Rural HSPF modelling

Technical Guide

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Contents

1. Introduction

This document serves as a technical guide for the processing of data, model operation and exporting of results from the Hydrological Simulation Program – Fortran (HSPF) model which has been used in WP2 (diffuse rural modelling) of the Cloud To Coast project.

The document has been written in process order, and details the steps required to prepare and operate the model in the required sequence for a user starting the process from scratch. These steps detail the data and software required for the modelling process, the preparation of the data for use in the HSPF model, the creation and configuration of the HSPF model, running the model and outputting model results. Additional resources are also signposted (and included in Appendix H), which provide further information and detail.

If pre-prepared models are being used, the initial steps will explain their construction. Potential modifications and alterations to the model, for example in exploring management or climate change scenarios are possible using the existing models, and steps to accomplish this are detailed in later sections of this document.

2. Data and Software Requirements

2.1 Data required

Dataset	Use	Source
DEM	Watershed delineation and topographic parameters	EDINA Digimap: Ordnance Survey Collection
River Network	Used to burn into DEM for additional hydrologic accuracy (optional)	CEH
Precipitation data (EA rain gauge)	Time series rainfall data (including locations)	Environment Agency
Potential Evapotranspiration (MORECS)	Time series potential evapotranspiration data (including locations)	United Utilities
Land Use Data (Land Cover Map 2007)	Information on land use.	EDINA Digimap: Environment Collection
Agricultural information (agcensus - Livestock numbers)	Data to quantify grazing numbers in sub-catchments	EDINA
River flow data (EA flow gauge)	Calibration of modelled flow output	Environment Agency
FIO water quality data	Calibration of Faecal Coliform output	C2C project field work

Table 1.1: Data Required

2.2 Software required

Software	Notes	Source
BASINS (including WinHSPF)	Provided by U.S. EPA. Test version may solve any compatibility issues.	http://water.epa.gov/scitech/datait/models/basins/download.cfm (stable release) http://www.aquaterra.com/resources/downloads/basins4.php (test version)
WDMUtil/ GenScn	Maybe included with BASINS but also available as a standalone package, which may be more convenient.	http://www.aquaterra.com/resources/downloads/basins4.php
ESRI ArcGIS Desktop (ArcMap)	The GIS package used for this project and guide.	Commercial software
Arc Hydro Tools	Geoprocessing toolset for GIS software. Login and password for ftp site, as well as further instruction and tutorials can be found from the Arc Hydro forum: http://forums.arcgis.com/forums/88-Arc-Hydro	https://mft.esri.com/ (FTP site)
MS Excel	Spreadsheet software	Commercial software
MS Notepad	Text editor software	Commercial software (provided with windows)

Table 2.1: Software Required

3. Preliminary Model Data Preparation

3.1 Model catchment(s)

Reason: Define outer boundaries for model limits. This is based on the rivers being modelled and where they drain. In the case of C2C the model extent and the rivers to be modelled had been identified by the strategic partners. The locations where the rural HSPF modelled drained into the river/estuary model created additional points within this larger catchment that defined the boundaries of the rural HSPF models.

- Use GIS to calculate a watershed from a DEM based on the rivers to be modelled and/or the points to be drained to.

3.2 Model sub-catchment delineation (Topography)

Reason: To create model sub-catchments (the spatial units used to define and configure the model) within the overall model catchment(s) and calculate topographic parameters for these (slope, area, and channel length).

Two methods were used to delineate the watersheds. One using the U.S. EPA BASINS software which is packaged together with the HSPF model. In some cases the watershed delineation using this software was problematic and did not produce acceptable catchments. Predominantly these were smaller, lower-level catchments which were topographically more homogenous. In these instances a manual method was undertaken using Arc Hydro Tools for ArcGIS and tools within ArcGIS itself to process and delineate the required watersheds. Small model catchments which comprised only a single sub-catchments were also processed using the manual Arc Hydro method.

Both methods are outlined below.

3.2.1 Basins method

- Open BASINS software
- Create New Project
- Without selecting any features, click *Build*
- Click *Yes* to dismiss the *Data Extraction* message.
- Save the project in an appropriate directory
- Enter Projection Properties as shown in figure 3.1 – these match GB National Grid.

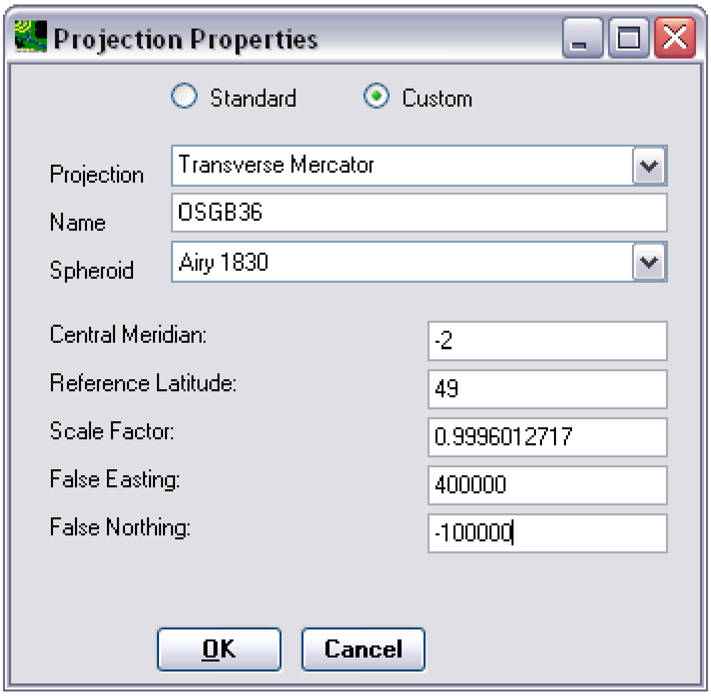


Figure 3.1: BASINS Projection Properties

- Use the Add data button (figure 3.2) to add data

Figure 3.2: BASINS Add Data Button

- Add:
  - *DEM*
  - *Model catchment shapefile*
  - *Rivers shapefile*
- On the top menu options, go to *Watershed Delineation>Automatic*
- Fill out the form as in figure 3.3, with the exception of *# of cells* – leave that as the value set by the BASINS software.

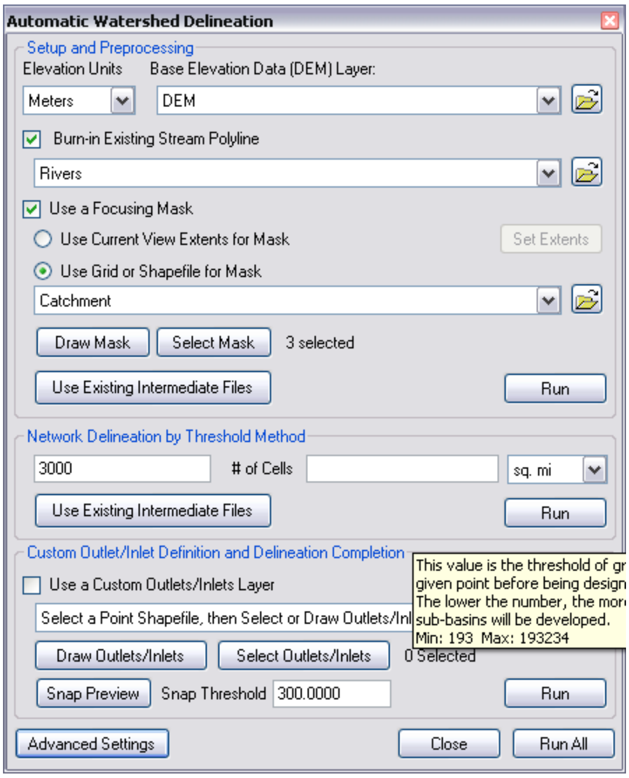


Figure 3.3: BASINS Automatic Watershed Delineation

- Check *Advanced Settings* for more options if you wish
- Click *Run All*
- Note: If errors occur in the processing of the sub-catchments, either software based (with error message windows) or in the shape of the expected sub-catchment delineations (e.g. areas for the model catchment not covered by sub-catchments) then inspect the DEM and consider using the Arc Hydro (manual method instead).
- Locate the created *Watershed Shapefile* (*demw.shp*) and *Stream Reach Shapefile* (*demnet.shp*). These should be saved in the same directory in which your BASINS project was saved. Take a copy of these shapefiles.
- Save BASINS project for later use in preparing the model input files (Model Input File Creation>BASINS method)

3.2.2 Arc Hydro Tools Method (Manual)

Sub-catchment delineation can also be performed in ArcGIS using Arc Hydro Tools, which are a set of geoprocessing tools designed to support water resource applications. Using Arc Hydro Tools to delineate the sub-catchments allows a greater amount of user control over the delineation and processing of the sub-catchments. It also allows for the processing of individual sub-catchments for smaller catchment models. The disadvantage of using Arc Hydro Tools and ArcGIS over BASINS is that more manual processing is required to prepare the data into the correct format for entry into the HSPF model. The below method requires ArcGIS complete with the Spatial Analyst extension and Arc Hydro Tools to be installed and activated.

The initial step involves processing the DEM. This can be done once for a DEM that covers the entire C2C area before further processing the individual model catchments.

- Open ArcGIS ArcMap and open the Arc Hydro Tools toolbar by right-clicking in an empty section of the toolbar and selecting *Arc Hydro Tools*
- Add to ArcMap:
    - *DEM*
    - *Rivers shapefile*
- Save the ArcMap document (a .mxd file). Arc Hydro Tools will save output files in the same directory as the .mxd file.
- Create a reconditioned DEM by burning-in the channel outline from the Rivers file:
    - Click *Terrain Preprocessing* on the Arc Hydro Tools Toolbar
    - In the menu that drops down go to *DEM Manipulation>DEM Reconditioning* (figure 3.4).

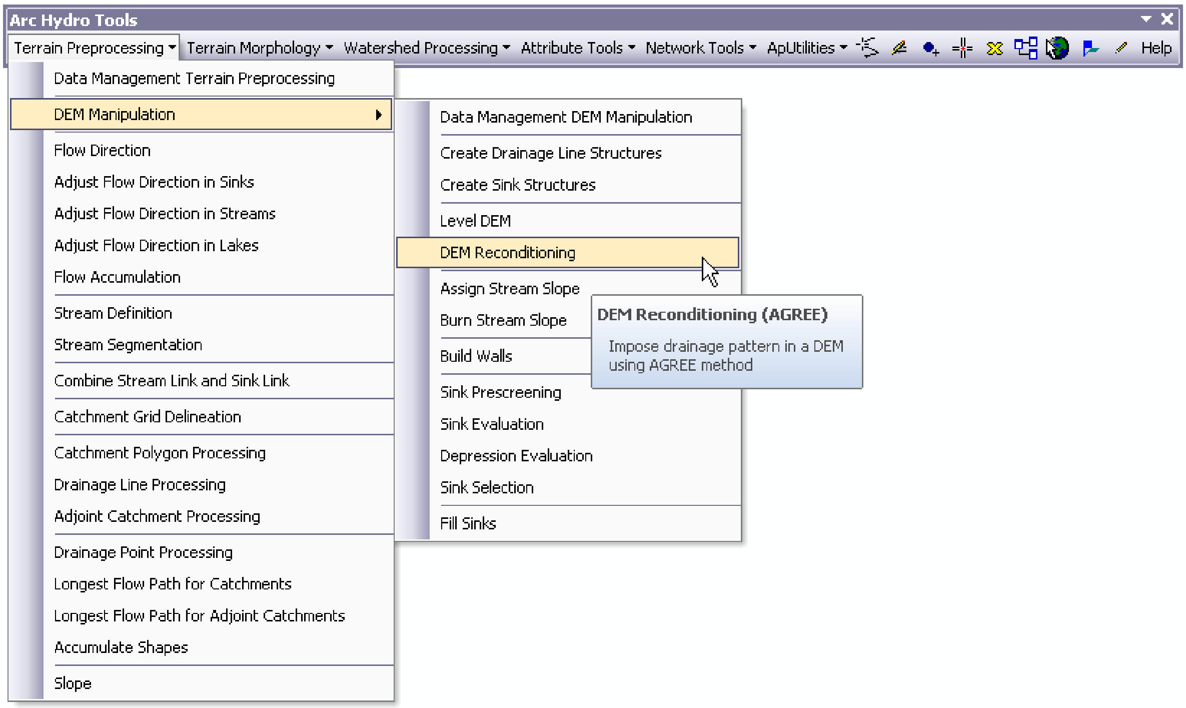


Figure 3.4: Arc Hydro Tools Toolbar

- Select the *DEM* for the *Raw DEM*
- Select the *Rivers shapefile* for the *Agree Stream*
- Leave other fields as their default values, as in figure 3.5.

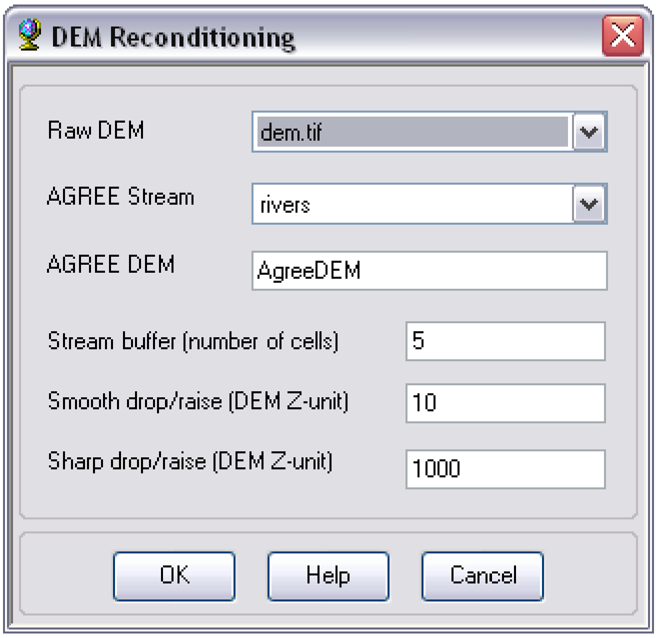


Figure 3.5 Arc Hydro Tools – DEM Reconditioning

- Click *OK*
- Fill sinks
    - Click *Terrain Preprocessing* on the Arc Hydro Tools Toolbar
    - In the menu that drops down go to *DEM Manipulation>Fill Sinks*
    - Select the newly created *AgreeDEM* as the *DEM* and fill out the rest of the details as in figure 3.6.

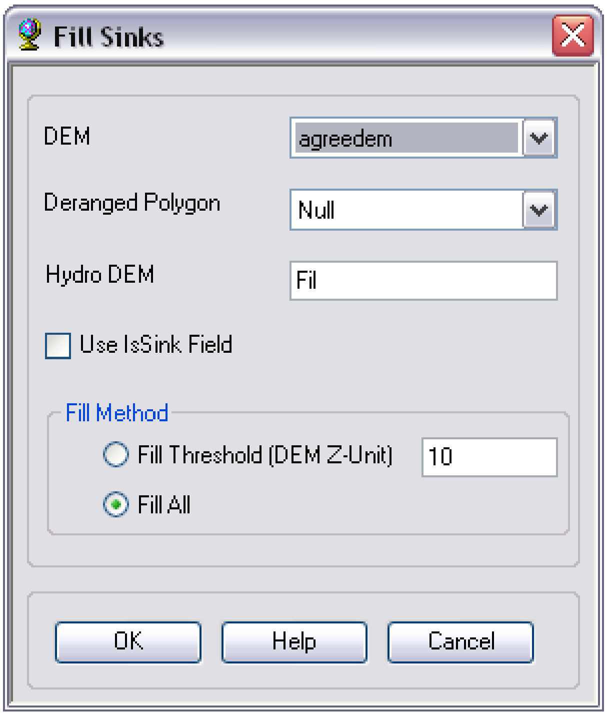


Figure 3.6 Arc Hydro Tools – Fill Sinks

- Click *OK*

Having prepared a DEM for the entire C2C area, the model sub-catchments can be processed individually for better speed and error checking. This process will need to be completed for each of the model catchments to be run.

- Open a new ArcMap document
- Add to ArcMap:
  - The Filled DEM (*Fil*) which was created in the previous step.
  - A *model catchment shapefile*
- Save the ArcMap document (a .mxd file). Arc Hydro Tools will save output files in the same directory as the .mxd file. This .mxd document will be specific to the one model (the model represented by the loaded catchment shapefile).

- Calculate Flow Direction
  - Click *Terrain Preprocessing* on the Arc Hydro Tools Toolbar
  - In the menu that drops select *Flow Direction*
  - Enter *Fil* (the filled DEM) as the *Hydro DEM*
  - Enter the *model catchment* as the *Outer Wall Polygon*
  - Leave the remaining options as in figure 3.7.

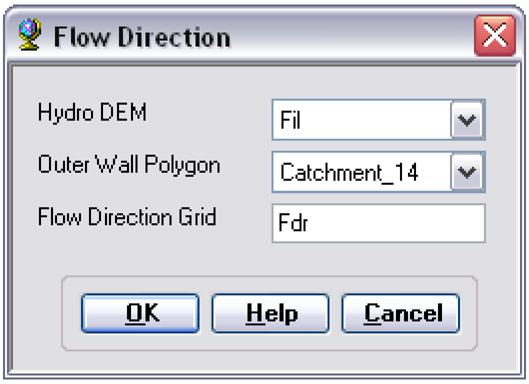


Figure 3.7: Arc Hydro Tools – Flow Direction

- Click *OK*

- Calculate Flow accumulation
  - Click *Terrain Preprocessing* on the Arc Hydro Tools Toolbar
  - In the menu that drops select *Flow Accumulation*
  - Check that the details are entered correctly as in figure 3.8.

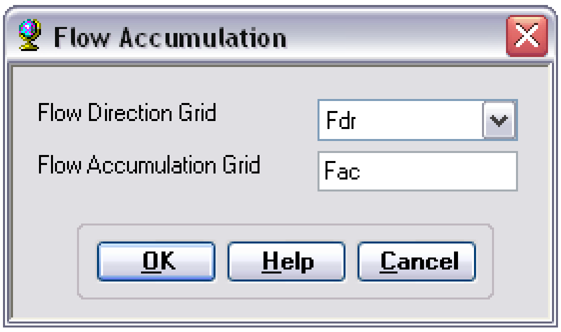


Figure 3.8: Arc Hydro Tools – Flow Accumulation

- Click *OK*

- Create Stream Definition
  - Click *Terrain Preprocessing* on the Arc Hydro Tools Toolbar
  - In the menu that drops select *Stream Definition*
  - Enter the *Number of cells* as *20000* (used for single sub-catchment or small size model catchments) or the use the BASINS cell threshold (for erroneous BASIN outputs) if the cell threshold is greater than 20000. The BASINS cell threshold is given as the *# of cells* value when attempting *Automatic Watershed Delineation* (see section 3.2.1).
  - Check that the details are entered correctly as in figure 3.9.

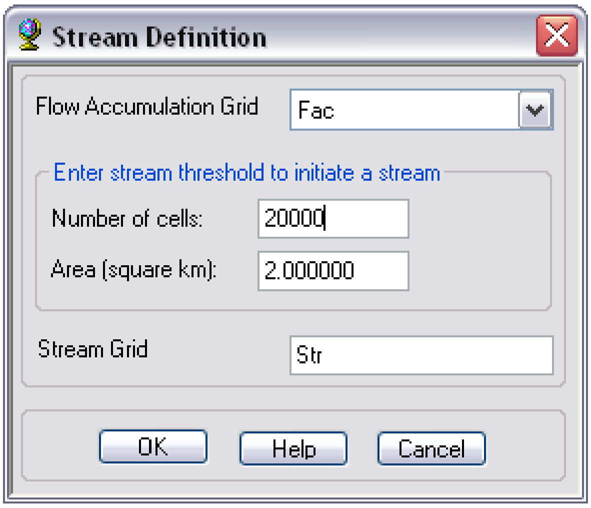


Figure 3.9: Arc Hydro Tools – Stream Definition

- Click *OK*

- Create Stream Segmentation
  - Click *Terrain Preprocessing* on the Arc Hydro Tools Toolbar
  - In the menu that drops select *Stream Definition*
  - Check that the details are entered correctly as in figure 3.10.

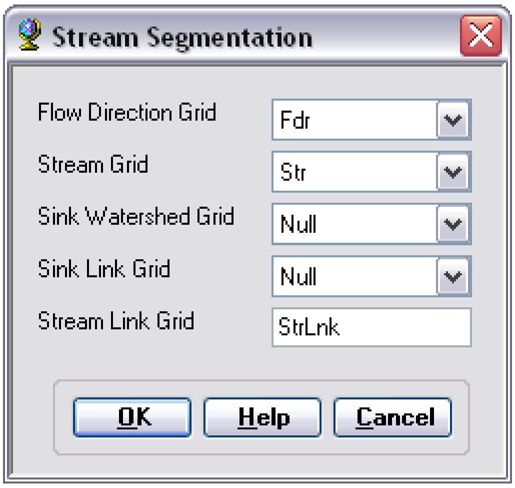


Figure 3.10: Arc Hydro Tools – Stream Segmentation

- Click *OK*

- Perform Catchment Grid Delineation
    - Click *Terrain Preprocessing* on the Arc Hydro Tools Toolbar
    - In the menu that drops select *Catchment Grid Delineation*
    - Check that the details are entered correctly as in figure 3.11.

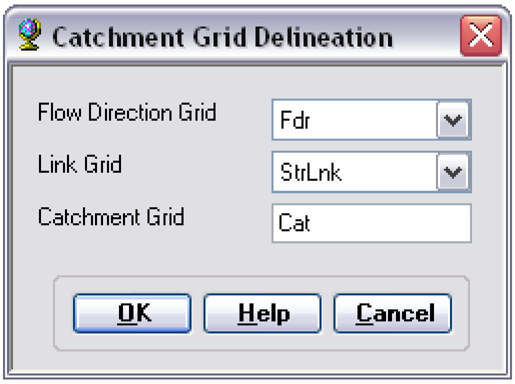


Figure 3.11: Arc Hydro Tools – Catchment Grid Delineation

- Click *OK*

- Perform Catchment Polygon Processing
    - Click *Terrain Preprocessing* on the Arc Hydro Tools Toolbar
    - In the menu that drops select *Catchment Polygon Processing*
    - Check that the details are entered correctly as in figure 3.12.

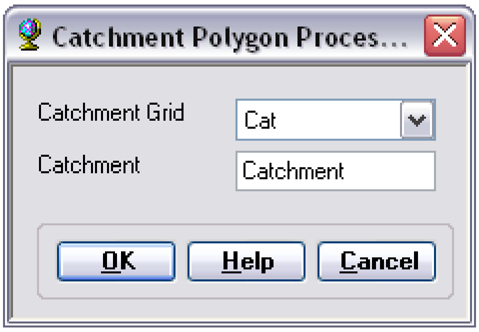


Figure 3.12: Arc Hydro Tools – Catchment Polygon Processing

- Click *OK*

- Perform Drainage Line Processing
    - Click *Terrain Preprocessing* on the Arc Hydro Tools Toolbar
    - In the menu that drops select *Drainage Line Processing*
    - Check that the details are entered correctly as in figure 3.13.

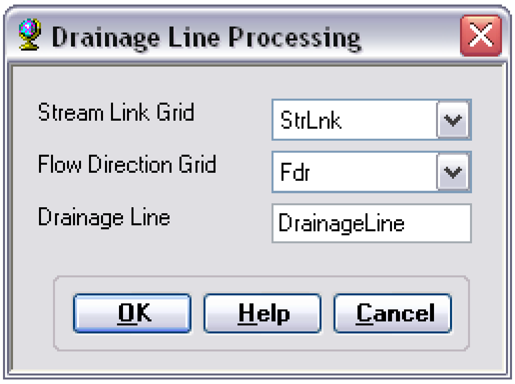


Figure 3.13: Arc Hydro – Drainage Line Processing

- Click *OK*

- Save the .mxd to include a reference of the processing for the catchment.
- Right-click each of the following in the table of contents window and using *Data>Export Data…* Save a copy of them as shapefiles:
    - *DrainageLine*
    - *Catchment*
- Close ArcMap.

The *DrainageLine* and *Catchment* shapefiles are used in the calculation of topographic values that represent the model sub-catchments. The *Catchment* shapefile identifies the delineated HSPF sub-catchments and their areas, the *DrainageLine* shapefile stores the representative channel or reach of each sub-catchment and the sub-catchment downstream flow order.

3.3 Met data – Part 1

The met data (precipitation and potential evapotranspiration) that is required to drive the hydrological component of the HSPF model needs to be pre-prepared. The data needs to be inspected for errors and repaired with as much accuracy as possible. The data also needs to be converted into the required model time steps and measurement units as well as being formatted correctly to facilitate entry into the .wdm (Watershed Data Management) format in which the data is stored for use with the HSPF model. Location data marking where the data was collected from also needs to be recorded.

The processing steps outlined in this section can be undertaken using MS Excel.

3.3.1 Precipitation

- Conversion to inches from m^3s^{-1}.

Reason: Model is run using imperial units.

- Multiply mm by 0.0393700787 to get inches.

- Fill-in missing data:

Reason: To create a complete time-series of precipitation data

- Gauge data checked for number of missing/error values (comments can record why data is missing)
- If count of missing cells is over 100 they are substituted with data from the closest neighbouring rain gauge.
- Gauge data rechecked for missing/error values
- If count of missing cells remains over 100 they are substituted with data from the second closest neighbouring rain gauge.
- Process is repeated until count of missing cells is less than 100 (or if neighbouring stations become too far away to be broadly comparable).
- Any remaining cells are assigned a value of 0, following an inspection to check that appears sensible within the time series.
- Cleaned, interpolated rainfall series is saved as a new file.

- Convert 15 min data into hourly

Reason: Model will run in hourly time-steps. All input data will need to be in the same time units. If they differ the model will not run correctly.

- Calculate the sum of 4, 15 minute precipitation cells so that the precipitation at XX:00 = the sum of the precipitation at that time and the 3 values prior to it. Figure 3.14 demonstrates an example of this.

Time	**Precipitation**
XX:15	
XX:30	
XX:45	
XX:00	=sum(XX:15, XX:30, XX:45, XX:00)

Figure 3.14: MS Excel – Conversion to Hourly Time-Steps

- Clean the data so that only the hourly summed values remain (with date and time).

- Save precipitation data in correct format for importing into .wdm

Reason: Saving the data following the template provided below and as a .csv format allows for relatively simple import into a .wdm file using WDMUtil. This is the format used to store time-series data in by HSPF.

- Prepare the data in the column format illustrated in figure 3.15.

Value	Year	Month	Day	Hour	Minute

Figure 3.15: MS Excel – Precipitation Data Column Format

- Remove any header row
- Save the data as a .csv file

- Rain gauge location

Reason: Rain gauge station locations are needed by HSPF when saving the data within a .wdm file and when selecting an initial met station and assigning met segments (section 5.4) when creating an HSPF model. Coordinates need to be recorded as latitude and longitude in decimal degrees for .wdm file entry. Additionally rain gauge locations are used to determine which rain gauge data should be used for each model sub-catchment according to proximity.

- Plot OS Nation Grid coordinates of rain gauges using GIS (grid references available in station header information)
- Convert OS National Grid References into latitude and longitude in decimal degrees (WGS84 format) and record for later use when storing data in .wdm file.
- Create Thiessen Polygon layer (using ArcMap) to create polygons representing the area of influence for each rain gauge based on Euclidean geometry.
- Use GIS to perform a spatial Join on the model sub-catchments with the rain gauge locations so that each sub-catchment is assigned the rain gauge which falls within it or the gauge which is closest to it.
- Can visually check the spatial join using Thiessen Polygon layer created previously.
- This data can be used to assign an initial model met segment (section 5.1 and 5.2) and to add and assign met segments for all model operations when creating the HSPF model (see section 5.4).

3.3.2 Potential Evapotranspiration

- MORECS values come in a weekly time series.

Reason: Model will run in hourly time-steps. All input data will need to be in the same time units. If they differ the model will not run correctly. A complete time-series of evapotranspiration data is also required.

- Use linear interpolation to compute daily values from the weekly data within a spreadsheet.

- Data should be converted from mm to inches.

Reason: Model is run using imperial units.

- Multiply mm by 0.0393700787 to get inches.

- Save potential evapotranspiration data in correct format for importing into .wdm

Reason: Saving the data following the template provided below and as a .csv format allows for relatively simple import into a .wdm file using WDMUtil. This is the format used to store time-series data in by HSPF.

- Prepare the data in the column format illustrated in figure 3.16.

Value	Year	Month	Day	Hour	Minute

Figure 3.16: MS Excel – Potential Evapotranspiration Data Column Format

- Remove any header row
- Save the data as a .csv file

- An additional step is required to disaggregate the evapotranspiration from a daily time-step into an hourly one. This is undertaken in the WDMUtil software once the evapotranspiration data has been imported.

3.4 Land Use – Part 1

The Land Cover Map (LCM2007) data from CEH has more categories than is ideal for modelling in HSPF. A greater number of categories causes a greater level of model complexity which can lead to a greater chance of errors. Simplifying the categories to land uses of relevance will aid the modelling process.

Should changes in land use categories be required they can be made by repeating this process and rebuilding the model. Having reclassified the land cover map into a HSPF land use layer this file can then be used by BASINS or through manual processing to build the model input files.

The processing of the land use date can be achieved using ArcMap using the following steps.

- Convert the downloaded LCM2007 data from raster format to a vector shapefile in ArcMap
- A lookup table is provided (Table 3.1) which enables the *LCM2007 GridCode* values to be linked with the relevant LCM2007 classification and the HSPF land use categories.
- Save the lookup table as a table (an Excel workbook is suitable)
- In ArcMap load the lookup table
- Join the lookup table to the converted LCM2007 shapefile using the *GridCode* values
- Save the joined output allowing you to reclassify LCM2007 land use categories into HSPF land use categories
- Merge polygons based on HSPF land use category and save output.

GridCode	LCM2007Class	HSPFLandUse
0	Unclassified	Unclassified
1	Broadleaved, mixed and yew woodland	Woodland
2	Coniferous woodland	Woodland
3	Arable and horticulture	Arable & horticultural
4	Improved grassland	Grassland
5	Rough grassland	Grassland
6	Neutral grassland	Grassland
7	Calcareous grassland	Grassland
8	Acid grassland	Grassland
9	Fen, marsh and swamp	Mountain, heath, bog
10	Heather	Mountain, heath, bog
11	Heather grassland	Mountain, heath, bog
12	Bog	Mountain, heath, bog
13	Montane habitats	Mountain, heath, bog
14	Inland rock	Mountain, heath, bog
15	Saltwater	Coast, Sea
16	Freshwater	Water
17	Supra-littoral rock	Coast, Sea
18	Supra-littoral sediment	Coast, Sea
19	Littoral rock	Coast, Sea
20	Littoral sediment	Coast, Sea
21	Saltmarsh	Coast, Sea
22	Urban	Built-up areas
23	Suburban	Built-up areas

Table 3.1: Land use Lookup - LCM2007 land use categories to HSPF land use categories.

3.5 Met data – Part 2

3.5.1 Import data into WDM file (precipitation and evapotranspiration)

Reason: .wdm (Watershed Data Management) files are the format in which HSPF stores input and output time series data. Input time series data includes the precipitation and evapotranspiration data. Having prepared the data in the way described above the saved .csv files can be imported into a .wdm file using the WDMUtil software. The import steps below are the same regardless of data-type unless otherwise stated.

- Open WDMUtil
- Create a new .wdm file (*File>New*) or open an existing .wdm file (*File>Open*)
- Select *File>Import*
- Locate a saved Met data .csv file
- Optionally create a template for input or select a previously created template (this can save time) or select Blank Script and Click *Edit*
- Uncheck the *Skip* option under *Header*
- Check *Character*: under *Column Format* and check that a , [comma] is entered
- Check that the data is displayed correctly in the preview – similar to figure 3.17.

- Open WDMUtil
- Create a new .wdm file (*File>New*) or open an existing .wdm file (*File>Open*)
- Select *File>Import*
- Locate a saved Met data .csv file
- Optionally create a template for input or select a previously created template (this can save time) or select Blank Script and Click *Edit*
- Uncheck the *Skip* option under *Header*
- Check *Character*: under *Column Format* and check that a , [comma] is entered
- Check that the data is displayed correctly in the preview – similar to figure 3.17.

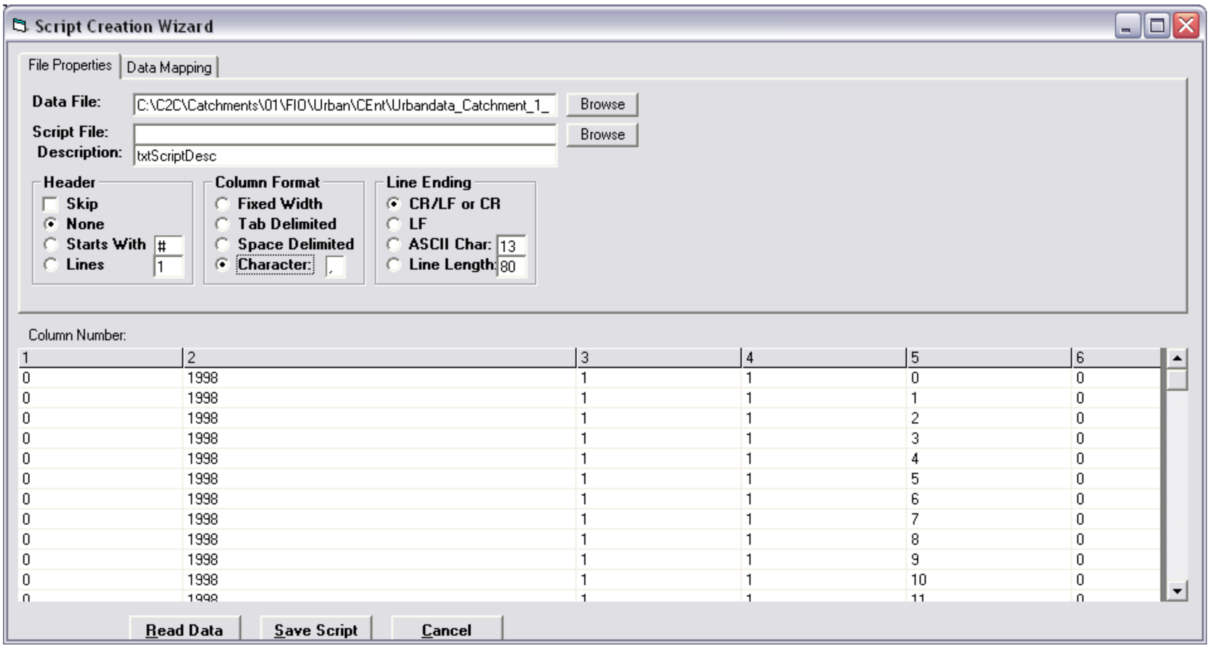


Figure 3.17: WDMUtil – Import Script Creation

- Click the *Data Mapping* Tab

- Enter the values in the input column as shown in figure 3.18.

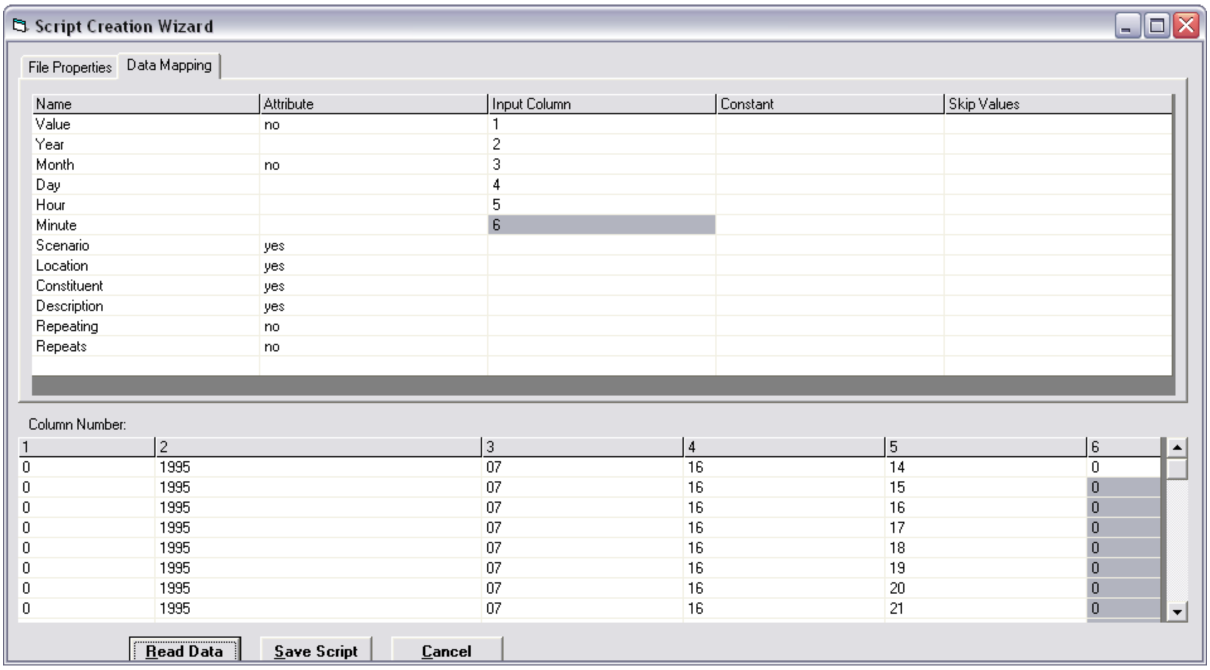


Figure 3.18 WDMUtil – Import Script Creation – Data Mapping

- Click *Read Data*
- Double-click on new time series entry to open the Edit Time Series Attributes window and allow editing of the attributes.
- Add the attributes in table 3.2 according to the dataset and data type you are importing:

Attribute	Precipitation Data	Potential Evapotranspiration Data
Scenario	OBSERVED	OBSERVED
Location	*(Name of location – 8 characters)*	*(Name of location – 8 characters)*
Constituent	PREC	EVAP
Description	*(Description of location/data)*	*(Description of location/data)*
LATDEG	*(Latitude)*	*(not required)*
LNGDEG	*(Longitude)*	*(not required)*

Table 3.2: WDMUtil – Time Series Attributes Entry (Capitalised text indicates default text entry, descriptions in brackets indicate user determined value that needs to be entered)

- The *LATDEG* and *LNGDEG* attributes for precipitation data will need to be added manually before entering coordinates.
  - In the *Edit Time Series Attributes* window click *Add Attributes*
  - Scroll down to the new attribute row, left click in the empty attribute cell and enter the attribute name (*LATDEG* or *LNGDEG*)
  - Enter the corresponding coordinate in the *DSN1* field.
  - Repeat the process for the other coordinate.

- An example of a completed *Edit Time Series Attribute* window for precipitation data is shown in figure 3.19.

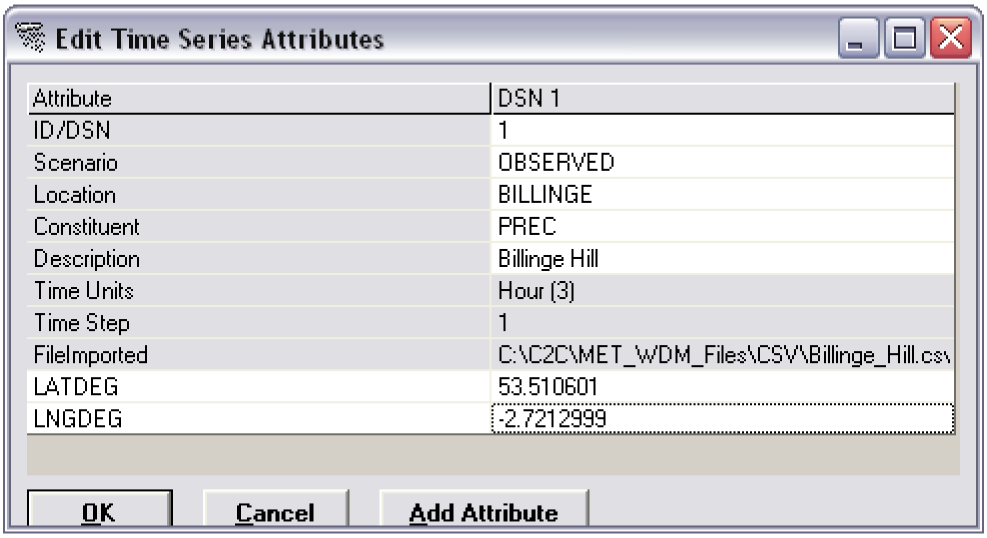


Figure 3.19: WDMUtil – Time Series Attributes

- Click *OK*
- Click the Write Time Series to WDM button (outlined in red in figure 3.20)

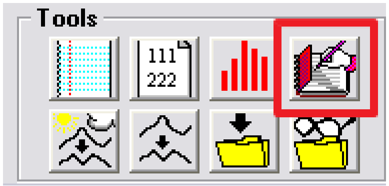


Figure 3.20: WDMUtil – Write Time Series Tool

  - In the Write to WDM dialogue assign an Output DSN value based on the next available number from the stored time series (if any).
  - Consider using a different range of DSN values for precipitation and potential evapotranspiration data.

3.5.2 Potential Evapotranspiration

Reason: Model will run in hourly time-steps. All input data will need to be in the same time units. If they differ the model will not run correctly.

- Use WDMUtil to disaggregate the daily time series into hourly – distribution of data is based on latitude and time of year.
  - Select the *Compute* button from the Tools frame (outlined in red in figure 3.21)

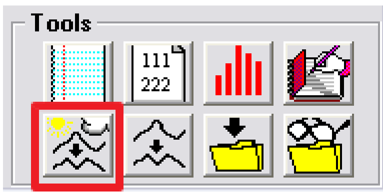


Figure 3.21: WDMUtil – Compute button

  - Select *Disaggregate* in the Operation frame

- Select *Evapotranspiration* in the Disaggregate Functions frame
- In the Input(s) selection in the Timeseries frame select the relevant weekly potential evapotranspiration *EVAP* dataset.
- In the Output selection enter the next available DSN value.
- Enter a Latitude in the additional inputs, these needs to be in d, m, s.sss format which can be converted from the location of the potential evapotranspiration data recording (see OS coordinate transformation tool in Appendix H).
- The completed form should appear similar to figure 3.22.

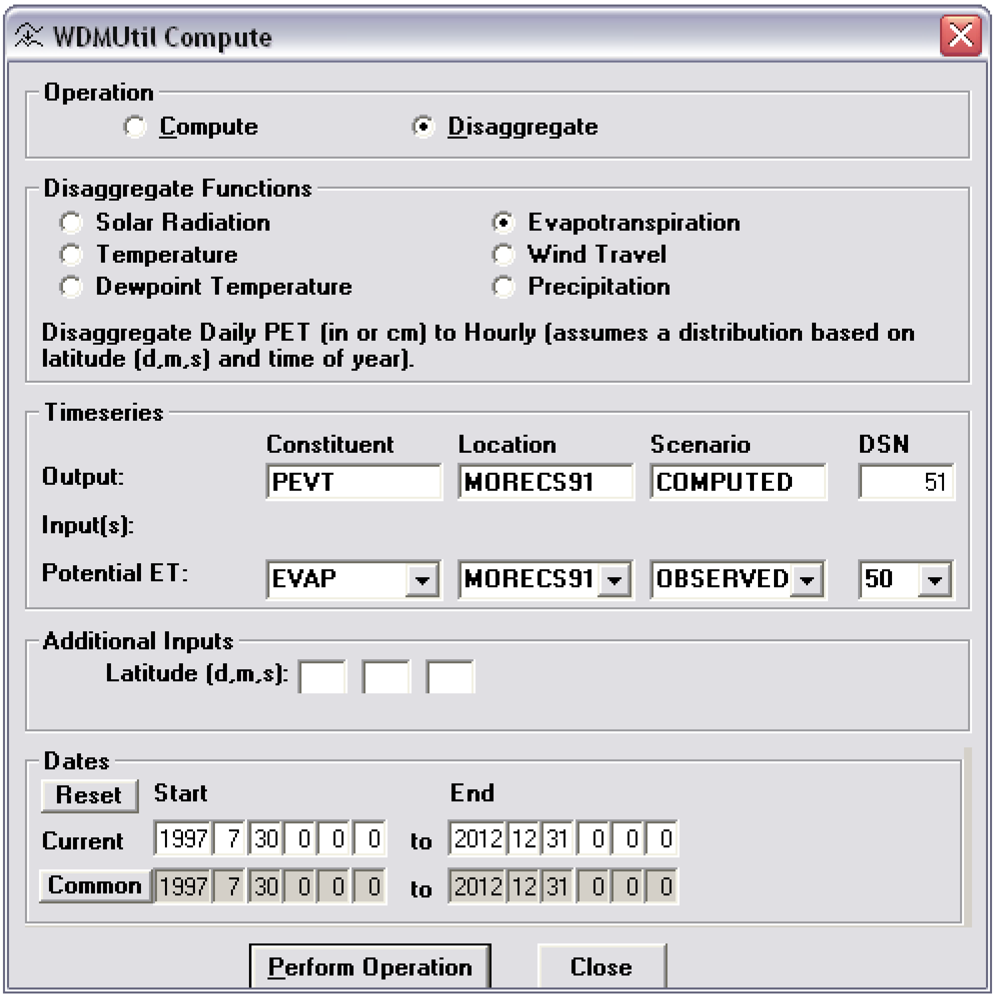


Figure 3.22: WDMUtil – Compute

- Click *Perform operation* and *OK* to any subsequent messages.
- Click *Close* on the Compute form.
- An adjustment may be required to account for British Summer Time in the data – it should be manually checked to ensure peak Evapotranspiration rates occur at the appropriate time of day (Midday – early PM) throughout the time series.

3.6 Land Use – Part 2

Reason: Necessary for manual model input file creation. Also used in calculation of BIT tool.

- Combine land use with HSPF sub-catchments
    - Open ArcMap and add:
        - A shapefile of HSPF category land use (from section 3.4)
        - A shapefile of the HSPF model sub-catchments (either the *Watershed demw*.shp shapefile created by BASINS in section 3.2.1 or the *Catchment* shapefile from Arc Hydro Tools processing in Section 3.2.2).
    - Use the *Clip* Tool to clip the HSPF land use to the sub-catchment area.
- This output can now be used in BASINS (section 4.1) but will require some additional processing for the manual Arc Hydro Tools method (section 4.2).

4. Model Input File Creation

The HSPF model can be created using a combination of four files: a *Point Sources* file (.psr), a *Channel Geometry* file (.ptf), a *Reach* file (.rch) and a *Watershed* file (.wsd) (Appendices C – F). They files describe the character of the sub-catchments, a representative channel that flows through each sub-catchment and the land use composition within each sub-catchments. BASINS will automatically create the necessary input files. Sub-catchments which were delineating manually using Arc Hydro Tools require additionally processing in order to create these input files. The steps below outline the process required for both methods.

4.1 Basins method

- If not already open, open the saved BASINS project from section 3.2.1.
- Use the *Add data* button (see figure 4.1) to add the relevant clipped *catchment HSPF Land Use* data (from Section 3.6)

Figure 4.1: BASINS – Add Data Button

- Save the BASINS project
- Go to *Models>HSPF*
- Select *Other Shapefile* for *Land Use Type*
- Check the remaining details as the same as in figure 4.2.

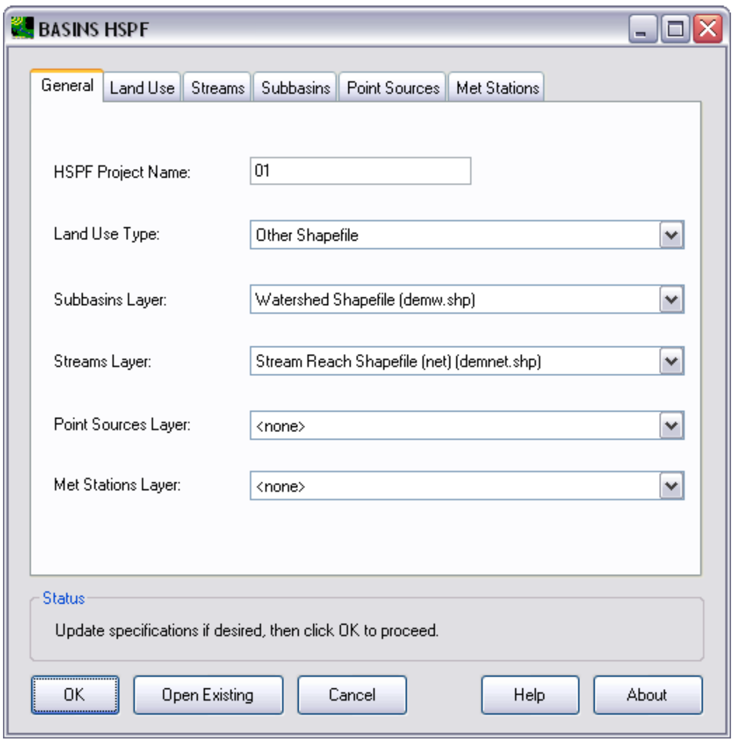


Figure 4.2: BASINS – Create HSPF Model - General

- Click the *Land Use* tab
- Select the *Land Use Layer* as the *HSPF Land Use*
- Select the field which stores the HSPF land use category data in for *Classification Field*
- Enter an *Impervious Percent* of 50% for *Built-up areas*. Leave the rest at 0%
- The completed form should look similar to figure 4.3.

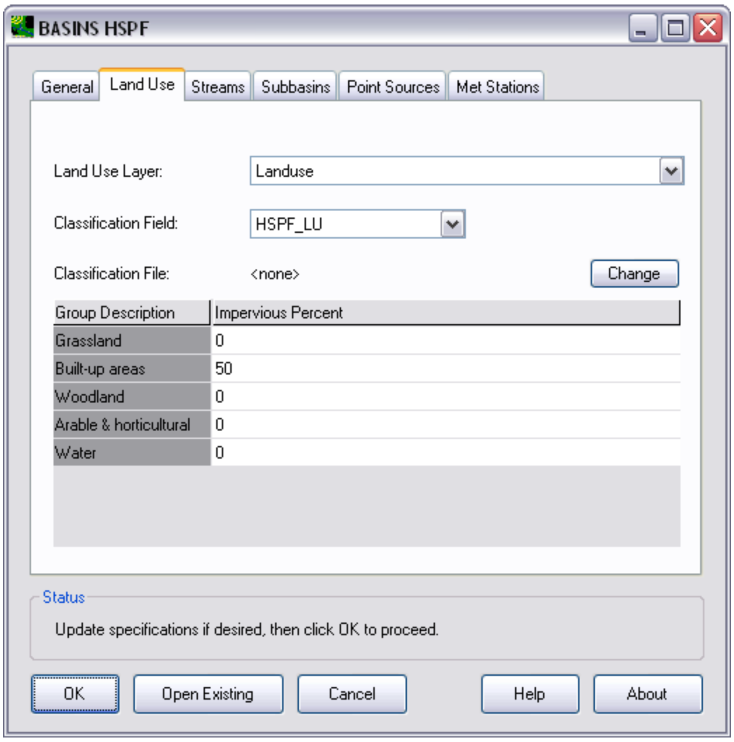


Figure 4.3: BASINS – Create HSPF Model – Land Use

- Inspect the *Streams*, *Subbasins* and *Point Sources* tabs – values on these should be able to be left at their defaults.
- Click on the *Met Stations* tab
- Click *Select* and navigate and open the Met data .wdm file
- Select a Met station in the list provided (figure 4.4).
- Note – some .wdm files will not load and display the correct Met Stations in BASINS. It is acceptable to use a proxy MET station that works correctly and then substitute the correct Met data .wdm file when the model is being created in WinHSPF.

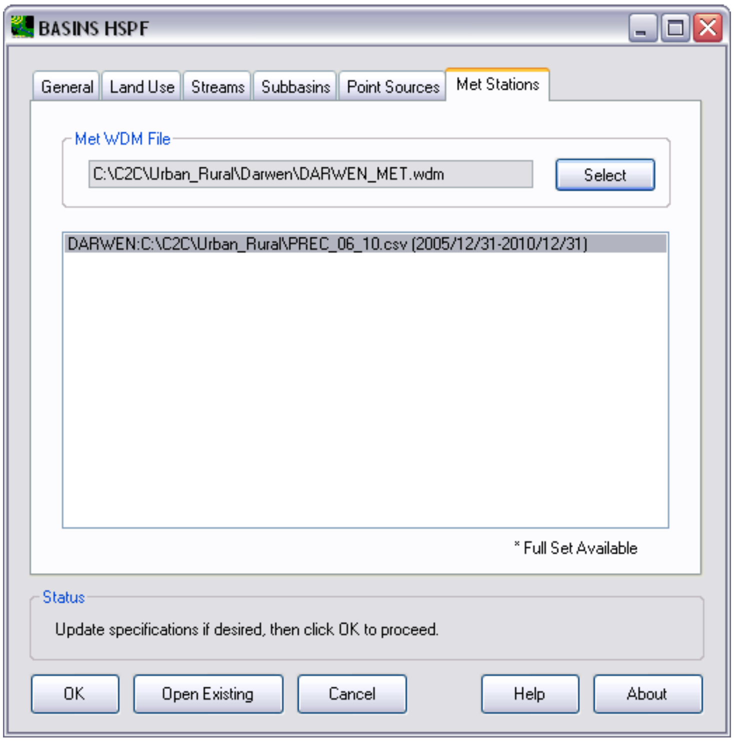


Figure 4.4: BASINS – Create HSPF Model –Met Stations

- Click *OK*.
- The BASINS software will then create the HSPF input files and attempt to launch WinHSPF directly. This later stage is likely to produce error warnings and eventually crash. The required HSPF input files will have been created successfully though.
- Input files needed (.psr, .ptf, .rch and .wsd) will have been created in a folder called *modelout* in the basins directory (\Basins or \BASINS41). These files should be copied for use in creating the HSPF model.
- The .uci file and other files in the model out directory can be ignored.

4.2 Arc Hydro Tools Method (Manual)

The processing of the WinHSPF input files (Appendices A-D) following the manual sub-catchment delineation using ArcMap and Arc Hydro Tools requires some additional processing in GIS. The work is undertaken in ArcMap to extract and organise the relevant data. Final preparation of the data can be undertaken in Excel and Notepad to save the input files in the correct format. Models were built in ArcMap to semi-automate this process, copies of these, outlining the workflow have been included in Appendix A and Appendix B. Descriptions of the required data to calculate and an overview as to how to achieve this are also listed below. Finally tables for the four input files show where these calculated values are used and also the appropriate default values used in the remainder of the files. Examples of the four input files are included in Appendices C – F.

4.2.1 GIS Processing

For each HSPF model the following values will need to be calculated for and predominantly using the *DrainageLine* shapefile produced by the Arc Hydro Tools manual processing method (section 3.2.2). Calculations are undertaken in ArcMap in order to create the .ptf (channel geometry) and .rch (reach) HSPF input files. Further detail can be found in Appendix A.

- **Catchment ID**
  - Indicates the HSPF model and is used for reference.
  - Manually added to an attribute field, based on the model being processed.

- **Sub-Catchment ID**
  - Indicates the HSPF model sub-catchment.
  - Reclassified from the feature attributes in the *DrainageLine* shapefile.

- **Reach Length (miles)**
  - Length of the representative drainage line (reach) contained in each sub-catchment in miles.
  - Creation of a new field (Float type) called *RCH_len_mi* to the Arc Hydro *DrainageLine* shapefile and populated by calculating the length of each *DrainageLine* feature in *miles*.

- **Reach Length (feet)**
  - Length of the representative drainage line (reach) contained in each sub-catchment in feet.
  - Creation of a new field (Float type) called *RCH_len_ft* to the Arc Hydro *DrainageLine* shapefile and populating the new field by calculating the length of each *DrainageLine* feature in *feet*.

- **Delth**
  - The difference in maximum and minimum elevation (in feet) along the sub-catchment reaches.
  - The *Zonal Statistics as Table* tool is used to extract the range of elevation (difference in minimum and maximum elevations) from the *DEM* which coincide with the *DrainageLine* shapefile features.
  - The table containing the elevation range is joined to the *DrainageLine* shapefile by their sub-catchment IDs and the values stored in a new *Delth* field (Float type).

- **Reach - Average Elevation**
  - The average elevation (in feet) along the sub-catchment reaches.
  - The *Zonal Statistics as Table* tool is used to extract average elevation from the *DEM* which coincide with the *DrainageLine* shapefile features (this can be calculated consecutively elevation range).
  - The table containing the average elevations is joined to the *DrainageLine* shapefile by their sub-catchment IDs and the average elevation transferred to a new field (Float type).

- **Reach - Average Slope**
  - The average percent rise slope along the sub-catchments reaches.
  - A Slope grid in percent rise is calculated from the DEM using the *Slope* Tool.
  - The *Zonal Statistics as Table* tool is used to extract average slope from the *Slope* grid where it coincides with the *DrainageLine* shapefile features.
  - The table containing the average slope values per sub-catchment reach is joined to the *DrainageLine* shapefile by their sub-catchment IDs and the average slope is transferred to a new field (float type) and is divided by 100 to put the values in a range of 0 and 1, instead of 0 and 100.

- **Downstream Sub-catchment ID**
  - This data records the linkages between the sub-catchments and shows which downstream sub-catchment each sub-catchment drains into.
  - It requires the conversion of the *NextDownID* field in the *DrainageLine* attributes into HSPF sub-catchment IDs.
  - This is achieved by joining the *DrainageLine* shapefile to itself using the *NextDownID* and *HydroID* fields. The *HydroID* field acts as an intermediary field to allow the NextDownID to be translated to the HSPF sub-catchment ID.
  - A sub-catchment which does not drain into another sub-catchment (i.e. it exits the model) should be given a downstream sub-catchment ID of *-1*. There should only be one exit for each model.

For each HSPF model the following values will also need to be calculated for and predominantly using the *Catchment* shapefile produced by the Arc Hydro Tools manual processing method (section 3.2.2). Calculations are undertaken in ArcMap in order to create the .wsd (Watershed) HSPF input file. Further detail can be found in Appendix B.

- **HSPF Land Use Category**
  - The HSPF land use categories present in each model sub-catchment
  - Taken from the HSPF land use file (section 3.4 and 3.6) and processed using a combination of *clip*, *union* and *dissolve* geoprocessing tools to create multipart features which are represented by a single attribute record per land use category, per sub-catchment.
  - Areas representing he HSPF category 'Built-up areas' are duplicated and their calculated area halved to represent a 50% split between impervious and pervious land type.

- **Sub-catchment – Average Slope**
  - The average percent rise slope within the sub-catchments.
  - Uses the Slope grid in percent rise that has been calculated from the DEM using the *Slope* Tool (used for *Reach – Average Slope*).
  - The *Zonal Statistics as Table* tool is used to extract average slope from the *Slope* grid where it coincides with the *Catchment* shapefile HSPF sub-catchment features
  - The table containing the average slope values per sub-catchment reach is joined to the *Catchment* shapefile by their sub-catchment IDs and the average slope is transferred to a new field (float type) and is divided by 100 to put the values in a range of 0 and 1, instead of 0 and 100.

- **Sub-catchment Area**
  - The area of each HSPF sub-catchment in *acres*.
  - Creation of a new field (Float type) called *Area* to the Arc Hydro *Catchment* shapefile and populating the new field by calculating the area of each *Catchment* shapefile HSPF sub-catchment feature in *acres*.

- **Type**
  - Indicates if the land is impervious or pervious, only relevant to the 'Built-up areas' HSPF land use category.
  - A value of *1* = impervious, *2* = pervious.

4.2.2 HSPF Input File Formatting

Once the processing and calculation of the necessary values for the creation of the HSPF input files in ArcMap has been completed the attribute tables of the *DrainageLine* shapefiles and *Catchment* shapefiles (or the subsequently created *WSD* shapefiles if following the process detailed in Appendix B) can be exported.

The exported attribute data can be opened in MS Excel which can then be used to sort the data into the correct order and add additional fields which contain a series of default values. This data should be saved as a space delimited text file, without header information. The text files can then be opened and the header row inserted separately – this is because the header row is comma delimited. The exact formatting is described in Appendices C – F and examples have been included for each of the four HSPF input files. Care should be taken with speech marks that are required for certain text fields (these can be added in Excel prior to saving as a text file) and the variation in number of decimal places used for different fields.

The source of the contents of each of the four HSPF input fields is detailed in the tables below. These are a combination of the values calculated from GIS (4.2.1) and default values which are entered manually.

- **.psr File (Point Sources)**

Point source data in HSPF is added at a later stage as it is represented by time-series .wdm data files. A default entry is used (as shown in Appendix C) and the same file can be renamed and used for all HSPF catchments.

- **.ptf File (Channel Geometry)**

The .ptf file contains the fields listed in table 4.1. Values taken from the GIS processing of the *DrainageLine* shapefile are shown in square brackets, other values are default values shown in the appropriate format. No speech marks are required for the *Type of x-section* entry.

An example of the .ptf file and additional description is provided in Appendix D.

Field	Value
Reach Number	[Sub-catchment ID]
Length(ft)	[Reach Length (ft)]
Mean Depth(ft)	5.00000
Mean Width (ft)	30.00000
Mannings Roughness Coeff.	0.05
Long. Slope	[Reach - Average Slope]
Type of x-section	Trapezoidal
Side slope of upper FP left	0.5
Side slope of lower FP left	0.5
Zero slope FP width left(ft)	30.000
Side slope of channel left	1
Side slope of channel right	1
Zero slope FP width right(ft)	30.000
Side slope lower FP right	0.5
Side slope upper FP right	0.5
Channel Depth(ft)	6.2500
Flood side slope change at depth	9.3750
Max. depth	312.500
No. of exits	1
Fraction of flow through exit 1	1
Fraction of flow through exit 2	0
Fraction of flow through exit 3	0
Fraction of flow through exit 4	0
Fraction of flow through exit 5	0

Table 4.1: Fields and Values Required for the Creation of the HSPF .ptf Input File

- **.rch File (Reach)**

The .rch file contains the fields listed in table 4.2. Values taken from the GIS processing of the *DrainageLine* shapefile are shown in square brackets, other values are default values shown in the appropriate format. Speech marks are required either side of the value provided in the *Pname* field regardless of if the value is numeric or text.

An example of the .rch file and additional description is provided in Appendix E.

Field	Value
Rivrch	[Sub-catchment ID]
Pname	[Sub-catchment ID]
Watershed-ID	[Sub-catchment ID]
HeadwaterFlag	0
Exits	1
Milept	0
Stream/Resevoir Type	S
Segl	[Reach length (miles)]
Delth	[Delth]
Elev	[Reach - Average Elevation]
Ulcsm	0
Urcsm	0
Dscsm	[Downstream subcatchment ID]
Ccsm	0
Mnflow	0
Mnvelo	0
Svtnflow	0
Svtnvelo	0
Pslope	[Reach - Average slope]
Pdepth	5.0000
Pwidth	30.000
Pmile	0
Ptemp	0
Pph	0
Pk1	0
Pk2	0
Pk3	0
Pmann	0
Psod	0
Pbgdo	0
Pbgnh3	0
Pbgbod5	0
Pbgbod	0
Level	0
ModelSeg	1

Table 4.2: Fields and Values Required for the Creation of the HSPF .rch Input File

- **.wsd File (Watershed)**

The .wsd file contains the fields listed in table 4.3. Values taken from the GIS processing of the *Catchment* (and subsequent *WSD*) shapefile are shown in square brackets, other values are default values shown in the appropriate format. Speech marks are required either side of the value provided in the *LU Name* field. The data in the .wsd file is delimited by five spaces (as opposed to a standard single space in the other input files). This was adhered to in order to be consistent with the format provided by other .wsd examples and the .wsd files create using BASINS.

An example of the .wsd file and additional description is provided in Appendix F.

Field	**Value**
LU Name	[HSPF Land use category]
Type (1=Impervious, 2=Pervious)	[Type]
Watershd-ID	[Sub-catchment ID]
Area	[Sub-catchment Area]
Slope	[Sub-catchment – Average Slope]
Distance	0

Table 4.3: Fields and Values Required for the Creation of the HSPF .wsd Input File

Once created the four HSPF input files should all be given the same file name while keeping their respective file extensions. It is sensible for the filename to be the same as the HSPF model ID. The four HSPF input files are also required to be stored in the same directory, only the .wsd file is located when creating an HSPF model using WinHSPF – the program expects the remaining files to be located in the same directory.

5. Create HSPF Model (Part 1 - Hydrological)

The WinHSPF software has been used to create the HSPF model. It does this by constructing a .uci (User Control Input) file (see Appendix G) from the model configuration and parameters that are selected. WinHSPF streamlines and standardises the creation of the .uci file and also provides a GUI with which to make changes to the model configuration and parameters. It is also possible to make changes directly to the .uci file, but in general using WinHSPF reduces the possibility of errors and allows for a consistent method to be adopted. The GUI provided by WinHSPF also allows for some visual inspection as you configure the model.

The following steps take you through the process of creating a new hydrological HSPF model using WinHSPF. This model can then be run to obtain outputs for flow and can be edited subsequently to change hydrological parameters as well as add the water quality component to the model and simulate Faecal Coliform.

5.1 Create HSPF Project

- Open WinHSPF from windows start menu
- Create a new project
  - *File>Create*
- Choose BASINS Watershed File
  - Click *Select*
  - Navigate to and open a saved HSPF input .wsd file
  - Click *Open*
- Choose Met WDM File
  - Click *Select*
  - Navigate to and open Met .wdm file
  - Click *Open*
- Create output Project WDM File
  - Click *Select*
  - Navigate to the desired output directory
  - Enter a name for the output .wdm file
  - Click *Open*
- Set the Initial Met Station
  - Choose the most common rain gauge location from the sub-catchments within the model catchment – this saves work when assigning met segments later. (See *Rain gauge location* in section 3.3.1).
- Set Model Segmentation
  - Check *Individual*

- The WinHSPF – Create Project should appear similar to the screenshot in figure 5.1.

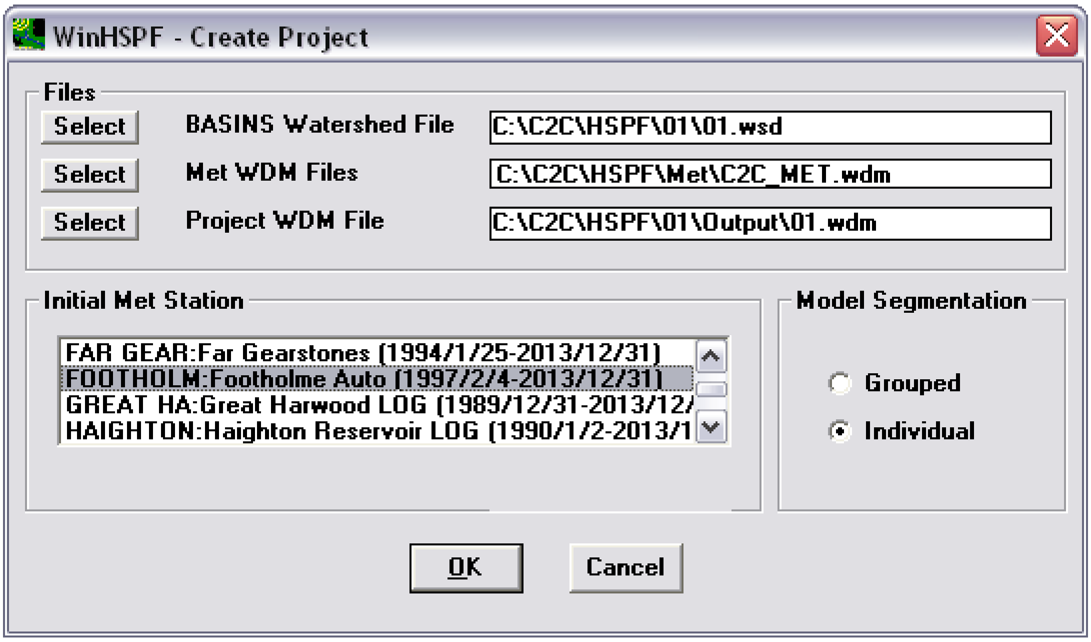


Figure 5.1: WinHSPF – Create Project

- Click *OK*

5.2 Define Initial Met Segment

- An Initial Met Segment window opens.
- For *Precip* and *Pot Evap* select the *TSTYPE* and *Data Set* values indicated in Table 5.1 by double-clicking in the corresponding cell in the Initial Met Segment window and choosing the value from the drop down list:

Constituent	TSTYPE	Data Set
Precip	PREC	[rain gauge dataset location]
Pot Evap	PEVT	[potential evapotranspiration dataset location]

Table 5.1: WinHSPF – Initial Met Segment Data

- Clear the *TSTYPE* entries for the remaining constituents by double-clicking the corresponding cell and pressing backspace or delete, then clicking out of the cell.
- Clearing the *TSTYPE* entries should also clear the *Data Set* entries, if not these should be cleared as well.
- The initial Met Segment window should look similar to figure 5.2.

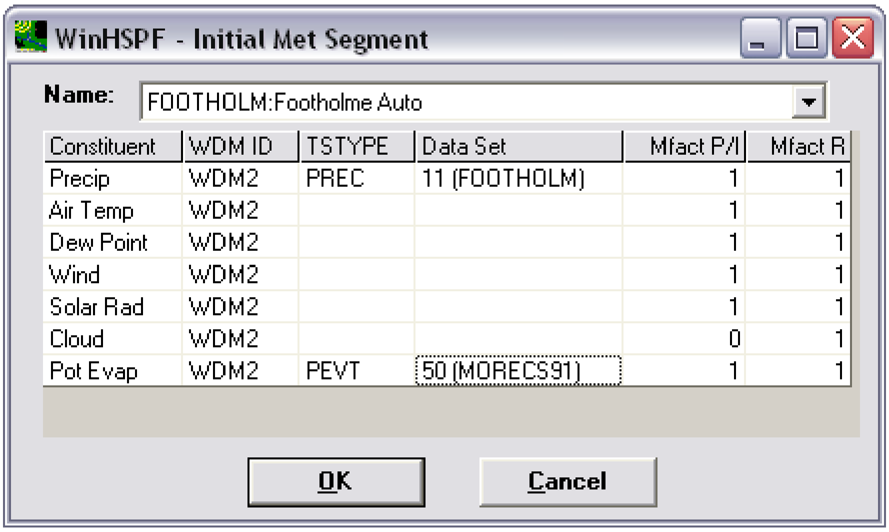


Figure 5.2: WinHSPF – Initial Met Segment

- Click *OK*

5.3 WinHSPF GUI

- The WinHSPF GUI will open and appear similar to figure 5.3.

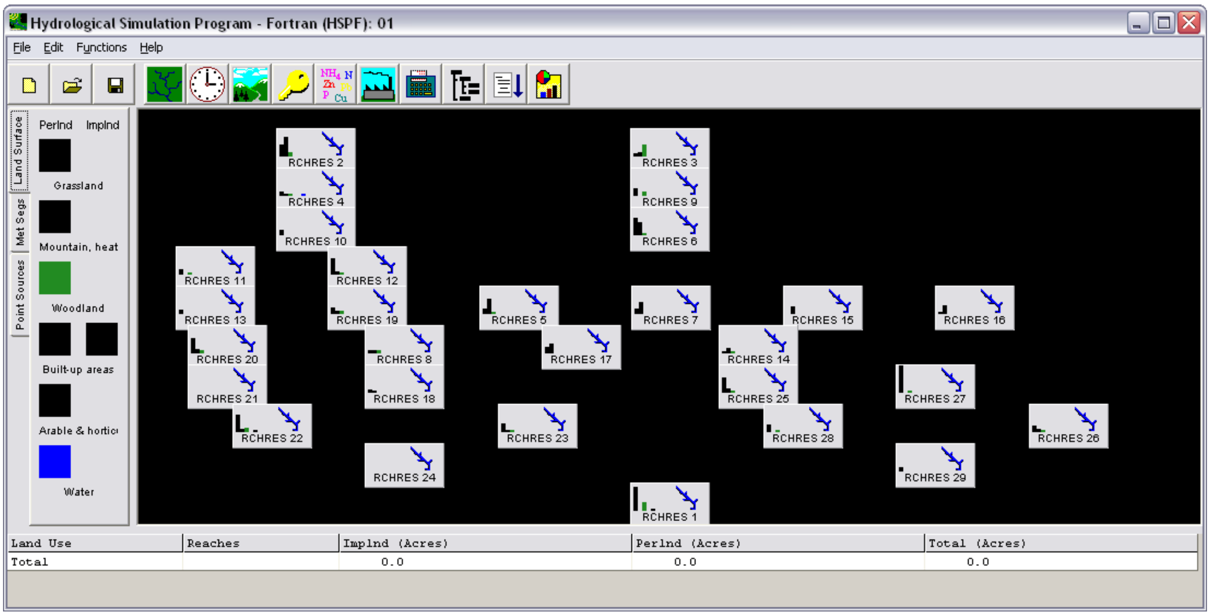
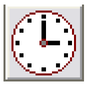


Figure 5.3: WinHSPF GUI

The main window shows the layout of the model sub-catchments (other versions of the WinHSPF software will have the connections between the sub-catchments visible) along with a bar chart indicating the land use breakdown for each sub-catchment. The model can be configured using the buttons on the toolbar on the top. Parameters for the model can be changed and inspected by double-clicking on each sub-catchment in the main window.

5.4 Set Model Simulation Time and Met Segments

- Click the *Simulation Time and Meteorological Data* button 
- Enter the start date and time as: 2003/01/01 00:00
- Enter the end date and time as: 2012/12/30 00:00

Reason: The dates are encompassed in the temporal range of all of the rain gauge and potential evapotranspiration data and provide sufficient 'run in' time for the model to be accurate for the chosen 2012 analysis year. The end date was limited by the data that was available for potential evapotranspiration, rain gauge data went beyond that date.

- The *Simulation Time and Meteorological Data* window will appear similar to figure 5.4.

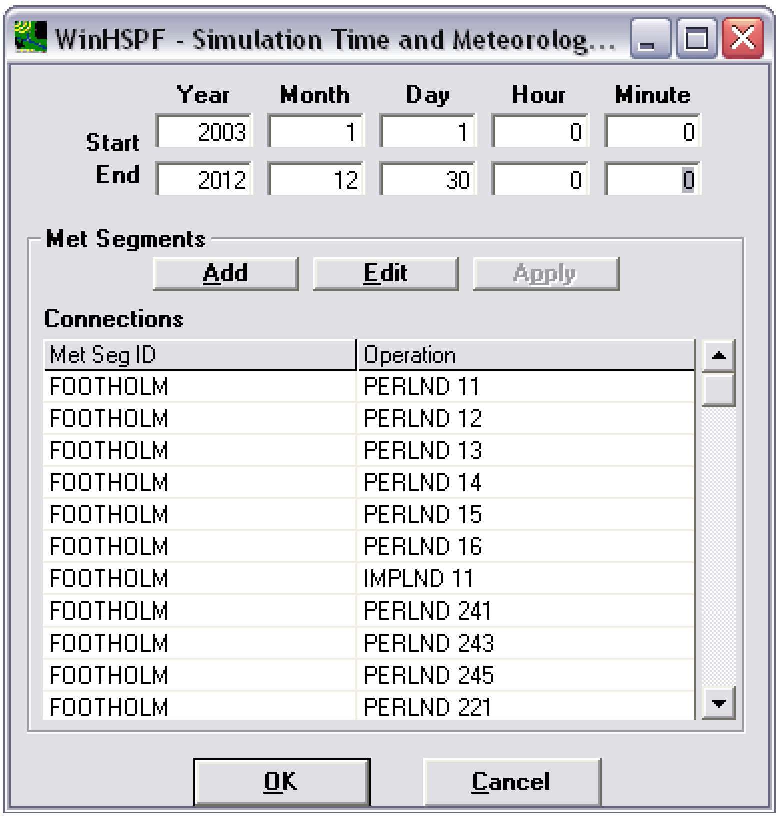


Figure 5.4: WinHSPF – Simulation Time and Meteorological Data

- In the *Met Segments* section click *Add*
- Fill out the Met Segment information for each *Precip* and *Pot Evap* combination present in the model catchment (see *Rain gauge location* in section 3.3.1).
- Click the drop down arrow next to the segment *Name* to select the next Met (rain gauge) location from the list.
- Link the Met constituents with the appropriate datasets. This is done in the same way as setting up the initial met segment.
- An example is shown in figure 5.5.

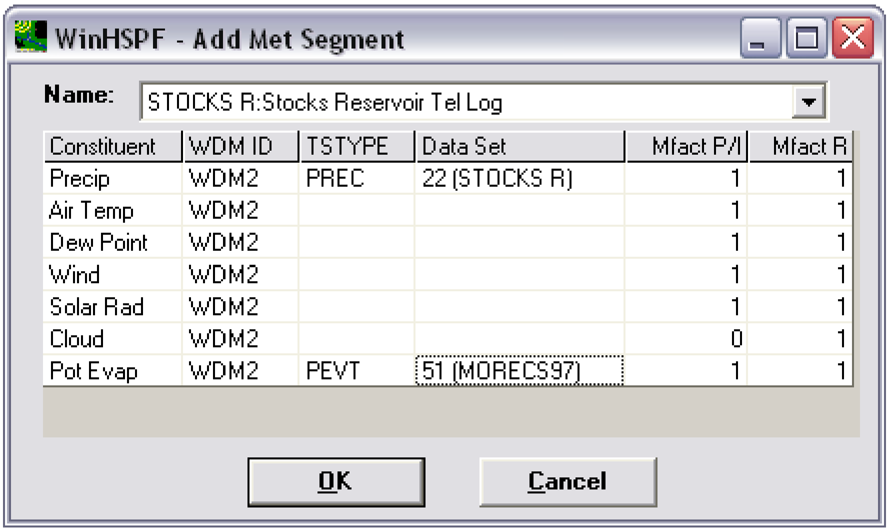


Figure 5.5: WinHSPF – Add Met Segment

- Click *OK*
- Repeat the process until all Met Segments present in the model catchment have been defined and added.
- Note: Having two Met Segments with the same *Precip* location and different *Pot Evap* data sets is problematic for data entry – they are not clearly distinguishable when it comes to selection, either by the user or the software. For this reason select a single *Pot Evap* data set which is most common for the sub-catchments at each *Precip* data set location.

As the model has been set to individual segmentation the Met Segments need to be linked to both the land uses and the reaches within each sub-catchment. This is done by assigning a Met Segment to each model *Operation*. These are listed as PERLND (pervious land), IMPLND (impervious land) and RCHRES (reach/reservoir). In the case of PERLND and IMPLND the included number identifies the sub-catchment and the land use type. The final value indicates the land use number, the (1 or 2) numbers prior to that indicate the sub-catchment. For example:

PERLND 14 = sub-catchment 1, land use type 4
IMPLAND 251 = sub-catchment 25, land use type 1

For RCHRES operations the number listed identifies the sub-catchment only. For example:

RCHRES 14 = sub-catchment 14.

- Double-click the *Met Seg ID* cell for each *Operation* and choose the appropriate Met Segment by identifying the *Operation* sub-catchment (as detailed above). You only need to amend the *Met Seg ID* of the *Operations* where the Met Segment is not correct (this is why the initial Met Station was selected as the most common location from the sub-catchments.
- Amend all *Met Seg ID* values.
- The *Simulation Time and Meteorological Data* window will now appear similar to figure 5.6.

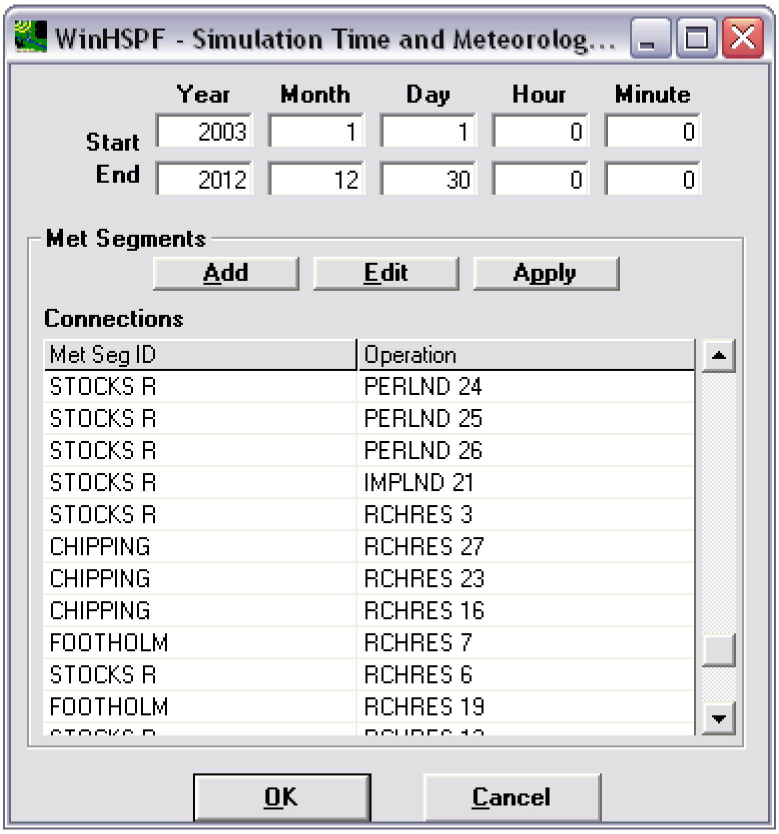


Figure 5.6: WinHSPF - Simulation Time and Meteorological Data with Completed Met Segments

- Click *OK*
- Click the *MET Segs* tab on the left of the programme window to get a visual overview of the Met Segments. This is useful to check that you have entered all of the Met Segments in correctly.
- See figure 5.7 for an example view (*MET Segs* tab highlighted with red box):

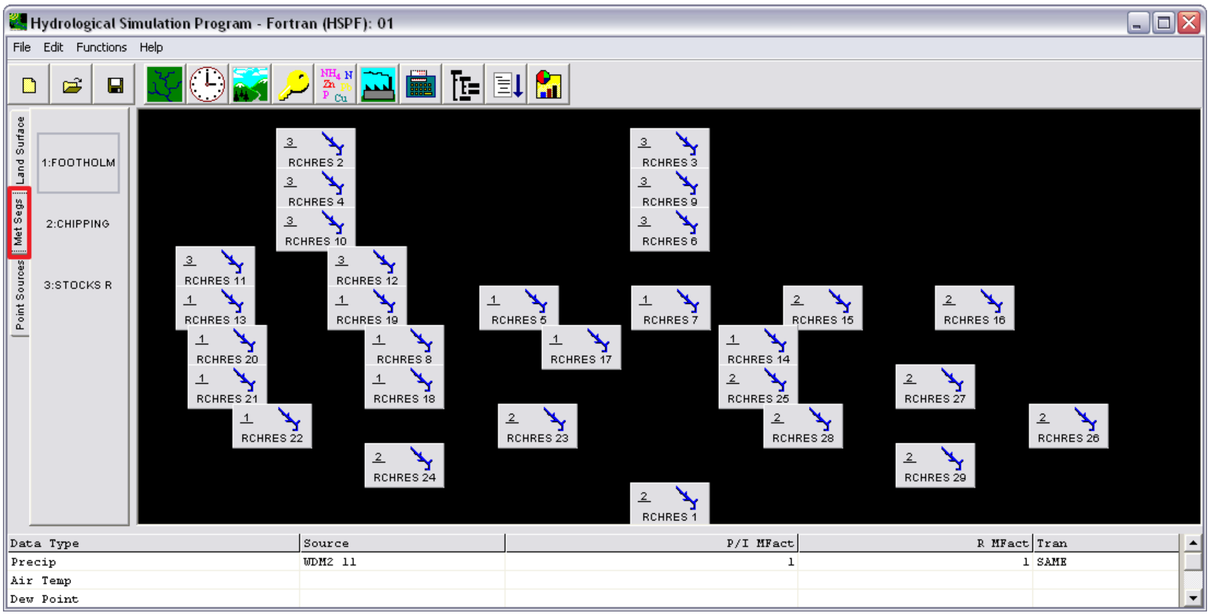


Figure 5.7: WinHSPF – Met Segments Visual Overview

5.5 Change Hydrological Parameters

Hydrological parameters can be adjusted to replicate observed or estimated values of the conditions present in the mode catchments. They will also be adjusted during the calibration process. The hydrological parameters are stored in the model .uci file. It is possible to change these parameters through WinHSPF, which ensures file format consistency, or directly in the .uci text file. Parameters can be stored for individual model components or operations, that is to say for each land use type within each sub-catchment. Where parameters are common between consecutive operations they can be grouped to represent a range of model operations. Because a large number of edits may be required to the .uci when adjusting parameters it is recommended to edit the .uci text file directly. For single edits to model operations editing within WinHSPF may be preferable.

5.5.1 HSPF Hydrological Parameters

A full description of the HSPF parameters is provided in the BASINS Technical Note # 6 (see Appendix H). The key Hydrological parameters are listed in the pervious land hydrology section (PWATER) and the impervious land hydrology section (IWATER).

5.5.2 Editing Parameters within WinHSPF

Editing parameters within WinHSPF requires selecting each model operation individually and opening a series of forms and windows. This makes for a time consuming process when multiple parameter changes are required. The advantage of editing parameters within WinHSPF is that the .uci formatting is undertaken by WinHSPF are removes the chances of breaking the strict .uci file formatting. Some guidance and description is also given as to the nature of the parameters and some appropriate value ranges which can make this a useful way of learning about the model parameters.

- Have WinHSPF open with a model loaded
- To access the HSPF model parameters go to *Edit>OPN* Sequence

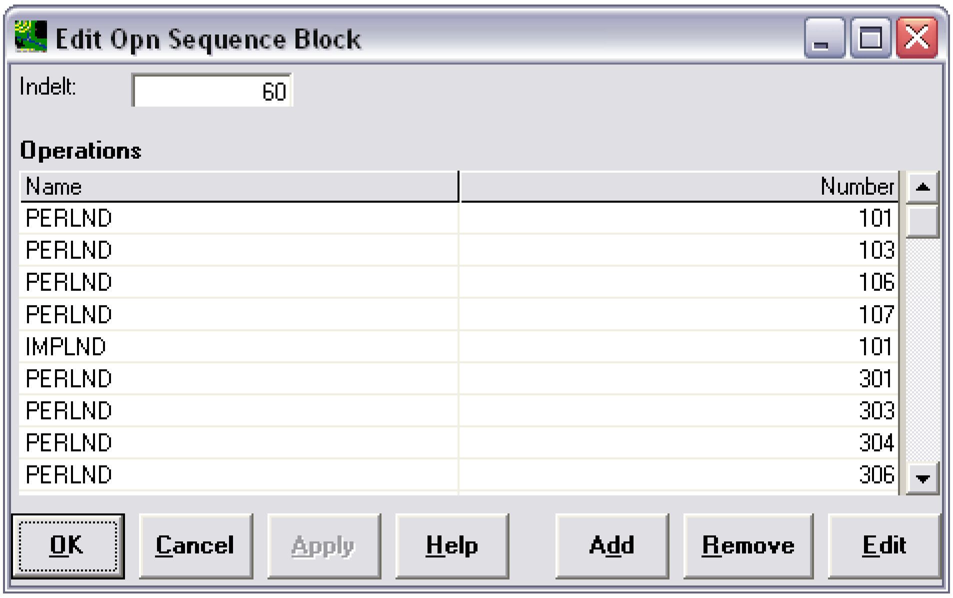


Figure 5.8: Edit Opn Sequence Block Window

- In the *Edit Opn Sequence Block* window that opens (figure 5.8) select the required *Operation* and click *Edit*
- The *Edit Operation* window for the selected *Operation* is opened (figure 5.9). This lists the parameter and configuration tables in use (both required and optional) as well as additional optional tables that are not in use.

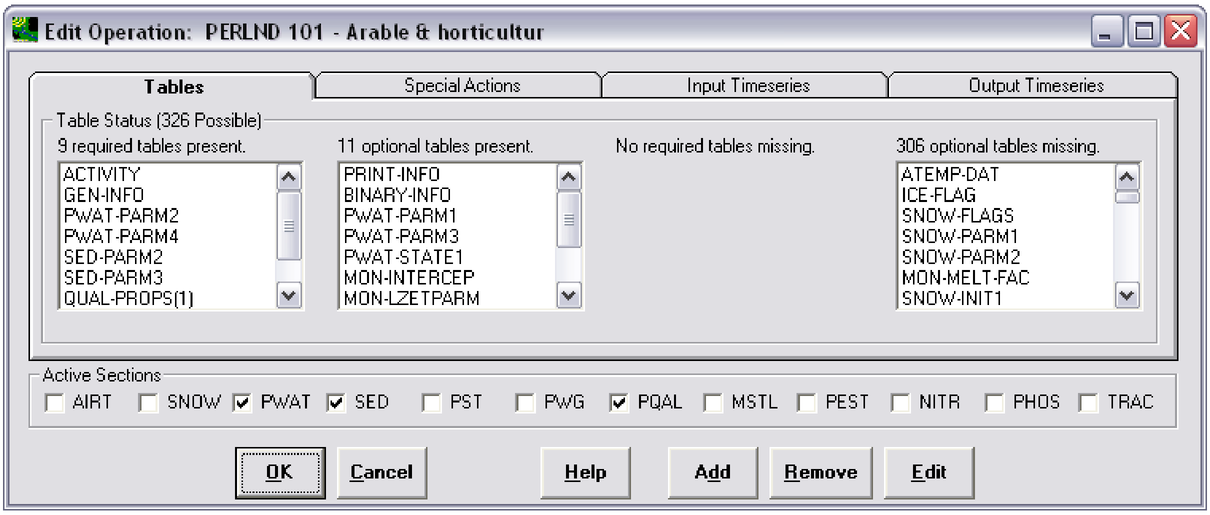


Figure 5.9: Edit Operation Window (PERLND 101)

- To open a parameter table, select one from the required or optional tables present lists and click *Edit*.
- Note: Hydrological parameters are stored in *PWAT* tables for pervious (*PERLND*) operations and *IWAT* tables for impervious (*IMPLND*) operations.

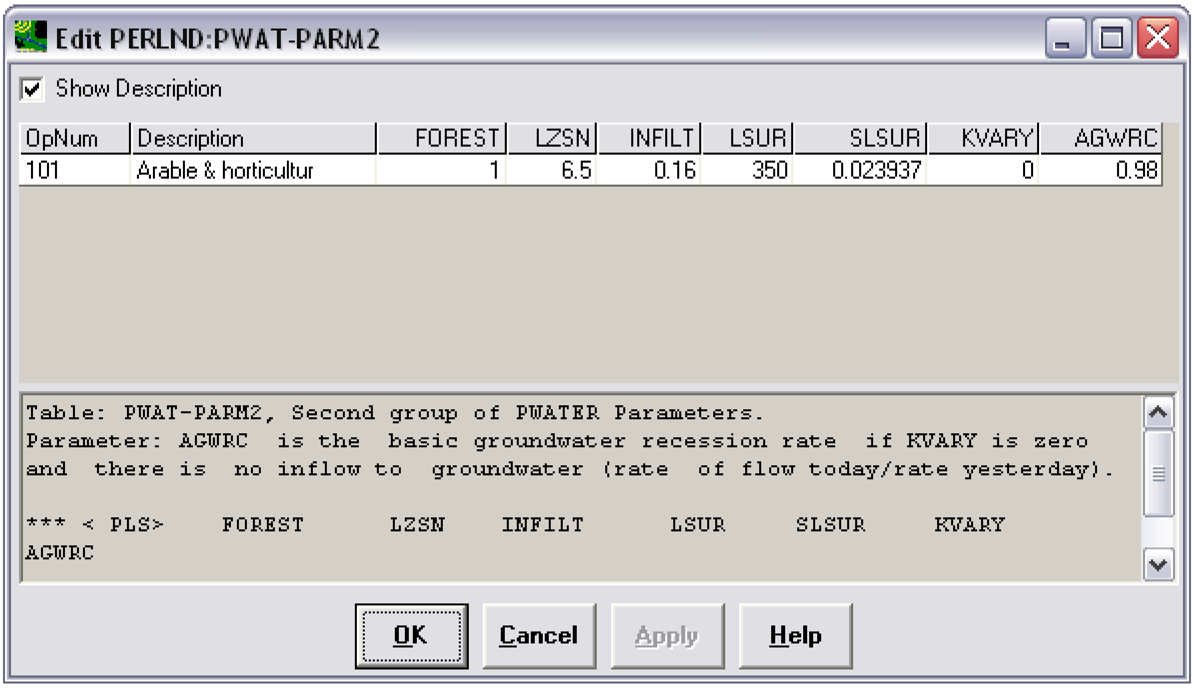


Figure 5.10: Edit PERLND:PWAT-PARM2 Window

- Figure 5.10 shows an example of an *Edit PERLND:PWAT-PARM2* window which opens when choosing to edit a *PWAT-PARM2* table from the *Edit Operation* window.
- Parameter values can be changed by clicking in the table and editing the entries.

- Clicking on each header or entry will also provide a description of the parameter in the text box below.
- To save any parameter changes made to the *Edit PERLND:PWAT-PARM2* window click *Apply* or *OK*.
- Repeat the steps to make edits to parameters in any other tables and for any other model operations required.

5.5.3 Editing Parameters Directly in the .uci File

If multiple parameter changes are required, which will need to be performed in several parameter tables and for different model operations then it is more efficient to make the changes direct to the .uci file. Care needs to be taken to maintain the formatting of the .uci file when editing parameter values. The HSPF model relies on the formatting to be able to read the .uci file and perform the instructions accordingly, even small changes can cause the .uci file to become unreadable and corrupt.

- Locate the relevant model .uci file
- Create a copy of the .uci file as a backup in case of error.
- Open the .uci file using a text editor such as MS Notepad.
- Scroll down the .uci file (a full example is included in Appendix G) to find the PWAT (for pervious land) or IWAT (for impervious land) parameter sections or modules. These sections are where the parameter data is stored and so are directly equivalent to the tables that can be opened in WinHSPF (section 5.5.2).

```
PWAT-PARM2
*** < PLS>    FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
*** x  - x                (in)   (in/hr)      (ft)              (1/in)   (1/day)
  101  102        1.       6.5      0.16       350  0.022366        0.      0.98
  103             0.        4.      0.16       350  0.022366        0.      0.98
  104  105        1.       6.5      0.16       350  0.022366        0.      0.98
  201  205        1.       6.5      0.16       350  0.028335        0.      0.98
  301  302        1.       6.5      0.16       350  0.026583        0.      0.98
  303             0.        4.      0.16       350  0.026583        0.      0.98
  304  305        1.       6.5      0.16       350  0.026583        0.      0.98
  END PWAT-PARM2
```

Figure 5.11: PWAT-PARM2 Module of HSPF .uci File

- Figure 5.11, 5.12 and 5.13 show examples of the *PWAT-PARM2*, *PWAT-PARM3* and *PWAT-PARM4* parameter sections. The < PLS> column identifies the model *Operation number* and can be seen to group the operations in different ways. Figure 5.11 shows the operations grouped by land use (with the exception of operation 103 and 303). Figures 5.12 and 5.13 show all operations grouped together, indicating that the same parameter values in those sections are applied throughout.

```
  PWAT-PARM3
*** < PLS>    PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
*** x  - x   (deg F)   (deg F)
  101  305       40.       35.        2.        2.       0.1      0.02        0.
  END PWAT-PARM3
```

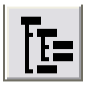
Figure 5.12: PWAT-PARM3 Module of HSPF .uci File

```
  PWAT-PARM4
*** <PLS >     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP
*** x -  x      (in)      (in)                       (1/day)
  101  305       0.1     1.128       0.2      0.75       0.5       0.1
  END PWAT-PARM4
```

Figure 5.13: PWAT-PARM4 Module of HSPF .uci File

- Changes to the groupings maybe as a result of user intervention, land use differences or different met segments.
- To edit values simply type over the existing values for the appropriate operation and parameter.
- Ensure that you are replacing the value with a matching format and that you are maintaining the space separation between parameters.
- To save edits to the model parameters chose *File>Save* (in MS Notepad).
- Close Notepad
- Reopen the model by selecting the saved .uci file in WinHSPF (*File>Open*).
- Direct changes to the .uci file can be checked in WinHSPF using the steps outlined in section 5.5.2.
- If an error occurs when opening or running a model in which direct parameter changes have been made, revert back to the backup copy and attempt to make the changes again.

5.6 Add Model Flow Output

- Click the *Output Manager* button 
- Select the *Output Type* as *Flow*.
- Click *Add*.
- An *Add Output* window opens.
- In the *Operation* window select the furthest downstream or exit sub-catchment. (By default the model includes a daily output of flow for this sub-catchment so you can find the sub-catchment number from the RCHRES number listed in the *Output Locations*.
- Check *Hourly*.
- Other values can remain at their defaults.
- The *Add Output* window will appear similar to figure 5.14.

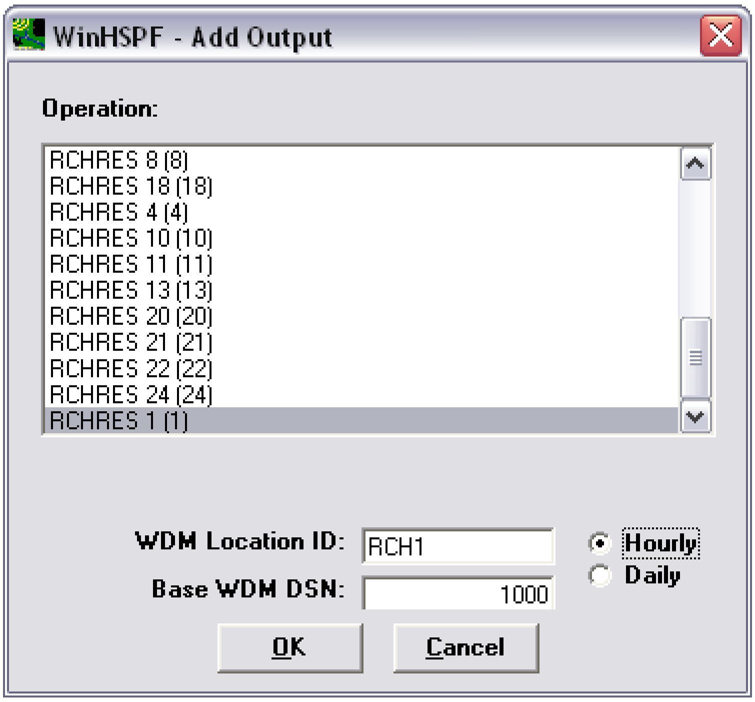


Figure 5.14: WinHSPF – Add Output Window

- Click *OK*.
- The *Output Manager* window will look similar to figure 5.15.

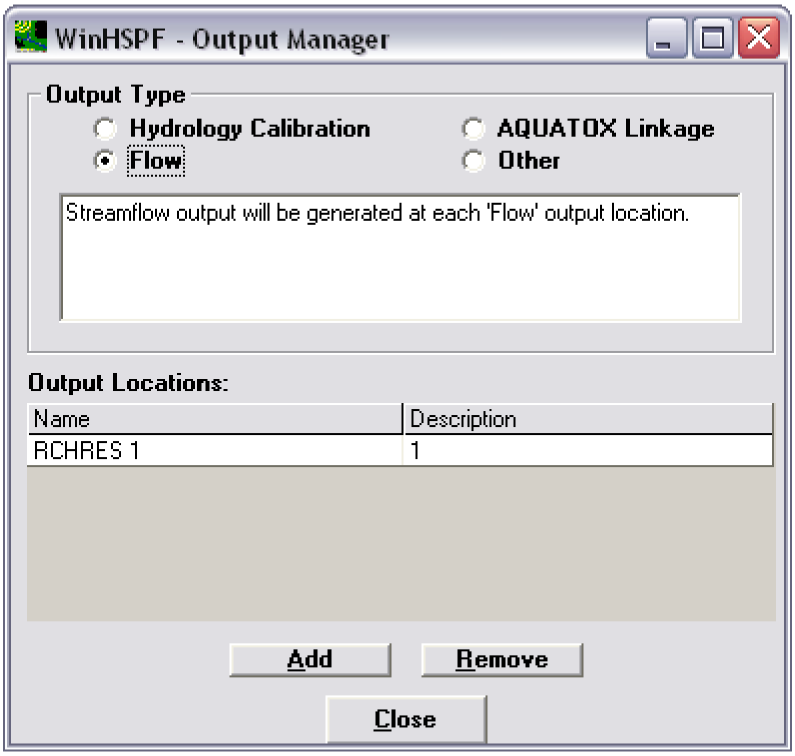


Figure 5.15: WinHSPF – Output Manager

- Click *Close*.

The model can now be run to generate hourly (and daily) flow for the modelled catchment. At this point you can attempt further calibration of the hydrological HSPF model and generate further outputs. Further information on how to do this is available in later sections.

- Click the *Run HSPF* button 
- WinHSPF asks if you wish to save new changes to the model (see figure 5.16)

Figure 5.16: WinHSPF – Save New Changes & Run

- Click *Save/Run* to save and run the model.
- You can also save the model without running it by going to *File>Save* or *File>Save As*.

6. FIO

FIO data is entered into the model separately for rural and urban regions. Rural FIO accumulation is undertaken using the U.S. EPA Bacteria Indicator Tool (BIT) spreadsheet which takes a range of data and reference values and uses them to quantify bacteria contribution from multiple sources. The urban data is produced by Will Shepherd in WP1 using the InfoWorks model. FIO data in the form of E.Coli and Confirmed Enterococci are provided as time series data inputs which can be added as point sources to the HSPF model.

6.1 Bacteria Indicator Tool

The Bacteria Indicator Tool is a tool provided by the U.S. EPA in the form of a spreadsheet. The spreadsheet contains a series of worksheets which cover land use, animal populations, manure application and grazing habits. The user inputs values for these factors which are then combined with reference bacteria accumulation rates from literature to calculate bacteria accumulation for the model catchment. Additional worksheets to represent direct bacteria input to streams by cattle and contributions from failing septic tanks are also included, these can be entered into the HSPF model as point source inputs.

A full set of documentation for the BIT spreadsheet as well as the spreadsheet itself and working examples is available for download from the U.S. EPA website (for link see Bacteria Indicator Tool (BIT) section in Appendix H). The U.S. EPA documentation should be used as the primary reference for the BIT. A practical exercise is also available for preparing the BIT and entering accumulation values from the BIT into WinHSPF as covered in section 7.4 (see BASINS Tutorials and Training: Exercise 10 in Appendix H).

This section will detail steps undertaken to prepare data for entry into the BIT spreadsheets for the C2C HSPF models and any C2C specific modifications that have been made to the BIT spreadsheets. Data is taken from the preparation of the HSPF input files as well as the processing of additional sources such as agcensus for animal populations. A restrictive data entry length in the HSPF model has also required a workaround to be found to resolve this issue by converting the values.

6.1.1 Sub-catchments

A BIT spreadsheet is required for each model catchment. The BIT spreadsheets need to be modified so that they are calculating values based on the correct number of sub-catchments present in each HSPF model. This has to be performed for each worksheet in the BIT spreadsheet with additional sub-catchment rows being accounted for in the BIT spreadsheet formulas and calculations. Models with the same number of sub-catchments can use the same blank BIT templates but should be saved separately following data entry.

6.1.2 Land Use

Areas (in acres) of the different land uses within each sub-catchment are required in the *Land Use* worksheet of the BIT spreadsheet. These areas can be taken from the processing of the categorised HSPF Land Use data in the preparation of the *.wsd* HSPF input file (see section 4.2.1).

Built-up areas are not included in the BIT calculations as these are substituted with the urban point source inputs from InfoWorks, which are deemed more accurate. The Cropland, Pastureland and Forest entries in the BIT are represented by the '*Arable & horticultural*', '*Grassland*' and '*Woodland*' HSPF land use categories respectively. The HSPF categories of '*Mountain, heath, bog*', '*Coast, Sea*' and '*Water*' are not used as these land use types are considered to be less significant sources for the rural HSPF models.

6.1.3 Animal numbers (agcensus)

Livestock numbers (and wildlife) are entered into the Animals worksheet in the BIT spreadsheet. Estimates for livestock numbers come from the agcensus dataset provided by EDINA. This dataset converts agricultural census data collected by the government departments concerned with agricultural and rural affairs (DEFRA for England). The original data is collected via postal questionnaire for a stratified random sample of agricultural holdings. The sample data is then imputed to provide estimates for all agricultural holdings in the UK. EDINA use algorithms to convert the data from recognised geographies into 1 km grid squares. These grid squares are then further aggregated into a coarser resolution to ensure anonymity of the data. The smallest resolution of the final agcensus data available is in 2km grid squares, this is the dataset used for C2C BIT calculations. The most recent agcensus data is based on agricultural survey data from 2010.

The agcensus data is provided in tabular spreadsheet form. Each row contains values for a range of surveyed elements which have been aggregated to a 2km by 2km grid square. Coordinates are provided which give the location of the South West (bottom left) corner of the agcensus grid square.

The following describes the steps undertaken to extract the relevant information from the agcensus data, convert the data to a spatial format and then combine the agcensus grid with the HSPF catchments and sub-catchments. This provides a means by which animal counts can be apportioned by area and then summed for each sub-catchment. Ultimately this provides the animal numbers required for entry into the BIT spreadsheet.

- Create a new spreadsheet of data from the original agcensus data table containing data for the following:
    - Easting (X) coordinate
    - Northing (Y) coordinate
    - Beef Cattle
    - Dairy Cattle
    - Sheep
    - Pigs
    - Horses
    - Other
    - Chickens
- If totals are not available for individual livestock types then you may have to sum different groups to create one. For example cattle are grouped by gender, age and purpose (intended for breeding etc.). These need to be combined into totals for dairy and beef cattle.

The next steps are undertaken using the GIS package ArcMap.

- Use the coordinates in the new table of agcensus data to create a point layer.

- Use the *Create Fishnet* tool to create a 2 km by 2km polygon grid which cover the C2C catchments and is based on the locations and spacing of the agcensus data points (See Figure 6.1).

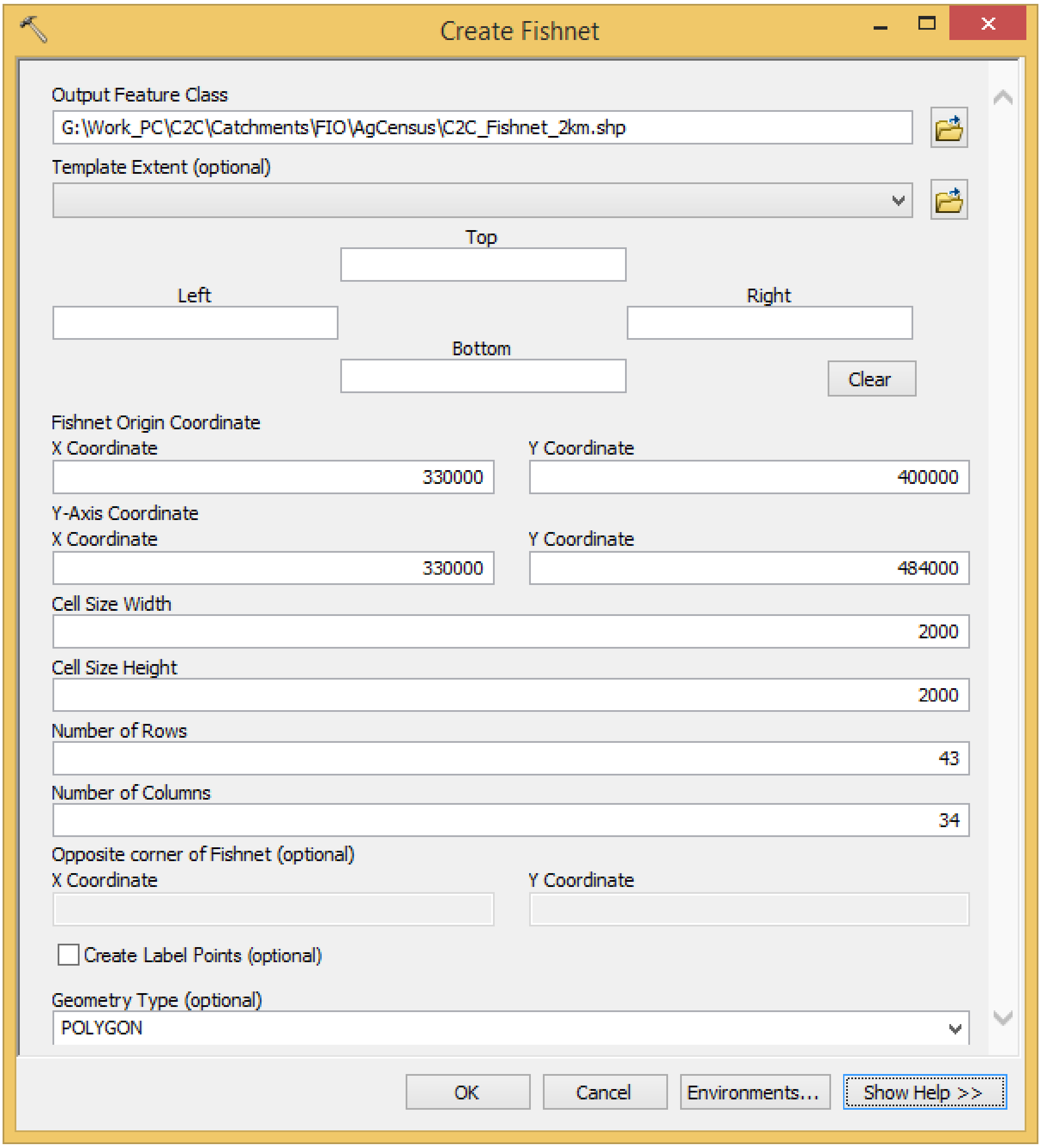


Figure 6.1: Completed Create Fishnet Form

- Use *Select by Location...* to select the fishnet cells that intersect with (lie on top of) the C2C model catchments (Figure 6.2).
- Export the selection of fishnet cells
  - Right-click the fishnet layer in the ArcMap ToC, go to *Data>Export Data...*. Export selected features as a new shapefile.

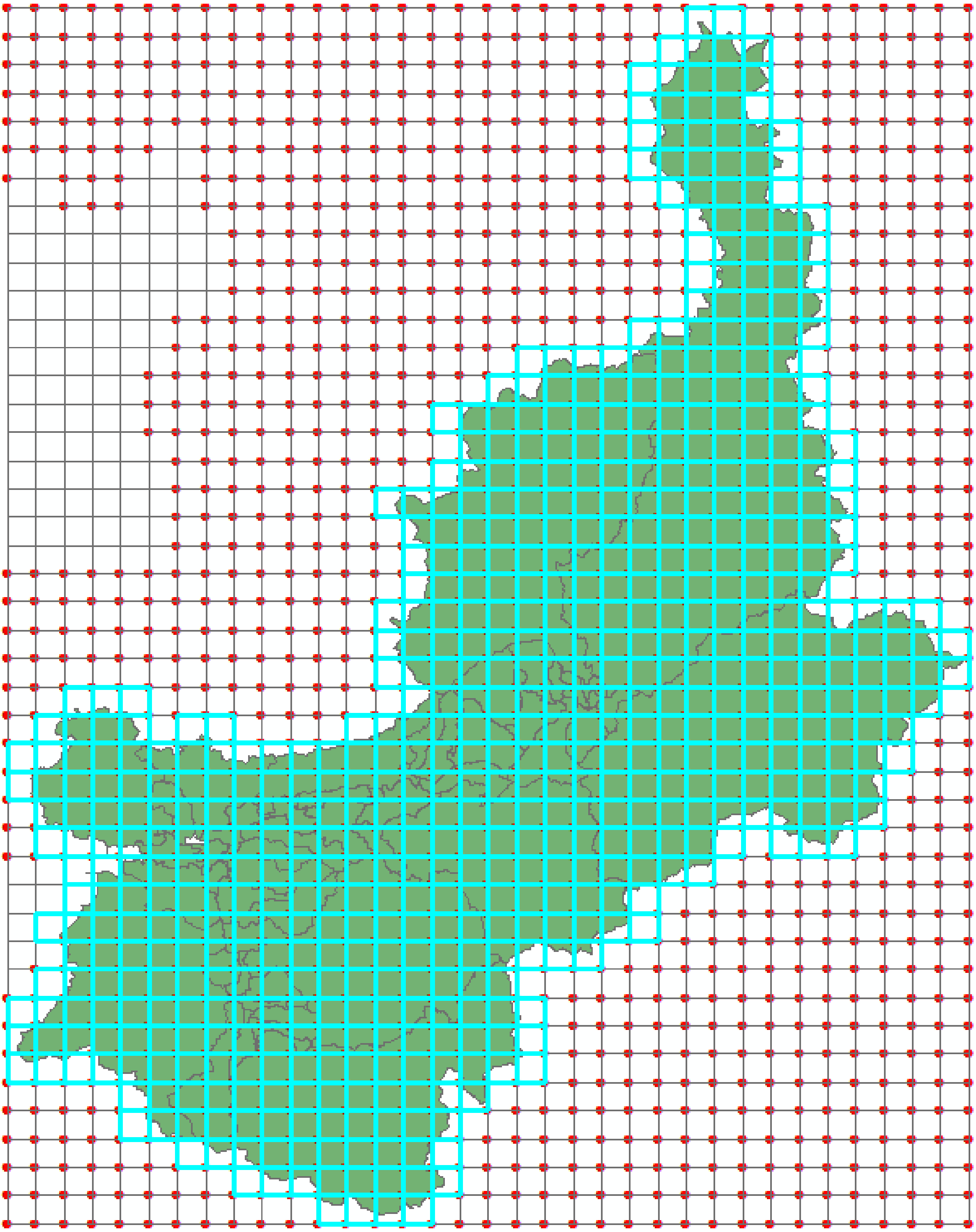


Figure 6.2: Selected Fishnet Cells Intersecting the C2C Model Catchments. Red Points Indicate the Provided agcensus Data Locations.

- Modify the coordinates of the agcensus subset data (create new fields either in ArcGIS or Excel) and calculate the coordinates so that they are equal to the original *X* or *Y* coordinate values *+ 100*. This is so the points fall inside the fishnet cells as opposed to lying on the SW corner.
- Create a new point layer for the agcensus subset data based on these modified coordinates.

- Perform a *Spatial Join* of the modified coordinate agcensus subset data to the C2C fishnet cells. This links the agcensus data to the relevant fishnet cell.
    - Right-click the C2C fishnet layer in the ToC, select *Joins and Relates>Joins…*. Fill out the form as shown in figure 6.3

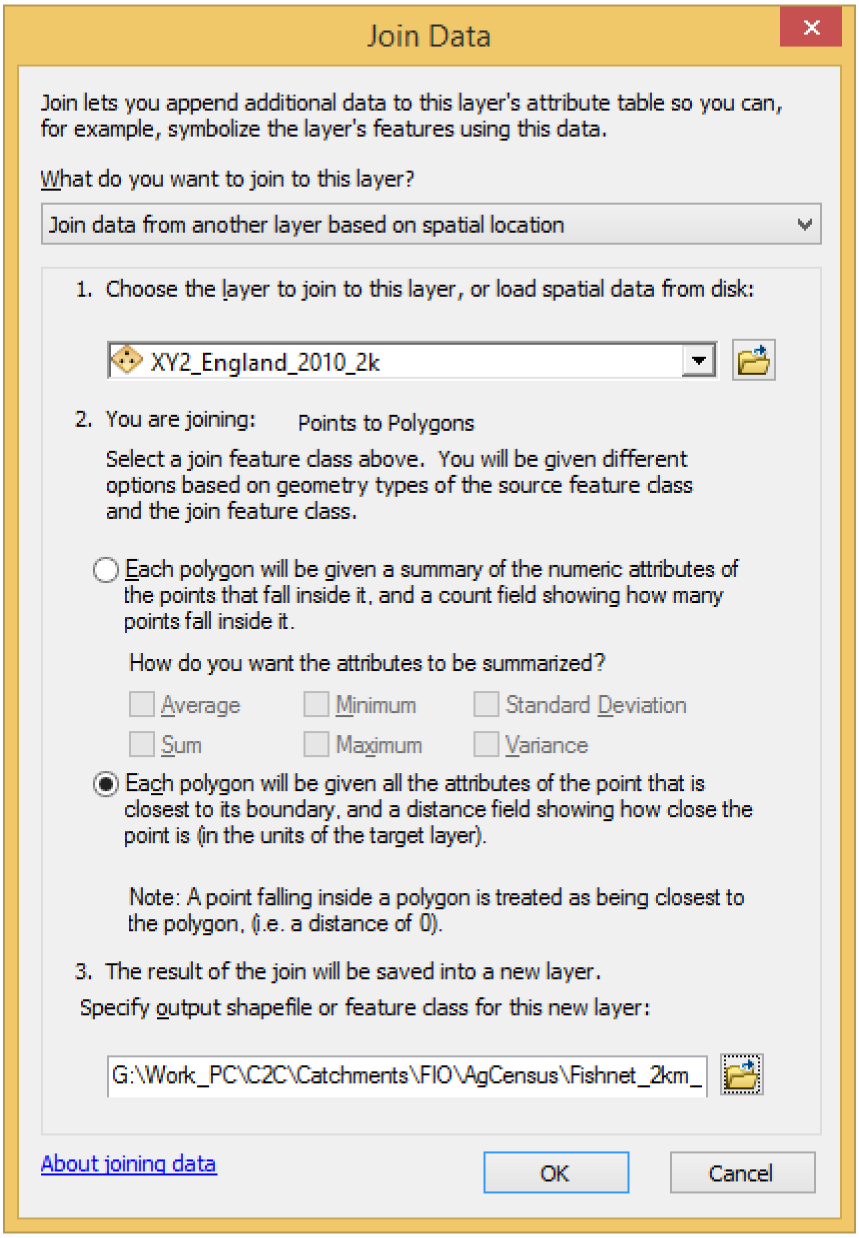


Figure 6.3: Completed Join Data Form

- Use the *Union* tool to combine the spatially joined fishnet output with the C2C model sub-catchment areas. It is possible to do this for all model sub-catchments at once to save time. The C2C model sub-catchments data should have fields detailing HSPF catchment number and sub-catchment number.
    - Search for and open the *Union* tool, add the spatially joined fishnets and the model sub-catchments as I*nput Features* and assign an *Output Feature class*.
- Open the attribute table for the new Union output layer. Select (using *Select by Attributes…*) any rows which are not within a sub-catchment (FID of sub-catchment field in Union layer = -1).
- Delete selected rows (*Delete Rows* tool)

- Add a new field to the Union layer, called *Area*, of type *double*.
- Right-click the new *Area* field heading, select *Calculate Geometry…* and calculate the Area for the field (a metric unit can be used here – this is to be allow calculation of proportional area).
- Export the table of the union layer for use in Excel
    - Click the *Table Options* button in the (attribute) *Table* window and select *Export….*Save the table as a *Text File*.

The remainder of the calculations can be performed in Excel.

- Open the exported table in Excel, selecting commas as the delimiter.
- Add a new column called *Proportion*
- Calculate values for the *Proportion* column as the *Area* value divided by the area of a full 2 km by 2 km fishnet cell. (match the units used to calculate *Area* in ArcMap – for example if using square metres the total fishnet area would be 4000000 m^2)
- Create new columns for each of the animal counts, call them *Prop_[animal]* (where *[animal]* is the relevant animal name for the field).
- Calculate values for each of these new animal fields by multiplying the original count by the *Proportion* value. This gives a proportional count of animals based on the area of each feature row.
- If calculations are being undertaken for all catchments (and their sub-catchments) at once, add another new field called *ID*.
    - Use the *concatenate* formula to create a unique ID based on the model *catchment* and *sub-catchment* numbers. Use additional letters to distinguish between the catchment and sub-catchment values so that, for example, catchment 1, sub-catchment 11 is distinct from catchment 11, sub-catchment 1.
    - An example formula would be *=CONCATENATE("C",[catchment value cell],"SC",[sub-catchment value cell])*
- Copy the *Catchment*, *sub-catchment* and *ID* fields and paste (as values) into a new area of the worksheet.
    - Select all cells in these three columns (including headers) and choose *Advanced* from the *Sort & Filter* section of the *Data* tab.
    - In the *Advanced Filter* form enter the details as shown in figure 6.4.
    - Click *OK*

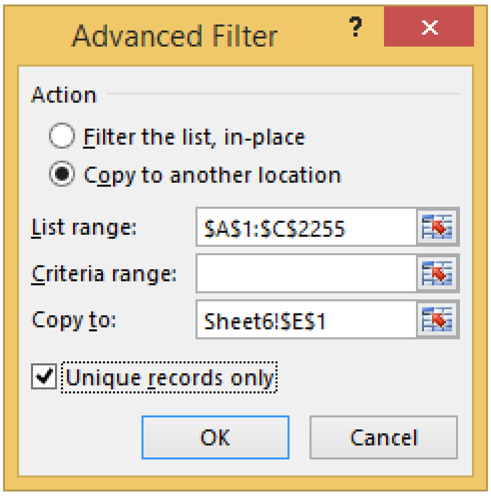


Figure 6.4: Completed Excel Advanced Filter Form

- Use the filtered list of unique combinations of catchments, sub-catchments and IDs as a new table.
- Add columns to the new table for each of the animal types.
    - The animal column order should match that of the Animal worksheet in the BIT spreadsheet to assist with data entry.
- Calculate summed proportional numbers for each animal type based on the unique ID code, rounded to the nearest whole number.
    - An example formula would be: =ROUND(SUMIF($W$2:$W$2255,$AG2,X$2:X$2255),0) where:
        - the range $W$2:$W$2255 = range of all ID codes (or sub-catchments numbers if processing models individually)
        - $AG2 = the unique ID code (or sub-catchments number if processing models individually)
        - X$2:X$2255 = the range of proportional animal numbers.
- Copy the calculated data and overwrite it by pasting (as values) in the same location. This is to stop the spreadsheet recalculating the formula.
- If all model catchments have been calculated together, use filters to filter according to model catchment. This allows for the animal count data to be copied into the Animal worksheet of the relevant catchment BIT spreadsheet.

6.1.4 Manure Application Practices

Manure applications are entered as describe in the BIT documentation and following the instructions including in the *Manure Application* worksheet. For each different type of manure applications are based on the proportion that is applied in each month over a year and also the proportion that is assumed to be incorporated into the soil.

Advice was taken as to the manure application practices used within the catchments for this purpose. Consideration has to be taken that, depending on the type of manure, these values are representative of and applied to all sub-catchments which contain cropland or pastureland. As a result the monthly proportions will be slightly smoothed under the assumption that, while practice trends are observed in general, there will be an element of temporal variation in actual manure application.

6.1.5 Conversion of accumulation values

The HSPF model has a restrictive character length limit for the input values of accumulation (*MON-ACCUM*) values and limiting storage (*MON-SQOLIM*) from the BIT spreadsheet into HSPF. Values produced by the BIT spreadsheets for the C2C model catchments have sub-catchments which exceed this length, especially for the limiting storage values. This resolved in inaccurate results as the excess character length was excluded leaving much lower values or even a failure of the model to run if the limiting storage values were falsely recorded as being lower than the equivalent accumulation values. After consultation with the U.S. EPA BASINS community (see section 9.5) a workaround was employed to resolve this issue.

The workaround entails that accumulation (*MON-ACCUM*) and limiting storage (*MON-SQOLIM*) values are divided by 10^6 to ensure that their input length does not exceed the characters length restriction in the HSPF code. Additional worksheets have been added to the BIT spreadsheets (the worksheets are called *MON-ACCUM* and *MON-SQOLIM*) which perform this conversion and also correctly format the *MON-ACCUM* and *MON-SQOLIM* values for easier entry into the WinHSPF (see section 7.4).

Once the model has been run any FIO output must be multiplied by 10^6 to restore the original values. In practice, the model output data has been multiplied by 10^5 as HSPF outputs FIO (Faecal Coliform) water quality components as cfu/litre instead of the more widely used cfu/100ml. If this step is not performed model data will be several orders of magnitude out from any observed data.

A final additional worksheet which has been added to the original BIT spreadsheet is *Monthly HSPF input & check*. This worksheet was used in the investigation of why the model was not working before the character length restriction issue was found. It checks that the *MON-SQOLIM* are greater than the *MON-ACCUM* values. It is redundant in use now, but left for reference.

6.2 Point Sources

Point source information for urban areas is provided by Will Shepherd in WP1 using the InfoWorks model. The data from the InfoWorks models are combined according to the model catchment and sub-catchment into which they drain. A sub-catchment may have more than one InfoWorks model outflow but these are summed together as the sub-catchment is essentially the smallest spatial unit which can be used for point source entry.

The InfoWorks model provide separate urban contributions for E.Coli and Confirmed Enterococci. E.Coli contributions have been used initially as point sources in the HSPF model runs. The HSPF model is only capable of outputting a single FIO during a model run. In order to run the model to simulate Confirmed Enterococci, all catchment models would need to be run again with Confirmed Enterococci point sources used instead of the E.Coli ones.

The InfoWorks outputs are provided per sub-catchment as a time-series output and saved as a .csv text file in an identical format to that used when preparing the precipitation and potential evapotranspiration data (sections 3.3.1 and 3.3.2). Although the InfoWorks models are capable of outputting at a shorter time-step, hourly time-steps are provided to match the HSPF model time-step. The units of the InfoWorks FIO data are also converted to match those of the rural FIO inputs which are amended as a result of a model restriction workaround (see section 6.1.5).

Due to practical consideration of InfoWorks model runtime the InfoWorks models are only run for 2012. The time-series is modified and extended so that it runs from 00:00 01/01/1998 – 23:00 31/12/2012. Data values prior to 00:00 01/01/2012 are substituted with the average value during the 2012 model run.

6.2.1 Add to Point Source to .wsd

In order for HSPF to use the InfoWorks time-series data as point sources the relevant .csv files need to be imported into the catchment model project *.wdm* that was assigned when the model was created (section 5.1). The *.wdm* file can be opened by the WDMUtil file to allow for the import of the *.csv* files. The overall process is similar to that detailed in section 3.5.1 when importing .csv files for met data into a met *.wdm* file. The process for adding the point source data is listed here.

- Open WDMUtil
- Open the relevant HSPF catchment model project *.wdm* file (*File>Open*)
- Select *File>Import*
- Locate a saved point source time-series *.csv* file
- Optionally create a template for input or select a previously created template (this can save time) or select Blank Script and Click *Edit*
- Uncheck the *Skip* option under *Header*
- Check *Character*: under *Column Format* and check that a , [comma] is entered
- Check that the data is displayed correctly in the preview – similar to figure 6.5.

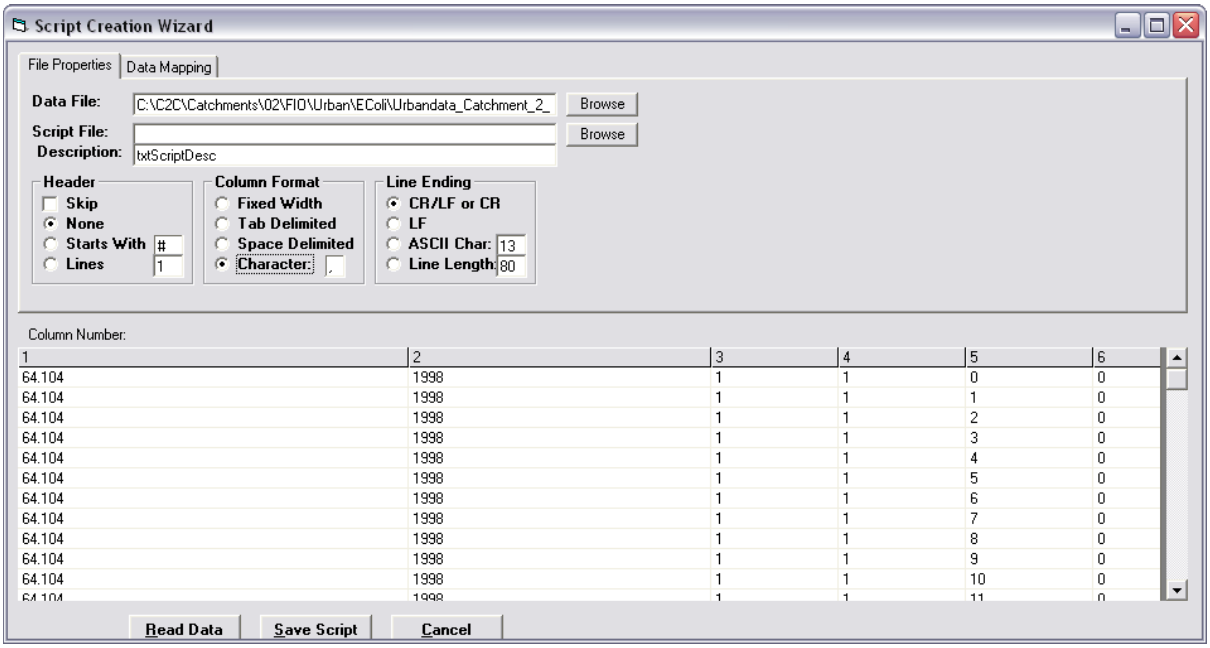


Figure 6.5: WDMUtil – Import Script Creation

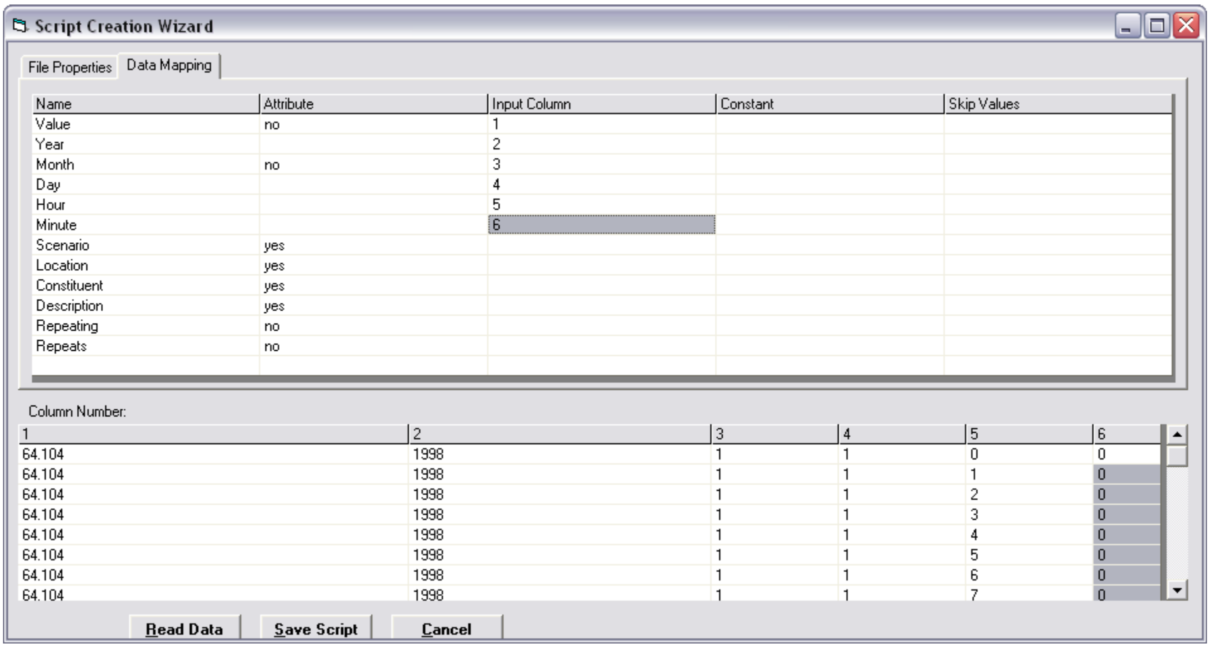


Figure 6.6: WDMUtil – Import Script Creation – Data Mapping

- Click the *Data Mapping* Tab
- Enter the values in the input column as shown in figure 6.6.
- Click *Read Data*
- Double-click on new time series entry to open the Edit Time Series Attributes window and allow editing of the attributes.
- Add the attributes in table 6.1 according to the dataset and data type you are importing:

Attribute	Point Source Data
Scenario	PT-OBS
Location	RCHx *(Where x = sub-catchment number)*
Constituent	F.COLIFORM
Description	Hourly

Table 6.1: WDMUtil – Time Series Attributes Entry

- An example of a completed *Edit Time Series Attribute* window for precipitation data is shown in figure 6.7.

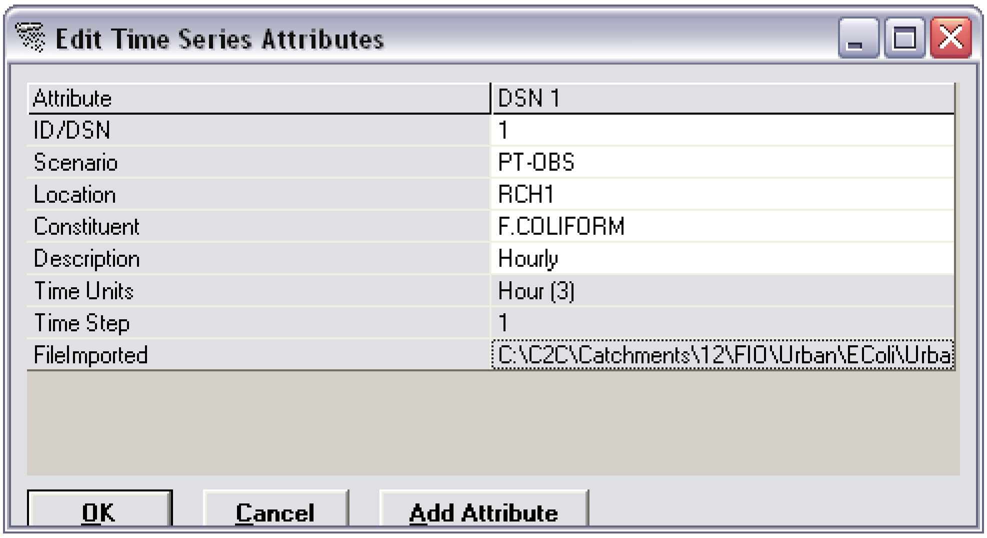


Figure 6.7: WDMUtil – Time Series Attributes

- Click *OK*
- Click the Write Time Series to WDM button (outlined in red in figure 6.8)

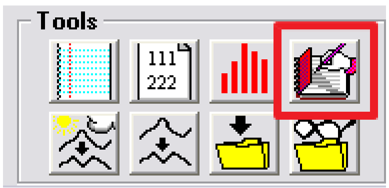


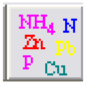
Figure 6.8: WDMUtil – Write Time Series Tool

  - In the Write to WDM dialogue assign an Output DSN value based on the next available number from the stored time series.
- Repeat the import process for all point source *.csv* files that represent sub-catchments in the opened *.wsd* HSPF catchment model project file.
- Repeat for the *.wdm* project files of all HSPF catchment models.

7. Create HSPF Model (Part 2 – FIO)

- If not already open, open WinHSPF and load the saved HSPF model (*File>Open*)

7.1 Add Pollutant

- Click the *Pollutant Selection* button 

- In the *Pollutant Selection* window, select *F.COLIFORM* from the *Available* pollutants list and click *Add ->*.
- The *Pollutant Selection* window should look the same as figure 7.1.

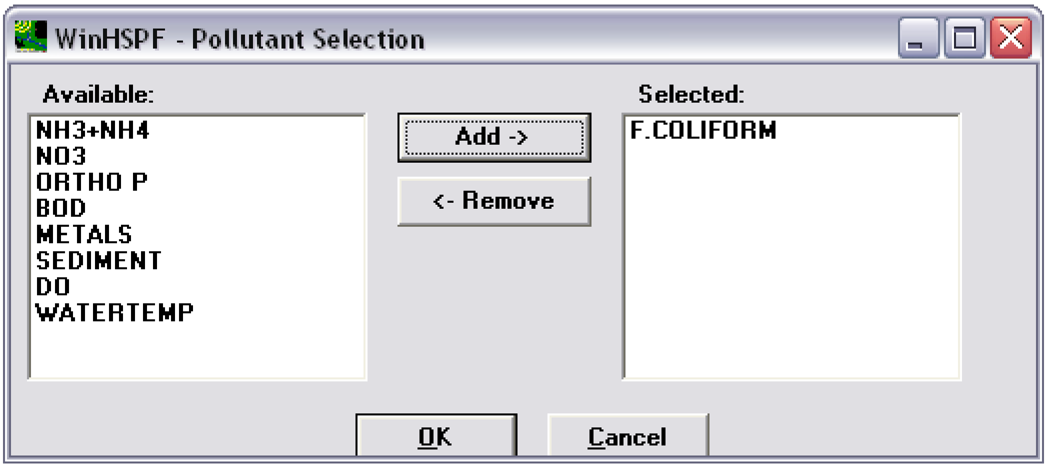
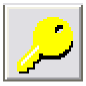


Figure 7.1: WinHSPF – Pollutant Selection

- Click *OK*.

7.2 Edit Control Cards

- Click the *Control Cards* button 
- In the *Control Window Selection* window that opens select *Descriptions*.
- In the *Control Cards* window select the *Reaches/Reservoirs* tab.
- Uncheck *HTRCH* (this requires additional temperature data) (figure 7.2).

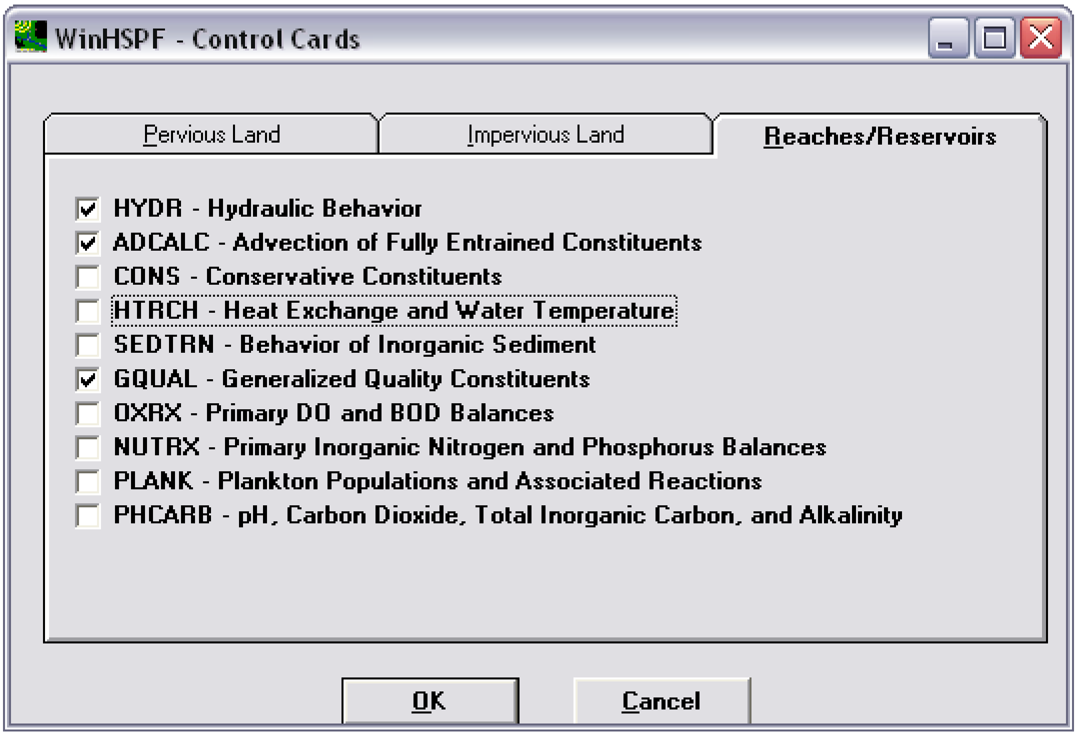
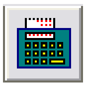


Figure 7.2: WinHSPF – Control Cards

- Click *OK*.
- Two *Control Card Query* windows will open, prompting that additional tables are required as a result of the changes that have been made and asking if you would like to add them automatically.
- Click *OK* for each window.

7.3 Edit Properties and Enter Accumulations from the BIT

- Click the *Input Data Editor* button 
- In the *Input Data Editor* window that opens, navigate to *PERLAND>PQUAL*
  - Double-click *QUAL-PROPS*
  - In the *Edit PERLND:QUAL*-PROPS window enter 0 in first row of the *QIFWFG* column (you may need to scroll right or expand the window to see the column).
  - With the text cursor still in the first row cell, double-click the column header to copy the 0 value down in all rows of that column.
  - Repeat this process entering 0 values for columns *VIQCFG*, *QAGWFG* and *VAQCFG*.
  - The finished *Edit PERLND:QUAL*-PROPS window should look similar to figure 7.3.

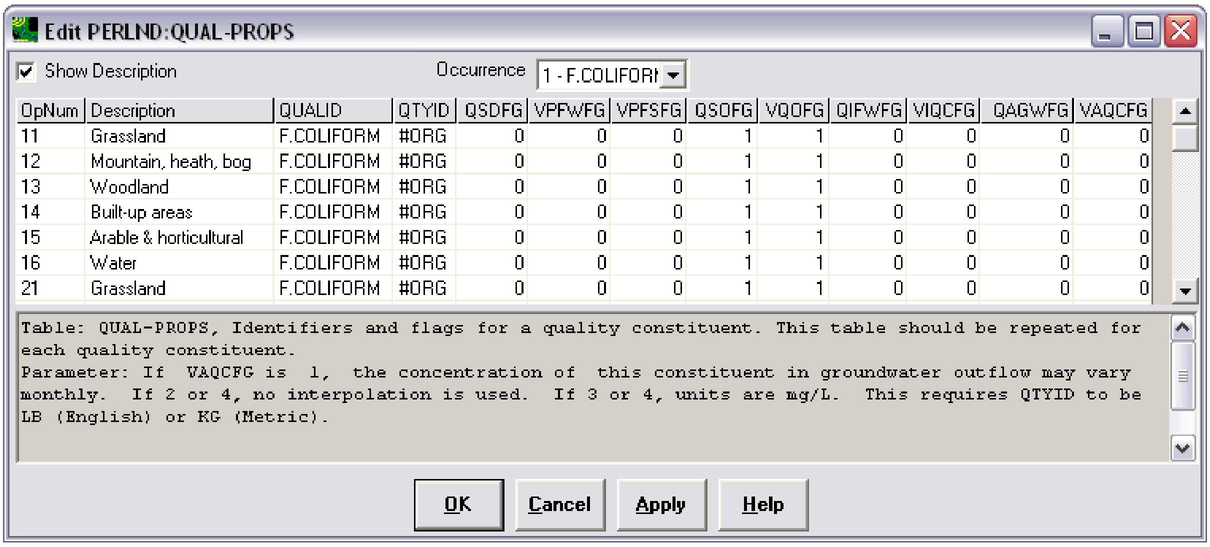


Figure 7.3: WinHSPF - Finished Edit PERLND:QUAL-PROPS Window

- Click *OK*.

- In the *Input Data Editor* window, return to the first tree level and navigate to *IMPLND>IQUAL*
    - Double-click on *QUAL-INPUT*
    - In the *Edit IMPLND:QUAL-INPUT* window enter *0.001* in first row of the *SQO* column
    - With the text cursor still in the first row cell, double-click the column header to copy the *0.001* value down in all rows of that column.
    - Repeat this process entering the values from table 7.1 for columns *POTFW*, *ACQOP* and *SQOLIM*.

Parameter	Value
SQO	0.001
POTFW	0
ACQOP	0
SQOLIM	0.00001

Table 7.1: WinHSPF Input Data

- The finished *Edit IMPLND:QUAL-INPUT* window should look similar to figure 7.4.

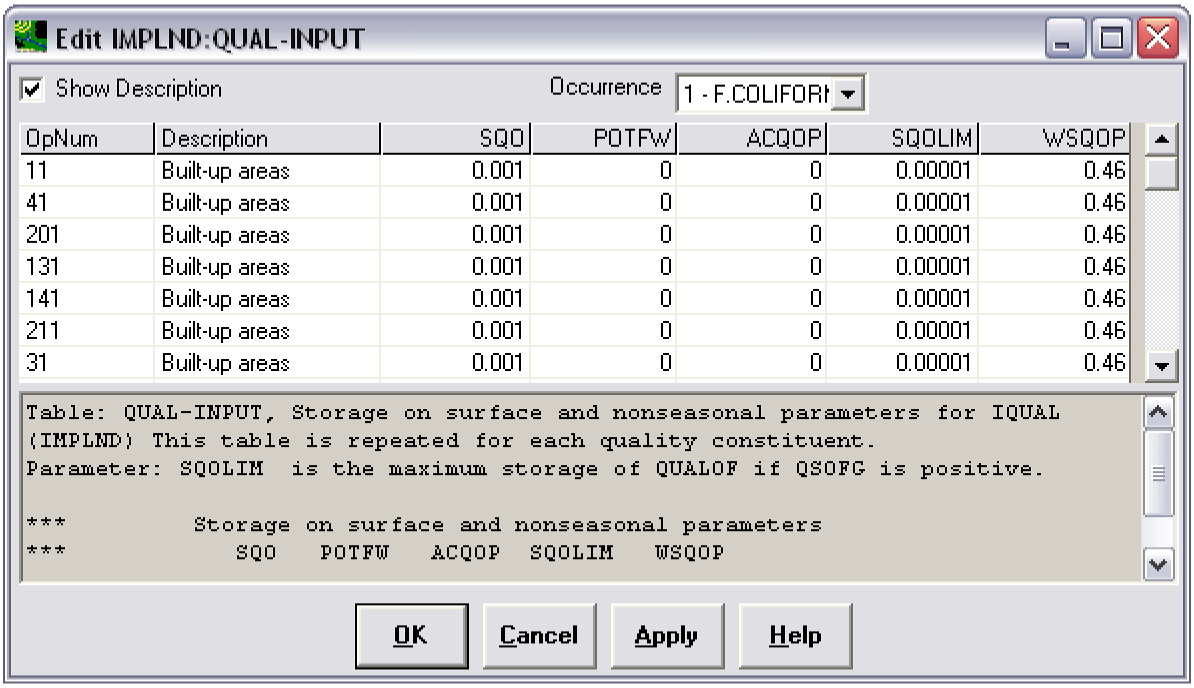
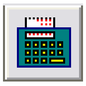


Figure 7.4: WinHSPF - Finished Edit IMPLND:QUAL-INPUT Window

- Click *OK*.

7.4 Add Monthly Accumulation Rates and Limiting Storage Values from BIT

This section makes the final preparations to format data in the BIT spreadsheet for input into the HSPF model. This requires some entry of values from the HSPF model into the modified BIT spreadsheets and then formatting and ordering of the BIT accumulation and limiting storage values before they are then copied into WinHSPF's input data editor.

- If it is not already open, click the *Input Data Editor* button 
- In the *Input Data Editor* window, navigate to *PERLAND>PQUAL* from the first tree level
    - Double-click on *MON-ACCUM*
    - Open the relevant prepared BIT spreadsheet (this must have a matching number of sub-catchments as well as having been setup as described in section 6.1).
    - Switch to the *MON-ACCUM* worksheet in the BIT spreadsheet.
    - Yellow highlighted cells indicate where user input to the worksheet is required.
    - In *column A* of the BIT spreadsheet the Land use numbers for the specific model need to be entered. These can be found by inspecting the *OpNum* and *Description* columns in the *Edit PERLND:MON-ACCUM* window. The land use number corresponds to the final number (the furthest right character) in the *OpNum*. Table 7.2 shows an example of this process and figure 7.5 compares the MON-ACCUM OpNum and Description columns to the equivalent entry in the BIT spreadsheet.

OpNum (HSPF)	Description (HSPF)	HSPF Landuse No. (BIT)
11	Mountain, heath, bog	1
16	Water	6

Table 7.2: Identification of HSPF Land Use Number from OpNum.

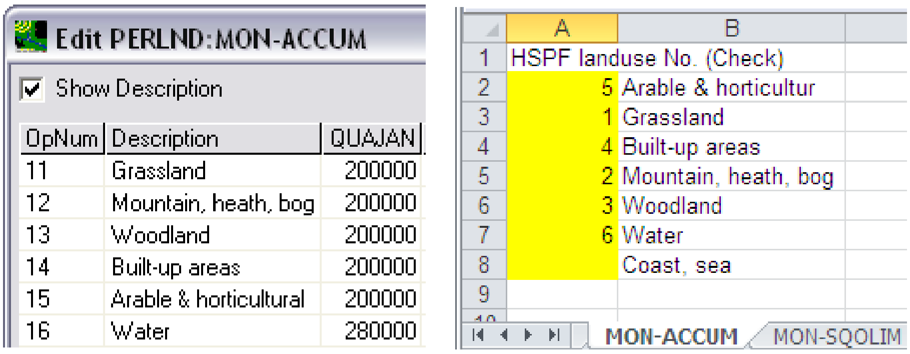


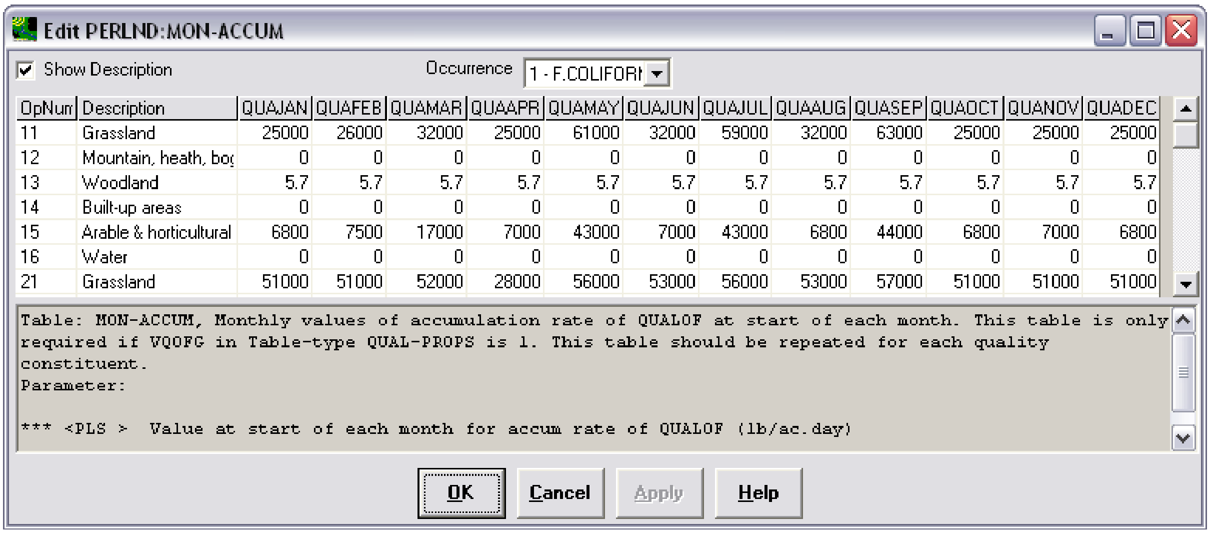
Figure 7.5: OpNum and Land Use description in WinHSPF - Edit PERLND:MON-ACCUM Window Compared with Equivalent HSPF Landuse No. in the MON-ACCUM worksheet of the BIT Spreadsheet.

- Note: *OpNum* values may change between models or if recreating a model so this step needs to be checked and/or repeated each time. It is also important to ensure all land use categories within the model are accounted for. In the example above the model does not have any "*Coast, sea*" land use in any of the sub-catchments. In other cases you may have to scroll down in the *Edit PERLND:MON-ACCUM* window to find all land uses present
- In the Bit Tool spreadsheet, on the *MON-ACCUM* worksheet scroll right until you find the yellow highlighted *Conversion* cell (*cell V2*).
- This value should be defaulted to *1000000* (*10^6*).

Reason: There is a coded length limit in the input of accumulation (*MON-ACCUM*) values into HSPF. For this reason the values are divided by 10^6 to ensure their input length does not exceed the number of characters and a lower value is erroneously stored.

- In the *Edit PERLND:MON-ACCUM* window select all of the *OpNum* values by clicking in the first cell and dragging down.
- Copy the selection by pressing *Ctrl+C*
- In the Bit Tool spreadsheet, on the *MON-ACCUM* worksheet scroll right until you find the yellow highlighted *OpNum* column (*column AN*)
- Click in the first cell below the header (*cell AN2*) and paste the copied *OpNum* values.
- The monthly accumulation data is now ordered according to the pasted *OpNum* list.
- Select the Monthly Accumulation values which have a corresponding *OpNum* (entries beyond the list of pasted *OpNum* should be ignored so you cannot simply copy the entire columns).
- Copy the selected values from the BIT spreadsheet.

- In the *Edit PERLND:MON-ACCUM* window in WinHSPF, click in the first cell for *QUAJAN* at the top of the data input table. Take care not to re-order the table by clicking on the column headers.
- Right-click and select *Paste* or press *Ctrl+V* to paste the *MON-ACCUM* values from the BIT spreadsheet into the *Edit PERLND:MON-ACCUM* window.
- Visually check that values have copied across correctly for the full range of *OpNum* values and months (you will need to scroll the input table to check this).
- Your completed table in the *Edit PERLND:MON-ACCUM* window should look similar to figure 7.6.



OpNum	Description	QUAJAN	QUAFEB	QUAMAR	QUAAPR	QUAMAY	QUAJUN	QUAJUL	QUAAUG	QUASEP	QUAOCT	QUANOV	QUADEC
11	Grassland	25000	26000	32000	25000	61000	32000	59000	32000	63000	25000	25000	25000
12	Mountain, heath, bo	0	0	0	0	0	0	0	0	0	0	0	0
13	Woodland	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
14	Built-up areas	0	0	0	0	0	0	0	0	0	0	0	0
15	Arable & horticultural	6800	7500	17000	7000	43000	7000	43000	6800	44000	6800	7000	6800
16	Water	0	0	0	0	0	0	0	0	0	0	0	0
21	Grassland	51000	51000	52000	28000	56000	53000	56000	53000	57000	51000	51000	51000

Figure 7.6: WinHSPF – Completed table in the Edit PERLND:MON-ACCUM Window

- Click *OK*.

- In the *Input Data Editor* window, navigate to *PERLAND>PQUAL* from the first tree level
  - Double-click on *MON-SQOLIM*
  - Open the relevant prepared BIT spreadsheet (this must have a matching number of sub-catchments as well as having been setup as described in section 6.1).
  - Switch to the *MON-SQOLIM* worksheet in the BIT spreadsheet.
  - As with the *MON-ACCUM* worksheet, yellow highlighted cells indicate where user input to the worksheet is required.
  - In *column A* of the BIT spreadsheet the Land use numbers for the specific model need to be entered. These can be found by inspecting the *OpNum* and *Description* columns in the *Edit PERLND:MON-SQOLIM* window (Figure 7.7). The land use number corresponds to the final number (the furthest right character) in the *OpNum*.
  - Note: The Land use numbers will be the same as those used for *MON-ACCUM* for the same model, so these can be reused.

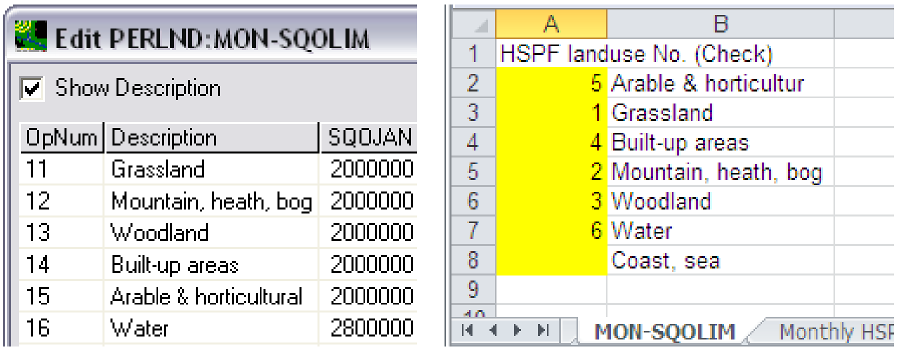


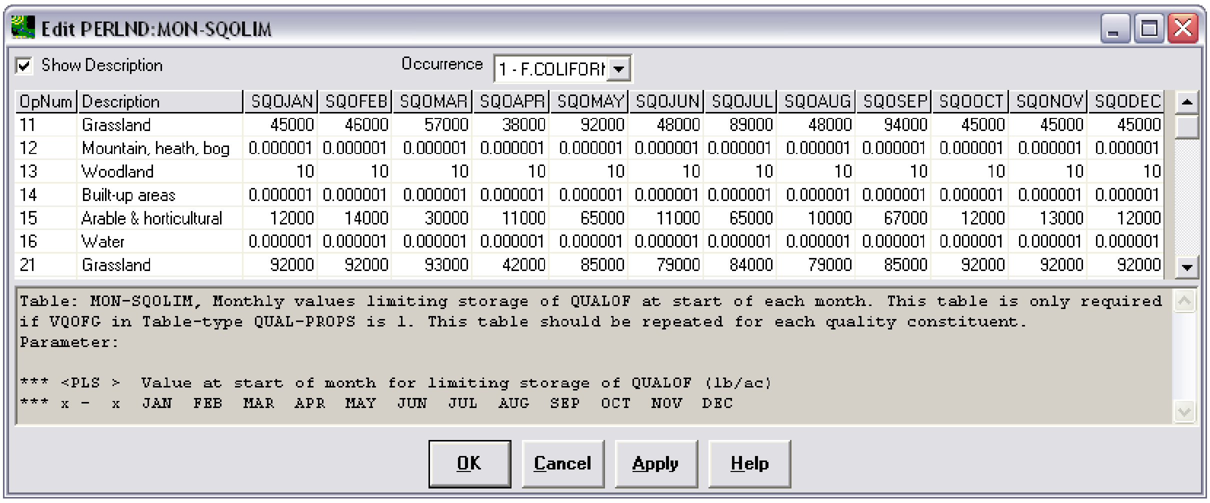
Figure 7.7: OpNum and Land Use description in WinHSPF - Edit PERLND:SQOLIM Window Compared with Equivalent HSPF Landuse No. in the MON-SQOLIM worksheet of the BIT Spreadsheet.

- Note: *OpNum* values will be the same for in the *MON-ACCUM* and *MON-SQOLIM* data input tables of the same model but may change between models or if recreating a model. It is also important to ensure all land use categories within the model are accounted for. In the example above the model does not have any "*Coast, sea* land" use in any of the sub-catchments. In other cases you may have to scroll down in the *Edit PERLND:MON-SQOLIM* window to find all land uses present
- In the Bit Tool spreadsheet, on the *MON-SQOLIM* worksheet scroll right until you find the yellow highlighted *Conversion* cell (*cell V2*).
- This value should be defaulted to *1000000* (*10^6*).

Reason: There is a coded length limit in the input of limiting storage (*MON-SQOLIM*) values into HSPF. For this reason the values are divided by 10^6 to ensure their input length does not exceed the number of characters and a lower value is erroneously stored.

- In the *Edit PERLND:MON-SQOLIM* window select all of the *OpNum* values by clicking in the first cell and dragging down.
- Copy the selection by pressing *Ctrl+C*
- Note: OpNum values will be the same as those used for *MON-ACCUM* for the same model, so these can be reused.
- In the Bit Tool spreadsheet, on the *MON-SQOLIM* worksheet scroll right until you find the yellow highlighted *OpNum* column (*column AN*)
- Click in the first cell below the header (*cell AN2*) and paste the copied *OpNum* values.
- The limiting storage data is now ordered according to the pasted *OpNum* list.
- Select the limiting storage values which have a corresponding *OpNum* (entries beyond the list of pasted *OpNum* should be ignored so you cannot simply copy the entire columns).
- Copy the selected values from the BIT spreadsheet.
- In the *Edit PERLND:MON-SQOLIM* window in WinHSPF, click in the first cell for *QUAJAN* at the top of the data input table. Take care not to re-order the table by clicking on the column headers.
- Right-click and select *Paste* or press *Ctrl+V* to paste the *MON-SQOLIM* values from the BIT spreadsheet into the *Edit PERLND:MON-SQOLIM* window.
- Visually check that values have copied across correctly for the full range of *OpNum* values and months (you will need to scroll the input table to check this).

- Your completed table in the *Edit PERLND:MON-SQOLIM* window should look similar to figure 7.8.



OpNum	Description	SQOJAN	SQOFEB	SQOMAR	SQOAPR	SQOMAY	SQOJUN	SQOJUL	SQOAUG	SQOSEP	SQOOCT	SQONOV	SQODEC
11	Grassland	45000	46000	57000	38000	92000	48000	89000	48000	94000	45000	45000	45000
12	Mountain, heath, bog	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001
13	Woodland	10	10	10	10	10	10	10	10	10	10	10	10
14	Built-up areas	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001
15	Arable & horticultural	12000	14000	30000	11000	65000	11000	65000	10000	67000	12000	13000	12000
16	Water	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001
21	Grassland	92000	92000	93000	42000	85000	79000	84000	79000	85000	92000	92000	92000

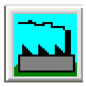
Figure 7.8: WinHSPF - Completed Table in the Edit PERLND:MON-SQOLIM Window

- Click *OK*.

- On the *Input Data Editor* window, Click *Close*

7.5 Add Point Sources

The point source FIO time-series data can now be added and activated in the model. The data can be easily added to or removed from the model, which is useful for source apportionment model runs.

- In WinHSPF, with a model open, click the *Point Sources* button. 
- In the Point Source window that opens, select the *HOURLY (OBS)* entry in the *Available* point sources list.
- Click *Add ->*
- Select *HOURLY (OBS)* which is now in the *In Use* point sources list
- Check *Show Details*
- Double-click the *In Use* value in the first row and set the value to *Yes* in the drop down menu.
- Double-click the *In Use* field header to copy down the *Yes* value to all model reaches.
- Double-click the *Target Member* value in the first row and set the value to *IDQAL(1) | dissolved F.COLIFORM* in the drop down menu.
- Double-click the *Target Member* field header to copy down the set value to all model reaches.
- The completed Point Sources form should look similar to Figure 7.9.
- Click *OK*.

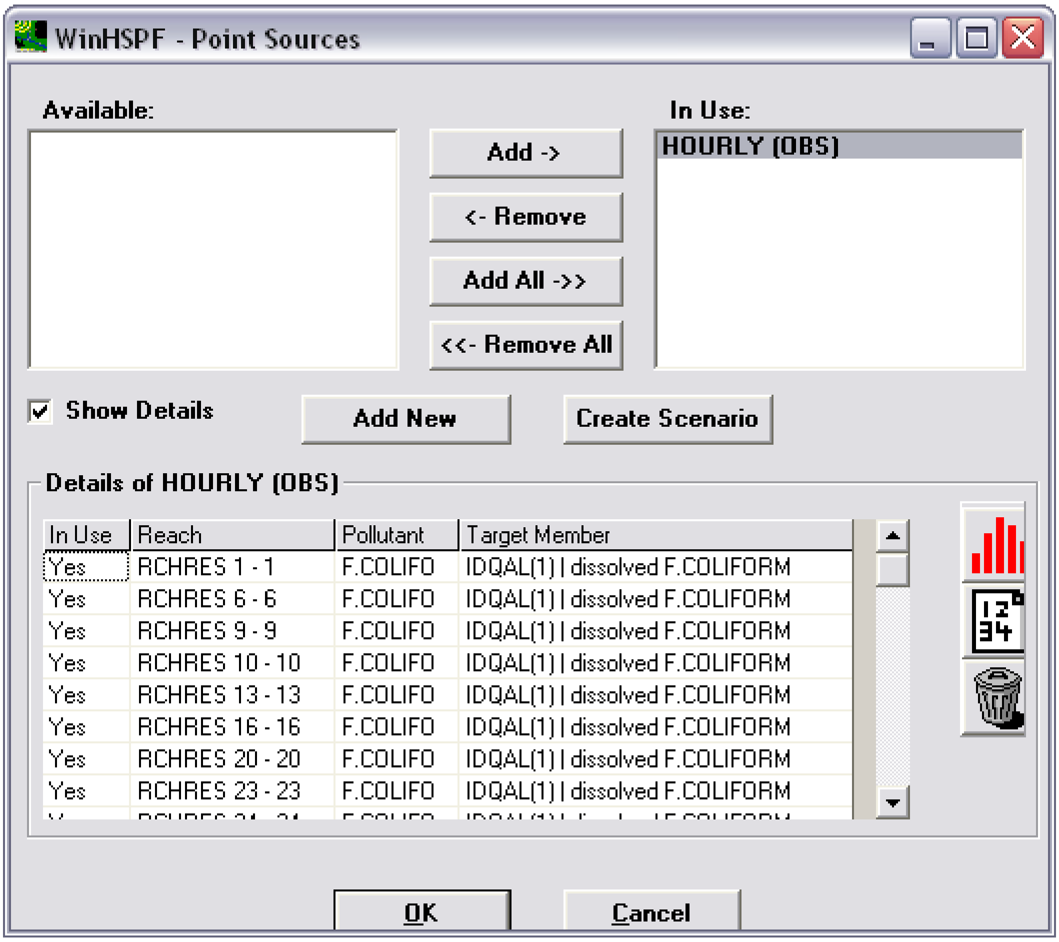
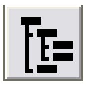


Figure 7.9: Completed Point Sources Window

7.6 Add Model Water Quality (Faecal Coliform) Output

- Click the *Output Manager* button 
- Select the *Output Type* as *Other*.
- Click *Add*.
- An *Add Output* window opens.
- In the *Operation* list select *RCHRES X (X)*, where X is the furthest downstream or exit sub-catchment. This will be the same number as the flow output you have already added.
- In the *Group/Member* list select *GQUAL:DQUAL(1,1)*
- Check *Hourly*.
- Other values can remain at their defaults.
- The *Add Output* window will appear similar to figure 7.10.

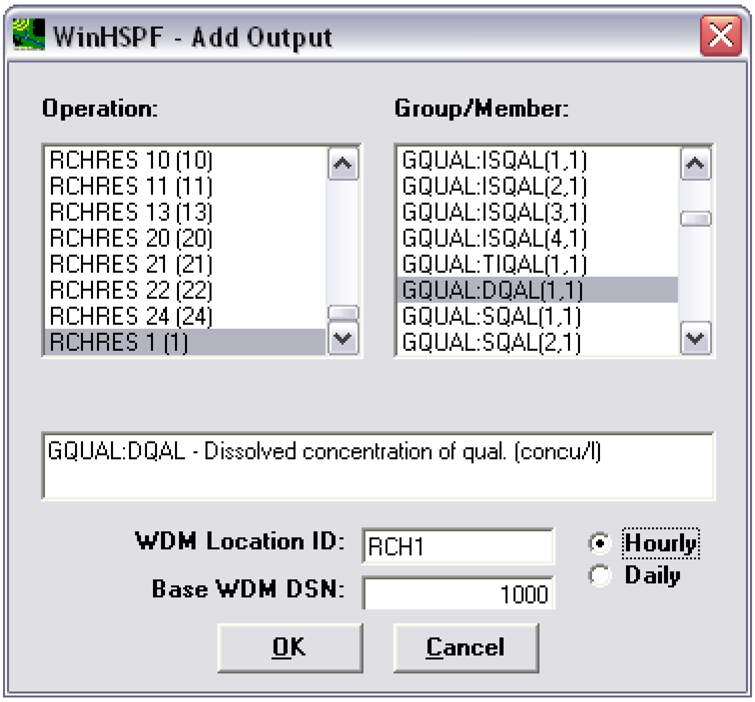


Figure 7.10: WinHSPF – Add Output

- Click *OK*.
- The *Output Manager* window will look similar to figure 7.11.

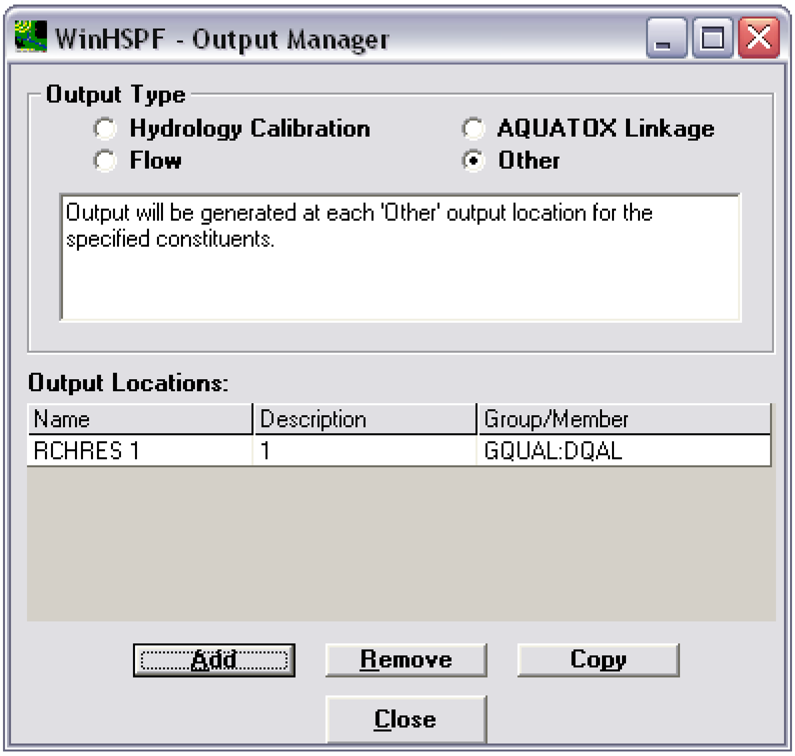


Figure 7.11: WinHSPF – Output Manager

- Click *Close*.

The model can now be run to generate hourly concentrations of faecal coliform for the modelled catchment. At this point you can attempt further calibration of the Water Quality HSPF model and generate further outputs. Further information on how to do this is available in later sections.

- Click the *Run HSPF* button 
- WinHSPF asks if you wish to save new changes to the model (see Figure 7.12).

Figure 7.12: WinHSPF – Save New Changes & Run

- Click *Save/Run* to save and run the model.
- You can also save the model without running it by going to *File>Save* or *File>Save As*.

8. Running the Model

- If not already open, open WinHSPF and load a saved HSPF model (*File>Open*)
- Click the *Run HSPF* button 
- WinHSPF asks if you wish to save new changes to the model (see below):

Figure 8.1: WinHSPF – Run HSPF

- Click *Save/Run* to save and run the model.

9. Common Model Errors

The section is intended to indicate some of the common model errors and issues that have been experienced when running the HSPF model. The HSPF model provides error reporting which does offer useful suggestions as to the faults, particularly in identifying the reach of model segment which is problematic. Other common errors are listed below.

9.1 Issues with input Met data

This can be as a result of erroneous, missing or incorrectly formatted data. Unusually high precipitation events can indicate an issue with the rain gauge station equipment, if errors such as this are left unchecked they can percolate through the rest of the model. It is important to check unusual outputs and link compare them back to the met data (especially precipitation), this may reveal a previously unidentified issue.

9.2 Data conversion

An issue with both Met data and model output data is that of conversion. It is important to be vigilant with the conversion of met data from metric to imperial for model processing and again when converting model output data from imperial to metric. Observed flow data that is used for calibration will also need to be prepared so that the data matches the same time-step as the model output to ensure a fair comparison. The FIO model output is complicated by having to be divided by 10^6 as a workaround to a value character length limit in the model. This units must be restored by multiplying the output value by 10^5 (see section 6.1.5).

9.3 FTABLES

FTABLES are Hydraulic Function Tables are used to represent the geometric and hydraulic properties or each model reach. The values are stored in the .uci file and are generated when creating the model based on the values stored in the HSPF input files. One of the properties is linked with the reach length, this can lead to issues with small sub-catchments with short reach lengths. Because of the small size of the model sub-catchment the generated FTABLES may not accurately represent the nature of the channel at that point.

This can lead to errors where the volume of water attempting to flow through that reach exceeds capacity and causes the model calculations to break. The HSPF reporting will identify which reach the fault has occurred on and the FTABLE that needs attention.

FTABLES can be created both manually and automatically from channel geometries that are representative of the reach in each sub-catchment. It is possible to edit any problem FTABLES with real values and using the tools and steps described in BASINS Technical Notes #1 and #2 (see Appendix H).

Literature has indicated that model accuracy is not dependent on the accuracy of FTABLES and as a result it is practical to use a common set of FTABLE values when troubleshooting the model. To do this you should identify the FTABLE reach which has caused the problems from the HSPF error messages. Then find the FTABLE entry for that reach in the HSPF .uci file see figure 9.1 for an example). A problematic FTABLE will have a small range of depth values and generally low values throughout the FTABLE. Select another FTABLE from the same .uci file if practical (or another working model .uci file if not) and copy the FTABLE to replace the problematic one. Save changes to the .uci file and attempt to run the model again. Remember to save a copy of the original .uci file when making manual edits.

```
FTABLE       1
 rows cols                               ***
    8    4
     depth       area     volume  outflow1 ***
        0.       1.69         0.        0.
       0.5       1.78       0.87     20.89
        5.       2.54      10.58     988.9
      6.25       2.75      13.88   1456.99
      7.81       8.36      26.53   2169.22
      9.38       8.88        40.   4119.32
    160.94      60.19   5274.223820278.75
     312.5     111.49   18283.63 20067014.
  END FTABLE  1
```

Figure 9.1: Example FTABLE in a .uci File

9.4 Errors when using BASINS to delineate sub-catchments

BASINS can struggle with delineation of small model catchments and low relief topography. It also is less intuitive to process single sub-catchment model outputs. If the BASINS delineated sub-catchments do not match the full model extent or fail to generate entirely the sub-catchment delineation should be attempted using the Arc Hydro Tools method (section 3.2.2).

9.5 Getting additional help

The U.S. EPA run an online community which is very helpful in solving problems with BASINS and HSPF. The community operates as a Listserv, details for joining the BASINS Listserv are included below and are taken from the Contact Information at http://water.epa.gov/scitech/datait/models/basins/index.cfm

BASINS Listserv: Join this online community of BASINS users to exchange questions and answers regarding the use of BASINS.

Join the BASINS listserv by sending an email to lyris@lists.epa.gov, leaving the "Subject:" field blank and putting "subscribe basinsinfo firstname lastname" in the body of the text. Once you have subscribed, you will receive a welcome message confirming your membership.

Search the BASINS listserv archives (as well as other EPA forums to which you are subscribed) by going to https://lists.epa.gov/read/. Login, then go to "My Forums". Select the forum you want (e.g., basinsinfo). Then click on "Search". There is also a link for Advanced Search.

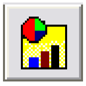
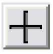
You can also contact EPA's BASINS Support Team to find additional information on BASINS not answered through the BASINS Listserv.

From: http://water.epa.gov/scitech/datait/models/basins/index.cfm

10. Outputting Model Results

Once a model Run has completed the model outputs can be viewed and plotting using the GenScn program that is provided with WinHSPF and BASINS. The GenScn software also allows the data to be exported so that it can be used in spreadsheet and other software for further analysis.

10.1 Viewing Model Results

- For a model that has just been run, or has been run previously and saved, click the *View Output through GenScn* button in WinHSPF. 
- The GenScn window opens and provides lists of model *Locations*, *Scenarios* and *Constituents* (Figure 10.1).
- In the *Constituents* list select *DQAL1* and *FLOW* so they are highlighted in grey.
- In the *Time Series* section click the *add to Time-series List* button 
- Time series data of the *FLOW* and *DQAL1* constituents are added to the list

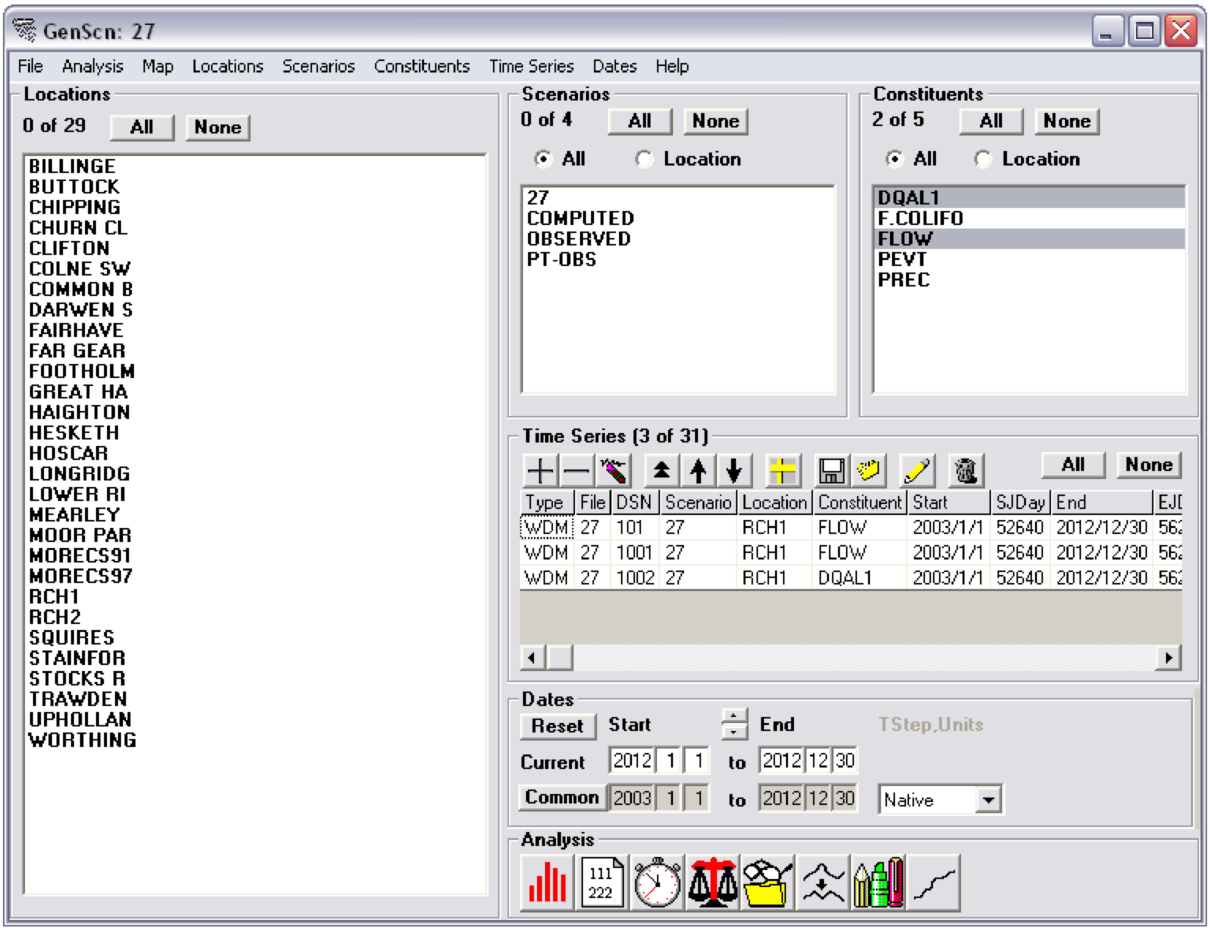
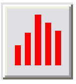


Figure 10.1: GenScn Window

- You can double click the data to view the attributes of each time series. This is useful to identify which is the hourly flow time series (typically DSN 1001) from the daily flow data (typically DSN 101).

- Click on the hourly *FLOW* data in the *Time Series* list to highlight it grey.
- In the *Dates* section under *Current* enter the date range 2012/1/1 – 2012/12/30 (in YYYY/MM/DD format) as shown in figure 10.1.

Reason: 2012 was selected as the year in which to run both rural and urban models and provide input to the river and estuary model. The end date of 30th December 2012 marks the end date of the currently provided MORECS potential evapotranspiration data. And as a result determines the end date of the 2012 model output.

- To view the data in a plot, click the *Generate Graphs* button 
- In the *Graph* window that is opened click *Generate*.
- A plot of the selected flow data for the entered data range is produced (similar to figure 10.2)

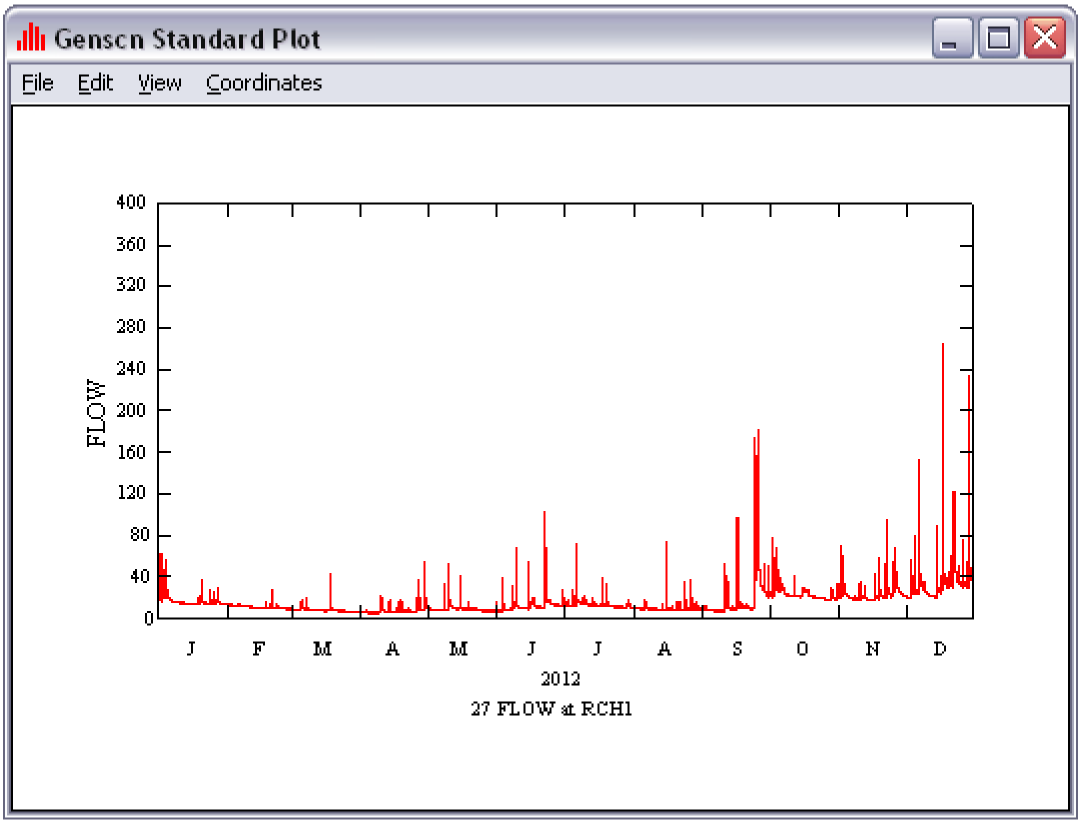
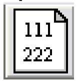


Figure 10.2: Example GenScn Plot

- The plot type, style and format can be adjusted with the settings found under the *Edit* menu in the *Genscn Standard Plot* window.
- Plots can be copied to the clipboard or saved as image files by going to *File>Save*
- Once finished close the *Genscn Standard Plot* and *Graph* windows.

10.2 Exporting Model Output Data

- Returning to the *GenScn* window and ensure the *FLOW* and *DQAL1* constituents are still added to the *Time Series* list and the *Current* date range in the *Dates* section is entered as 2012/1/1 – 2012/12/30 (as described in section 10.1).

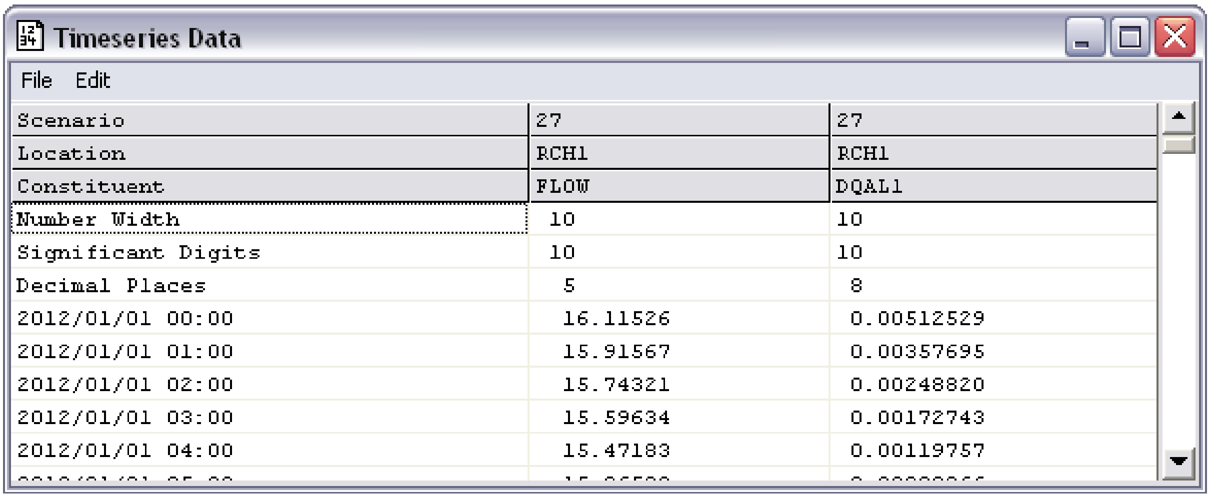
- In the *Time Series* section, select both the hourly *FLOW* (likely to be DSN 1001, this can be confirmed by double-clicking the time series entry and inspecting the attributes) and the *DQAL1* time series entries. Hold down Ctrl when selecting multiple entries.
- Click the *List Timeseries Values* button in the *Analysis* section 

- In the *Timeseries Data* window which opens go to *Edit>Number Format* to be able to edit the number format of the model outputs.
- Using the value as shown in table 10.1, click in the corresponding cells in the Timeseries Data window table, pressing return to ensure the changes are applied.

Number Format	FLOW	DQAL1
Number Width	10	10
Significant Digits	10	10
Decimal Places	5	8

Table 10.1 Number Format Values for Model Outputs

- The completed and correctly formatted output table should look similar to the one shown in figure 10.3.



Scenario	27	27
Location	RCH1	RCH1
Constituent	FLOW	DQAL1
Number Width	10	10
Significant Digits	10	10
Decimal Places	5	8
2012/01/01 00:00	16.11526	0.00512529
2012/01/01 01:00	15.91567	0.00357695
2012/01/01 02:00	15.74321	0.00248820
2012/01/01 03:00	15.59634	0.00172743
2012/01/01 04:00	15.47183	0.00119757

Figure 10.3: Timeseries Data Window with Number Format Options Completed

- To export the data table go to *File>Save to Text File*
- Check *Character delimited:* and ensure a , [comma] is entered in the character text box
- Navigate to and select the location to save the output text file.
- Enter an appropriate filename and include a *.csv* file extension.
- The completed dialog window should look similar to figure 10.4.

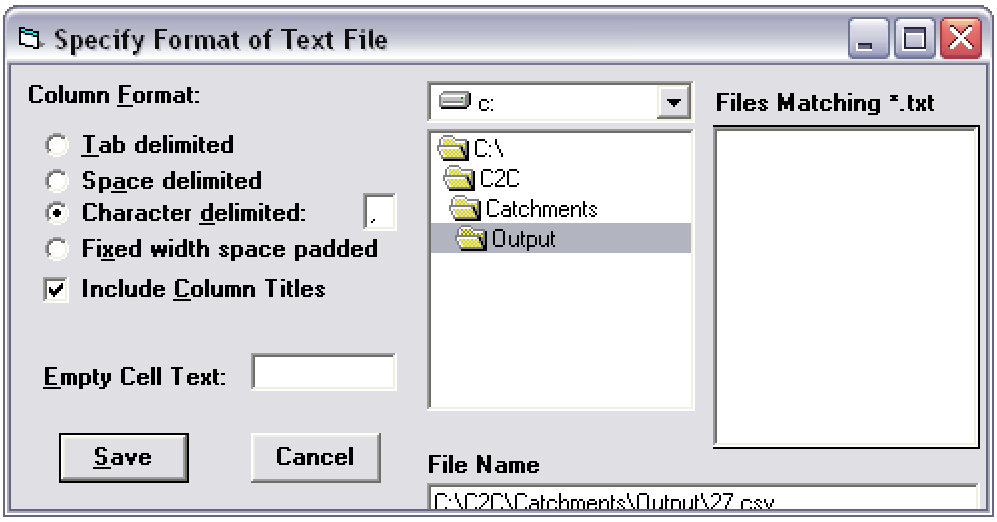


Figure 10.4: Save To Text File Dialog

- Click *OK*
- The exported .csv file can be opened in MS Excel and other comparable software. The file will contain both flow data (in ft^3s^{-1}) and FIO data (in (cfu/litre) x 10^{-6}) which can be converted back to metric data, analysed further and used to plot outputs accordingly. In the case of the FIO data multiplying the model output by 10^5 will convert it to correct values in the more commonly used cfu/100ml units.

11. Calibration

A brief overview of some of the considerations to HSPF model calibration is given in this section. Additional sources (links to which are provided in Appendix H) are also suggested which give much further detail and guidance. A reminder on ensuring the model outputs are converted into appropriate units is also included.

11.1 Hydrological Calibration

Hydrological calibration is performed by comparing the model output data against observed flow data at the same locations in the catchment if the data is available. Calibration methods can target overall agreement, agreement at high or low flow and response to specific storm events. This calibration targets may be determined by the purpose of the model or where the model results appear weakest. Checks can be made visually to the hydrograph of the modelled flow plotted against the observed flow. Statistical analysis should also be made to the two sets of data. Visual checks and checks against volumes should be made at annual, seasonal, month and storm event time periods. Detailed information on the calibration process is provided by the *BASINS Tutorials and Training* documentation, in particular *Exercise 6 - WinHSPF Hydrology Calibration* and *Lecture 15 - Watershed Model Calibration and Validation*. Links to these are provided in Appendix H.

Changes made to the model parameters can have different influences on the model outputs. Some may raise the base level flow, while others can storm response and affect peak flows. The manual process is iterative with each change made to a parameter having the new output analysed to assess the difference it makes. Descriptions of the different hydrological parameters are provided in *Technical Note #6 - Estimating Hydrology and Hydraulic Parameters for HSPF*. Advice of which parameters to change based on the differences between observed and modelled data is provided in Appendix A of the *HSPEXP* documentation. Links to both documents are provided in Appendix H

11.1.1 Interactive and Automated Hydrological Calibration

A (semi-) automated calibration process is also possible with additional programmes and utilities such as *HSPEXP* and *PEST*. *HSPEXP* is provides an interactive process to compare plots and statistics of observed values against simulated ones, it also provides expert advice on which parameters should be changed to improve calibration. Additional exercises and material regarding HSPEXP are provided in Appendix H (See Exercise 7 and Appendix D in the BASINS Tutorials and Training and the HSPEXP section). PEST is a software package that provides model-independent parameter estimation and uncertainty analysis. It is compatible with a modified version of the HSPF model (such as the one used here) and can automate the calibration process. Further information is available for the links provided under the PEST section in Appendix H.

11.1.2 Flow Data Conversion

The HSPF model runs, by default, in imperial units. It was decided that that should be maintained to avoid unforeseen conversion issues. Input data was converted into the relevant imperial units. The output modelled data should be converted back to metric units for calibration.

- Conversion to ft^3s^{-1} from m^3s^{-1}.
    - Multiply m^3s^{-1} values by 35.3146667 to get ft^3s^{-1}.

11.2 FIO calibration

Calibration of FIO data is more difficult that calibrating the hydrological element of the model as observed FIO data is not available in a continuous time-series. For this reason it is important to concentrate on the overlap of model and observed data and also to select key points in the sampling period.

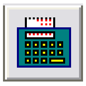
Making calibration adjustments to the FIO outputs can be made either through modifications to the Bacteria Indicator Tool (BIT) spreadsheets, which results in changes to the FIO accumulations, or by changing the parameter that controls the decay rate of the FIO constituent being modelled in HSPF.

11.2.1 BIT calibration

Changes to the BIT spreadsheets can be made in any of the worksheets (see section 6.1). Each change would have a knock-on effect to the final FIO accumulations. It may also be advisable to make changes to the reference values on the *References* worksheet. These values are based on literature and are used in all calculations of accumulation rates. Changing these values will have an overall impact without having to alter livestock counts and sub-catchment land use areas. The reference values can be replaced by more accurate locally measured values or simply calibrated based on the modelled FIO output.

11.2.2 FIO Decay rate

Changes to the decay rate of FIO will also have an influence on the FIO model outputs. The decay rate parameter can be accessed using the Input Data Editor following the steps outlined below (see also section 7.3).

- Click the *Input Data Editor* button 
- In the *Input Data Editor* window that opens, navigate to *RCHRES>GQUAL*
    - Double-click *GQ-GENDECAY*
    - The *FSTDEC* column stores the first order decay rate for the FIO constituent.
    - You can make edits to the *FSTDEC* values directly to the cells in the *GQ-GENDECAY* table.
    - The *OpNum* values in the *GQ-GENDECAY* table refer to the model sub-catchment numbers.
    - You can copy a value entered in the first cell of the *FSTDEC* column down to all cells in the column by double-clicking the column header (with the text cursor still in the first row cell).
    - The finished *Edit PERLND:QUAL*-PROPS window should look similar to figure 11.1.
    - Click *OK* to save changes
- Save or Save and Run the model before exiting WinHSPF.

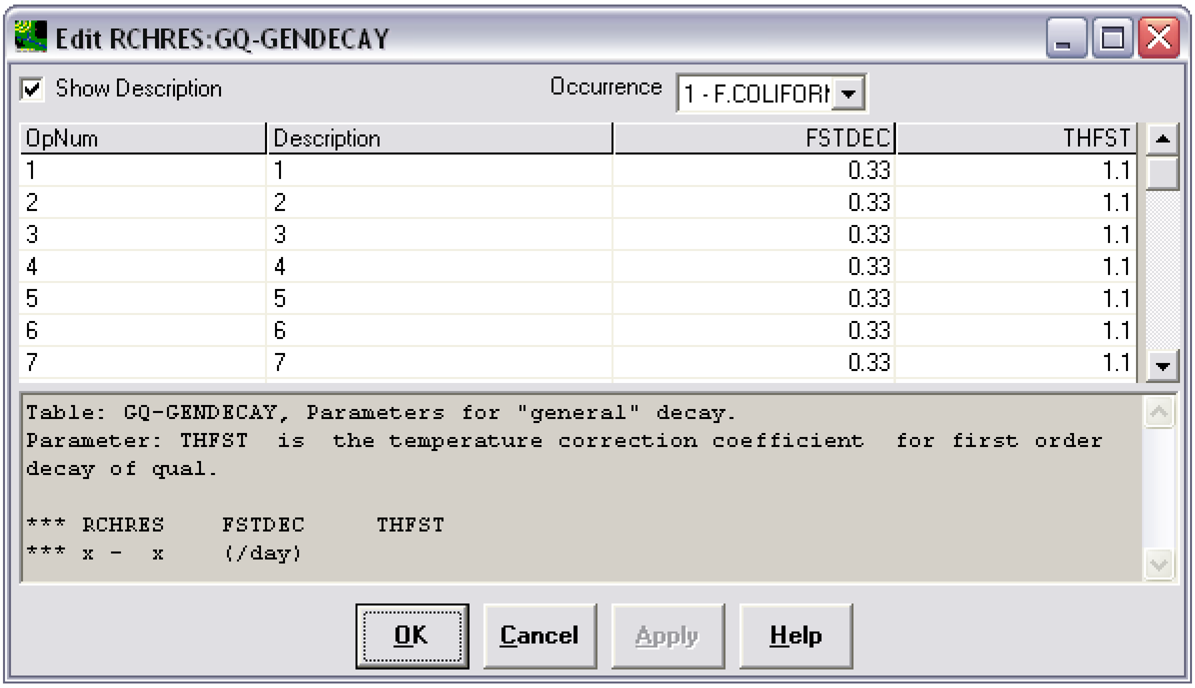


Figure 11.1: WinHSPF – Edit RCHRES:GQ-GENDECAY Window

11.2.3 FIO Data Conversion

The HSPF model runs, by default, in imperial units. It was decided that that should be maintained to avoid unforeseen conversion issues. For FIO data model input values also have to be modified for a workaround to overcome a character length restriction in their data entry. The model output values must be converted back to be able to compare them against observed data.

- Conversion to cfu/100ml from (cfu/litre) x 10^6.
    - Multiply (cfu/litre) x 10^6 values by 10^5 to get cfu/100ml.

12. Model Changes for Scenario Modelling

This provides some suggestions as to how scenario modelling could be implemented using the HPSF model, which input files would require changing and how the original model would be affected. Considerations have been made for both future management and climate scenarios.

12.1 Management Scenarios

Management scenario changes could be reflected in the HSPF model be modifications to the BIT spreadsheet FIO accumulation values, changes to the urban point source FIO contributions and amending the land use areas or configuration within the model sub-catchments.

12.1.1 BIT spreadsheet changes

Exploring possible future management scenarios with HSPF will likely be achieved by making changes to the BIT spreadsheet and the resulting FIO accumulation values. Changes could be made to individual worksheets. This may be as changes to animal numbers, changes to manure application (in terms of trends, amount and associated FIO concentrations), changes to grazing practices and changes to the access to streams for cattle. This method would allow for direct and tangible ‘real world’ changes to be explored. Information on the BIT spreadsheet can be found in section 6.1.

An alternate would be to apply a proportional reduction or increase to the final *MON-ACCUM* values for each land use and sub-catchment. A change to the *MON-ACCUM* values should also be reflected in the *MON-SQOLIM* values. A simple method to achieve a change would be to amend the conversion value found in the BIT spreadsheet *MON-ACCUM* and *MON-SQOLIM* worksheets (see section 7.4). This value is used to reduce the size of the accumulation values but in theory could also be used to modify the value as well.

12.1.2 Urban Point Source Changes

Changes to FIO contributions in urban areas would need to be reflected in the point source files provided by InfoWorks (section 6.2). If the data is modified as a result of new InfoWorks model runs then new output .csv time series files would need to be created and input into the HSPF *.wdm* project file. These could be in place alongside the current condition point sources time-series and identified using a different range of *DSN numbers* as well as a modified description. In WinHSPF the a new set of point sources should be shown in the *available* list which could then be added and set to being *in use*, while the current condition point sources are removed (see section 7.5). It may be more practical to take of copy of an existing model and replace the point source time-series data in the copied *.wdm* file.

If simple, mathematical, modifications are to be performed on the urban point sources this could be achieved within the WDMUtil software. Steps to achieve this are the same as those suggested in section 12.2.2 for modifying met data.

12.1.3 Land Use Changes

Future changes in land use can also be explored. A redistribution of areas within each model sub-catchment could be achieved by the following:

- Manually amended the area values in the *SCHEMATIC* section of the *.uci* file (see Appendix G)
    - Note - the total area of all land use types within the sub-catchment should be unchanged.
- Updating the *land use* worksheet of the BIT spreadsheet with the redistributed area values.
- Updating the recalculated *MON-ACCUM* and *MON-SQOLIM* values from the revised BIT spreadsheet.
- Re-running the model.

The above suggested method is untested but should work in theory. An alternative would be to modify the *.wsd* HSPF input file (section 4.2.1 and 4.2.2) and recreate the HSPF model (section 5).

Changing the *.wsd* HSPF input file and recreating the model would also allow for changes in the configuration of the land use within the sub-catchments. While the sub-catchments themselves should remain unchanged, it would allow for the removal or addition of any model operations (i.e. the unique combination of land use categories within each sub-catchment). For example removing "*Arable & horticultural*" land use from a sub-catchment or adding "*Grassland*" as a new land use within a sub-catchment would be possible. Attempting to make a change such as that without recreating the model, would likely cause further complications and break the HSPF model. (It might be possible to set land uses you wish to delete to 0 in the *.uci* file, but that is again untested and may remain problematic).

12.2 Climate Scenarios

Future climate change scenarios would be reflected in the HSPF model by modifying the met data that is input into the model and drives the hydrological component of HSPF. The met time-series data would either be replaced by newly generated time-series or the existing time-series data could be modified if simple mathematical changes are acceptable.

12.2.1 Generating New Met Data

The generation of new met data would require the use of an additional resource to provide the met data. Potential options that have been preliminarily explored are:

- Future Flows (CEH)
- Weather Generator (DEFRA)
- Hyetos

Links for further information on the above are provided in the Climate Change Met Data Generation section of Appendix H.

Any newly generated time-series data for precipitation and/or evapotranspiration would need preparing and importing into a new *.wdm* file using the same steps as detailed in sections 3.3 and 3.5.

A copy of the current model could be taken and the repointed to a new met *.wdm* file. This would be achieved by modifying the *.uci* file and changing the location of the *WDM2* file in the *.uci File* section (see Appendix G). Hopefully the copied model will open successfully and you to replace the existing met segments by adding the new ones and reassigning the connections (see section 5.3). This process is untested, if it fails to work or breaks the model an alternative would be to recreate the model and use the new met .wdm file when creating it (as in section 5.1 and 5.2).

12.2.2 Modifying Existing Met Data

Simple mathematical changes can be made to existing met time-series data using the WDMUtil software. The tool allows for calculations to be made using existing time-series data or numeric values. Using precipitation as an example, it would be possible to multiply a value to create a new time-series of proportionally increased or decreased precipitation or evapotranspiration. It would also be possible to generate an additional time-series of varying (perhaps by month or season) proportional values and using that to multiply with the existing precipitation time-series. This method could be used to generate, for example, a time-series with wetter summers and drier winters based on the existing precipitation time-series data.

The steps to access this functionality in the WDMUtil software are shown below.

- Open the WDMUtil software and load an existing met .wdm file (*File>Open*)
- Click the *Generate Time Series* button in the *Tools* section (highlighted in red in figure 12.1)

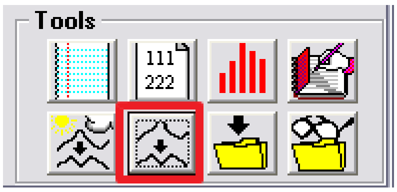


Figure 12.1: WDMUtil - Generate Time Series Button

- In the *New Time Series* window that opens click on the *Math* tab.
- Calculations can be performed on the existing time series on this tab using the provided mathematical functions or operators and selecting the relevant existing time-series data or entering numeric values. An example is shown in figure 12.2.
- Edit the *Description* of the *New Properties* for the output time-series
- Leave the *Save in* option as *<in memory>*, this gives you the option of saving the output as a new time-series (with a new *DSN* value) or overwriting the existing time-series by saving it with the same *DSN* value.
    - The former option should be used if retaining all met time-series data in the same met *.wdm* file.
    - The latter option can be used if a copy of the met *.wdm* file has been taken.
    - The steps to save an *in memory* time-series are described in section 3.5.1.

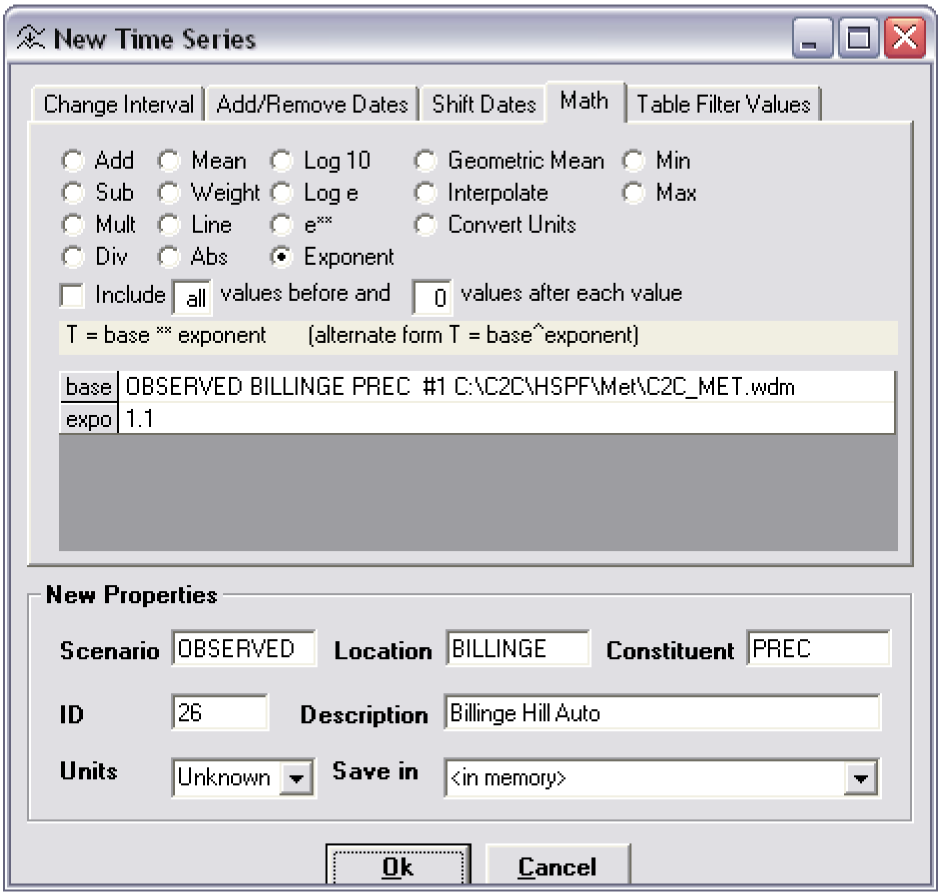


Figure 12.2: WDMUtil – New Time Series Window

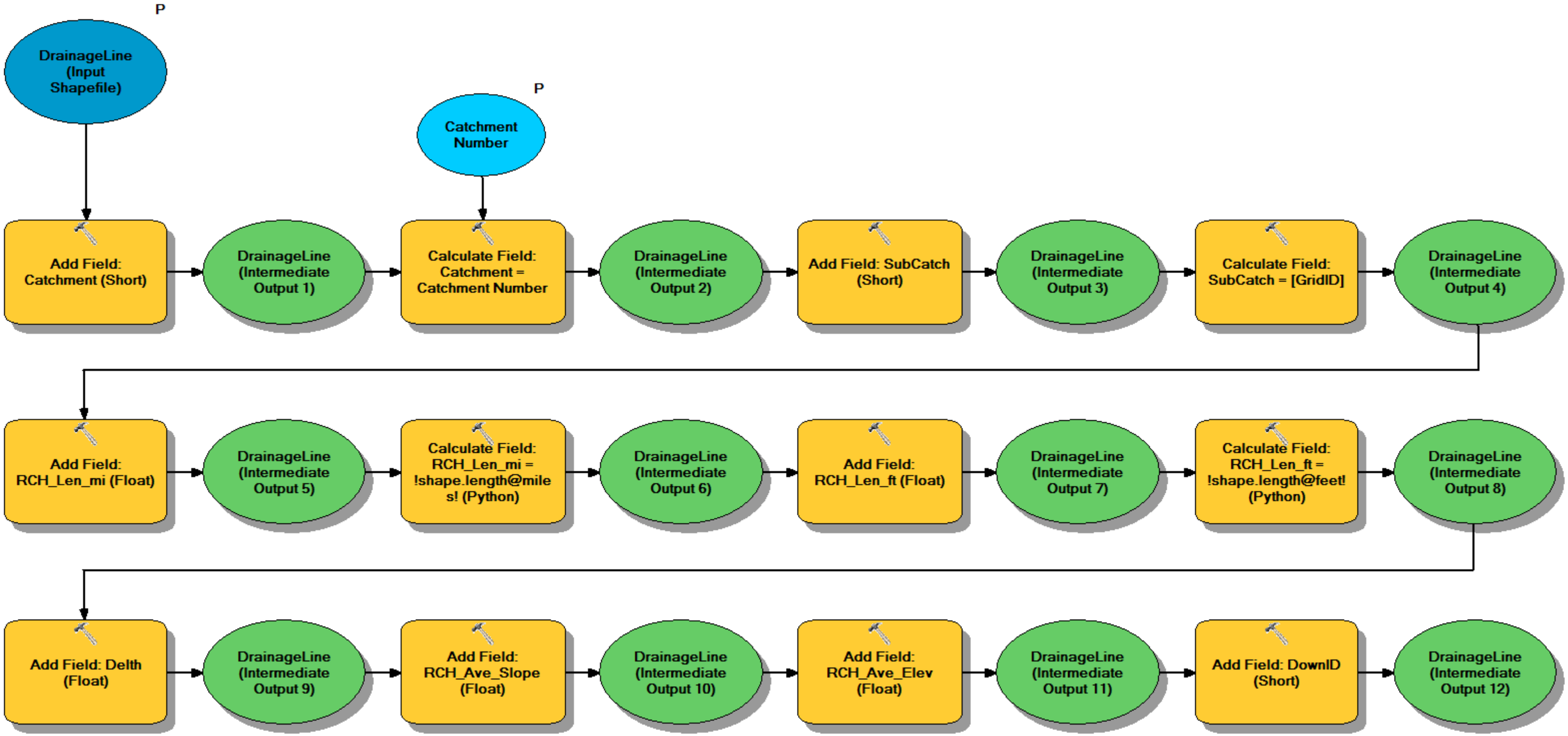
With modified met data, the HSPF model can be run once the following changes have been:

- If the new climate change time-series data has been saved in the original met .wdm (with existing observed time-series) then the model met segments will need to be amended - see section 5.3
- If a new met .wdm has been created then the model *.uci* file will need modifying by changing the location of the *WDM2* file in the *.uci File* section (see Appendix G).
    - This process is untested, if it fails to work or breaks the model an alternative would be to recreate the model and use the new met .wdm file when creating it (as in section 5.1 and 5.2).

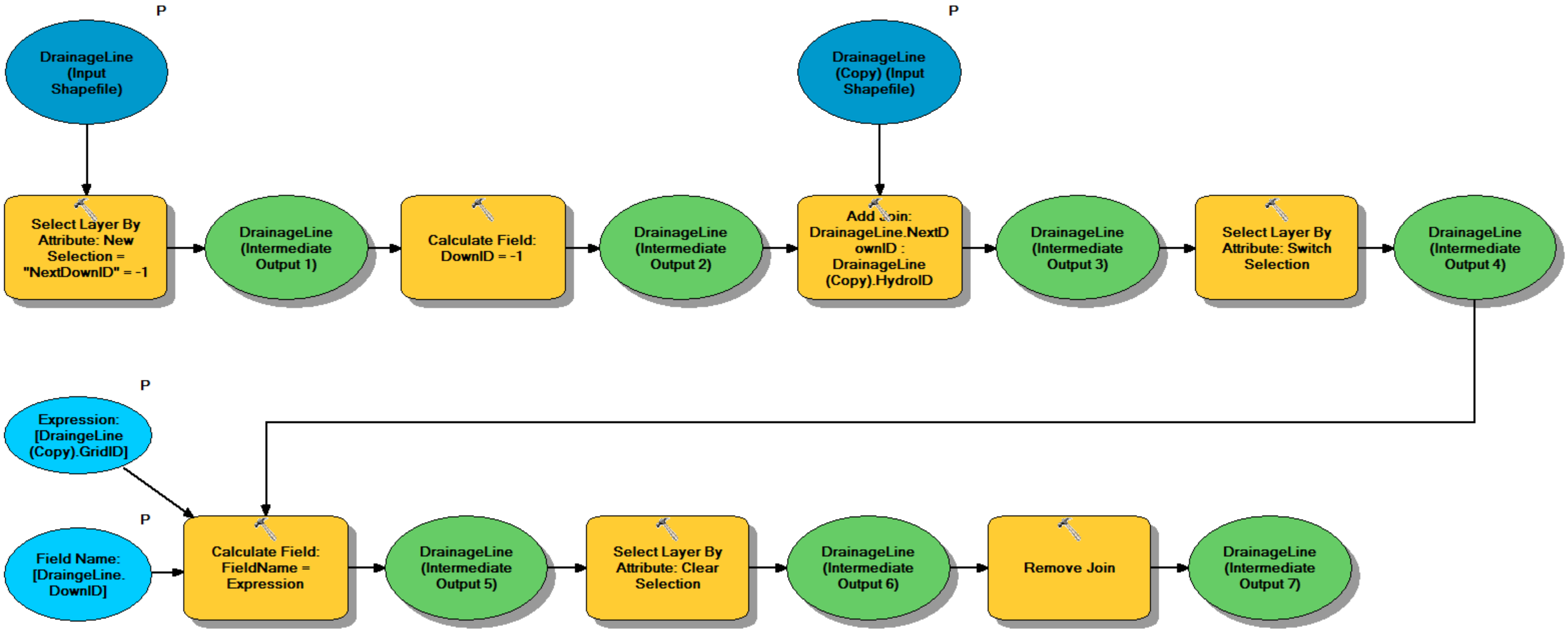
Appendices

Appendix A – ArcMap Model Builder Diagrams for .ptf and .rch HSPF Input Files

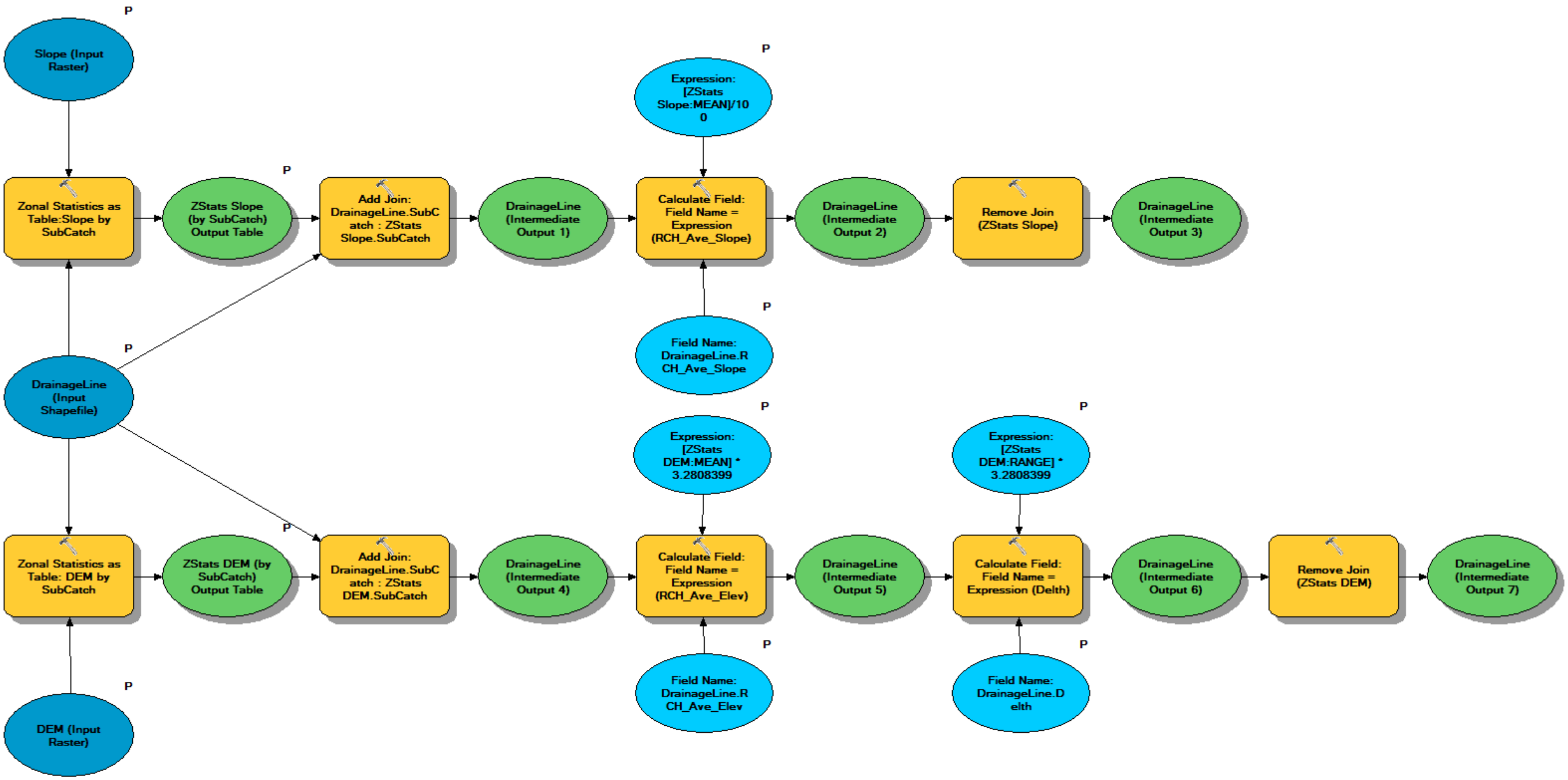
The following ArcMap Model Builder diagrams detail the work flow in creating a shapefile based on the Arc Hydro tools DrainageLine output (see section 3.2.2). The output contains measured values required in the creation of the .ptf and .psr HSPF model input files. There are three Model Builder diagrams which should be performed in sequence. The first prepares new fields in the DrainageLine shapefile and calculates HSPF sub-catchment numbers and values of reach length based on the DrainageLine features and attributes.



The second diagram continues processing the DrainageLine shapefile. Here it identifies the exit sub-catchment and then joins a copy of the DrainageLine shapefile as an intermediary file to translate the Arc Hydro Tools NextDownID field into HSPF sub-catchment numbers.



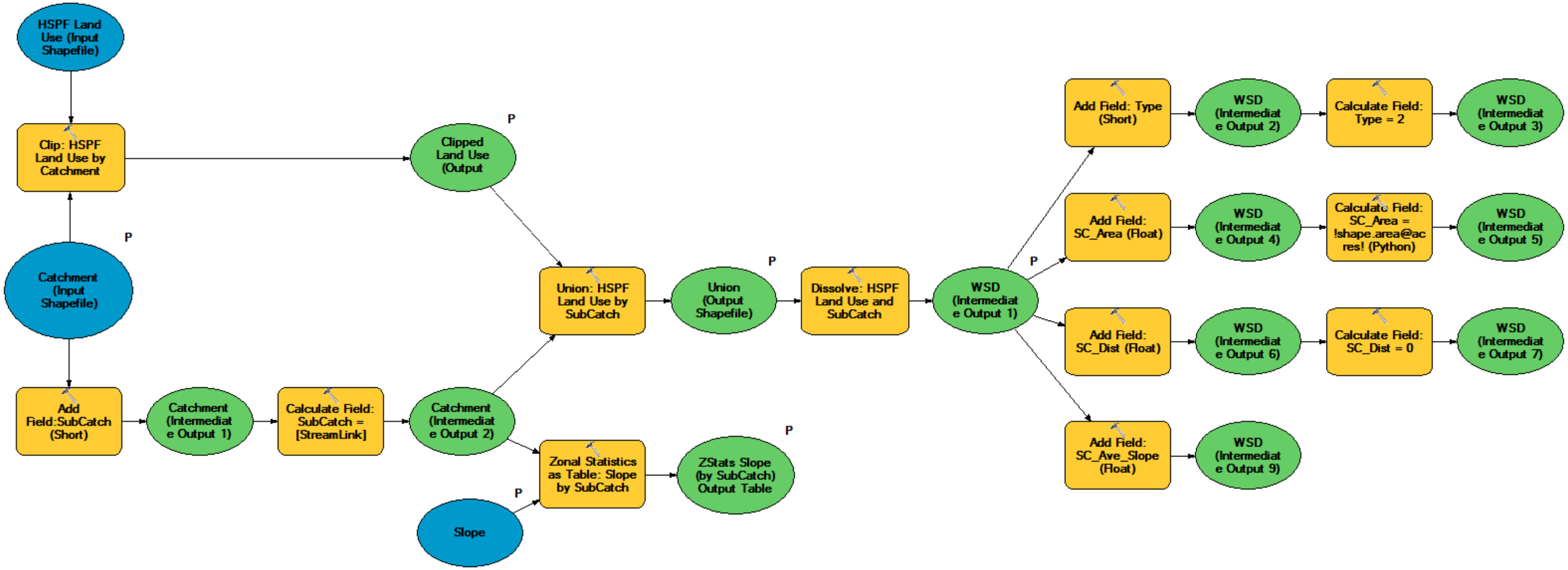
The final diagram, and step in the calculations, uses the DEM and a percent rise slope raster (calculated separately from the DEM) to calculate and add the final values of average slope along the reach, average elevation along the reach and the difference between the minimum and maximum elevation along the reach. All values that are required to create the .ptf and .rch HSPF input files are now contained in the processed DrainageLine shapefile.



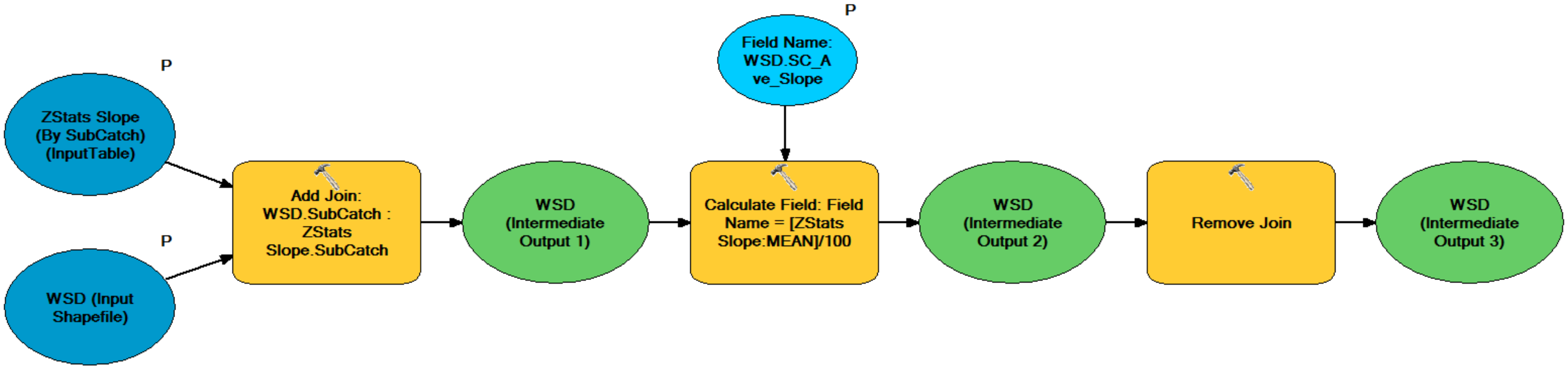
Appendix B – ArcMap Model Builder Diagrams for .wsd HSPF Input File

The following ArcMap Model Builder diagrams detail the work flow in creating a shapefile based on the Arc Hydro tools Catchment output (see section 3.2.2). The output contains measured values required in the creation of the .wsd HSPF model input files. The Model Builder diagrams should be performed in sequence although first two diagrams are used for processing a model catchment that contains multiple sub-catchments and the third diagram performs the equivalent steps for a model catchment consisting of a single sub-catchment. The fourth diagram contains the final steps for both types of model catchment.

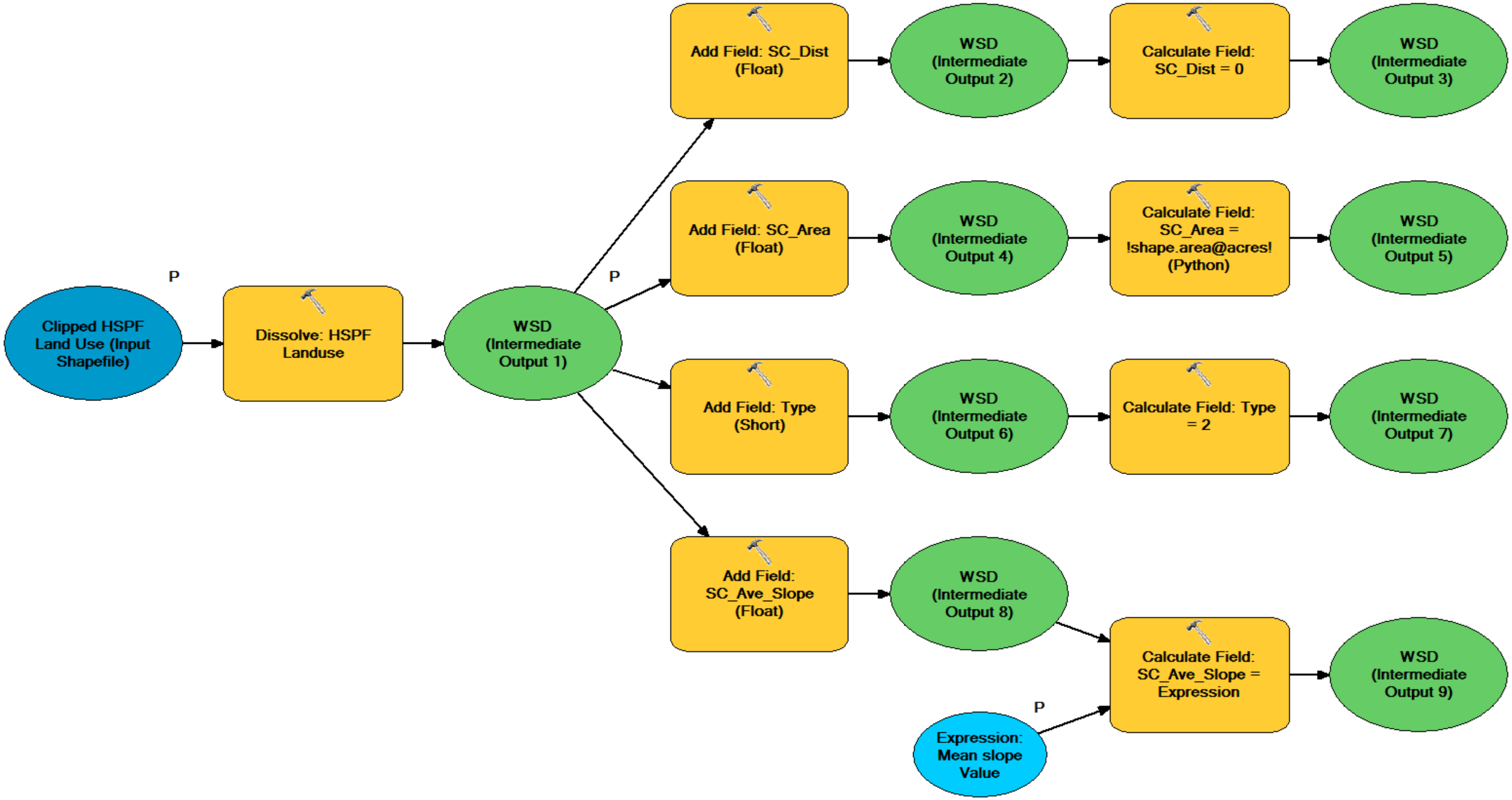
The Diagram below should be the initial step for a model catchment with multiple sub-catchments. The model processes the HSPF categorised land use data for each sub-catchment, allowing the area of each land use category within each sub-catchment to be calculated. The model creates a new shapefile called WSD to store these areas and also adds additional fields required for the .wsd HSPF input file and assigns HSPF sub-catchment numbers and appropriate default values. The model also performs the initial calculation of average percent rise slope values per sub-catchment.



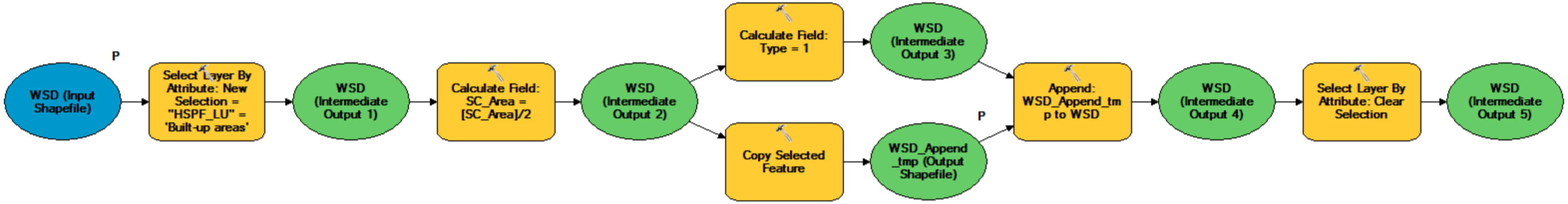
The model below is the second step for processing model catchments with multiple sub-catchments. The model uses the pre-processing of average percent rise slope values for the sub-catchments and joins and writes the data to the appropriate field in the WSD shapefile output.



The Diagram below is the initial step for a model catchment with a single sub-catchment. The model processes the HSPF categorised land use data for the sub-catchment, allowing the area of each land use category to be calculated. The model creates a new shapefile called WSD to store these areas and also adds additional fields required for the .wsd HSPF input file and assigns HSPF sub-catchment numbers and appropriate default values. The model also records the average percent rise slope of the sub-catchment, which is based on a value calculated outside of this model and entered as a parameter manually.



The final model diagram shows the final stage of processing that should be performed on the WSD shapefiles from models with both single and multiple sub-catchments. The model details the steps required to duplicate 'Built-up areas' so that this HSPF land use category is represented by both an impervious and pervious entry. The 'Built-up areas' are divided equally between the two types, accordingly the areas are halved meaning that the sum of the pervious and impervious areas of 'Built-up areas' equals the total area for the 'Built-up areas' in the model sub-catchment or sub-catchments.



Appendix C – .psr File Example

The .psr file stores *Point Sources* information. It is a text file saved as *XX.psr*, where *XX* is the filename.

Note: all HSPF input files must have the same filename and be stored in the same directory when creating an HSPF model in WinHSPF.

The .psr input file is left as the default, point sources used within the model are added as time series data in the model output .wdm file and selected and marked in use in WinHSPF.

```
0

FacilityName Npdes Cuseg Mi

OrdinalNumber Pollutant Load(lbs/hr)
```

Appendix D – .ptf File Example

The .ptf file store *Channel Geometry* information. It is a text file saved as *XX.ptf*, where *XX* is the filename.

Note: all HSPF input files must have the same filename and be stored in the same directory when creating an HSPF model in WinHSPF.

The example file below is for 7 sub-catchments within the model. The header row (stored on one line – it is word wrapped here) is comma delimited with all header text qualified with speech marks (“). The data entries are space delimited, speech marks are not required for the data text entry. The data for each sub-catchment is entered on a new row. The number of decimal places varies with column, the formatting was matched to the outputs produced by BASINS for consistency and compatibility.

```
"Reach Number","Length(ft)","Mean Depth(ft)","Mean Width (ft)","Mannings Roughness Coeff.","Long. Slope","Type of x-section","Side slope of upper FP left","Side slope of lower FP left","Zero slope FP width left(ft)","Side slope of channel left","Side slope of channel right","Zero slope FP width right(ft)","Side slope lower FP right","Side slope upper FP right","Channel Depth(ft)","Flood side slope change at depth","Max. depth","No. of exits","Fraction of flow through exit 1","Fraction of flow through exit 2","Fraction of flow through exit 3","Fraction of flow through exit 4","Fraction of flow through exit 5"
1 3686 5.00000 30.00000 0.05 0.01249 Trapezoidal 0.5 0.5 30.000 1 1 30.000 0.5 0.5 6.2500 9.3750 312.500 1 1 0 0 0 0
3 4464 5.00000 30.00000 0.05 0.00844 Trapezoidal 0.5 0.5 30.000 1 1 30.000 0.5 0.5 6.2500 9.3750 312.500 1 1 0 0 0 0
2 9755 5.00000 30.00000 0.05 0.02327 Trapezoidal 0.5 0.5 30.000 1 1 30.000 0.5 0.5 6.2500 9.3750 312.500 1 1 0 0 0 0
4 415 5.00000 30.00000 0.05 0.03414 Trapezoidal 0.5 0.5 30.000 1 1 30.000 0.5 0.5 6.2500 9.3750 312.500 1 1 0 0 0 0
5 10024 5.00000 30.00000 0.05 0.03480 Trapezoidal 0.5 0.5 30.000 1 1 30.000 0.5 0.5 6.2500 9.3750 312.500 1 1 0 0 0 0
6 5213 5.00000 30.00000 0.05 0.00905 Trapezoidal 0.5 0.5 30.000 1 1 30.000 0.5 0.5 6.2500 9.3750 312.500 1 1 0 0 0 0
7 10801 5.00000 30.00000 0.05 0.12221 Trapezoidal 0.5 0.5 30.000 1 1 30.000 0.5 0.5 6.2500 9.3750 312.500 1 1 0 0 0 0
```

Appendix E – .rch File Example

The .rch file stores *Reach* information. It is a text file saved as *XX.rch*, where *XX* is the filename.

Note: all HSPF input files must have the same filename and be stored in the same directory when creating an HSPF model in WinHSPF.

The example file below is for 7 sub-catchments within the model. The header row (stored on one line – it is word wrapped here) is comma delimited with all header text qualified with speech marks ("). The data entries are space delimited, speech marks are required to surround the entry of data in the *Pname* column. The data for each sub-catchment is entered on a new row. The number of decimal places varies with column, the formatting was matched to the outputs produced by BASINS for consistency and compatibility.

```
"Rivrch","Pname","Watershed-ID","HeadwaterFlag","Exits","Milept","Stream/Resevoir
Type","Segl","Delth","Elev","Ulcsm","Urcsm","Dscsm","Ccsm","Mnflow","Mnvelo","Svtnflow","Svtnvelo","Pslope","Pdepth","
Pwidth","Pmile","Ptemp","Pph","Pk1","Pk2","Pk3","Pmann","Psod","Pbgdo","Pbgnh3","Pbgbod5","Pbgbod","Level","ModelSeg"
1 "1" 1 0 1 0 S 0.70 10.50 41 0 0 4 0 0 0 0 0 0.012494 5.0000 30.000 0 0 0 0 0 0 0 0 0 0 0 0 0 1
3 "3" 3 0 1 0 S 0.85 9.19 46 0 0 4 0 0 0 0 0 0.008445 5.0000 30.000 0 0 0 0 0 0 0 0 0 0 0 0 0 1
2 "2" 2 0 1 0 S 1.85 36.09 52 0 0 5 0 0 0 0 0 0.023272 5.0000 30.000 0 0 0 0 0 0 0 0 0 0 0 0 0 1
4 "4" 4 0 1 0 S 0.08 8.53 38 0 0 5 0 0 0 0 0 0.034140 5.0000 30.000 0 0 0 0 0 0 0 0 0 0 0 0 0 1
5 "5" 5 0 1 0 S 1.90 34.12 28 0 0 8 0 0 0 0 0 0.034800 5.0000 30.000 0 0 0 0 0 0 0 0 0 0 0 0 0 1
6 "6" 6 0 1 0 S 0.99 6.23 13 0 0 8 0 0 0 0 0 0.009055 5.0000 30.000 0 0 0 0 0 0 0 0 0 0 0 0 0 1
7 "7" 7 0 1 0 S 2.05 26.25 10 0 0 -1 0 0 0 0 0 0.122214 5.0000 30.000 0 0 0 0 0 0 0 0 0 0 0 0 0 1
```

Appendix F – .wsd File Example

The .wsd file is the *Watershed* information. It is a text file saved as *XX.wsd*, where *XX* is the filename.

Note: all HSPF input files must have the same filename and be stored in the same directory when creating an HSPF model in WinHSPF.

The example file below is for 7 sub-catchments within the model. Each sub-catchment has a separate entry for each land use type within the sub-catchment. *Built-up areas* are duplicated with an *impervious* entry and a *pervious* entry, the combined area of both *Built-up area* entries for each sub-catchment equals the total *Built-up area* within the sub-catchment. The division of *impervious* and *pervious Built-up area* used here is equal – 50% allocated to each.

The header is comma delimited with all header text qualified with speech marks ("). The data entries are space delimited (5 spaces are used in this file), speech marks are required to surround the entry of data in the *LU Name* column. The data for each land use area and type (pervious/impervious) within each sub-catchment is entered on a new row. The number of decimal places varies with column, the formatting was matched to the outputs produced by BASINS for consistency and compatibility.

```
"LU Name","Type (1=Impervious, 2=Pervious)","Watershd-ID","Area","Slope","Distance"
"Arable & horticultural"     2     1     181.0     0.023937     0.0000
"Arable & horticultural"     2     2     467.1     0.029466     0.0000
"Arable & horticultural"     2     3     268.8     0.032704     0.0000
"Arable & horticultural"     2     5     185.8     0.025124     0.0000
"Arable & horticultural"     2     6     225.9     0.017593     0.0000
"Arable & horticultural"     2     7     255.4     0.016834     0.0000
"Built-up areas"     1     1     5.6     0.023937     0.0000
"Built-up areas"     1     2     281.4     0.029466     0.0000
"Built-up areas"     1     3     11.4     0.032704     0.0000
"Built-up areas"     1     5     86.2     0.025124     0.0000
"Built-up areas"     1     6     65.8     0.017593     0.0000
"Built-up areas"     1     7     64.5     0.016834     0.0000
"Coast, Sea"     2     7     64.4     0.016834     0.0000
"Grassland"     2     1     407.8     0.023937     0.0000
"Grassland"     2     2     541.3     0.029466     0.0000
"Grassland"     2     3     414.1     0.032704     0.0000
"Grassland"     2     4     2.5     0.035626     0.0000
"Grassland"     2     5     851.2     0.025124     0.0000
```

```
"Grassland"     2     6     790.0     0.017593     0.0000
"Grassland"     2     7     639.1     0.016834     0.0000
"Mountain, heath, bog"     2     2     5.6     0.029466     0.0000
"Mountain, heath, bog"     2     3     3.6     0.032704     0.0000
"Mountain, heath, bog"     2     6     0.4     0.017593     0.0000
"Water"     2     7     12.0     0.016834     0.0000
"Woodland"     2     1     0.4     0.023937     0.0000
"Woodland"     2     2     46.5     0.029466     0.0000
"Woodland"     2     3     34.5     0.032704     0.0000
"Woodland"     2     6     38.1     0.017593     0.0000
"Woodland"     2     7     7.6     0.016834     0.0000
"Built-up areas"     2     1     5.6     0.023937     0.0000
"Built-up areas"     2     2     281.4     0.029466     0.0000
"Built-up areas"     2     3     11.4     0.032704     0.0000
"Built-up areas"     2     5     86.2     0.025124     0.0000
"Built-up areas"     2     6     65.8     0.017593     0.0000
"Built-up areas"     2     7     64.5     0.016834     0.0000
```

Appendix G – .uci File Example

The .uci file is the *User Control Input* file which contains all parameters and instructions needed to run the HSPF model. The text file is tightly formatted and arranged in a preordained order which is readable by the HSPF model software. The file is created by WinHSPF from the model input files that are either created by BASINS or manually using the Arc Hydro method. Changes to parameters and model configuration made in WinHSPF will be recorded and stored in the .uci file. It is also possible (and sometimes simpler) to edit the .uci file directly, making quick parameter adjustments in a text editor, saving the changes and then reading them into HSPF when the model is next opened.

The included .uci file example is for a model of 7 sub-catchments.

```
RUN

GLOBAL
  UCI Created by WinHSPF for 12
  START       2003/01/01 00:00  END    2012/12/30 00:00
  RUN INTERP OUTPT LEVELS    1    0
  RESUME     0 RUN     1                          UNITS    1
END GLOBAL

FILES
<FILE>  <UN#>***<----FILE NAME------------------------------------------------->
MESSU      24   12.ech
           91   12.out
WDM1       25   12.wdm
WDM2       26   ..\..\Met\C2C_MET.wdm
BINO       92   12.hbn
END FILES

OPN SEQUENCE
    INGRP              INDELT 01:00
      PERLND     101
      PERLND     103
      PERLND     106
      PERLND     107
      IMPLND     101
      PERLND     301
      PERLND     303
      PERLND     304
      PERLND     306
      PERLND     307
      IMPLND     301
      PERLND     201
      PERLND     203
      PERLND     204
      PERLND     206
      PERLND     207
      IMPLND     201
      PERLND     403
      PERLND     501
      PERLND     503
      PERLND     507
      IMPLND     501
      PERLND     601
      PERLND     603
      PERLND     604
```

```
      PERLND     606
      PERLND     607
      IMPLND     601
      PERLND     701
      PERLND     702
      PERLND     703
      PERLND     705
      PERLND     706
      PERLND     707
      IMPLND     701
      RCHRES       1
      RCHRES       3
      RCHRES       2
      RCHRES       4
      RCHRES       5
      RCHRES       6
      RCHRES       7
    END INGRP
END OPN SEQUENCE

PERLND
  ACTIVITY
*** <PLS >               Active Sections                               ***
*** x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
  101  707    0    0    1    1    0    0    1    0    0    0    0    0
  END ACTIVITY

  PRINT-INFO
*** < PLS>                       Print-flags                           PIVL  PYR
*** x  - x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC
  101  707    4    4    4    4    4    4    4    4    4    4    4    4    1    9
  END PRINT-INFO

  BINARY-INFO
*** < PLS>               Binary Output Flags                           PIVL  PYR
*** x  - x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC
  101  707    4    4    4    4    4    4    4    4    4    4    4    4    1    9
  END BINARY-INFO

  GEN-INFO
***            Name                  Unit-systems   Printer BinaryOut
*** <PLS >                               t-series Engl Metr Engl Metr
*** x -  x                                in  out
  101     Arable & horticultur             1    1    0    0   92    0
  103     Grassland                        1    1    0    0   92    0
  106     Woodland                         1    1    0    0   92    0
  107     Built-up areas                   1    1    0    0   92    0
  201     Arable & horticultur             1    1    0    0   92    0
  203     Grassland                        1    1    0    0   92    0
  204     Mountain, heath, bog             1    1    0    0   92    0
  206     Woodland                         1    1    0    0   92    0
  207     Built-up areas                   1    1    0    0   92    0
  301     Arable & horticultur             1    1    0    0   92    0
  303     Grassland                        1    1    0    0   92    0
  304     Mountain, heath, bog             1    1    0    0   92    0
  306     Woodland                         1    1    0    0   92    0
  307     Built-up areas                   1    1    0    0   92    0
  403     Grassland                        1    1    0    0   92    0
  501     Arable & horticultur             1    1    0    0   92    0
  503     Grassland                        1    1    0    0   92    0
  507     Built-up areas                   1    1    0    0   92    0
```

```
  601     Arable & horticultur            1    1    0    0   92    0
  603     Grassland                       1    1    0    0   92    0
  604     Mountain, heath, bog            1    1    0    0   92    0
  606     Woodland                        1    1    0    0   92    0
  607     Built-up areas                  1    1    0    0   92    0
  701     Arable & horticultur            1    1    0    0   92    0
  702     Coast, Sea                      1    1    0    0   92    0
  703     Grassland                       1    1    0    0   92    0
  705     Water                           1    1    0    0   92    0
  706     Woodland                        1    1    0    0   92    0
  707     Built-up areas                  1    1    0    0   92    0
  END GEN-INFO

  PWAT-PARM1
*** <PLS >                  Flags
*** x -  x CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE IFFC  HWT IRRG IFRD
  101  707    0    1    1    1    0    0    0    0    1    1    0    0    0
  END PWAT-PARM1

  PWAT-PARM2
*** < PLS>    FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
*** x  - x                (in)   (in/hr)      (ft)              (1/in)   (1/day)
  101  107        1.       6.5      0.16       350  0.023937        0.      0.98
  201  207        1.       6.5      0.16       350  0.029466        0.      0.98
  301  307        1.       6.5      0.16       300  0.032704        0.      0.98
  403             1.       6.5      0.16       300  0.035626        0.      0.98
  501  507        1.       6.5      0.16       350  0.025124        0.      0.98
  601  607        1.       6.5      0.16       350  0.017593        0.      0.98
  701  703        1.       6.5      0.16       350  0.016834        0.      0.98
  705             0.        4.      0.16       350  0.016834        0.      0.98
  706  707        1.       6.5      0.16       350  0.016834        0.      0.98
  END PWAT-PARM2

  PWAT-PARM3
*** < PLS>    PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
*** x  - x   (deg F)   (deg F)
  101  707       40.       35.        2.        2.       0.1      0.02        0.
  END PWAT-PARM3

  PWAT-PARM4
*** <PLS >     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP
*** x -  x      (in)      (in)                       (1/day)
  101  707       0.1     1.128       0.2      0.75       0.5       0.1
  END PWAT-PARM4

  PWAT-STATE1
*** < PLS>  PWATER state variables (in)
*** x  - x      CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
  101  707      0.01      0.01       0.3      0.01       1.5      0.01      0.01
  END PWAT-STATE1

  MON-INTERCEP
*** <PLS >  Interception storage capacity at start of each month (in)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  101  707  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  END MON-INTERCEP

  MON-LZETPARM
*** <PLS >  Lower zone evapotransp   parm at start of each month
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  101  707  0.2  0.2  0.3  0.3  0.4  0.4  0.4  0.4  0.4  0.3  0.2  0.2
```

```
  END MON-LZETPARM

  SED-PARM2
*** <PLS >      SMPF      KRER      JRER     AFFIX     COVER      NVSI
*** x -  x                                  (/day)            lb/ac-day
  101  707        1.      0.14        2.      0.03      0.88        0.
  END SED-PARM2

  SED-PARM3
*** <PLS >  Sediment parameter 3
*** x -  x      KSER      JSER      KGER      JGER
  101  707       0.1        2.      0.01        1.
  END SED-PARM3

  NQUALS
*** <PLS >
*** x -  xNQUAL
  101  707    1
  END NQUALS

  QUAL-PROPS
*** <PLS >  Identifiers and Flags
*** x -  x    QUALID      QTID  QSD VPFW VPFS  QSO  VQO QIFW VIQC QAGW VAQC
  101  707F.COLIFORM      #ORG    0    0    0    1    1    0    0    0    0
  END QUAL-PROPS

  QUAL-INPUT
***         Storage on surface and nonseasonal parameters
***            SQO   POTFW   POTFS   ACQOP  SQOLIM   WSQOP    IOQC    AOQC
*** <PLS >  qty/ac qty/ton qty/ton    qty/  qty/ac   in/hr qty/ft3 qty/ft3
*** x -  x                          ac.day
  101  707    100.      0.      0.      0.      0.     0.2      0.      0.
  END QUAL-INPUT

  MON-ACCUM
*** <PLS >  Value at start of each month for accum rate of QUALOF (lb/ac.day)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  101      14000150003700014000990001400099000014000 1.e5140001400014000
  103      24000260003800040000990004000094000040000 1.e5240002500024000
  106        5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7
  107          0    0    0    0    0    0    0    0    0    0    0    0
  201      160001800043000170001.1e5170001.1e5160001.2e5160001700016000
  203      320003400048000520001.2e5530001.2e5530001.3e5320003300032000
  204          0    0    0    0    0    0    0    0    0    0    0    0
  206        5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7
  207          0    0    0    0    0    0    0    0    0    0    0    0
  301      130001500036000140009600014000960001300099000130001400013000
  303      280002900041000450001.1e5460009900046000 1.1e5280002800028000
  304          0    0    0    0    0    0    0    0    0    0    0    0
  306        5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7
  307          0    0    0    0    0    0    0    0    0    0    0    0
  403      210002300033000170006900022000690002100071000210002200021000
  501      130001400048000130001.3e5130001.3e5130001.3e5130001300013000
  503      230002400035000340008900035000850003400091000230002300023000
  507          0    0    0    0    0    0    0    0    0    0    0    0
  601      140001600047000150001.3e5150001.3e5140001.3e5140001500014000
  603      270002900041000420001.1e543000 1.e5420001.1e5270002700027000
  604          0    0    0    0    0    0    0    0    0    0    0    0
  606        5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7
  607          0    0    0    0    0    0    0    0    0    0    0    0
  701      110001300036000120009500012000950001100098000110001200011000
```

```
  702          0    0    0    0    0    0    0    0    0    0    0    0
  703      250002600036000370008900039000840003900091000250002500025000
  705          0    0    0    0    0    0    0    0    0    0    0    0
  706        5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7  5.7
  707          0    0    0    0    0    0    0    0    0    0    0    0
  END MON-ACCUM

  MON-SQOLIM
*** <PLS >  Value at start of month for limiting storage of QUALOF (lb/ac)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  101      25000270006700021000l.5e521000l.5e520000l.5e525000250002500025000
  103      44000460006800060000l.5e560000l.4e559000l.5e544000450004400000
  106         10   10   10   10   10   10   10   10   10   10   10   10
  107      1.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-6
  201      29000320007700025000l.7e525000l.7e524000l.7e529000300002900000
  203      58000610008700078000l.9e580000l.8e579000l.9e558000590005800000
  204      1.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-6
  206         10   10   10   10   10   10   10   10   10   10   10   10
  207      1.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-6
  301      24000270006600021000l.4e521000l.4e520000l.5e524000250002400000
  303      50000530007400067000l.6e569000l.5e568000l.6e550000510005000000
  304      1.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-6
  306         10   10   10   10   10   10   10   10   10   10   10   10
  307      1.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-6
  403      39000410006000026000 1.e533000 1.e532000l.1e539000390003900000
  501      23000250008600020000 2.e520000 2.e519000 2.e523000230002300000
  503      41000430006300050000l.3e552000l.3e551000l.4e541000410004100000
  507      1.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-6
  601      26000290008500022000l.9e522000l.9e522000 2.e526000270002600000
  603      49000510007500063000l.6e564000l.5e564000l.6e549000490004900000
  604      1.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-6
  606         10   10   10   10   10   10   10   10   10   10   10   10
  607      1.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-6
  701      21000230006400018000l.4e518000l.4e517000l.5e521000210002100000
  702      1.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-6
  703      45000470006500055000l.3e559000l.3e558000l.4e545000450004500000
  705      1.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-6
  706         10   10   10   10   10   10   10   10   10   10   10   10
  707      1.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-61.e-6
  END MON-SQOLIM

  MON-IFLW-CONC
*** <PLS >  Conc of QUAL in interflow outflow for each month (qty/ft3)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  101   7031.0E41.0E41.0E41.0E41.0E41.0E41.0E41.0E41.0E41.0E41.0E41.0E4
  705      0.2E30.2E30.2E30.2E30.2E30.2E30.2E30.2E30.2E30.2E30.2E30.2E3
  706   7071.0E41.0E41.0E41.0E41.0E41.0E41.0E41.0E41.0E41.0E41.0E41.0E4
  END MON-IFLW-CONC

  MON-GRND-CONC
*** <PLS >  Value at start of month for conc of QUAL in groundwater (qty/ft3)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  101   7039.8E49.8E49.8E49.8E49.8E49.8E49.8E49.8E49.8E49.8E49.8E49.8E4
  705      1.0E21.0E21.0E21.0E21.0E21.0E21.0E21.0E21.0E21.0E21.0E21.0E2
  706   7079.8E49.8E49.8E49.8E49.8E49.8E49.8E49.8E49.8E49.8E49.8E49.8E4
  END MON-GRND-CONC

END PERLND

IMPLND
  ACTIVITY
```

```
*** <ILS >               Active Sections
*** x -  x ATMP SNOW IWAT  SLD  IWG IQAL
  101  701    0    0    1    1    0    1
  END ACTIVITY

  PRINT-INFO
*** <ILS > ******** Print-flags ******** PIVL  PYR
*** x -  x ATMP SNOW IWAT  SLD  IWG IQAL *********
  101  701    4    4    4    4    4    4    1    9
  END PRINT-INFO

  BINARY-INFO
*** <ILS > **** Binary-Output-flags **** PIVL  PYR
*** x -  x ATMP SNOW IWAT  SLD  IWG IQAL *********
  101  701    4    4    4    4    4    4    1    9
  END BINARY-INFO

  GEN-INFO
***             Name             Unit-systems   Printer BinaryOut
*** <ILS >                           t-series Engl Metr Engl Metr
*** x -  x                            in  out
  101  701Built-up areas               1    1    0    0   92    0
  END GEN-INFO

  IWAT-PARM1
*** <ILS >        Flags
*** x -  x CSNO RTOP  VRS  VNN RTLI
  101  701    0    0    0    0    0
  END IWAT-PARM1

  IWAT-PARM2
*** <ILS >      LSUR     SLSUR      NSUR     RETSC
*** x -  x      (ft)                          (in)
  101            350  0.023937      0.05       0.1
  201            350  0.029466      0.05       0.1
  301            300  0.032704      0.05       0.1
  501            350  0.025124      0.05       0.1
  601            350  0.017593      0.05       0.1
  701            350  0.016834      0.05       0.1
  END IWAT-PARM2

  IWAT-PARM3
*** <ILS >    PETMAX    PETMIN
*** x -  x   (deg F)   (deg F)
  101  701       40.       35.
  END IWAT-PARM3

  IWAT-STATE1
*** <ILS >  IWATER state variables (inches)
*** x -  x      RETS      SURS
  101  701      0.01      0.01
  END IWAT-STATE1

  SLD-PARM2
***             KEIM      JEIM    ACCSDP    REMSDP
*** <ILS >                         tons/      /day
*** x -  x                        ac.day
  101  701       0.1        2.    0.0044      0.03
  END SLD-PARM2

  NQUALS
```

```
*** <ILS >
*** x -  xNQUAL
  101  701    1
  END NQUALS

  QUAL-PROPS
*** <ILS >    Identifiers and Flags
*** x -  x      QUALID    QTID  QSD VPFW  QSO  VQO
  101  701F.COLIFORM      #ORG    0    0    1    0
  END QUAL-PROPS

  QUAL-INPUT
***         Storage on surface and nonseasonal parameters
***            SQO   POTFW   ACQOP  SQOLIM   WSQOP
*** <ILS >  qty/ac qty/ton    qty/  qty/ac   in/hr
*** x -  x                  ac.day
  101  701   0.001      0.       0 0.00001    0.46
  END QUAL-INPUT

END IMPLND

RCHRES
  ACTIVITY
*** RCHRES  Active sections
*** x -  x HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG
    1    7    1    1    0    0    0    1    0    0    0    0
  END ACTIVITY

  PRINT-INFO
*** RCHRES  Printout level flags
*** x -  x HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR
    1    7    4    4    4    4    4    4    4    4    4    4    1    9
  END PRINT-INFO

  BINARY-INFO
*** RCHRES  Binary Output level flags
*** x -  x HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR
    1    7    4    4    4    4    4    4    4    4    4    4    1    9
  END BINARY-INFO

  GEN-INFO
***              Name        Nexits   Unit Systems   Printer
*** RCHRES                               t-series  Engl Metr LKFG
*** x -  x                                 in  out
    1     1                       1         1    1   91    0    0   92    0
    2     2                       1         1    1   91    0    0   92    0
    3     3                       1         1    1   91    0    0   92    0
    4     4                       1         1    1   91    0    0   92    0
    5     5                       1         1    1   91    0    0   92    0
    6     6                       1         1    1   91    0    0   92    0
    7     7                       1         1    1   91    0    0   92    0
  END GEN-INFO

  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
    1    7   0  1  1  1    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
  END HYDR-PARM1

  HYDR-PARM2
```

```
*** RCHRES FTBW FTBU       LEN      DELTH      STCOR         KS       DB50
*** x -  x              (miles)      (ft)       (ft)                  (in)
    1        0.    1       0.7         10        3.2        0.5       0.01
    2        0.    2      1.85         36        3.2        0.5       0.01
    3        0.    3      0.85          9        3.2        0.5       0.01
    4        0.    4      0.08          9        3.2        0.5       0.01
    5        0.    5       1.9         34        3.2        0.5       0.01
    6        0.    6      0.99          6        3.2        0.5       0.01
    7        0.    7      2.05         26        3.2        0.5       0.01
  END HYDR-PARM2

  HYDR-INIT
***         Initial conditions for HYDR section
***RC HRES       VOL  CAT Initial value  of COLIND     initial  value  of OUTDGT
*** x  - x     ac-ft       for each possible   exit  for each possible exit,ft3
    1    7      0.01        4.2  4.5  4.5  4.5  4.2        2.1  1.2  0.5  1.2  1.8
  END HYDR-INIT

  GQ-GENDATA
*** RCHRES NGQL TPFG PHFG ROFG CDFG SDFG PYFG  LAT
*** x -  x                                     deg
    1    7    1    2    2    2    2    2    2    0
  END GQ-GENDATA

  GQ-QALDATA
*** RCHRES                GQID       DQAL    CONCID       CONV     QTYID
*** x -  x                         concid
    1    7F.COLIFORM                  50.      OR/L    0.0353  #ORG
  END GQ-QALDATA

  GQ-QALFG
*** RCHRES HDRL OXID PHOT VOLT BIOD  GEN SDAS
*** x -  x
    1    7    0    0    0    0    0    1    0
  END GQ-QALFG

  GQ-GENDECAY
*** RCHRES    FSTDEC     THFST
*** x -  x    (/day)
    1    7      0.33       1.1
  END GQ-GENDECAY

END RCHRES

FTABLES

  FTABLE      1
 rows cols                              ***
    8    4
     depth      area    volume  outflow1 ***
        0.      1.69        0.        0.
       0.5      1.78      0.87     20.89
        5.      2.54     10.58     988.9
      6.25      2.75     13.88   1456.99
      7.81      8.36     26.53   2169.22
      9.38      8.88       40.   4119.32
    160.94     60.19   5274.223820278.75
     312.5    111.49  18283.63 20067014.
  END FTABLE  1

  FTABLE      3
```

```
rows cols                               ***
   8    4
     depth       area    volume  outflow1 ***
        0.       2.05        0.        0.
       0.5       2.15      1.05     17.17
        5.       3.07     12.81    812.91
      6.25       3.33     16.81    1197.7
      7.81      10.12     32.12   1783.17
      9.38      10.76     48.44   3386.23
    160.94      72.89   6387.453140400.75
     312.5     135.02  22142.74 16495777.
 END FTABLE  3

 FTABLE      2
rows cols                               ***
   8    4
     depth       area    volume  outflow1 ***
        0.       4.48        0.        0.
       0.5        4.7       2.3     28.51
        5.       6.72     27.99    1349.8
      6.25       7.28     36.74   1988.72
      7.81      22.11      70.2   2960.88
      9.38      23.51    105.85   5622.67
    160.94     159.28  13958.23 5214492.5
     312.5     295.05  48387.65 27390486.
 END FTABLE  2

 FTABLE      4
rows cols                               ***
   8    4
     depth       area    volume  outflow1 ***
        0.       0.19        0.        0.
       0.5        0.2       0.1     34.53
        5.       0.29      1.19   1634.95
      6.25       0.31      1.56   2408.84
      7.81       0.94      2.99   3586.36
      9.38         1.       4.5   6810.46
    160.94       6.78    593.81 6316050.5
     312.5      12.55   2058.52 33176708.
 END FTABLE  4

 FTABLE      5
rows cols                               ***
   8    4
     depth       area    volume  outflow1 ***
        0.        4.6        0.        0.
       0.5       4.83      2.36     34.87
        5.        6.9     28.76   1650.68
      6.25       7.48     37.75   2432.01
      7.81      22.72     72.14   3620.86
      9.38      24.16    108.77   6875.98
    160.94     163.67  14343.13  6376810.
     312.5     303.18  49721.96 33495862.
 END FTABLE  5

 FTABLE      6
rows cols                               ***
   8    4
     depth       area    volume  outflow1 ***
        0.       2.39        0.        0.
       0.5       2.51      1.23     17.78
```

```
         5.       3.59     14.96    841.78
       6.25       3.89     19.63   1240.22
       7.81      11.82     37.51   1846.49
       9.38      12.57     56.56   3506.46
     160.94      85.12   7459.173251907.25
      312.5     157.67    25858. 17081494.
  END FTABLE  6

  FTABLE      7
 rows cols                               ***
    8    4
     depth      area    volume  outflow1 ***
        0.      4.96        0.        0.
       0.5      5.21      2.54     65.34
        5.      7.44     30.99   3093.33
      6.25      8.06     40.68   4557.53
      7.81     24.49     77.73   6785.41
      9.38     26.04     117.2  12885.41
    160.94    176.36  15454.93 11949981.
     312.5    326.68  53576.11 62770404.
  END FTABLE  7
END FTABLES

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member-> ***
<Name>   x <Name> x tem strg<-factor->strg <Name>   x   x        <Name> x x ***
*** Met Seg CLIFTON
WDM2     5 PREC     ENGL              SAME PERLND 101 707 EXTNL  PREC
WDM2    51 PEVT     ENGL              SAME PERLND 101 707 EXTNL  PETINP
*** Met Seg CLIFTON
WDM2     5 PREC     ENGL              SAME IMPLND 101 701 EXTNL  PREC
WDM2    51 PEVT     ENGL              SAME IMPLND 101 701 EXTNL  PETINP
*** Met Seg CLIFTON
WDM2     5 PREC     ENGL              SAME RCHRES   1   7 EXTNL  PREC
WDM2    51 PEVT     ENGL              SAME RCHRES   1   7 EXTNL  POTEV

WDM1     1 F.CO     ENGL              SAME RCHRES   5     INFLOW IDQAL  1
WDM1     2 F.CO     ENGL              SAME RCHRES   2     INFLOW IDQAL  1
WDM1     3 F.CO     ENGL              SAME RCHRES   6     INFLOW IDQAL  1
WDM1     4 F.CO     ENGL              SAME RCHRES   7     INFLOW IDQAL  1
END EXT SOURCES

SCHEMATIC
<-Volume->                  <--Area-->     <-Volume->  <ML#> ***       <sb>
<Name>   x                  <-factor->     <Name>   x        ***        x x
PERLND 101                         181     RCHRES   1      2
IMPLND 101                         5.6     RCHRES   1      1
PERLND 103                       407.8     RCHRES   1      2
PERLND 106                         0.4     RCHRES   1      2
PERLND 107                         5.6     RCHRES   1      2
PERLND 301                       268.8     RCHRES   3      2
IMPLND 301                        11.4     RCHRES   3      1
PERLND 303                       414.1     RCHRES   3      2
PERLND 304                         3.6     RCHRES   3      2
PERLND 306                        34.5     RCHRES   3      2
PERLND 307                        11.4     RCHRES   3      2
PERLND 201                       467.1     RCHRES   2      2
IMPLND 201                       281.4     RCHRES   2      1
PERLND 203                       541.3     RCHRES   2      2
PERLND 204                         5.6     RCHRES   2      2
PERLND 206                        46.5     RCHRES   2      2
```

```
PERLND 207                      281.4     RCHRES   2      2
PERLND 403                        2.5     RCHRES   4      2
RCHRES   1                                RCHRES   4      3
RCHRES   3                                RCHRES   4      3
PERLND 501                      185.8     RCHRES   5      2
IMPLND 501                       86.2     RCHRES   5      1
PERLND 503                      851.2     RCHRES   5      2
PERLND 507                       86.2     RCHRES   5      2
RCHRES   2                                RCHRES   5      3
RCHRES   4                                RCHRES   5      3
PERLND 601                      225.9     RCHRES   6      2
IMPLND 601                       65.8     RCHRES   6      1
PERLND 603                        790     RCHRES   6      2
PERLND 604                        0.4     RCHRES   6      2
PERLND 606                       38.1     RCHRES   6      2
PERLND 607                       65.8     RCHRES   6      2
PERLND 701                      255.4     RCHRES   7      2
IMPLND 701                       64.5     RCHRES   7      1
PERLND 702                       64.4     RCHRES   7      2
PERLND 703                      639.1     RCHRES   7      2
PERLND 705                         12     RCHRES   7      2
PERLND 706                        7.6     RCHRES   7      2
PERLND 707                       64.5     RCHRES   7      2
RCHRES   5                                RCHRES   7      3
RCHRES   6                                RCHRES   7      3
END SCHEMATIC

EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x        <Name> x x<-factor->strg <Name>   x <Name>qf  tem strg strg***
RCHRES   7 HYDR   RO     1 1           AVER WDM1   101 FLOW   1 ENGL AGGR REPL
RCHRES   7 HYDR   RO     1 1           AVER WDM1  1001 FLOW   1 ENGL AGGR REPL
RCHRES   7 GQUAL  DQAL   1 1                WDM1  1002 DQAL1  1 ENGL AGGR REPL
END EXT TARGETS

MASS-LINK

  MASS-LINK        2
<-Volume-> <-Grp> <-Member-><--Mult-->     <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->     <Name>                <Name> x x  ***
PERLND     PWATER PERO       0.0833333     RCHRES         INFLOW IVOL
PERLND     PWTGAS PODOXM                   RCHRES         INFLOW OXIF   1
PERLND     PWTGAS POHT                     RCHRES         INFLOW IHEAT  1
PERLND     PEST   SOSDPS 1                 RCHRES         INFLOW ISQAL  1 1
PERLND     PEST   SOSDPS 1                 RCHRES         INFLOW ISQAL  2 1
PERLND     PEST   SOSDPS 1                 RCHRES         INFLOW ISQAL  3 1
PERLND     SEDMNT SOSED  1          0.05   RCHRES         INFLOW ISED   1
PERLND     SEDMNT SOSED  1          0.55   RCHRES         INFLOW ISED   2
PERLND     SEDMNT SOSED  1           0.4   RCHRES         INFLOW ISED   3
PERLND     PQUAL  POQUAL 1                 RCHRES         INFLOW IDQAL  1
  END MASS-LINK    2

  MASS-LINK        1
<-Volume-> <-Grp> <-Member-><--Mult-->     <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->     <Name>                <Name> x x  ***
IMPLND     IWATER SURO       0.0833333     RCHRES         INFLOW IVOL
IMPLND     IWTGAS SODOXM                   RCHRES         INFLOW OXIF   1
IMPLND     IWTGAS SOHT                     RCHRES         INFLOW IHEAT  1
IMPLND     SOLIDS SOSLD  1          0.05   RCHRES         INFLOW ISED   1
IMPLND     SOLIDS SOSLD  1          0.55   RCHRES         INFLOW ISED   2
IMPLND     SOLIDS SOSLD  1           0.4   RCHRES         INFLOW ISED   3
```

```
IMPLND     IQUAL  SOQUAL 1                  RCHRES         INFLOW IDQAL  1
  END MASS-LINK    1

  MASS-LINK        3
<-Volume-> <-Grp> <-Member-><--Mult-->     <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->     <Name>                <Name> x x  ***
RCHRES     ROFLOW                          RCHRES         INFLOW
  END MASS-LINK    3
END MASS-LINK

END RUN
```

Appendix H – Additional Resources

Ordnance Survey

Coordinate transformation tool:
http://www.ordnancesurvey.co.uk/gps/transformation

BASINS/HSPF

BASINS User Manual:
http://water.epa.gov/scitech/datait/models/basins/userinfo.cfm#manuals

BASINS Tutorials and Training:
http://water.epa.gov/scitech/datait/models/basins/userinfo.cfm#tutorials

Of direct relevance:

Lecture 1	Introduction to BASINS (PDF)
Lecture 2	Introduction to the HSPF Model (PDF)
Lecture 3	Watershed Delineation (PDF)
Exercise 2	Manual and Automatic Watershed Delineation (PDF)
Lecture 4	Weather Data and WDM Utility (PDF)
Exercise 3	WDM Utility (PDF)
Lecture 8	Watershed Segmentation (PDF)
Exercise 4	Introduction to HSPF and GenScn (PDF)
Exercise 5	Segmentation (PDF)
Exercise 6	WinHSPF Hydrology Calibration (PDF)
Exercise 7	HSPEXP (PDF)
Lecture 12	Water Quality Modeling: Temperature, Sediment, and General Constituents (PDF)
Exercise 10	Bacteria and Temperature (PDF)
Lecture 15	Watershed Model Calibration and Validation (PDF)
Appendix B	Connecting Exercise 4 to Exercise 5: Begin Hydrology Calibration (PDF)
Appendix C	Calculating Observed Flow Volumes for Calibration (PDF)
Appendix D	Downloading HSPEXP (PDF)
Appendix F	Manually Adding Temperature and Fecal Coliform (PDF)

BASINS Technical Notes:
http://water.epa.gov/scitech/datait/models/basins/userinfo.cfm#technical

Of direct relevance:

- Technical Note #1 (PDF) - Creating Hydraulic Function Tables (FTABLES) for Reservoirs in BASINS
- Technical Note #2 (PDF) - Two Automated Methods for Creating Hydraulic Function Tables (FTABLES)
- Technical Note #6 (PDF) - Estimating Hydrology and Hydraulic Parameters for HSPF
    - Addendum to Technical Note #6 (PDF) - Additional notes for HSPF users.

Bacteria Indicator Tool (BIT) (example spreadsheets and documentation):
http://water.epa.gov/scitech/datait/models/basins/upload/bit.zip

HSPEXP

USGS HSPEXP link:
http://water.usgs.gov/software/HSPexp/

HSPEXP documentation: (Appendix A useful for hydrological calibration)
http://water.usgs.gov/software/HSPexp/code/doc/hspexp.pdf

PEST

PEST homepage:
http://www.pesthomepage.org/Home.php

PEST and HSPF:
http://www.pesthomepage.org/Surface_Water_Utilities.php#hdr3

Climate Change Met Data Generation

Future Flows (CEH):
http://www.ceh.ac.uk/sci_programmes/water/futureflowsandgroundwaterlevels.html

Weather Generator (DEFRA):
http://ukclimateprojections.defra.gov.uk/22540

Hyetos:
http://www.itia.ntua.gr/en/softinfo/3/