Exercise 7 – HSPEXP

BASINS/HSPF Application Steps

Study Definition/Modeling Strategy	Timeseries Data Management	Parameter Development/Model Setup	Hydrologic Calibration/ Validation	Water Quality Calibration/ Validation	Scenario Analysis
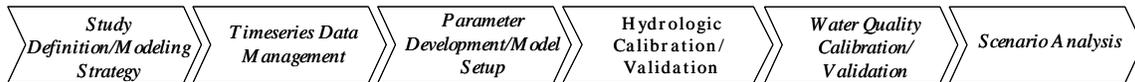
After a WinHSPF project is created, the hydrology should be calibrated to match observed data as closely as possible. Calibration requires various parameters in the watershed model to be adjusted in order to adapt the model to a specific watershed. Some parameters are better suited for calibration than others. Keep in mind that all parameter values should be realistic and accurately represent the conditions in the watershed (make physical sense). A list of HSPF hydrology and hydraulic parameters and corresponding recommended value ranges is found in *BASINS Technical Note 6*, *Estimating Hydrology and Hydraulic Parameters for HSPF*. One drawback of using highly parameterized models such as HSPF is the large number of parameters that can be adjusted, making calibration a somewhat long and tedious process. HSPEXP was developed by practiced modelers as an expert system to assist modelers with hydrology calibration. HSPEXP advises the user on which parameters can be meaningfully adjusted to reduce simulation error. It also provides explanations regarding the modifications so that the less experienced modeler gains practical understanding of calibration techniques.

It is important to note that although HSPEXP can be an extremely useful tool in the calibration process, it has limitations. The user should have practical knowledge of the watershed and of the HSPF algorithms, and should be able to make good judgments regarding parameter adjustment decisions.

HSPEXP requires a User Control Input (*.uci*) file, a Watershed Data Management (*.wdm*) file, and a Basin Specification (*.exs*) file as input for simulation. The *.uci* and *.wdm* files are created when WinHSPF is launched from BASINS. Additional time series required by HSPEXP are added automatically within the WinHSPF interface. The *.exs* file is created by the user in HSPEXP. The *.exs* file contains acceptable limits for errors, output data-set numbers for 10 time series, ancillary data, storm periods, and location names. The ancillary data are a series of yes/no/unknown questions used by HSPEXP to help determine which parameters to adjust. Once these files are prepared, HSPEXP is used to run a simulation, provide advice on parameter changes, make the recommended modifications, and run the simulation until errors are at a minimum (Lumb, et al., 1994).

Questions answered in this exercise:
1) How do I output the time series required by HSPEXP to my *.wdm* file?
2) How do I create an *.exs* file?
3) How do I open an *.exs* file that was previously created?
4) How do I run HSPEXP, compute statistics, and view percent errors between simulated and observed flows?

5) How do I obtain and use HSPEXP parameter modification advice?

A. HSPEXP Time Series Requirements

QUESTION ANSWERED:
1) How do I output the time series required by HSPEXP to my *.wdm file?

In order to use HSPEXP, the program must be downloaded as specified in Appendix D. The uncalibrated **.uci* and corresponding **.wdm* file that we will use in this exercise were previously created and are located in *c:\basins\modelout\EXP_Cal*. The **.uci* file is the same uncalibrated file that was used in Exercise 6 for manual calibration. In this exercise, we will learn to calibrate hydrology by using the Expert System, HSPEXP, instead of manually running simulations and comparing model output versus observed flow. Note that the **.uci*, **.exs*, and **.wdm* files must all be in the same folder for HSPEXP to find them properly

HSPEXP requires specific time series related to hydrology calibration. Before we open HSPF, we will open our **.uci* file in WinHSPF, specify these specific time series as output, and run the model in order to generate the time series required by HSPF.

1.   From the **Start** menu under **Programs**, select **BASINS** and then **WinHSPF**.

2.   Click ![open file icon] (Open File).

3.   Navigate to *c:\basins\modelout\EXP_Cal*, select "*hyd_exp.uci*," and click OPEN.

   Note: We will not change anything in this WinHSPF project. As with Exercise 6, we
            are using an input file (*hyd_exp. uci*) that has all the required site-specific
            information covered within Appendix B. The only required changes within the
            WinHSPF interface are to the specified output.

4.   Click ![output manager icon] (Output Manager).

5.   Click the radio button beside "Hydrology Calibration" if it is not already selected.

   Note: The "Hydrology Calibration" button will already be selected when the "Output
            Manager" window is opened. Below the buttons is a text box explaining which
            output time series will be generated during the HSPF model run. There are
            eight output time series required by HSPEXP for HSPF Hydrology Calibration.
            The list below the text box will be empty because (by default) no hydrology
            calibration locations are specified (Duda, et al.) In the following steps, we will
            specify Reach 5 as a hydrology calibration output location.

6.   Click ADD.

7.   In the "WinHSPF- Add Output" window, select "RCHRES 5 (Western Branch

Patux).” Make sure that “1000” is entered as the “Base *.wdm* DSN.”

> **Note:** This means that the new simulation time series will have data set numbers (DSNs) beginning with 1000.

8. Click OK. “RCHRES 5” will appear under “Output Locations.”

9. Click CLOSE to exit the “WinHSPF- Output Manager” window.

10. Click [≣↓] (Run HSPF).

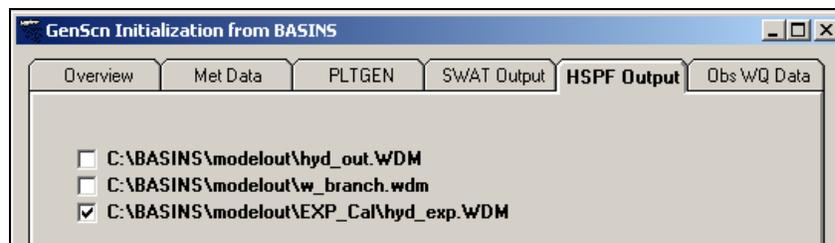11. When the “Confirm Save UCI” window appears, click SAVE/RUN.

12. When HSPF has completed the run, click [📊] (View Output through GenScn).

13. Click the “HSPF Output” tab.

GenScn Initialization from BASINS

Overview | Met Data | PLTGEN | SWAT Output | **HSPF Output** | Obs WQ Data

☐ C:\BASINS\modelout\hyd_out.WDM
☐ C:\BASINS\modelout\w_branch.wdm

> **Note:** GenScn requires the user to specify the project *.wdm* file to which the output was written. In general, GenScn expects to read a *.wdm* file from the *c:\basins\modelout* folder. However, since HSPEXP requires the *.wdm* file to be in the same folder as the *.uci* file, the *.wdm* file isn't in the *modelout* folder and therefore the user must direct GenScn to the folder containing the *.wdm* file.

14. Make sure the box beside “*c:\basins\modelout\EXP_Cal\hyd_exp.wdm*” is checked and click OK.

GenScn Initialization from BASINS

Overview | Met Data | PLTGEN | SWAT Output | **HSPF Output** | Obs WQ Data

☐ C:\BASINS\modelout\hyd_out.WDM
☐ C:\BASINS\modelout\w_branch.wdm
☑ C:\BASINS\modelout\EXP_Cal\hyd_exp.WDM

15. We want to view the simulated time series that were added to this *.wdm* file. In the “Locations” frame, click “RCH5.”

16. In the "Scenarios" frame, click "HYD_EXP."
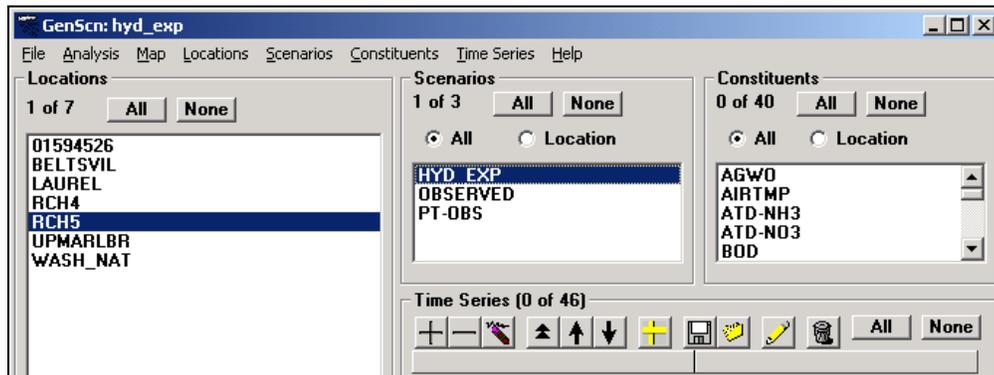
17. Click [+] (Add to Time Series List) in the Time Series frame.
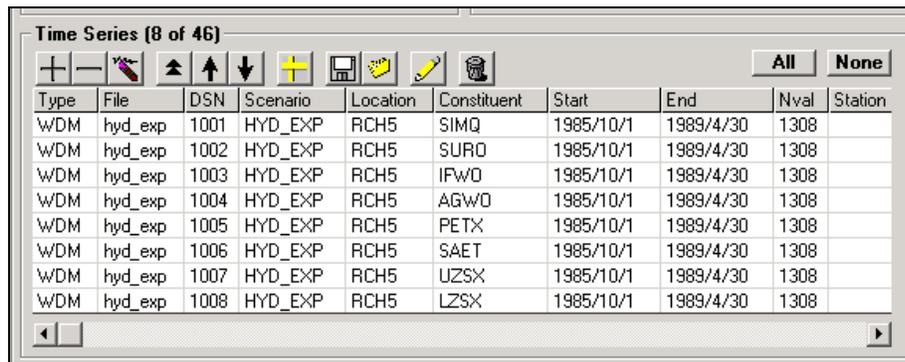
> **Note:** Notice that the corresponding time series for the DSNs 1001-1008 have been added to the **.wdm* file. These time series were written to the **.wdm* file because we specified "Hydrology Calibration" in the WinHSPF Output Manager. These time series will be used by HSPEXP. The corresponding DSN numbers for these time series will be used later when creating a HSPEXP project. Feel free to view the WinHSPF output in GenScn.

18. Close GenScn.

19. Close WinHSPF.

B. Opening HSPEXP and Creating a New HSPEXP Project

QUESTION ANSWERED:
2) How do I create a new HSPEXP project?

In this section, we will open HSPEXP and create a new HSPEXP project. This process requires the **.uci* file used in the previous WinHSPF simulation, the time series generated by the WinHSPF simulation, the project **.wdm* file, and information about storms.

1.   Using My Computer or Windows Explorer, navigate to *c:\basins\modelout\EXP_Cal*.

2.   **Double click** "*hspexp.bat*" to open HSPEXP.
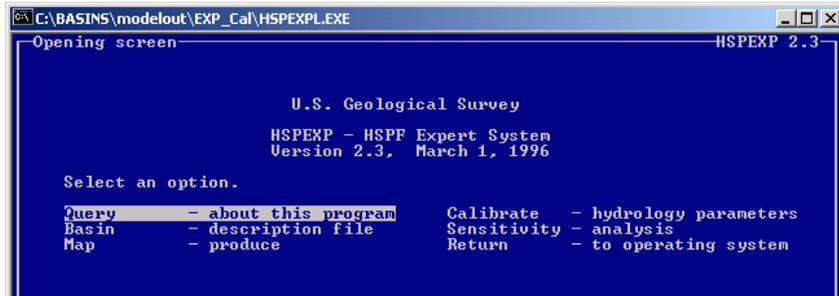
> **Note:** HSPEXP is a DOS-based program. While using this program, it will be necessary to use the arrow keys and function (F1, F2, etc.) keys on your keyboard rather than the mouse. When you are instructed to **arrow** to a particular field or menu item, simply use the right, left, up, and down arrow keys to navigate within the window. You can also use the "Tab" key to navigate within the windows.

3.   Make the HSPEXP program window active. **Arrow** to "Basin - description file" and press **Enter**.
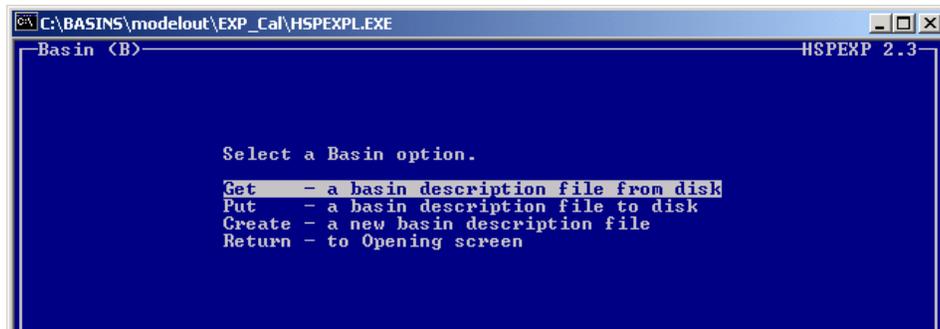

> **Note:** The BASIN options in HSPEXP provide the user with a list of operations that can be performed on the data set. These operations are defined below.
> - GET opens existing files from a disk in HSPEXP.
> - PUT saves a created or a modified file to a disk. This must be performed before exiting HSPEXP to save changes to parameters, the **.uci* file, and /or the basin description file.
> - CREATE allows the user to manually input the required data for a basin description (**.exs*) file or modify already imported data.

4.   **Arrow** to "Create – a new basin description file" and press **Enter**.
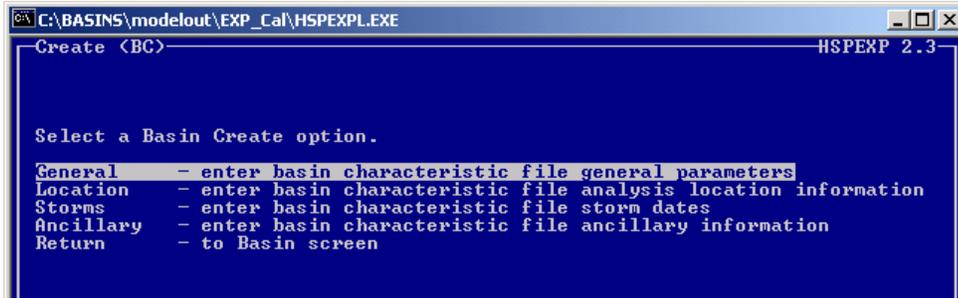
5. Make sure "General" is selected and press **Enter**.
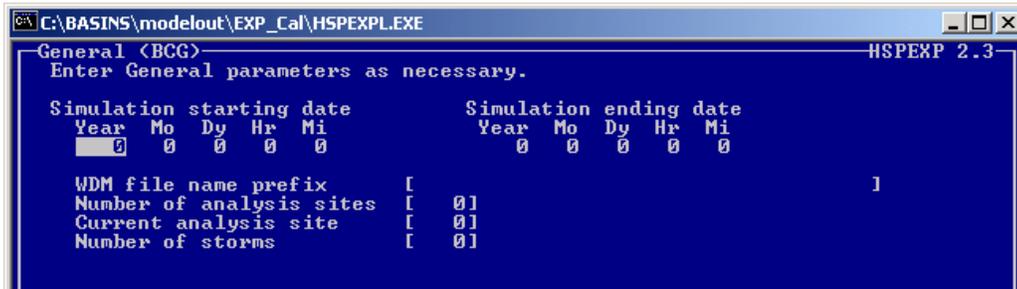
Note: The "General" screen allows the user to specify the simulation time period, the number of analysis sites, and number of storms.

6. Under "Simulation starting date," enter the following numbers:
   Year: 1986
   Month: 1
   Day: 1
   Hour: 0
   Minute: 0

   Note: Our simulation period is 1/1/1986-12/31/1988. These starting and ending dates can be found in the GLOBAL block of the *hyd_exp.uci* file. You can also view the dates in the WinHPSF interface by clicking the "Simulation Period and Meteorological Data" button, .
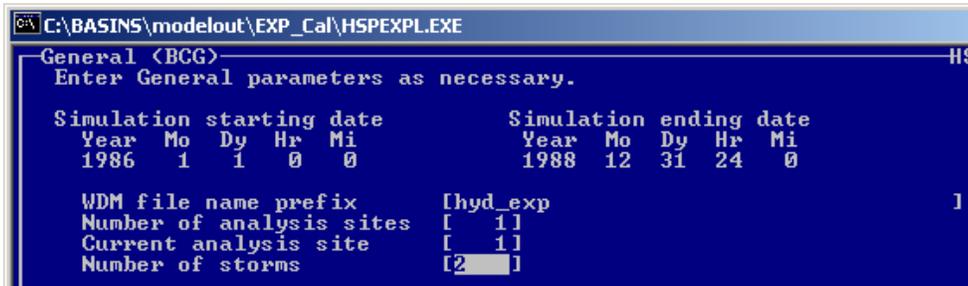
7. Under "Simulation ending date," enter the following numbers:
   Year: 1988
   Month: 12
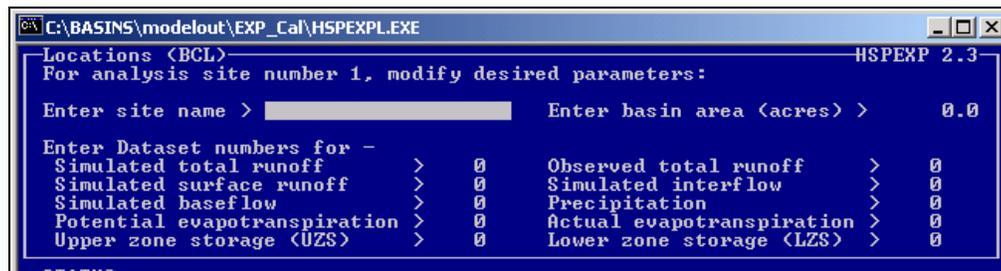   Day: 31
   Hour: 24
   Minute   0

8. The "WDM file name prefix" is found in the FILES block of the *hyd_exp.uci* file. We are using the **.wdm* file we opened in GenScn, "*hyd_exp.wdm*." **Arrow** to the "WDM file name prefix" box and enter "hyd_exp."

Note: We must specify the number of analysis sites and the number of storms to be used in the calibration. We will use one analysis site. There are 35 storms within the specified time period, but, for simplification purposes, we will enter information for only two storms. This will sufficiently demonstrate the process for entering storm information but it's important to keep in mind that if you wanted to accurately calibrate this model, you would need to enter storm information for more than two storms. Later, we will open a file containing information for all 35 storms and use that file for model calibration.

9.   Enter "1" as the "Number of analysis sites."

10.   Enter "1" as the "Current analysis site."

11.   Enter "2" as the "Number of storms." Your "General" screen should look like the following:

```
C:\BASINS\modelout\EXP_Cal\HSPEXPL.EXE
┌General (BCG)──────────────────────────────────────────────────────────HS
   Enter General parameters as necessary.

   Simulation starting date          Simulation ending date
     Year  Mo  Dy  Hr  Mi              Year  Mo  Dy  Hr  Mi
     1986   1   1   0   0              1988  12  31  24   0

     WDM file name prefix       [hyd_exp                            ]
     Number of analysis sites   [    1]
     Current analysis site      [    1]
     Number of storms           [2    ]
```

12.   Press **F2** to go to the next screen.

13.   Arrow to "Location" and press **Enter**.

```
C:\BASINS\modelout\EXP_Cal\HSPEXPL.EXE                          _□×
┌Locations (BCL)──────────────────────────────────HSPEXP 2.3─
   For analysis site number 1, modify desired parameters:

   Enter site name >  ▓▓▓▓▓▓▓▓▓▓▓▓     Enter basin area (acres) >      0.0

   Enter Dataset numbers for -
     Simulated total runoff      >    0    Observed total runoff     >    0
     Simulated surface runoff    >    0    Simulated interflow       >    0
     Simulated baseflow          >    0    Precipitation             >    0
     Potential evapotranspiration >   0    Actual evapotranspiration >    0
     Upper zone storage (UZS)    >    0    Lower zone storage (LZS)  >    0
```

In the "Locations" screen, you must specify the name of the calibration site and the total drainage area. You also need to specify the data set numbers for the eight simulation parameters, the precipitation data, and the actual evaporation data. The data set numbers for these time series can be found by viewing the WinHSPF output in GenScn or by opening the *.wdm* file in WDMUtil. We previously viewed the simulated time series in GenScn. Below is a table of the necessary time series and their corresponding data set numbers.

DSN	Scenario	Location	Constituent	Parameter Name

1001	HYD_EXP	RCH5	SIMQ	Simulated Total Runoff
1002	HYD_EXP	RCH5	SURO	Simulated Surface Runoff
1003	HYD_EXP	RCH5	IFWO	Simulated Interflow
1004	HYD_EXP	RCH5	AGWO	Simulated Base Flow
1005	HYD_EXP	RCH5	PETX	Potential Evapotranspiration
1006	HYD_EXP	RCH5	SAET	Actual Evapotranspiration
1007	HYD_EXP	RCH5	UZSX	Upper Zone Storage
1008	HYD_EXP	RCH5	LZSX	Lower Zone Storage
105	OBSERVED	UPMARLBR	HPRECIP	Hourly Precipitation
261	OBSERVED	UPMARLBR	FLOW	Observed Total Runoff

14.   In the Location screen, enter "Upper Marlboro" as the "site name."

15.   Enter "51931" as the "Basin Area." This number was determined by adding each of
       the individual PERLND and IMPLND areas in the SCHEMATIC block of the
       hyd_exp.uci file. You can also find this number in the WinHSPF interface by
       selecting each landuse type in the "Land Surface tab," selecting each reach in the
       watershed schematic, and reading the total "Total (Acres)" area in the auxiliary table.
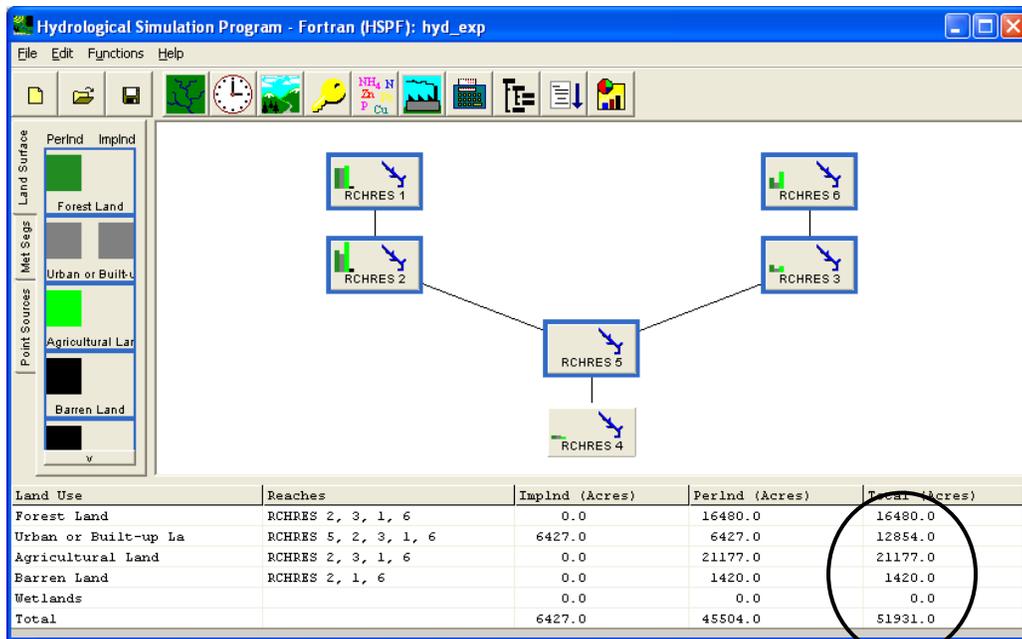
16.   Enter the appropriate DSN numbers for each parameter as listed in the above table.

You may need to press "Tab" to get from the left side of the screen to the right side. Your "Locations" screen should look like the following:

```
┌─Locations (BCL)───────────────────────────────────────HSPEXP 2.4─┐
│ For analysis site number 1, modify desired parameters:           │
│                                                                  │
│ Enter site name > Upper Marlboro         Enter basin area (acres) >  51931.0 │
│                                                                  │
│ Enter Dataset numbers for -                                      │
│  Simulated total runoff      > 1001    Observed total runoff    >   261  │
│  Simulated surface runoff    > 1002    Simulated interflow      > 1003  │
│  Simulated baseflow          > 1004    Precipitation            >   105  │
│  Potential evapotranspiration > 1005   Actual evapotranspiration > 1006  │
│  Upper zone storage (UZS)    > 1007    Lower zone storage (LZS) > 1008  │
└──────────────────────────────────────────────────────────────────┘
```

17.   Press **F2** to accept these values.

18.   From the "Basin Create" menu, **arrow** to "Storms" and press **Enter**.

```
C:\BASINS\modelout\EXP_Cal\HSPEXPL.EXE                        _ □ ×
┌─Storms (BCS)──────────────────────────────────────HSPEXP 2.3─┐
│ Enter starting and ending dates for storms.                  │
│                                                              │
│  ---- Starting Date -----      ------ Ending Date -----      │
│  Year Mon Day  Hr Min Sec      Year Mon Day  Hr Min Sec      │
│    0   0   0   0   0   0         0   0   0   0   0   0        │
│    0   0   0   0   0   0         0   0   0   0   0   0        │
│                                                              │
│                                                              │
│ ┌─STATUS──────────────────────────────────────────────────┐ │
│ │                                                          │ │
│ │          site: Upper Marlboro                            │ │
│ │                                                          │ │
│ └──────────────────────────────────────────────────────────┘ │
│ ┌─INSTRUCT────────────────────────────────────────────────┐ │
│ │            Enter data in highlighted field(s).           │ │
│ │  Use carriage return or arrow keys to enter data and move between fields. │ │
│ │    Use 'Accept' command to go to next screen when done entering data.     │ │
│ └──────────────────────────────────────────────────────────┘ │
│ Help:F1  Accept:F2  Prev:F4  Limits:F5  Status:F7  Intrpt:F6  Quiet:F8  Cmhlp │
└──────────────────────────────────────────────────────────────┘
```

The "Storms" option allows entry of up to 36 major storms. In general, analyzing the simulation of a larger number of storms in HSPEXP will help you improve the model's calibration. Storms can be selected by examining the precipitation data set specified in the "Locations" screen. Plots of daily precipitation and daily mean flow can be used as a basis for selecting storms. The following tips provide guidelines for selecting storms:
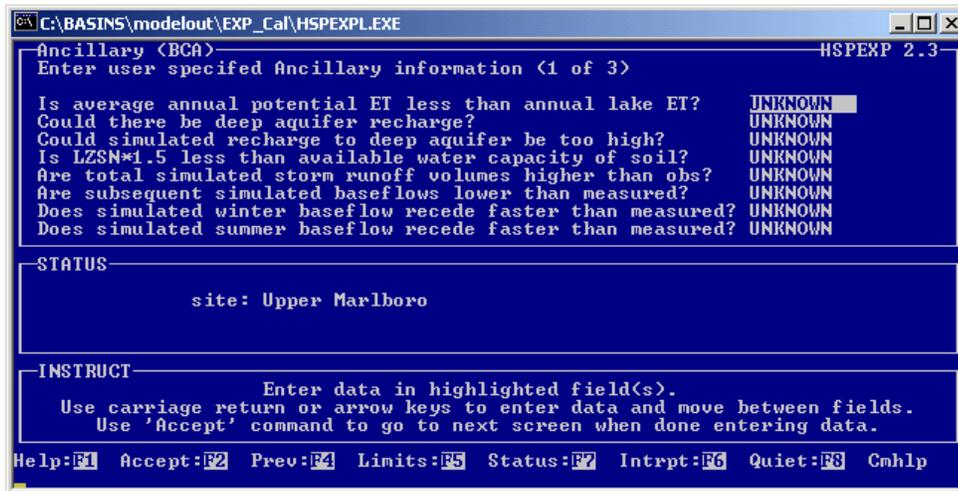
- HSPEXP needs a sufficient number of storms to calculate storm statistics that adequately characterize the simulation.
- Be sure to choose storms of reasonable size that cover a range of peak flows
- Storm selection should be distributed evenly over the range of seasons and years. Approximately the same number of storms should be selected for each season and year. Recall that HSPEXP defines 'winter' as December through February, and 'summer' as June through August. This may not be accurate for all climates. You need to understand this limitation when looking at your output statistics.
- The storm period should start on the first day of significant precipitation and extend for several days to the time when flow returns to near pre-storm levels and/or the

hydrograph flattens out significantly. Typically, this may take 3-8 days.
- Storms with both high peaks and storms with moderate to low peaks should be included so that storms of all types are represented. Storms should also represent low and high flow years.
- Look at the plot of observed precipitation and runoff. Leave out any storms that exhibit obvious discrepancies between precipitation and runoff. This eliminates localized storms that cannot be captured in the model. (*BASINS Technical Note 5*)

19. As mentioned previously, our simulation includes many storm periods; however, in order to save time, we will enter information for only 2 storm events. Enter the following information in the first line below "Starting Date:"

Year:	1986
Month:	1
Day:	25
Hour:	0
Minute:	0
Second:	0

20. **Tab** to the first line below "Ending Date" and enter the following information:

Year:	1986
Month:	1
Day:	30
Hour:	24
Minute:	0
Second:	0

21. **Arrow** or **tab** to the second line under "Starting Date" and enter the following information:

Year:	1986
Month:	2
Day:	19
Hour:	0
Minute:	0
Second:	0

22. **Arrow** or **tab** to the second line under "Ending Date" and enter the following information:

Year:	1986
Month:	2
Day:	22
Hour:	24
Minute:	0
Second:	0

Your screen should look like the following:

```
C:\BASINS\modelout\EXP_Cal\HSPEXPL.EXE                              _ □ ×
Storms (BCS)                                              HSPEXP 2.3
Enter starting and ending dates for storms.

      ---- Starting Date -----        ------ Ending Date -----
      Year Mon Day  Hr Min Sec        Year Mon Day  Hr Min Sec
      1986   1  25   0   0   0        1986   1  30  24   0   0
      1986   2  19   0   0   0        1986   2  22  24    0   0
```
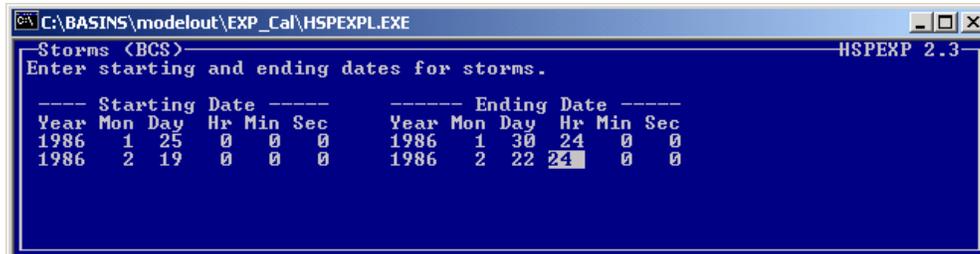
23.   Press **F2** to accept these values and return to the "Basin Create" screen.

24.   **Arrow** to "Ancillary" and press **Enter**.

```
C:\BASINS\modelout\EXP_Cal\HSPEXPL.EXE                              _ □ ×
Ancillary (BCA)                                          HSPEXP 2.3
Enter user specifed Ancillary information (1 of 3)

Is average annual potential ET less than annual lake ET?   UNKNOWN
Could there be deep aquifer recharge?                      UNKNOWN
Could simulated recharge to deep aquifer be too high?      UNKNOWN
Is LZSN*1.5 less than available water capacity of soil?    UNKNOWN
Are total simulated storm runoff volumes higher than obs?  UNKNOWN
Are subsequent simulated baseflows lower than measured?    UNKNOWN
Does simulated winter baseflow recede faster than measured? UNKNOWN
Does simulated summer baseflow recede faster than measured? UNKNOWN

STATUS
              site: Upper Marlboro


INSTRUCT
                    Enter data in highlighted field(s).
      Use carriage return or arrow keys to enter data and move between fields.
          Use 'Accept' command to go to next screen when done entering data.

Help:F1  Accept:F2  Prev:F4  Limits:F5  Status:F7  Intrpt:F6  Quiet:F8  Cmhlp
```

The "Ancillary" tool is used to gather additional information about the drainage basin. This information is used by HSPEXP in determining which advice to give. The ancillary data is a series of Yes/No/Unknown questions to be answered by the user. If the answers to the questions are known, the expert system may use that information as a condition when offering advice. It is beneficial to answer as many questions as possible. If the answer to a question is left as "UNKNOWN," HSPEXP will not consider that piece of information. (Lumb, et al., 1994)

25.   **Arrow** to "Are total simulated storm runoff volumes higher than obs?" and type "NO."

26.   Press **F2** to go to the next screen of "Ancillary Data." Leave these answers as "UNKNOWN."

27.   Press **F2** to go to the final "Ancillary Data" screen.

28.   **Arrow** to "Are there urban areas in the watershed?" and type "YES."

29.   **Arrow** to "Could the amount of IMPLND be too high?" and type "NO."
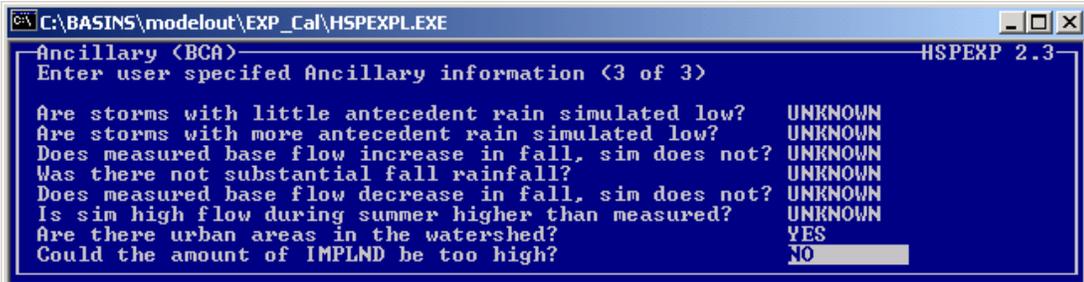
>   **Note:** We have answered all of the questions for which we have accurate knowledge.

30.   Press **F2** to accept these values. The "Create Basin" screen will appear.

31.   **Arrow** to "Return – to Basin screen" and press **Enter**.

We will now save the newly created "Basin description file" to a disk.

32.   **Arrow** to "Put" and press **Enter**.

33.   Type "example" as the name of the basin characteristic file.

>   **Note:** The name chosen for the "basin characteristic" file must contain eight or fewer
>   characters. When this file is saved, a blank *.uci* file is created with the same
>   name.
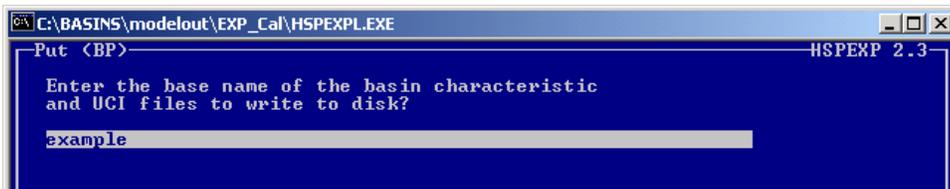
34.   Press **Enter**. Look at the "STATUS" box and notice that "example" is listed as the
         "Current basin file."

>   **Note:** The files "*example.exs*" and "*example.uci*" are now saved in the directory
>   *c:\basins\modelout\EXP_Cal*. You may navigate there to view them. Now we
>   will learn how to open an *.exs* file that has been previously created. The file
>   that we are opening includes the information that we entered in steps 1-31. It
>   also contains storm information for all 35 storms used in the simulation.

C. Opening an Existing HSPEXP Project

QUESTION ANSWERED:
3) How do I open an *.exs file that was previously created?

1.   From the "Basin" screen, **arrow** to "Get" and press **Enter**.

2.   Enter "hyd_exp" as the name of the **.exs* and **.uci* file to read from disk and press **Enter**.

```
C:\BASINS\modelout\EXP_Cal\HSPEXPL.EXE                    _|□|×|
┌Get <BG>─────────────────────────────────────HSPEXP 2.3─┐
│                                                         │
│   Enter the base name of the basin characteristic (.exs)│
│   and UCI files to read from disk?                      │
│                                                         │
│   hyd_exp                                               │
│                                                         │
│                                                         │
```
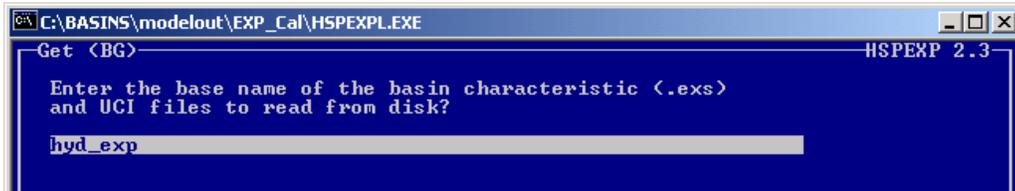
Note: Look at the "STATUS" box. Notice that "hyd_exp" is identified as the "Current basin file." To examine the additional storm dates, from the Opening Screen, select "Calibrate," then select "Modify," then select "Basin." This method allows you to view the Basin data without using the "Basin Create" tool. Now that we have a "Basin description file," we can run a simulation, obtain advice, and modify parameters in order to calibrate our model.

D. Running HSPEXP Simulations and Viewing Results

QUESTION ANSWERED:
4) How do I run an HSPEXP simulation, compute statistics, and view percent errors between simulated and observed flows?

1.   **Arrow** to "Return – to opening screen" and press **Enter**.

2.   From the main HSPEXP screen, **arrow** to "Calibrate" and press **Enter**.

```
C:\BASINS\modelout\EXP_Cal\HSPEXPL.EXE                    _|□|×|
┌Calibrate <C>────────────────────────────────HSPEXP 2.3─┐
│                                                         │
│ Calibrate Options:              View Options:           │
│   SImulate - and calculate stats   Output  - statistics │
│   STats    - calculate stats       Graph   - results    │
│   Advise   - parameter adjustments History - of changes │
│   Location - of current site                            │
│   Modify   - parameters         Put - the basin and UCI files to disk│
│                                                         │
│ Return - to Opening Screen                              │
│                                                         │
│ ┌STATUS───────────────────────────────────────────────┐│
│ │Current basin file: hyd_exp                           ││
│ │            site: Upper Marlboro                      ││
│ │                                                      ││
│ │                                                      ││
│ ┌INSTRUCT─────────────────────────────────────────────┐│
│ │            Select an option using arrow keys         ││
│ │        then confirm selection with the F2 key,  or   ││
│ │           Type the first letter of an option.        ││
│ Help:F1  Accept:F2  Status:F7  Quiet:F8  Xpad:F9  Cmhlp │
```

3.   Make sure "Simulate – and calculate stats" is selected and press **Enter**. The **.uci* and **.wdm* files are used as input to simulate runoff from the watershed with HSPF.

Statistics are computed immediately after simulation. (Lumb, et al., 1994) The simulation screen will look similar to the following:
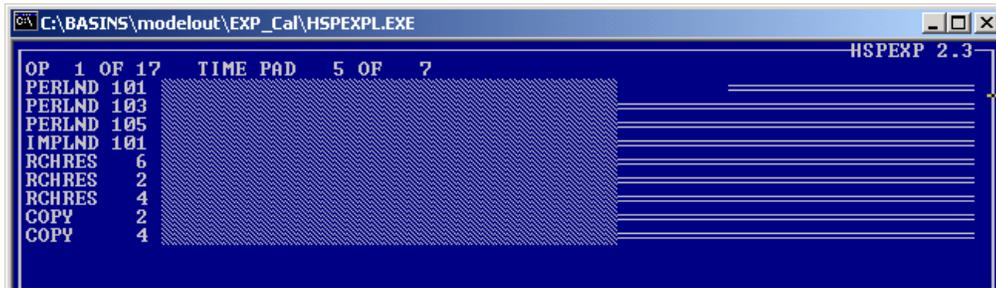
4.   The "Calibrate" screen will open again. From here, we can view the statistics calculated in the simulation. **Arrow** to "Output – statistics" and press **Enter**.

The output statistics are used by HSPEXP to determine which advice will be given to the user. These statistics include simulated and observed values for nine flow characteristics, simulated and potential evapotranspiration, interflow and surface runoff, and seven error terms and acceptable levels of error. (Lumb, et al., 1994)

5.   From this screen, we can view the output on your screen and/or save the output to a file. We will do both. Select "Screen" and press **Enter**.
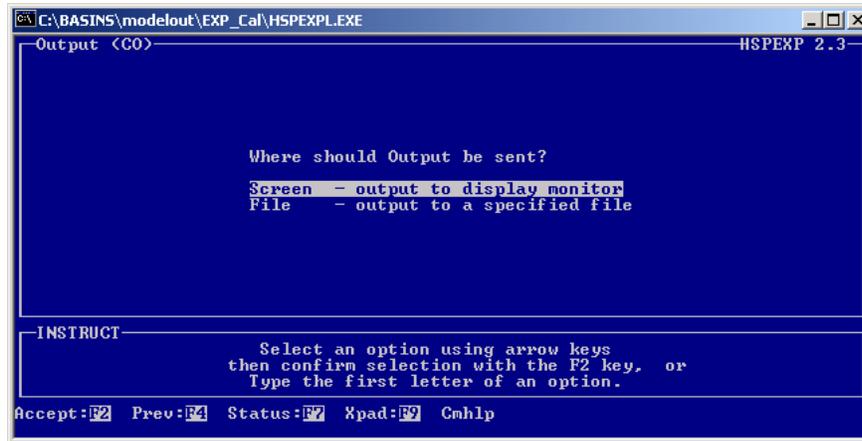
6.   Output is displayed on a series of four screens. These screens display simulated as well as observed data and the percent errors between the two. Press **F2** to view each of the "Output" screens and return to the "Calibrate" screen (you will press F2 four times).
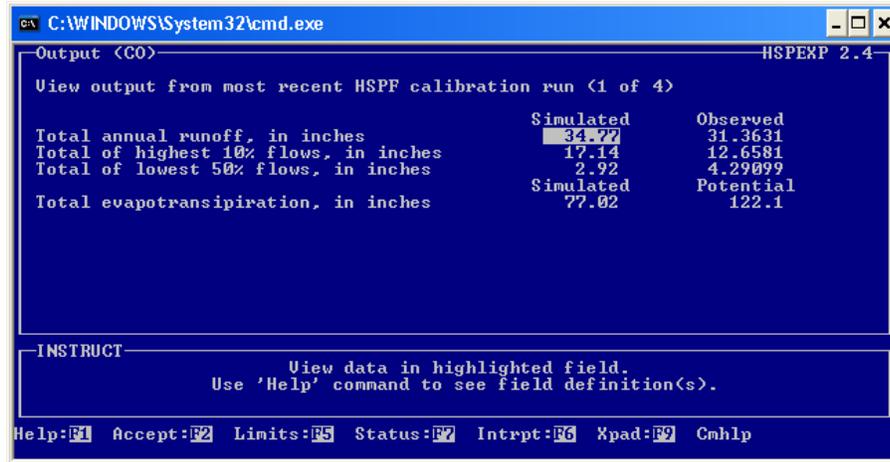
7.   From the "Calibrate screen," **arrow** to "Output" and press **Enter**.

8.   **Arrow** to "File" and press **Enter**.

9.   Type "output1.txt" and press **Enter**.

The output that you just viewed is now saved for future reference in
c:\basins\modelout\EXP_Cal. Using My Computer or Windows Explorer, navigate to
c:\basins\modelout\EXP_Cal and open "*output1.txt*" in a text editor like WordPad or
Notepad to view the calibration results and statistics. Saved files of output data are helpful
for keeping track of the model calibration process. This data can be used to support the
advice of HSPEXP, to help you decide by how much a parameter should be changed, and/or
to make decisions on changing other parameters than those recommended by the expert
system. (Lumb, et al., 1994)

The simulation statistics can also be viewed graphically. HSPEXP can generate 11 different
graphs including daily and monthly flow hydrographs, flow duration plots, duration of
recession rates plots, evapotranspiration plots, and stream flow error vs. upper zone storage,
lower zone storage, observed flow, or time. Plotting specifications can be altered and saved
for future use. (Lumb, et al., 1994)

10.   From the "Calibrate" screen, **arrow** to "Graph" and press **Enter**.
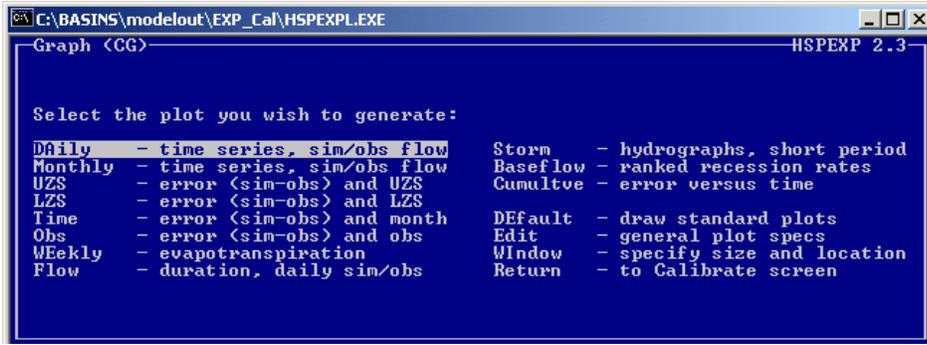
On this screen, you can specify which of the eleven graphs you want to view. You can also edit plotting specifications. When a plot is generated, HSPEXP will fill your entire monitor screen. To toggle between the large HSPEXP window and the normal-sized HSPEXP window, press **Alt-Enter**. We will view a few of the plots that are available in HSPEXP. For more information on each option for plotting and editing, see the *HSPEXP User's Manual*.

11.   **Arrow** to "Monthly – time series, sim/obs flow" and press **Enter**.
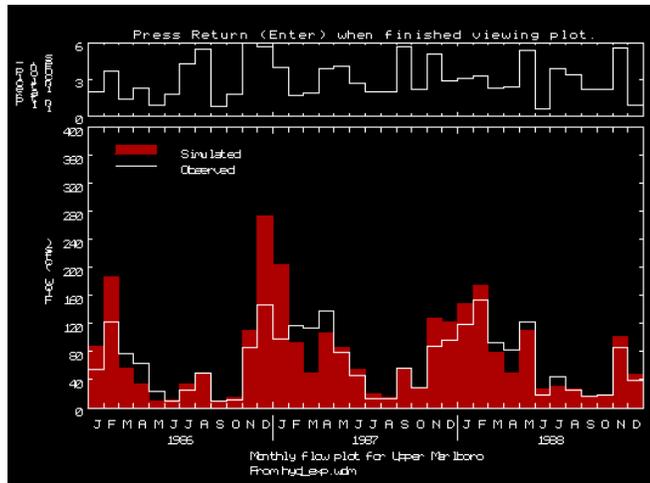
Notice that the graph takes up the entire screen. This is a hydrograph of simulated and observed flow with a monthly time step. Monthly plots of precipitation, base flow, and interflow can also be plotted on this graph. In this example, precipitation was plotted above the flow. Notice the correlation (or lack of correlation) between flow and precipitation.

Note: In addition to the monthly hydrograph, you may want to view a hydrograph of simulated and observed flow on a daily time step. In order to use the "Daily" plot, you will have to shorten the simulation time period because a three-year simulation is too large for one plot. The time span can be edited from the Graph screen by selecting "Edit," then "Time." Here you can alter the time span in order to fit a daily plot on the screen. One year is usually a sufficient period. In the interest of time, we will not create a daily plot.

12.   Press **Enter** to return to the "Graph" screen.

13.   **Arrow** to "Cumultve" and press **Enter**.
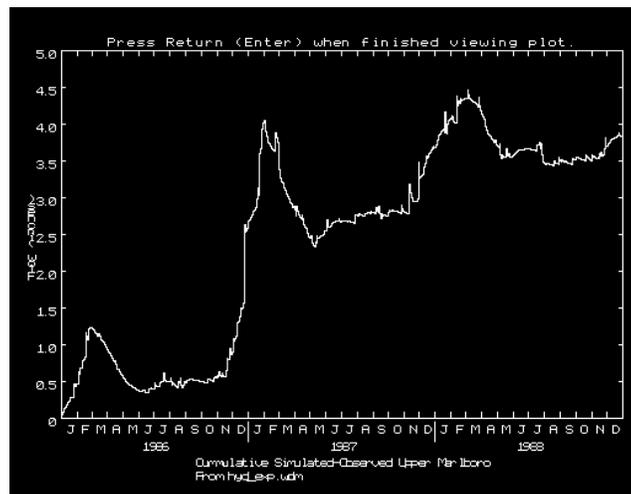
This is the "Cumulative Error Plot." It shows the difference between simulated and observed flows versus time, and may provide information on trends in simulation errors. Overall water-budget problems, seasonal problems, and/or problems in specific years can be identified with this plot. (Lumb, et al., 1994) Feel free to view any of the other plots or to experiment with editing plot specifications. Details can be found in the *HSPEXP User's Manual*.

14.   Press **Enter** to return to the "Graph" screen.

15.   Press **Alt-Enter** to return the HSPEXP window to its normal size.

16.   Arrow to "Return – to calibrate screen" and press **Enter**.

17.   Select "No" when asked whether you want to save current plot specifications.

18.   Press **Enter** to return to the "Calibrate" screen.

E. HSPEXP Parameter Modification

QUESTION ANSWERED:
5) How do I obtain and use HSPEXP parameter modification advice?

After an HSPEXP simulation has been run, HSPEXP can advise the user on which parameters should be modified in order to calibrate the model. In offering calibration advice, HSPEXP divides calibration procedures into four major phases: (1) water balance, (2) high/low flow distribution, (3) storm flow, and (4) seasonal adjustments. When HSPEXP runs a simulation, it goes through each of these phases in order. Each phase has associated calibration parameters that are evaluated during the simulation. HSPEXP will advise the

user to first calibrate for the overall water balance. Once the water balance is within an acceptable range, HSPEXP will give advice regarding high/low flow, storm flow, and seasonal adjustments, respectively. Each piece of advice is associated with one of the groups. If necessary, criteria for error terms can be modified to allow for greater discrepancies, or criteria can be tightened for finer calibration.

Each piece of advice consists of three parts: (1) the conditions that cause the advice to be given, (2) the advice, which suggests an increase or decrease in a parameter value, and (3) the reason the advice is given for the stated conditions. HSPEXP doesn't provide specific value recommendations for parameters; it suggests only that you increase or decrease a specific parameter. After advice is given and one or more parameters are modified, the simulation must be re-run and new, updated advice must be given. If the parameter change is too small, the same piece of advice will be given again. If the change is too large, the advice may be to change the parameter in the other direction or to change different parameters altogether. Advice usually consists of one to four screens, each detailing a parameter to be adjusted. (Lumb, et al., 1994)

1.   From the "Calibrate" screen, arrow to "Advise" and press **Enter**.

2.   As with the simulation statistics, we can look at the advice on the screen and/or save the advice to a file. We will do both. **Arrow** to "Both" and press **Enter**.
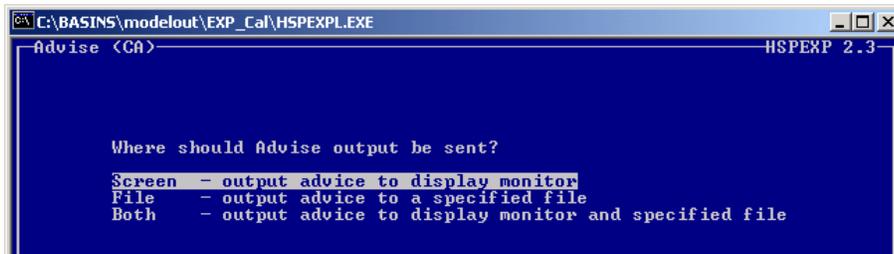
3.   Enter "advice1.txt" as the name of the file to which the advice will be saved.
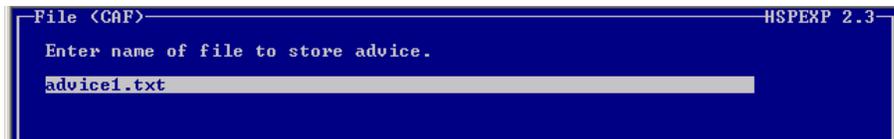
4.   Press **Enter**. The advice is now saved for future reference in *c:\basins\modelout\EXP_Cal*. You can navigate to this folder and open "*advic1.txt*" as a text file if you want.

        The "Advise" screen will appear. To toggle among pieces of advice, use **F2** to view the next screen and **F4** to view the previous screen. Notice that the header of the screen lists the advice as "1 of 4" and that the "Group" is "Water Balance."

The first piece of advice tells us that the error between simulated total runoff and observed total runoff is too great. According to *Rules and Advice for Calibration of HSPF*, *Appendix A* (Lumb, et al., 1994), model parameters cannot or should not be changed in order to account for major errors between input and output water balance. Depending on what you know about your simulation watershed, you can determine which adjustments to make. We are confident that we have captured all of our flow diversions in the West Branch watershed, and that our precipitation data is good. We can make an evapotranspiration adjustment and/or use the HSPEXP parameter advice given on the subsequent screens.

5.   Press **F2** to view the second piece of advice.

This advice explains that LZETP, the lower zone evapotranspiration parameter, should be increased so that there is greater opportunity for evapotranspiration resulting in decreased flows. Our monthly LZETP values reflect watershed conditions accurately, so we will move on to the next pieces of advice.

6.   Press **F2**.

This screen advises to increase LZSN, the lower zone storage parameter, in order to provide greater opportunity for evapotranspiration and thus reduce runoff. We will use HSPEXP to adjust this parameter after we examine our last piece of advice.

7.   Press **F2**.

This advice recommends that INFILT, the parameter controlling soil infiltration, be increased in order to delay how quickly the runoff reaches the stream. We will also use HSPEXP to adjust this parameter. Each piece of advice has been within the "Water Balance" category.

In order to follow good calibration techniques, we will only modify one of the advised parameter at a time. We will begin by modifying LZSN. After we run the simulation, we will see what advice HSPEXP offers. If still required, we will then increase INFILT. Remember that our goal is to make our simulated flow within 10% of the observed flow.

8.   Press **F2** to return to the "Calibrate" screen.

9.   **Arrow** to "Modify" and press **Enter**.
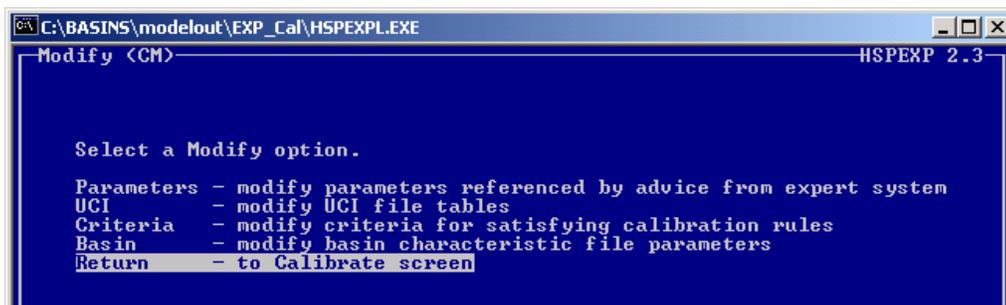
There are various options for modifying calibration parameters. "Parameters" is an option for changing PERLND parameters either by parameter name for all PERLNDs or all parameters for a specific PERLND. The "UCI" option allows modification of anything in the *.uci* file. This may be used to add or modify a monthly table for a PERLND parameter, modify an FTABLE, or change the area for an IMPLND or PERLND in the SCHEMATIC block. The "Criteria" option allows modification of acceptable error levels as well as values

that affect HSPEXP's advice. If no advice is given because computed error terms are within acceptable levels of error, criteria can be adjusted to refine the calibration. There is a point where no parameter sets can meet all criteria resulting in an infinite loop of readjustment with no progress. At this point, calibration is complete. (Lumb, et al., 1994)

10. Arrow to "Parameters" and press **Enter**.
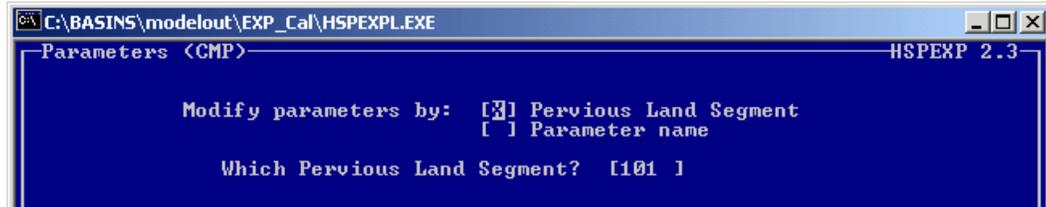
11. Press the space bar to select "Parameter Name."

12. **Arrow** to "Which Parameter?" and type "LZSN."
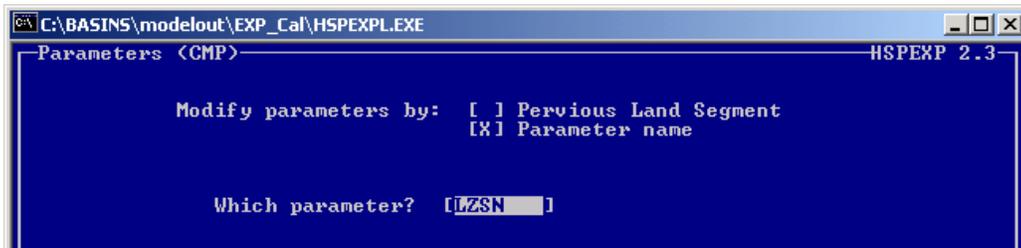
13. Press **Enter**.
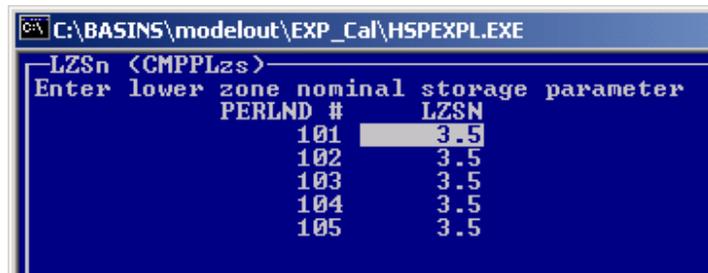
This shows that the value of LZSN for each PERLND is "3.5." According to *BASINS Technical Note 6*, *Estimating Hydrology and Hydraulic Parameters for HSPF*, the typical min/max range for LZSN is 3.0-8.0. There is a lot of room for the value of LZSN to be increased within this range. Because we need to correct our overall water balance (by increasing the opportunity for evapotranspiration), we will increase all LZSN values.

14. For each PERLND number, change the value of LZSN to "7."

15.   Press **F2**.

16.   From the "Modify" screen, select "Return" and press **Enter**.

17.   From the "Calibrate" screen, select "Simulate" and press **Enter**.

18.   After the simulation has completed, select "Advise" and press **Enter**.

19.   Select output advice to "Screen" and press **Enter**.

The advice offered is to increase INFILT. Notice that the category of calibration advice is "High-flow – low-flow distribution." This means that our annual water balance is within the acceptable range since there is "water balance" advice, it will be given before any other advice. Feel free to look at the output statistics and/or plots after running any of the simulations to see the calibration results and statistics.

20.   Press **F2** twice.

21.   Select "Modify" and press **Enter**.

22.   Arrow to "Parameters" and press **Enter**.

23.   Press the space bar to select "Parameter Name."

24.   **Arrow** to "Which Parameter?" and type "INFILT."

25.   Press **Enter**.

The current value of INFILT for all of the PERLNDs is "0.25." According to *BASINS Technical Note 6*, the typical INFILT range is 0.01-0.25, but the possible range is 0.001-0.5.

26.   For each PERLND number, enter "0.5" as the new value of INFILT.

27.   Press **F2**.

Now that we have changed the parameter values for INFILT, we will run the model and look at the results and new calibration advice.

28.   From the "Modify" screen, **arrow** to "Return" and press **Enter**.

29.   From the "Calibrate" screen, **arrow** to "Simulate" and press **Enter**.

30.   After the simulation has completed running, select "Advise" and press **Enter**.

31.   In the "Advise" screen, select "Screen" and press **Enter**.

Again, HSPEXP's advice is to increase INFILT. The value of INFILT is set at the maximum of the suggested range, and if it is raised any higher, the simulation and the calibration parameters may be unrealistic, unless there are specific known physical conditions in the watershed that justify abnormal values. Because no such conditions are known for this

watershed, we would prefer at this point to find another parameter to adjust that will affect base flow and consequently bring high/low flow distribution within an acceptable range. From *BASINS Technical Note 6*, we find that AGWRC is a parameter that affects base groundwater recession. We will use HSPEXP to modify it and see whether it affects the high/low flow distribution.

32.   Press **F2** twice.

33.   From the "Calibrate" screen, select "Modify" and press **Enter**.

34.   From the "Modify" screen, select "Parameters" and press **Enter**.

35.   Select "Parameter Name" and enter "AGWRC" as the parameter to be modified.

36.   Press **Enter**.

37.   The typical range for AGWRC is 0.92-0.99. We will increase the value of this parameter since we would like to increase the simulated groundwater recession rate (the amount of groundwater contributing reach flow today compared to the amount of groundwater contributing to flow yesterday). For each PERLND number, change the value of AGWRC to "0.99."


38.   Press **F2**.

39.   From the "Modify" screen, select "Return" and press **Enter**.

40.   From the "Calibrate" screen, select "Simulate" and press **Enter**.

41.   When the simulation has completed, select "Advise" and press **Enter**.

42.   From the "Advise" screen, select "Screen" and press **Enter**.
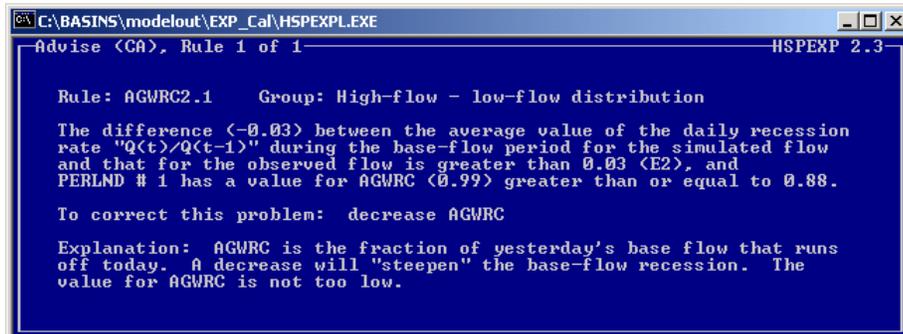
This advice tells us to decrease AGWRC, the parameter that we just increased. Note that the basis for parameter change is that the difference (-0.03) between the average value of the daily recession rate for simulated flow and calculated flow is greater than 0.03. This isn't accurate, since 0.03 is equal to 0.03. To see if this incongruity is due to a rounding problem, we will slightly adjust the error criteria parameter. We can then determine whether the value of AGWRC needs to be increased. One of the best ways to determine whether the value of AGWRC needs to be increased or decreased is to look at the baseflow recession in storm plots. This can be easily done in GenScn. If the simulated baseflow recession is too steep, then AGWRC should be increased, and conversely, decreasing AGWRC will steepen baseflow recession.

43.   Press **F2** twice.

44.   From the "Calibrate" screen, select "Modify" and press **Enter**.

45.   From the "Modify" screen, arrow to "Criteria" and press **Enter**.
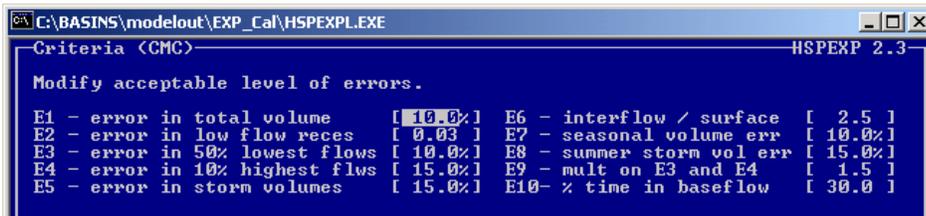
This screen lists the acceptable levels of error. These can either be decreased for a refined calibration or increased if error criteria cannot be met. See the *HSPEXP User's Manual* for a description of each error term. We are concerned with E2, the error term used in the previous advise screen.

46.   In the "E2 - error in low-flow recession" field, enter "0.031."

```
C:\BASINS\modelout\EXP_Cal\HSPEXPL.EXE                                    _ | □ | X |
─Criteria (CMC)────────────────────────────────────HSPEXP 2.3─

  Modify acceptable level of errors.

  E1 - error in total volume    [ 10.0%]  E6 - interflow / surface  [  2.5 ]
  E2 - error in low flow reces  [ 0.031 ]  E7 - seasonal volume err  [ 10.0%]
  E3 - error in 50% lowest flows [ 10.0%]  E8 - summer storm vol err [ 15.0%]
  E4 - error in 10% highest flws [ 15.0%]  E9 - mult on E3 and E4    [  1.5 ]
  E5 - error in storm volumes    [ 15.0%]  E10- % time in baseflow   [ 30.0 ]
```

47.   Press **F2**.

48.   From the "Modify" screen, select "Return" and press **Enter**.

49.   From the "Calibrate" screen, select "Simulate" and press **Enter**.

50.   Once the simulation has completed, **arrow** to "Advise" and press **Enter**.

51.   Select "Screen" from the "Advise" screen and press **Enter**.

```
C:\BASINS\modelout\EXP_Cal\HSPEXPL.EXE                                    _ | □ | X |
─Advise (CA), Rule 1 of 1────────────────────────────HSPEXP 2.3─

  Rule: INTFW1.1    Group: Stormflows

  Peak stormflow error (21.00%) is greater than 15.00% (E5)
  (simulated peak stormflow is 398.86, observed peak stormflow is 329.71), and
  interflow (2.70) is less than 2.50 (E6) times the surface runoff (15.31), and
  absolute value of the storm volume error (-5.50%) is less than 15.00% (E5)
  (simulated storm volume is 10.16, observed storm volume is 10.75).

  To correct this problem:  increase INTFW

  Explanation:  Runoff needs to be shifted from surface runoff to
  interflow to put the water in a slower drainage category. If IRC
  is too low, however, interflow will respond like surface runoff
  and the increase in INTFW will have little effect.
```

Notice that we have moved past the "High/Low Flow Distribution" phase to the "Stormflows" phase. Consequently, the error in low flow recession is sufficiently small and the value for AGWRC is acceptable. The current piece of advice instructs us to increase INTFW, the interflow inflow parameter. Read the "Explanation" for the rule. Our peak stormflow error is too great. You can view the discrepancy using the "Graph" option. Increasing INTFW will shift runoff from surface to interflow and consequently, storm flow will be more spread out over time.

52.   Press **F2** twice.

53.   From the "Calibrate" screen, select "Modify" and press **Enter**.

54.   Select "Parameters" on the "Modify" screen and press **Enter**.

55.   Press the space bar to select "Parameter Name" and enter "INTFW" as the parameter name to modify.
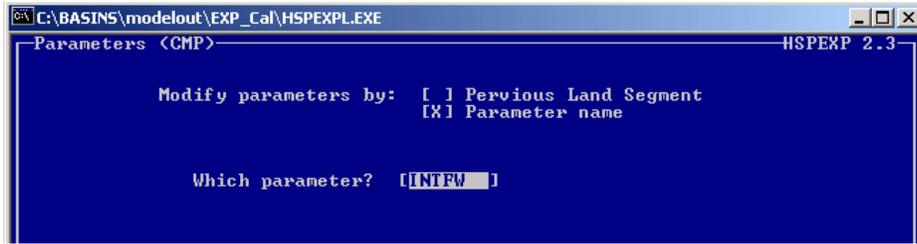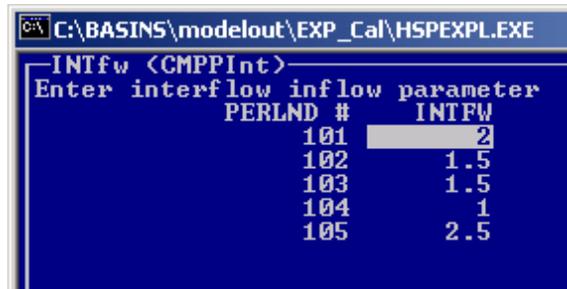
56.   Press **Enter**.
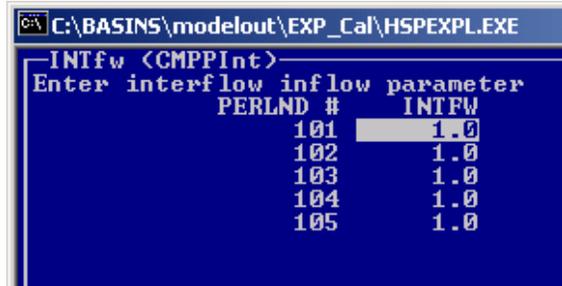
INTFW is set at "1" for all land use types. According to *BASINS Technical Note 6*, INTFW is typically between 1 and 3, but can be between 1 and 10. INTFW is a function of soils, topography and land use. Each PERLND will have unique interflow characteristics.

Land use types are found in the GEN-INFO block of the **.uci* file, and new INTFW values were determined by estimating reasonable interflow parameters for each land use based on soils and topography.

PERLND	Land Use	New INTFW
101	Forest Land	2
102	Urban or Built-up Land	1.5
103	Agricultural Land	1.5
104	Barren Land	1
105	Wetlands	2.5

57.   Replace INTFW values with the numbers in the table above. Your screen should look like the following:

58.   Press **F2**.

59.   From the "Modify" screen, select "Return" and press **Enter**.

60.   From the "Calibrate" screen, select "Simulate" and press **Enter**.

61.   After the simulation has finished running, select "Advise" and press **Enter**.

62.   Select "Screen" from the "Advise" screen.

We have corrected water balance, high/low flows, and storm flows. Next we will calibrate for seasonal flow balance. This piece of advice advises us to increase UZSN, upper zone storage, in order to raise the amount of water retained in the upper zone available for evapotranspiration. As the advice explanation states, UZSN has a minimal effect in the winter, but more influence in the summer because more evapotranspiration occurs. We will examine our UZSN values to see if they should be modified.

63.   Press **F2**.

The next piece of advice also concerns seasonal flows. Read through the advice. We are confident that our PERLND and IMPLND areas are accurate, so we will disregard this piece of advice.

64.   Press **F2** again.

65.   From the "Calibrate" screen, select "Modify" and press **Enter**.

66.   Select "Parameters" from the "Modify" screen and press **Enter**.

67.   Press the space bar to select "Parameter name" and type "UZSN" as the parameter to modify.
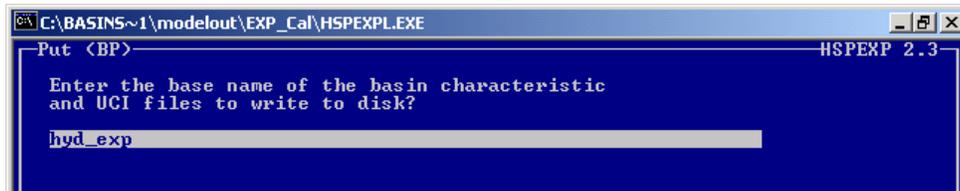

68.   Press **Enter**.

Since the values for UZSN appear to be within range and already adjusted for each land use, we will not adjust them. Although the seasonal flow distribution is inaccurate, our parameter settings will not effectively improve seasonal flows without disrupting overall water balance, high/low flows, and storm flows. If you examine the output, you will see that the errors for those categories are very low. Seasonal flow distribution is the most difficult of the categories to capture, and (luckily) is also the least important. Depending on the purposes of your model, you may want to improve seasonal flows. For the purposes of the West Branch Patuxent, this model is sufficiently calibrated.

In the interest of time, we only looked briefly at the HSPEXP output. In reality, the output statistics should be examined after every run. These statistics can offer a lot of insight on the specific discrepancies in the simulated and observed values rather than the general recommendations presented by the Advise function. For example, if you look at the statistics, the low flow error is actually too high and may require further calibration, although no advice was offered.

In the following steps, we will save the changes made to the *hyd_exp.uci* file.

69.   Press **F2**.

70.   From the "Modify" screen, select "Return" and press **Enter**.

71.   From the "Calibrate" screen, select "Put" and press **Enter**.

72.   Make sure "hyd_exp" is entered as the name of the file to be saved.

```
C:\BASINS~1\modelout\EXP_Cal\HSPEXPL.EXE                    _ |8|X|
Put <BP>                                                HSPEXP 2.3

    Enter the base name of the basin characteristic
    and UCI files to write to disk?

    hyd_exp
```

73.   Press **Enter**.

74.   From the "Calibrate" screen, select "Return" and press **Enter**.

75.   From the main HSPEXP screen, select "Return – to Operating System" and press **Enter**.

76.   Click the "X" in the upper right corner to exit HSPEXP.

Although HSPEXP is an "expert" system, it has limitations and requires modeler know-how and practical knowledge of the watershed. As shown in this exercise, not all of the advice offered by HSPEXP can be followed reasonably. HSPEXP checks the obvious and general areas of the water balance for errors, but there are many other steps that should be taken and other types of output that should be examined as detailed in Exercise 6. In addition to these outputs, documentation on possible parameter ranges and characteristics local to the watershed are important to employ for a more practical calibration. It should also be noted that there is not a unique calibration for each watershed. The quantity of parameters, the correlation between parameters, and the uncertainty in the parameter estimates and inputs allow for many combinations of parameters that result in good calibration. For example, Exercise 6 and this exercise began with the same input files and some of the parameter values chosen were different. It should be noted, however, that model calibration was not completed in either of these exercises.

Reference:

Duda, P., J. Kittle, Jr., M. Gray, P. Hummel, R. Dusenbury. *WinHSPF Version 2.0: An Interactive Windows Interface to HSPF (WinHSPF), User's Manual.* Washington, D.C.: U.S. Environmental Protection Agency, 2001.

Lumb, Alan M., Richard B. McCammon, and John L. Kittle, Jr. *User's Manual for an Expert system (HSPEXP) for Calibration of the Hydrological Simulation Program – Fortran.* Reston, VA: U.S. Geological Survey, 1994.

United States. U.S. Environmental Protection Agency. *Technical Note: Estimating Hydrology and Hydraulic Parameters for HSPF*. July 2000. Online posting. EPA-823-R-00-012. 11 June, 2002. http://www.epa.gov/waterscience/basins/tecnote6.html