.        .        .        .        .

```

Figure 14. An FTABLE generated for a trapezoidal channel

STEP 14. Set the appropriate number of exits in the GEN-INFO block of the RCHRES section of the RCHRES module (Figure 15). Note that only reach 8 has multiple exits.

Also, set the Print Flags (not shown here) to 2.0 for the RCHRES section to allow the model to generate an output for each time step. This is important for testing and evaluation.

```

GEN-INFO
***      Name      Nexits  Unit Systems  Printer
*** RCHRES          t-series Engr Metr LKFG
*** x - x          in out
  3  CIRCULAR PIPE    1    1  1  1  0  0  0  0
  4  CIRCULAR PIPE    1    1  1  1  0  0  0  0
  5  CIRCULAR PIPE    1    1  1  1  0  0  0  0
  6  CIRCULAR PIPE    1    1  1  1  0  0  0  0
  7  CIRCULAR PIPE    1    1  1  1  0  0  0  0
  8  NATURAL          5    1  1  1  0  1  0  0
  9  CIRCULAR PIPE    1    1  1  1  0  0  0  0

```

Figure 15. HSPF input table with bolded multiple exit reach

STEP 15. Select the exits that have control devices in HYDR-PARM1 and type those whose exit numbers are to be routed downstream. Users can select specific flow control exits by placing the exit numbers (4, 5, 6, 7, and 8) in the UCI file (Figure 15). Placing zero in a HYDR-PARM1 column allows HSPF to ignore the flow from that particular exit of the FTABLE.

```

HYDR-PARM1
***      Flags for HYDR section
***RC HRES VC A1 A2 A3 ODFVFG for each *** ODGTFG for each  FUNCT
for each
*** x - x FG FG FG FG possible exit *** possible exit possible exit
  3      0  1  1  1    4 0 0 0 0    0 0 0 0 0    3 3 3 3 3
  4      0  1  1  1    4 0 0 0 0    0 0 0 0 0    3 3 3 3 3
  5      0  1  1  1    4 0 0 0 0    0 0 0 0 0    3 3 3 3 3
  6      0  1  1  1    4 0 0 0 0    0 0 0 0 0    3 3 3 3 3
  7      0  1  1  1    4 0 0 0 0    0 0 0 0 0    3 3 3 3 3
  8      0  1  1  1    4 5 6 7 8    0 0 0 0 0    3 3 3 3 3
  9      0  1  1  1    4 0 0 0 0    0 0 0 0 0    3 3 3 3 3

END HYDR-PARM1

```

Figure 16. HSPF input table with bolded multiple exit reach

STEP 16. If more than one control device is used, one must modify the MASS-LINK block to allow that volume-dependent outflows from multiple exits are routed downstream (see bolded row of Figure 17).

```

MASS-LINK    5
<-Volume-> <-Grp> <-Member-><--Mult-->  <-Target vols> <-Grp> <-Member->  ***
<Name>      <Name> x x<-factor->  <Name>      <Name> x x  ***
***Reach Transfer of FLOW ***
RCHRES  ROFLOW                RCHRES  INFLOW
RCHRES  8 OFLOW                RCHRES  INFLOW  (multiple exit reach)
END MASS-LINK  5

```

Figure 17. A MASS-LINK Block with bolded multiple exit reach

STEP 17. Convert generated FTABLE channel length to miles and place it in the “LEN” Column 1 of HYDR-PARM2. To convert feet to miles multiply feet by 0.000189394 and substitute that number to the one for the existing FTABLE. Make sure to choose the correct FTABLE ID Number.

```

HYDR-PARM2
*** RCHRES FTBW FTBU  LEN  DELTH  STCOR  KS  DB50
*** x - x            (miles) (ft)   (ft)   KS   (in)
  1  0.  1.          2.8  22.   3.2   0.5  0.01
END HYDR-PARM2

```

Figure 18. HSPF input table showing reach length parameter in bold.

STEP 18. Save the UCI file and run the project with HSPFLite. If no errors are generated, users can import the project into WinHSPF.

D. Routing an Inflow Hydrograph through a Detention Basin (An example)

This example demonstrates how the HSPF model is used as a stormwater management model. The model was applied to a small watershed for a single storm event to generate an inflow hydrograph. The hydrograph was routed through a network of channels one of which is a detention basin that has several flow control devices (Figure 19).

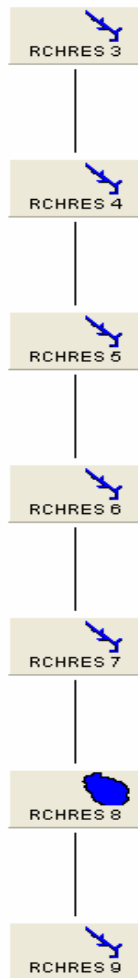


Figure 19. Schematic diagram of the channel network

Note that flow in Reach 3 in the WDM file (EXAMPLE 1.WDM) represents the inflow hydrograph while flow in Reach 9 is the outflow hydrograph after the inflow hydrograph was routed through the detention basin represented by Reach 8. The size and geometry of the detention basin is determined through an iterative process that starts with the selection of a basin geometry and size using the web-tool. This is followed by running the HSPF model to route the inflow hydrograph until the desired outflow hydrograph is obtained. The process is repeated until the desired size and geometry are achieved. In this example, we used a 1-foot diameter underdrain orifice. For LID or other urban stormwater modeling applications, consider the inflow hydrograph to represent post-development runoff without mitigation, and the outflow hydrograph to represent post-development runoff with BMPs in place. A goal may be to ensure that the post-development hydrograph with BMPs in place is similar to the pre-development hydrograph (Figure 20).

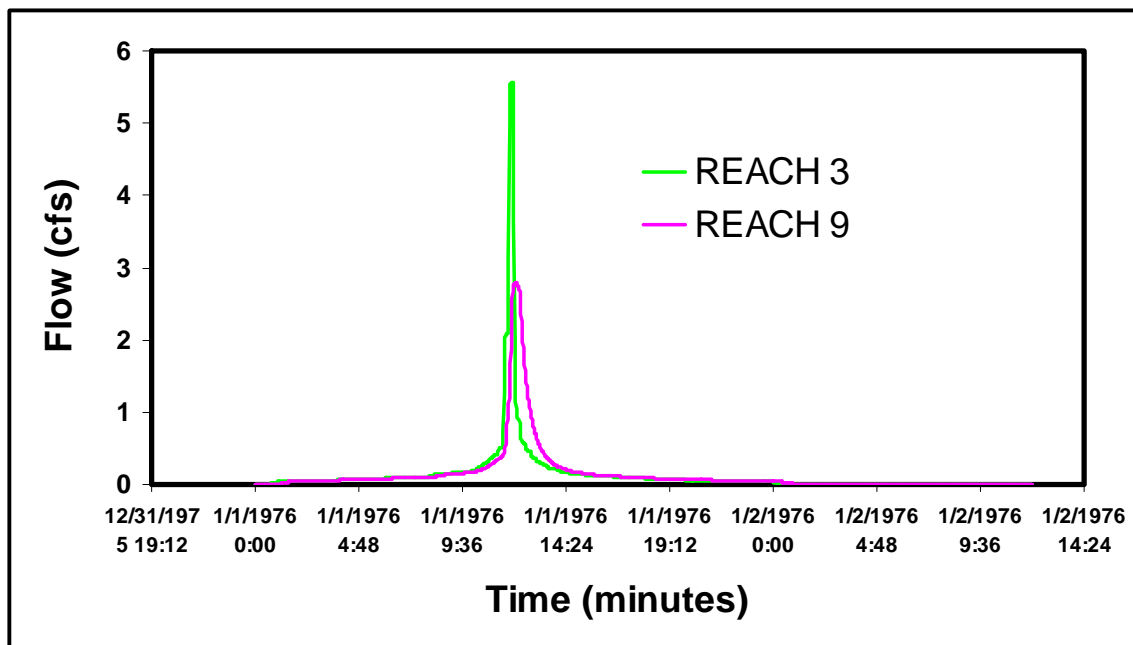


Figure 20. Inflow and outflow hydrographs simulated by the HSPF model

Users can download EXAMPLE1.UCI and EXAMPLE1.WDM files from this website (<http://www.epa.gov/athens/research/modeling/ftable/index.htm>) and generate FTABLES with and without control devices to replace those in the EXAMPLE1.UCI file. This assumes that users have a good understanding of the HSPF model and can make changes in the UCI using a text editor, run HSPF, and correct errors using the HSPFLite engine.

This web-tool extends HSPF applications to urban watersheds with limited sewer system networks. The modeling results are comparable to those achieved with the USEPA Stormwater Water Management Model's (SWMM5) under the Kinematic Wave option or the TRANSPORT option in SWMM4. HSPF does not account for backwater effects, entrance/exit losses, flow reversals, or pressurized flow. Under most circumstances, this is not expected to measurably impact the accuracy of model predictions. However, the

BMP simulation results are not strictly comparable to those achieved by using the SWMM5 model's dynamic wave option. As such, we do not recommend the tool for the design of complex sewer systems.

CONTACT US

If you have questions or would like to report bugs or make suggestions regarding the web-tool, please contact the Center for Exposure Assessment Modeling (CEAM) at CEAM-USERS@lists.epa.gov. Users may also contact the authors through the basins@epa.gov , making sure that the subject line is "HSPF Web-tools".

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