♦EPA BASINS Technical Note 6

Estimating Hydrology and Hydraulic Parameters for HSPF

CONTENTS

BASINS Technical Note 6
Estimating Hydrology and Hydraulic Parameters for HSPF
July, 2000

Introduction

This technical note provides BASINS users with guidance in how to estimate the input parameters
in the ATEMP, SNOW, PWATER, IWATER, HYDR, and ADCALC sections of the
Hydrological Simulation Program Fortran (HSPF) watershed model. For each input parameter,
this guidance includes a parameter definition, the units used in HSPF, and how the input value
may be determined (e.g. initialize with reported values, estimate, measure, and/or calibrate).
Where possible, the note discusses how to estimate initial values using the data and tools included
with BASINS. Also discussed, where appropriate, is the physical basis of each parameter and the
corresponding algorithms as described in the HSPF Users Manual (Bicknell, et al, 1997) and
earlier literature sources. In addition to the guidance provided below, model users are directed to
other sources, including the ARM Model User Manual (Donigian and Davis, 1978), as well as
studies of agricultural BMP representation with HSPF (Donigian and Crawford, 1973;Donigian et
al, 1983; and Casman, 1989).

Summary tables are attached that provide 'typical' and 'possible' (i.e. maximum 'expected')
ranges for the parameters discussed below, based on both the parameter guidance and experience
with HSPF over the past two decades on watersheds across the U. S. and abroad (Donigian,
1998). **The overarching principal in parameter estimation should be that the estimated
values must be realistic, i.e. make 'physical' sense, and must reflect conditions on the
watershed.** If the values estimated by the model user and/or derived from the guidance below, do
not agree with the value ranges in the summary table, the user should question and re-examine the
estimation procedures. The estimated values may still be appropriate, but the user needs to
confirm that the parameter values reflect unusual conditions on the watershed.

Another source of parameter information is the HSPF Parameter Database (HSPFParm) (US
EPA, 1999). Developed by AQUA TERRA Consultants, under contract to the EPA, HSPFParm
consists of parameter values from previous applications of HSPF across North America
assimilated into a single database, and with a customized graphical user interface for viewing and
exporting the data. The pilot HSPFParm Database contains parameter values for model
applications in over 40 watersheds in 14 states. The parameter values, contained in the database,
characterize a broad variety of physical settings, land use practices, and water quality constituents.
The database has been provided with a simplified interactive interface that enables modelers to
access and explore the HSPF parameter values developed and calibrated in various watersheds
across the United States, and to assess the relevance of the parameters to their own watershed
setting.

The parameter guidance below is listed in order of the parameter tables required by each module section (i.e. ATEMP, SNOW, PWATER, IWATER, HYDR, and ADCALC) in the HSPF UCI (users control input) file, and the parameters are grouped as required in each UCI table.

Air Temperature (ATEMP) Parameters

The ATEMP section variables are used by both the PERLND and IMPLND modules.   This section is not required for basic hydrology unless SNOW is being simulated.

ATEMP-DAT Table:

ELDAT   Elevation difference (feet), *(measure)*. ELDAT is the difference in elevation between the air temperature gage and the mean elevation of the associated pervious land segment (PLS). ELDAT is equal to the PLS elevation minus the gage elevation and can be either positive (PLS higher) or negative (gage elevation higher). ELDAT is used to adjust the gage air temperature to the PLS using a lapse rate; see Section 4.2(1).1 in the HSPF User Manual (Bicknell et al., 1997) for additional information.

Use of BASINS Data/Tools:
Weather station elevation is available in BASINS from the Elev_ft field in the WDM Weather Data Stations theme attribute table. To get the mean watershed elevation, run a *Watershed Topographic Report*. The mean elevation is available in the *Elevation Report*.

AIRTMP Initial air temperature (degrees F), *(measure/ estimate)*. Air temperature at start of simulation period.

Use of BASINS Data/Tools:
Open the WDM file in WDM Utility (WDMUtil) and select the hourly air temperature time series (ATEM) for the weather station to be used in the simulation. Specify both the current start *and end* dates as the model simulation *start* date and select an hourly time step. Use the List/Edit Time Series function to display the air temperature for the starting hour of the simulation.

Snow (SNOW) Parameters

The SNOW section variables are used in both the PERLND and IMPLND modules. Note: flag CSNOFG in PWATER and IWATER must be selected for snow melt to be taken into account.

ICE-FLAG Table:

The ICE-FLAG table contains only the flag to simulate ice formation in the snow pack. A value of 0 means ice formation is not simulated; 1 means that frozen water or frozen ground at the bottom of the snowpack is computed daily based on air temperature and inches of melt in the snowpack. This option is appropriate in regions where frozen ground conditions are observed.

SNOW-PARM1 Table:

LAT   Latitude (degrees), *(measure)*. LAT is positive for the northern hemisphere, negative for the southern hemisphere. LAT is used in the calculation of snow surface albedo to identify summer and winter time periods.

        Use of BASINS Data/Tools:
        The Lat_dd field in the WDM Weather Data Stations theme attribute table contains the latitude of the station in decimal degrees.

MELEV   Mean elevation (feet), *(measure)*. MELEV is used to compute the convective heat flux from the atmosphere to the snowpack.

        Use of BASINS Data/Tools:
        Generate a *Watershed Topographic Report*. The mean elevation for the watershed is located in the *Elevation Report*.

SHADE   Fraction of the land segment shaded from solar radiation by trees or slope (unitless), *(measure/estimate)*. SHADE controls short wave solar radiation that reaches the snowpack. SHADE is also used in the calculation of long wave radiation, based on Stefan's law of black body radiation (Bicknell et al, 1997).

        Use of BASINS Data/Tools:
        Estimate as the fraction of the watershed with coniferous forest (see FOREST in PWATER).

SNOWCF   Factor by which recorded precipitation is multiplied during snow events to account for poor gage catch efficiency (unitless), *(estimate)*. Snow catch in a gage is affected by wind speed, instrument characteristics (e.g. snow shields), and gage exposure/location. SNOWCF is normally 1.0 or greater. Crawford (1999) states that physically realistic values of SNOWCF are in the range of 1.0 to 1.5. Larson and Peck, 1974 present data relating snow catch factor (SCF - a SNOWCF analogue) to windspeed. For unshielded gages, they show a parabolic curve for

SCF with a value of 1.0 at 0.0 mph, 1.3 at 5 mph, and 1.8 at 10.0 mph. They also show a plot of the ratio of gage catch to true catch (the inverse variable) as roughly straight line plots, both starting from 1.0 at 0.0 mph. The shielded gage is roughly 0.75 at 10 mph, and the unshielded is roughly 0.55 at 10 mph. Only 200 out of 3500 weather stations in the U.S. are shielded; shielding of weather stations began in the mid 1940's (Doty, 2000).

COVIND   Maximum snowpack depth (water equivalent) at which the entire land segment is covered with snow (inches), *(estimate)*. COVIND is a function of topography and climatic conditions. The ARM Model User Manual (Donigian and Davis, 1978, p. 65, MPACK variable) says typical values are in the range of 1.0 to 6.0 inches. For mostly flat topography and where snow is a common occurrence, values will be near the low end of this range since complete coverage of the segment will result from low snowfall amounts; whereas in mountainous watersheds the COVIND values will be near the high end of the range reflecting the need for greater snowfall to achieve complete coverage. Note that COVIND is in water equivalent, so that a value of 1.0 inches corresponds to approximately 10 inches of snow.

SNOW-PARM2 Table:

RDCSN   Density of new snow relative to water when air temperature is at or below 0 degrees F (unitless ratio), *(estimate, then calibrate)*. The expected values are from 0.10 to 0.20. RDCSN can be calibrated by comparing field snow density data from snow courses with model snowpack (PACK) and density results (RDENPF). RDCSN is automatically adjusted in the model when the air temperature is above 0 degrees F. The snow density/ temperature functional relationship is described by Bicknell et al., (1997).

TSNOW   Wet bulb air temperature below which precipitation occurs as snow under saturated conditions (degrees F), *(estimate, then calibrate)*. Values of 31 to 33 degrees F are often used (Donigian and Davis, 1978). When the air temperature exceeds the value of TSNOW, precipitation is modeled as rain, not snow. TSNOW can vary between 30 and 40 degrees F; the initial estimate should be at or near 32 degrees F. Crawford (1999) states that TSNOW is the most obvious parameter to change to increase or reduce snow accumulation. However, changing TSNOW is effective only when significant snowfall occurs at or near 32 degrees F. If typical winter air temperatures are below 30 degrees F then TSNOW will have little or no effect.

SNOEVP   Factor to adjust evaporation (sublimation) from the snowpack (unitless), *(estimate, then calibrate)*. Values near 0.1 are expected (Donigian and Davis, 1978, p. 65, EVAPSN variable). Evaporation from the snowpack occurs only

when the vapor pressure of the air is less than that at the snow surface (Bicknell et al, 1997). Evaporation occurs only from the frozen content of the snowpack and is adjusted based on SNOEVP, wind movement, and the fraction of the land segment covered by the snowpack. Snow evaporation is not large in most watersheds, but can be important where windy, low humidity conditions are common (Crawford, 1999).

CCFACT Factor to adjust the rate of heat transfer from the atmosphere to the snowpack, due to condensation and convection, to match field conditions (unitless), *(estimate, then calibrate)*. CCFACT is a function of climatic conditions. Typical values are near 1.0, although a range of 0.5 to 2.0 has been observed (Donigian and Davis, 1978, p. 64, CCFAC variable). CCFACT is used in conjunction with wind movement and air temperature to compute heat transfer from the snowpack to the land surface.

MWATER Maximum liquid water holding capacity in the snowpack (in/in), *(estimate, then calibrate)*. MWATER is a function of the mass of ice layers; the size, shape, and spacing of snow crystals; and the degree of channelization and honeycombing of the snowpack to allow liquid water accumulation. Experimental values range from 0.01 to 0.05, with 0.03 a common value (Donigian and Davis, 1978, p. 64, WC).

MGMELT Maximum rate of snowmelt by ground heat (in/day), *(estimate, then calibrate)*. MGMELT is the rate of melt when the snowpack temperature is at 32 degrees F. A standard value is 0.01 in/day. Areas with deep frost penetration and/or frozen ground have MGMELT values approaching zero (Donigian and Davis, 1978, p. 64, DGM).

SNOW-INIT1 Table:

Pack-snow Initial quantity of snow (water equivalent) in the snowpack (inches), *(estimate)*. If the simulation starts at the beginning of the water year (October 1) Pack-snow is usually set to zero, except in arctic climates.

Pack-ice Initial quantity of ice (water equivalent) in the snowpack (inches), *(estimate)*. If the simulation starts at the beginning of the water year (October 1) Pack-ice is usually set to zero, except in arctic climates.

Pack-watr Initial quantity of liquid water in the snowpack (inches), *(estimate)*. If the simulation starts at the beginning of the water year (October 1) Pack-watr is usually set to zero, except in arctic climates.

RDENPF   Initial density of the frozen contents (Pack-snow and Pack-ice) of the snowpack relative to water (unitless ratio), *(estimate)*. If the simulation starts at the beginning of the water year (October 1) RDENPF is usually set to 0.01 (minimum value), except in arctic climates; otherwise see RDCSN.

DULL   Initial index to the dullness of the snowpack surface, from which the initial albedo is estimated (unitless), *(estimate)*. If the simulation starts at the beginning of the water year (October 1) DULL is usually set to zero (for perfectly reflectable snow), except in arctic climates. DULL ranges from zero to 800 and is an empirical index. It's increased by one for each hour in which new snow does not fall.

PAKTMP   Initial mean temperature of the frozen contents of the snowpack (degrees F), *(estimate)*. If the simulation starts at the beginning of the water year (October 1) PAKTMP is usually set to 32 degrees F, except in arctic climates.

SNOW-INIT2 Table:

COVINX   Initial snowpack depth (water equivalent) required for the entire land segment to be covered with snow (inches), *(estimate)*. If the simulation starts at the beginning of the water year (October 1) COVINX is usually set to its default value of 0.01, except in arctic climates; otherwise see COVIND, SNOW-PARM1.

XLNMLT   Initial increment to ice storage in the snowpack (inches), *(estimate)*. XLNMLT represents an equivalent heat deficit that must be overcome before snowmelt is released from the pack; otherwise some portion of the potential melt will freeze and become pack ice. For most simulations, XLNMLT can usually be set to zero, except possibly in arctic climates, because the values will be recalculated based on current (usually hourly) air temperatures. XLNMLT is used only if ICE-FLAG is set to 1.

SKYCLR   Initial fraction of sky assumed to be clear (unitless), *(estimate)*. Unless a storm is in progress at the start of simulation period, set SKYCLR to 1.0 (no clouds).

>   *Use of BASINS Data/Tools:*
>   Open the WDM file with the WDM Utility (WDMUtil) and select the CLOU time series for the weather station of interest. Identify the value of CLOU for the starting date and time in the model simulation. Set SKYCLR to 1-CLOU.

Pervious Land Hydrology (PWATER) Parameters

PWAT-PARM1 Table:
The PWAT-PARM1 table includes flags to indicate the selected simulation algorithm option, or the selection of monthly variability versus constant values for selected parameters. Where flags indicate monthly variability, the corresponding monthly values must be provided in *Monthly Input Parameters* (see below following the *PWAT_PARM4 Table* section). That section also provides guidance on which parameters are normally specified as monthly values.

CSNOFG   Flag to use snow simulation data; must be checked (CSNOFG=1) if SNOW is simulated.

RTOPFG   Flag to select overland flow routing method; choose either the method used in predecessor models (HSPX, ARM, and NPS) or the alternative method as described in the HSPF User Manual. Recommendation: Set RTOPFG=1; This method, used in the predecessor models is more commonly used, and has been subjected to more widespread application.

UZFG   Flag to select upper zone inflow computation method; choose either the method used in predecessor models (HSPX, ARM, and NPS) or the more exact numerical solution to the integral of inflow to upper zone, i.e the alternative method. Recommendation: Set UZFG=1; This method, used in the predecessor models, is more commonly used, and has been subjected to more widespread application.

VCSFG   Flag to select constant or monthly-variable interception storage capacity, CEPSC. Monthly value can be varied to represent seasonal changes in foliage cover; monthly values are commonly used for agricultural, and sometimes deciduous forest land areas.

VUZFG   Flag to select constant or monthly-variable upper zone nominal soil moisture storage, UZSN. Monthly values are commonly used for agricultural areas to reflect the timing of cropping and tillage practices.

VMNFG   Flag to select constant or monthly-variable Manning=s n for overland flow plane, NSUR. Monthly values are commonly used for agricultural, and sometimes deciduous forest land areas.

VIFWFG   Flag to select constant or monthly-variable interflow inflow parameter, INTFW. Monthly values are not often used.

VIRCFG   Flag to select constant or monthly varied interflow recession parameter, IRC. Monthly values are not often used.

VLEFG   Flag to select constant or monthly varied lower zone ET parameter, LZETP.
             Monthly values are commonly used for agricultural, and sometimes deciduous
             forest land areas.

PWAT-PARM2 Table:

FOREST   Fraction of land covered by forest (unitless) (***measure/estimate***). FOREST is the
             fraction of the land segment which is covered by forest which will continue to
             transpire in winter (i.e. coniferous). This is only relevant if snow is being
             considered (i.e., CSNOFG=1 in PWATER-PARM1).

       Use of BASINS Data/Tools:
             Run a Land Use Distribution Report on the watershed(s). Determine the acreage
             for *EVERGREEN FOREST LAND - 42*. Estimate the fraction of *MIXED
             FOREST LAND - 43* acreage which is coniferous. Add this to the *EVERGREEN
             FOREST LAND - 42* acreage and divide the sum by the Forest land subtotal
             acreage. This is the value of FOREST for the Forested land use in that watershed.
             Estimate from field survey for all other land use types.

LZSN   Lower zone nominal soil moisture storage (inches), (***estimate, then calibrate***).
             LZSN is related to both precipitation patterns and soil characteristics in the region.
             The ARM Model User Manual (Donigian and Davis, 1978, p. 56, LZSN variable)
             includes a mapping of calibrated LZSN values across the country based on almost
             60 applications of earlier models derived from the Stanford-based hydrology
             algorithms. LaRoche et al (1996) shows values of 5 inches to 14 inches, which is
             consistent with the 'possible' range of 2 inches to 15 inches shown in the Summary
             Table. Viessman, et al, 1989, provide initial estimates for LZSN in the Stanford
             Watershed Model (SWM-IV, predecessor model to HSPF) as one-quarter of the
             mean annual rainfall plus four inches for arid and semiarid regions, or one-eighth
             annual mean rainfall plus 4 inches for coastal, humid, or subhumid climates. These
             formulae tend to give values somewhat higher than are typically seen as final
             calibrated values; since LZSN will be adjusted through calibration, initial estimates
             obtained through these formulae may be reasonable starting values.

INFILT   Index to mean soil infiltration rate (in/hr); (***estimate, then calibrate***). In HSPF,
             INFILT is the parameter that effectively controls the overall division of the
             available moisture from precipitation (after interception) into surface and
             subsurface flow and storage components. Thus, high values of INFILT will
             produce more water in the lower zone and groundwater, and result in higher
             baseflow to the stream; low values of INFILT will produce more upper zone and
             interflow storage water, and thus result in greater direct overland flow and
             interflow. LaRoche et al (1996) shows a range of INFILT values used from 0.004

in/hr to 0.23 in/hr, consistent with the 'typical' range of 0.01 to 0.25 in/hr in the Summary Table. Fontaine and Jacomino (1997) show sediment and sediment associated transport to be sensitive to the INFILT parameter since it controls the amount of direct overland flow transporting the sediment. Since INFILT is not a maximum rate nor an infiltration capacity term, it's values are normally much less than published infiltration rates, percolation rates (from soil percolation tests), or permeability rates from the literature. In any case, initial values are adjusted in the calibration process.

INFILT is primarily a function of soil characteristics, and value ranges have been related to SCS hydrologic soil groups (Donigian and Davis, 1978, p.61, variable INFIL) as follows:

SCS Hydrologic Soil Group	INFILT Estimate (in/hr)	(mm/hr)	Runoff Potential
A	0.4 - 1.0	10.0 - 25.0	Low
B	0.1 - 0.4	2.5 - 10.0	Moderate
C	0.05 - 0.1	1.25 - 2.5	Moderate to High
D	0.01 - 0.05	0.25 - 1.25	High

An alternate estimation method that *has not been validated*, is derived from the premise that the combination of infiltration and interflow in HSPF represents the infiltration commonly modeled in the literature (e.g. Viessman et al, 1989, Chapter 4). With this assumption, the value of *2.0*INFILT*INTFW* should approximate the average measured soil infiltration rate at saturation, or mean permeability.

Use of BASINS Data/Tools:

Use of Soil Hydrologic Group/INFILT Table:
Use the identify tool on the State Soil theme to identify the map unit identification numbers (Muid's) for each soil layer overlapping the watershed. Open the *Soil Component Data* table and perform a query for all records for each map unit (e.g. ([Muid] = "PA044") or ([Muid] = "PA052")) in the watershed. Highlight the Hydgrp (soil hydrologic group) field and select summarize from the Table menu. Use the summary, together with the above table to estimate an average INFILT value for the watershed.

Use of Alternative 2.0*INFILT*INTFW Method:
The State Soil (STATSGO) data layer contains data on soil permeability, defined in the 1996 National Soil Survey Handbook (Soil Survey Staff, 1996), as the rate of water movement through completely saturated soils. Run the BASINS State Soil Characteristic Report and select mean estimate, area-weighted, surface layer, for permeability to get the value of 2*INFILT*INTFW. Note that although this

method has not been validated, it may produce reasonable starting values for adjustment through calibration.

LSUR   Length of assumed overland flow plane (ft) (***estimate/measure***).   LSUR approximates the average length of travel for water to reach the stream reach, or any drainage path such as small streams, swales, ditches, etc. that quickly deliver the water to the stream or waterbody. LSUR is often assumed to vary with slope such that flat slopes have larger LSUR values and vice versa; typical values range from 200 feet to 500 feet for slopes ranging from 15% to 1 %. It is also often estimated from topographic data by dividing the watershed area by twice the length of all streams, gullies, ditches, etc that move the water to the stream. That is, a representative straight-line reach with length, L, bisecting a representative square areal segment of the watershed, will produce two overland flow planes of width ½ L. However, LSUR values derived from topographic data are often too large (i.e. overestimated) when the data is of insufficient resolution to display the many small streams and drainage ways. Users should make sure that values calculated from GIS or topographic data are consistent with the ranges shown in the Summary Table.

Use of BASINS Data/Tools:
Since RF3 data is not of sufficient resolution, use of this BASINS data layer is not recommended for estimating LSUR.

SLSUR   Average slope of assumed overland flow path (unitless) (***estimate/measure***). Average SLSUR values for each land use being simulated can often be estimated directly with GIS capabilities. Graphical techniques include imposing a grid pattern on the watershed and calculating slope values for each grid point for each land use.

Use of BASINS Data/Tools:
Within the BASINS GIS, identify DEM polygons, along the length of the reach(es) being modeled, which happen to be bisected by the reach. Adjacent, uphill DEM grid cells, then, contain the elevation one grid cell away (i.e. 300 meters, measuring centerpoint to centerpoint). The approximate overland flow path slope at that point in the reach is then the difference in elevation between the bisected and the adjacent/uphill DEM grid cells, divided by the 300 meter (984 feet) width of a grid cell. Make multiple estimates along the length of the reach(es) and use these measurements to guide estimation of this parameter value.

KVARY   Groundwater recession flow parameter used to describe *non-linear* groundwater recession rate (/inches) (***initialize with reported values, then calibrate as needed***). KVARY is usually one of the last PWATER parameters to be adjusted; it is used when the observed groundwater recession demonstrates a seasonal variability with

a faster recession (i.e. higher slope and lower AGWRC values) during wet periods, and the opposite during dry periods. LaRoche, et al, 1996 reported an extremely high 'optimized' value of 0.66 mm^{-1} or (17 in^{-1}) (*much* higher than any other applications) while Chen, et al, 1995 reported a calibrated value of 0.14 mm^{-1} (or 3.6 in^{-1}). Value ranges are shown in the Summary Table. Users should start with a value of 0.0 for KVARY, and then adjust (i.e. increase) if seasonal variations are evident. Plotting daily flows with a logarithmic scale helps to elucidate the slope of the flow recession.

AGWRC Groundwater recession rate, or ratio of current groundwater discharge to that from 24 hours earlier (when KVARY is zero) (/day) (***estimate, then calibrate***). The overall watershed recession rate is a complex function of watershed conditions, including climate, topography, soils, and land use. Hydrograph separation techniques (see any hydrology or water resources textbook) can be used to estimate the recession rate from observed daily flow data (such as plotting on a logarithmic scale, as noted above); estimated values will likely need to be adjusted through calibration. Value ranges are shown in the Summary Table. LaRoche, et al, 1996 reported an optimized value of 0.99; Chen, et al, 1995 reported values that varied with land use type, ranging from 0.971 for grassland and clearings to 0.996 for high density forest; Fontaine and Jacomino, 1997 reported a calibrated value of 0.99. This experience reflects normal practice of using higher values for forests than open, grassland, cropland and urban areas.

PWAT-PARM3 Table:

PETMAX Temperature below which ET will be reduced to 50% of that in the input time series (deg F), unless it=s been reduced to a lesser value from adjustments made in the SNOW routine (where ET is reduced based on the percent areal snow coverage and fraction of coniferous forest). PETMAX represents a temperature threshold where plant transpiration, which is part of ET, is reduced due to low temperatures (***initialize with reported values, then calibrate as needed***). It is only used if SNOW is being simulated because it requires air temperature as input (also a requirement of the SNOW module), and the required low temperatures will usually only occur in areas of frequent snowfall. Use the default of 40°F as an initial value, which can be adjusted a few degrees if required.

PETMIN Temperature at and below which ET will be zero (deg F). PETMIN represents the temperature threshold where plant transpiration is effectively suspended, i.e. set to zero, due to temperatures approaching freezing (***initialize with reported values, then calibrate as needed***). Like PETMAX, this parameter is used only if SNOW is being simulated because it requires air temperature as input (also a requirement of the SNOW module), and the required low temperatures will usually only occur

in areas of frequent snowfall. Use the default of 35°F as an initial value, which can be adjusted a few degrees if required.

INFEXP   Exponent that determines how much a deviation from nominal lower zone storage affects the infiltration rate (HSPF Manual, p. 60) (*initialize with reported values, then calibrate as needed*). Variations of the Stanford approach have used a POWER variable for this parameter; various values of POWER are included in Donigian and Davis (1978, p. 58). However, the vast majority of HSPF applications have used the default value of 2.0 for this exponent. Use the default value of 2.0, and adjust only if supported by local data and conditions.

INFILD   Ratio of maximum and mean soil infiltration capacities (*initialize with reported value*). In the Stanford approach, this parameter has always been set to 2.0, so that the maximum infiltration rate is twice the mean (i.e. input) value; when HSPF was developed, the INFILD parameter was included to allow investigation of this assumption. However, there has been very little research to support using a value other than 2.0. Use the default value of 2.0, and adjust only if supported by local data and conditions.

  Use of BASINS Data/Tools:
    Run the BASINS State Soil Characteristic Report and select mean estimate, area-weighted, surface layer, for permeability. The report lists the mean and maximum permeability statistics by subwatershed. Use these values in conjunction with the guidance provided for INFILT.

DEEPFR   The fraction of infiltrating water which is lost to deep aquifers (i.e. inactive groundwater), with the remaining fraction (i.e. 1-DEEPFR) assigned to active groundwater storage that contributes baseflow to the stream (*estimate, then calibrate*). It is also used to represent any other losses that may not be measured at the flow gage used for calibration, such as flow around or under the gage site. This accounts for one of only three major losses from the PWATER water balance (i.e. in addition to ET, and lateral and stream outflows). Watershed areas at high elevations, or in the upland portion of the watershed, are likely to lose more water to deep groundwater (i.e. groundwater that does not discharge within the area of the watershed), than areas at lower elevations or closer to the gage (see discussion and figures in Freeze and Cherry, 1979, section 6.1). DEEPFR should be set to 0.0 initially or estimated based on groundwater studies, and then calibrated, in conjunction with adjustments to ET parameters, to achieve a satisfactory annual water balance.

BASETP   ET by riparian vegetation as active groundwater enters streambed; specified as a fraction of potential ET, which is fulfilled only as outflow exists (*estimate, then calibrate*). Typical and possible value ranges are shown in the Summary Table. If

significant riparian vegetation is present in the watershed then non-zero values of BASETP should be used. Adjustments to BASETP will be visible in changes in the low-flow simulation, and will effect the annual water balance. If riparian vegetation is significant, start with a BASETP value of 0.03 and adjust to obtain a reasonable low-flow simulation in conjunction with a satisfactory annual water balance.

AGWETP   Fraction of model segment (i.e. pervious land segment) that is subject to direct evaporation from groundwater storage, e.g. wetlands or marsh areas, where the groundwater surface is at or near the land surface, or in areas with phreatophytic vegetation drawing directly from groundwater. This is represented in the model as the fraction of remaining potential ET (i.e. after base ET, interception ET, and upper zone ET are satisfied), that can be met from active groundwater storage (***estimate, then calibrate***). If wetlands are represented as a separate PLS (pervious land segment), then AGWETP should be 0.0 for all other land uses, and a high value (0.3 to 0.7) should be used for the wetlands PLS. If wetlands are not separated out as a PLS, identify the fraction of the model segment that meets the conditions of wetlands/marshes or phreatophytic vegetation and use that fraction for an initial value of AGWETP. Like BASETP, adjustments to AGWETP will be visible in changes in the low-flow simulation, and will effect the annual water balance. Follow above guidance for an initial value of AGWETP, and then adjust to obtain a reasonable low-flow simulation in conjunction with a satisfactory annual water balance.

PWAT_PARM4 Table:

CEPSC   Amount of rainfall, in inches, which is retained by vegetation, never reaches the land surface, and is eventually evaporated (***estimate, then calibrate***). Typical guidance for CEPSC for selected land surfaces is provided in Donigian and Davis (1978, p. 54, variable EPXM) as follows:

Land Cover	Maximum Interception (in)
Grassland	0.10
Cropland	0.10 - 0.25
Forest Cover, light	0.15
Forest Cover, heavy	0.20

Donigian et al (1983) provide more detail guidance for agricultural conditions, including residue cover for agricultural BMPs.   As part of an annual water balance, Viessman, et al. 1989 note that 10-20% of precipitation during growing season is intercepted and as much as 25% of total annual precipitation is intercepted under dense closed forest stands; crops and grasses exhibit a wide

range of interception rates - between 7% and 60% of total rainfall. Users should compare the annual interception evaporation (CEPE) with the total rainfall available (PREC in the WDM file), and then adjust the CEPSC values accordingly. (See Monthly Input Values below).

UZSN   Nominal upper zone soil moisture storage (inches) (*estimate, then calibrate*). UZSN is related to land surface characteristics, topography, and LZSN. For agricultural conditions, tillage and other practices, UZSN may change over the course of the growing season. Increasing UZSN value increases the amount of water retained in the upper zone and available for ET, and thereby decreases the dynamic behavior of the surface and reduces direct overland flow; decreasing UZSN has the opposite effect. Donigian and Davis (1978, p. 54) provide initial estimates for UZSN as 0.06 of LZSN, for steep slopes, limited vegetation, low depression storage; 0.08 LZSN for moderate slopes, moderate vegetation, and moderate depression storage; 0.14 LZSN for heavy vegetal or forest cover, soils subject to cracking, high depression storage, very mild slopes. Donigian et al., (1983) include detailed guidance for UZSN for agricultural conditions. LaRoche shows values ranging from 0.016 in to 0.75 in. Fontaine and Jacomino showed average daily stream flow was relatively insensitive to this value but sediment and sediment associated contaminant outflow was sensitive; this is consistent with experience with UZSN having an impact on direct overland flow, but little impact on the annual water balance (except for extremely small watersheds with no baseflow). Typical and possible value ranges are shown in the Summary Table.

NSUR   Manning's n for overland flow plane (*estimate*). Manning=s n values for overland flow are considerably higher than the more common published values for flow through a channel, where values range from a low of about 0.011 for smooth concrete, to as high as 0.050-0.1 for flow through unmaintained channels (Hwang and Hita, 1987). Donigian and Davis (1978, p. 61, variable NN) and Donigian et al (1983) have tabulated the following values for different land surface conditions:

Smooth packed surface	0.05
Normal roads and parking lots	0.10
Disturbed land surfaces	0.15 - 0.25
Moderate turf/pasture	0.20 - 0.30
Heavy turf, forest litter	0.30 - 0.45
Agricultural Conditions	
Conventional Tillage	0.15 - 0.25
Smooth fallow	0.15 - 0.20
Rough fallow, cultivated	0.20 - 0.30
Crop residues	0.25 - 0.35
Meadow, heavy turf	0.30 - 0.40

For agricultural conditions, monthly values are often used to reflect the seasonal changes in land surfaces conditions depending on cropping and tillage practices. Additional tabulations of Manning's n values for different types of surface cover can be found in: Weltz, et al, 1992; Engman, 1986; and Mays, 1999. Manning's n values are not often calibrated since they have a relatively small impact on both peak flows and volumes as long as they are within the normal ranges shown above. Also, calibration requires data on just overland flow from very small watersheds, which is not normally available except at research plots and possibly urban sites.

INTFW   Coefficient that determines the amount of water which enters the ground from surface detention storage and becomes interflow, as opposed to direct overland flow and upper zone storage (***estimate, then calibrate***). Interflow can have an important influence on storm hydrographs, particularly when vertical percolation is retarded by a shallow, less permeable soil layer. INTFW affects the timing of runoff by effecting the division of water between interflow and surface processes. Increasing INTFW increases the amount of interflow and decreases direct overland flow, thereby reducing peak flows while maintaining the same volume. Thus it affects the shape of the hydrograph, by shifting and delaying the flow to later in time. Likewise, decreasing INTFW has the opposite effect. Base flow is not affected by INTFW. Rather, once total storm volumes are calibrated, INTFW can be used to raise or lower the peaks to better match the observed hydrograph. Typical and possible value ranges are shown in the Summary Table.

IRC   Interflow recession coefficient (***estimate, then calibrate***). IRC is analogous to the groundwater recession parameter, AGWRC, i.e. it is the ratio of the current daily interflow discharge to the interflow discharge on the previous day. Whereas INTFW affects the volume of interflow, IRC affects the rate at which interflow is discharged from storage. Thus it also affects the hydrograph shape in the 'falling' or recession region of the curve between the peak storm flow and baseflow. The maximum value range is 0.3 – 0.85, with lower values on steeper slopes; values near the high end of the range will make interflow behave more like baseflow, while low values will make interflow behave more like overland flow. IRC should be adjusted based on whether simulated storm peaks recede faster/slower than measured, once AGWRC has been calibrated. Typical and possible value ranges are shown in the Summary Table.

LZETP   Index to lower zone evapotranspiration (unitless) (***estimate, then calibrate***). LZETP is a coefficient to define the ET opportunity; it affects evapotranspiration from the lower zone which represents the primary soil moisture storage and root zone of the soil profile. LZETP behaves much like a 'crop coefficient' with values mostly in the range of 0.2 to 0.7; as such it is primarily a function of vegetation; Typical and possible value ranges are shown in the Summary Table, and the following ranges for different vegetation are expected for the 'maximum' value during the year:

Forest	0.6 - 0.8
Grassland	0.4 - 0.6
Row crops	0.5 - 0.7
Barren	0.1 - 0.4
Wetlands	0.6 - 0.9

Monthly Input Parameter Tables:
In general, monthly variation in selected parameters, such as CEPSC and LZETP should be included with the initial parameter estimates. However, adjustments to the monthly values should be addressed only after annual flow volumes are matched well with monitored data. All monthly values can be adjusted to calibrate for seasonal variations.

MON-INTERCEP Table:
Monthly values for interception storage. Monthly values can be developed based on the data presented in the discussion in PWAT-PARM4/CEPSC and the Summary Tables.

MON-UZSN Table:
Monthly values for upper zone storage. For agricultural areas under conventional tillage, lower values are used to reflect seedbed preparation in the spring with values increasing during the growing season until harvest and fall tillage. See PWAT-PARM4/UZSN discussion and Summary Tables for guidance.

MON-MANNING Table:
Monthly values for Manning=s n for the overland flow plane. Monthly values can be used to represent seasonal variability in ground cover including crop and litter residue. See discussion in PWAT-PARM4/NSUR for Manning's n as a function of agricultural conditions.

MON-INTERFLW Table:
Monthly values for interflow parameter (INTFW) are not often used.

MON-IRC Table:
Monthly values for interflow recession parameter are not often used.

MON-LZETPARM Table:
Monthly values for LZETP for evapotranspiration from the lower zone can be developed using an expected maximum value from the PWAT-PARM4/LZETP discussion and the range of values presented in the Summary Tables. Monthly variable values should be used to reflect the seasonality of evapotranspiration, in response to changes in density of vegetation, depth of root zone, and stage of plant growth.

PWAT-STATE1 Table:
CEPS, SURS, IFWS, UZS, LZS, AGWS, are initial values for storage of water in interception, surface ponding, interflow, the upper zone, lower zone, and active groundwater, respectively, and **GWVS** is the initial index to groundwater slope. All these storages pertain to the first interval of the simulation period.

The surface related storages (i.e. *CEPS*, *SURS*, *IFWS*) are highly dynamic, and will reach a dynamic equilibrium within a few days, at most. These state variables can be left blank, or set to 0.0 unless an individual storm is being simulated. The soil storages (i.e. *UZS*, *LZS*, and *AGWS*, and the *GWVS*) are much less dynamic, so their beginning values can impact the simulation for a period of months to a few years. If possible, users should allow as long a startup time period as possible (i.e. set the simulation period to begin prior to the period you=ll use for comparison against monitoring data or other use); as noted each of these storages should reach a dynamic equilibrium within a few years of simulation. *UZS* and *LZS* should be set equal to UZSN and LZSN respectively, unless it is known that the starting date is during a particularly wet or dry period; starting values can be increased or decreased if wet or dry conditions were evident prior to the simulation period. *AGWS* is a bit more problematic. If far too high or too low, baseflow will be excessive or skewed low for several months or years, depending on AGWRC and KVARY. Improper values of *GWVS* can also cause simulation accuracy problems again for lengths of time depending on values of AGWRC and KVARY. However, since when KVARY is set to 0.0 seasonal recession is not represented and GWVS is not calculated. To avoid problems, then, *AGWS* should be set to 1.0 inch and *GWVS* to 0.0 for initial simulation runs.

If the simulation period is limited in duration, you can check and reset these state variables to values observed for the same period in subsequent years with similar climatic conditions. However, if major calibration changes are made to the parameters controlling these storages (e.g. *UZSN*, *LZSN*, *INFILT*), then the initial conditions should be checked and adjusted during the calibration process. The values for *AGWS* and *GWVS* should be checked and adjusted as noted above, which assuming a yearly cycle of groundwater storage, can be compared to values during similar seasons in the simulation period. If the initial simulated baseflow (before the first significant rainfall) is much different from the initial observed streamflow, then further adjustments can be made to raise or lower the flow rates.

Impervious Land Hydrology (IWATER) Parameters

IWAT-PARM1 Table:
The IWAT-PARM1 table includes a number of flag variables to indicate either the selection of a simulation algorithm option, or whether the parameter will be treated as a constant or be varied monthly. As with PWAT-PARM1, where flags indicate monthly variability, corresponding monthly values must be provided in Monthly Input Parameter tables (see below following IWAT-PARM3 section).

CSNOFG   Flag to use snow simulation data; must be checked (CSNOFG=1) if SNOW module is run.

RTOPFG   Flag to select overland flow routing method. If RTOPFG=0, a new routing algorithm is used. RTOPFG=1 results in the use of the method used by predecessor models (HSPX, ARM, and NPS). Recommendation: set RTOPFG=1; this method is more commonly used and has been subjected to more widespread application.

VRSFG   Flag to select constant or monthly-variable retention storage capacity, RETSC. Monthly values are not often used.

VNNFG   Flag to select constant or monthly-variable Manning's n for overland flow plane, NSUR. Monthly values are not often used.

RTLIFG   Flag to determine if lateral surface inflow to the impervious land segment will be subject to retention storage (RTLIFG=1). This flag only has an impact if the another land segment drains to the impervious land segment; otherwise lateral surface inflow is nonexistent. This feature is not commonly used in most HSPF applications.

IWAT-PARM2 Table:

LSUR   Length of assumed overland flow plane (feet), *(measure/estimate)*. See PWAT-PARM2/ LSUR discussion. For impervious areas, LSUR reflects the overland flow length on directly connected, or effective impervious area (EIA), and is usually in the range of 50 to 150 feet, although longer lengths may apply in commercial or industrial regions of large metropolitan areas. Impervious surfaces that drain to pervious land, rather than to a reach, are considered part of the pervious land segment and not part of the EIA.

SLSUR   Average slope of the assumed overland flow path (unitless), *(measure/estimate)*. See PWAT-PARM2 / SLSUR discussion.

NSUR   Manning's n for overland flow plane *(estimate)*. See PWAT-PARM4 / NSUR discussion. Recommendation: set NSUR within the range of 0.05 to 0.10 for paved roads and parking lots.

RETSC   Retention (interception) storage of the impervious surface (inches) *(estimate)*. RETSC is the impervious equivalent to the interception storage variable (CEPSC) used for pervious land segments. RETSC is the depth of water that collects on the impervious surface before any runoff occurs. A study of five urban watersheds in the Puget Sound region conducted by the U.S. Geological Survey (Dinicola, 1990) found that a value of 0.10 for RETSC was appropriate. If parking lots and rooftops are designed for detention storage, larger values up to 0.5 inches may be reasonable.

IWAT-PARM3 Table:

The following two parameters are used only if SNOW is being simulated.

PETMAX   Temperature below which ET will be reduced by 50% of that in the input time series (degree F), *(estimate, then calibrate)*. See PWAT-PARM3 /PETMAX discussion.

PETMIN   Temperature at and below which ET will be set to zero (degree F), *(estimate, then calibrate)*. See PWAT-PARM3 /PETMIN discussion.

Monthly Input Parameter Tables:

MON-RETN Table:
Monthly values for retention storage. Monthly values can be varied to represent seasonal changes in surface retention storage due to litter accumulation or sediment deposition on the impervious surface. Monthly values are not often used.

MON-MANNING Table:
Monthly values for Manning's n for the overland flow plane. As described above for MON-RETN, monthly values can be changed to represent seasonal changes on the surface of the impervious area. Monthly values are not often used.

IWAT-STATE1 Table:
RETS and **SURS** are initial values for storage of water in retention and surface ponding, respectively. Both of these storages pertain to the first day of the simulation period. RETS and SURS are highly dynamic and are only non-zero if the simulation starts during or just following a storm event. They can be left blank or set to zero unless an individual storm is being simulated.

Flow Routing (HYDR and ADCALC) Parameters

HSPF computes streamflow through a stream reach or reservoir based on two assumptions: (1) there is a fixed relationship between depth, volume, and discharge, and (2) discharge is a function of volume (see ODGTFG discussion for exception). This means that flow reversals and backwater effects in an upstream reach are not simulated. Routing is computed using storage routing or kinematic wave routing. Momentum is not considered in the routing computations.

HYDR-PARM1 Table:

The HYDR-PARM1 table includes flags to indicate which auxiliary variables to compute and include in the RCHRES printout as well as flags to select routing options based on either volume, time, or both. The auxiliary variables can be output to the WDM and statistically analyzed like other time series.

VCONFG Flag to select constant or monthly-variable factors to adjust the outflow from the FTABLE discharge column, i.e. use the MON-CONVF table. Monthly values are not often used.

AUX1FG Flag to compute stream channel depth, stage, surface area, average depth (volume/surface area), top width (surface area/length), and hydraulic radius. AUX1FG must be set to 1 if precipitation and evaporation fluxes are calculated for the stream reach, or water quality is simulated for the reach.

AUX2FG Flag to compute average cross section area (volume/length) and average velocity (discharge/average cross sectional area). AUX2FG must be set to 1 if oxygen in the stream reach is simulated. If AUX2FG=1 then AUX1FG must equal 1.

AUX3FG Flag to compute bed shear velocity and bed shear stress. These values are used to calculate sediment deposition and scour (inorganic and organic) for a stream reach. If AUX3FG=1 then AUX2FG and AUX1FG must equal 1.

ODFVFG For use when the stream reach outflow demand is a function of volume. The value is the column in the appropriate FTABLE that contains stream reach discharge values. A maximum of five discharge exits can be specified for a single stream reach. For a stream reach with a single exit, the appropriate value of ODFVFG(1) is usually 4, since the FTABLE includes columns for depth, surface area, and volume in columns 1, 2, and 3, respectively. With two exits (e.g. natural exit plus a side diversion) ODFVFG(1)=4 and ODFVFG(2)=5.

If the value of ODFVFG is less than zero, then the absolute value is the column in the COLIND time series which designates which FTABLE column to use. The COLIND time series is used to vary the FTABLE column used in the computation

of discharge on a seasonal or daily basis. For example, if ODFVFG=-1 then the model checks the appropriate COLIND value for that time step and if the COLIND value equals 6 then column 6 in the FTABLE is used in the outflow calculations for that particular stream reach. In addition, a fractional value for COLIND can be used to interpolate between columns in the FTABLE, e.g. a value of 4.3 can be used to interpolate between columns 4 and 5, with 30% of the difference between columns 4 and 5 being added to column 4. This option can be used to simulate different rule curves and to vary from one set to another.

ODGTFG   Flag to specify that the stream reach outflow demand is a function of time. The value is the number corresponding to the OUTDGT subscript number specified in the External Sources Block. The OUTDGT number links the reach outflow demand to a flow time series data set in the WDM. A maximum of five discharge exits can be specified for a single stream reach. For a stream reach with a single exit, the appropriate value of ODGTFG(1) is usually 1 (the corresponding operation number of OUTDGT in External Sources will then be 1). With two exits (e.g. natural exit plus a side diversion) ODFVFG(1)=1 and ODFVFG(2)=2, corresponding to subscripts 1 and 2 of OUTDGT.

FUNCT   Flag to combine ODFVFG and ODGTFG functions, if appropriate. For each of a maximum of 5 possible exits the value of FUNCT can be 1 (select the smaller of the ODFVFG and ODGTFG values), 2 (larger of ODFVFG and ODGTFG), or 3 (sum of ODFVFG and ODGTFG).

HYDR-PARM2 Table:

FTBDSN   When the FTABLE is stored in the WDM file, this is the Data Set Number (DSN) in the WDM file for that reach's FTABLE. When the FTABLE is stored in the FTABLES block of the UCI file, FTBDSN is set to zero.

FTABNO   When FTBDSN is zero, this is the Id number of the FTABLE as included in the FTABLES block of the UCI file. When FTBDSN > 0, this is the indicator to identify a particular FTABLE data set in the FTBDSN DSN.

LEN   Length of the stream reach (miles), *(measure)***.** Length is used in the computation of auxiliary 1, 2, and 3 parameter values.

   Use of BASINS Data/Tools:
      This is populated automatically by BASINS during model initialization.

DELTH   Change in elevation from the upstream end of the stream reach to the downstream end (feet), *(measure)*. DELTH is used if reaeration is computed using the Tsivoglou-Wallace equation in the OXRX Block or if sandload transport capacity is computed using either the Toffaleti or Colby method in the SEDTRN Block.

          Use of BASINS Data/Tools:
          This is populated automatically by BASINS during model initialization for RF1 reaches. The RF3 data coverage, however, does not contain the top and bottom elevation data held in the RF1 (i.e. Ptopele, Pbotele). Instead use the identify tool on the DEM coverage to obtain the elevation at the top and bottom of each reach segment. DELTH is the reach top elevation minus the reach bottom elevation contained in the RF1.

STCOR   Stage correction to convert RCHRES depth (DEP) to an equivalent stage or elevation (feet), *(measure)*. STAGE (elevation) = DEP (depth) + STCOR. This parameter is relevant only if you want to compare reach depth reported as stage to modeled reach stage.

KS   Weighting factor for hydraulic routing (unitless), *(initialize with reported value)*. KS is a weighting factor applied in the computation of the stream reach outflow. The outflow for any given time step is KS times the outflow at the beginning of the time step plus the complement (1-KS) times the outflow at the end of the time step. Increasing KS from 0.0 to 1.0 increases the likelihood of model instability; the value 0.5 will produce the most accurate results. Recommendation: set KS=0.50.

DB50   Median diameter of the bed sediment (inches), *(estimate/measure)*. DB50 is used to calculate (1) the bed shear stress if the stream reach is a lake, and (2) the rate of sand transport if the Toffaleti or Colby method is used. Note: DB50 is not connected with the sand particle diameter (D) input in the SAND-PM table in the SEDTRN Block.

Monthly Input Parameter Table:

MON-CONVF Table:
Monthly values for the FTABLE discharge adjustment factors are not often used. Monthly values can be varied to represent seasonal changes in stream channel and flood plain volume-based discharge due to vegetation growth or other alterations.

HYDR-INIT Table:
VOL is the initial volume of water in the stream channel. For small streams VOL can be set to zero to represent a dry channel. Rivers and lakes should start with an initial volume appropriate for the time of year the simulation begins, or should be based on stream volume predicted by the model for previous runs for long time periods leading up to the current simulation starting period. **COLIND** is the initial value for the FTABLE discharge exit column and should be set to the same value as ODFVFG for the exit (usually 4). **OUTDGT** is the initial value for the time series outflow demand, if ODGTFG is set to one, and has units of cubic feet per second.

ADCALC-DATA Table:
ADCALC calculates values for variables which are necessary to simulate longitudinal advection of dissolved or entrained constituents. These values are dependent on the volume and outflow values computed by the hydraulics section (HYDR) of the model.

CRRAT   Ratio of the maximum velocity to the mean velocity in the stream channel cross section under typical flow conditions (unitless), *(estimate/measure)*. CRRAT must be 1.0 or greater, where a value of 1.0 corresponds to completely uniform velocity (plug flow) across the stream channel. CRRAT is used to determine the relative volumes of water stored in the stream reach versus that leaving the reach, in a given time step. If CRRAT is greater than the volume:outflow ratio then the outflow is assumed to be in part, made up of water that entered the reach in that same interval. The inflow constituent concentration, then alters the outflow constituent concentration.

VOL   Volume of water in the stream reach at start of simulation (acre-feet) *(estimate)*. VOL is only used if section HYDR is inactive, and thus HYDR-INIT/VOL is not used.

REFERENCES

Bicknell, B.R., J.C. Imhoff, J.L. Kittle Jr., A.S. Donigian, Jr. and R.C. Johanson. 1997. Hydrological Simulation Program -- FORTRAN, User's Manual for Version 11. EPA/600/R-97/080. U.S. EPA, National Exposure Research Laboratory, Athens, GA.

Casman, E. 1989. Effects of Agricultural Practices on Water Quality as Related to Adjustments of HSPF Parameters, A Literature Review. ICPRB Report No. 89-6. Interstate Commission on the Potomac River Basin in cooperation with the Maryland Department of the Environment, Baltimore, MD. 255 p.

Chen, Y.D., S.C. McCutcheon, R.F. Carsel, A.S. Donigian, J.R. Cannell, J.P. Craig. 1995. Validation of HSPF for the water balance simulation of the Upper Grande Ronde watershed, Oregon, USA. Man's Influence on Freshwater Ecosystems and Water Use (Proceedings of a Boulder Symposium), July, 1995. IAHS Publ. No. 230, 1995.

Crawford, N.H. 1999. Hydrologic Journal - Snowmelt Calibration. Hydrocomp, Inc. 'www.hydrocomp.com'.

Dinicola, R.S. 1990. Characterization and Simulation of Rainfall-Runoff Relations for Headwater Basins in Western King and Snohomish Counties, Washington. U.S. Geological Survey. Water-Resources Investigations Report 89-4052. Tacoma, WA. 52 pp.

Donigian, A.S., Jr. 1998. Personal communication, 1998.

Donigian, A.S., Jr. and N.H. Crawford. 1976. Modeling Pesticides and Nutrients on Agricultural Lands. Environmental Research Laboratory. Environmental Protection Agency. Athens, GA. EPA 600/2-76-043. 263 pp.

Donigian, A.S., Jr. and H.H. Davis, Jr. 1978. User's Manual for Agricultural Runoff Management (ARM) Model, U.S. Environmental Protection Agency, EPA- 600/3-78-080.

Donigian, A.S. Jr., Baker, D.A. Haith and M.F. Walter. 1983. HSPF Parameter Adjustments to Evaluate the Effects of Agricultural Best Management Practices, EPA Contract No. 68-03-2895, U.S. EPA Environmental Research Laboratory, Athens, GA, (PB-83-247171).

Doty, Stephen, 2000. Ex-oficio, American Association of State Climatologist (AASC). National Climatic Data Center. Asheville, NC. Personal communication, May, 2000.

Engman, Edwin T., 1986. Roughness Coefficients for Routing Surface Runoff. Journal of Irrigation and Drainage Engineering, Vol 112, No.1, Feb., 1986.

Fontaine, T.A., and V.M.F. Jacomino. 1997. Sensitivity Analysis of Simulated Contaminated Sediment Transport, Journal of the American Water Resources Association. Vol. 33, No. 2, April, 1997.

Freeze, R. A. and J. A. Cherry. 1979. *Groundwater*. Prentice Hall, Englewood Cliffs, NJ, 1979.

Hwang, N.H.C. and C.E. Hita. 1987. Fundamentals of Hydraulic Engineering Systems. 2nd Edition. Prentice-Hall, Inc. Houston, 1987.

Laroche, A., J. Gallichaud, R. Lagace, and A. Pesant. 1996. Simulating Atrazine Transport with HSPF in an Agricultural Watershed. ASCE Journal of Environmental Engineering, July, 1996.

L. Larson and Peck, E.L., 1974. Accuracy of Precipitation Measurements for Hydrologic Modeling. Water Resources Research: 857-862.

Mays, Larry W., 1999. Hydraulic Design Handbook. McGraw-Hill, New York, 1999.

Soil Survey Staff, 1996. Natural Resources Conservation Service, National Soil Survey Handbook, title 430-VI (Washington, D.C., U.S. Government Printing Office, September 1996) available on the web at: http://www.statlab.iastate.edu/soils/nssh/.

US EPA, 1999. HSPFParm: An Interactive Database of HSPF Model Parameters, Version 1.0. EPA-823-R-99-004. U.S. Environmental Protection Agency, Office of Water, Washington, DC.   Available from the BASINS web site, http://www.epa.gov/ost/basins/support.htm.

Viessman, W., G.L. Lewis, and J.W. Knapp. 1989. *Introduction to Hydrology*. Third Edition. Harper and Row, New York. 1989.

Weltz, Mark A., A. B. Arslan, L.J. Lane, 1992. Hydraulic Roughness Coefficients for Native Rangelands. Journal of Irrigation and Drainage Engineering, Vol 118, No. 5, Sept/Oct., 1992.

HSPF ATEMP AND SNOW PARAMETERS AND VALUE RANGES

NAME	DEFINITION	UNITS	RANGE OF VALUES				FUNCTION OF ...	COMMENT
			TYPICAL		POSSIBLE			
			MIN	MAX	MIN	MAX		
ATEMP - DAT								
ELDAT	Weather station/ watershed elevation diff.	feet	-1000	1000	none	none	Topography, station location	Only used in air temperature data calculations
AIRTMP	Initial air temperature	deg. F	30.0	70.0	0.0	90.0	Climate	Only used in air temperature data calculations
SNOW - PARM1								
LAT	Latitude of watershed segment	degrees	30.0	50.0	-90.0	90.0	Location	Positive for northern hemisphere
MELEV	Mean elevation of watershed segment	feet	50.0	3000	0.0	7000	Topography	Used in convective heat flux equation
SHADE	Fraction shaded from solar radiation	none	0.1	0.5	0.0	0.8	Forest cover, topography	Controls radiation to and from the snowpack
SNOWCF	Snow gage catch correction factor	none	1.1	1.5	1.0	2.0	Gage type, characteristics, location	**Calibrate** to snow depth observations
COVIND	Snowfall required to fully cover surface	inches	1.0	3.0	0.1	10.0	Topography, climate	Higher for mountainous watersheds
SNOW - PARM2								
RDCSN	Density of new snow	none	0.10	0.20	0.05	0.30	Climate, air temperature	Adjust with field snow density data, if available
TSNOW	Temperature at which precip becomes snow	deg. F	31.0	33.0	30.0	40.0	Climate, topography	Precip. is snow when temperature below TSNOW
SNOEVP	Snow evaporation factor	none	0.10	0.15	0.0	0.5	Climate, topography	Only important in windy, low humidity conditions
CCFACT	Condensation/convection melt factor	none	1.0	2.0	0.5	8.0	Climate	**Calibrate** to change rate/timing of snowmelt
MWATER	Liquid water storage capacity in snowpack	in/in	0.01	0.05	0.005	0.2	Climate	Adjust to change timing of snowmelt
MGMELT	Ground heat daily melt rate	in/day	0.01	0.03	0.0	0.1	Climate, geology	Usually small under frozen ground conditions

HSPF HYDROLOGY PARAMETERS AND VALUE RANGES

NAME	DEFINITION	UNITS	TYPICAL		POSSIBLE		FUNCTION OF ...	COMMENT
			RANGE OF VALUES					
			MIN	MAX	MIN	MAX		
PWAT - PARM2								
FOREST	Fraction forest cover	none	0.0	0.50	0.0	0.95	Forest cover	Only impact when SNOW is active
LZSN	Lower Zone Nominal Soil Moisture Storage	inches	3.0	8.0	2.0	15.0	Soils, climate	**Calibration**
INFILT	Index to Infiltration Capacity	in/hr	0.01	0.25	0.001	0.50	Soils, land use	**Calibration**, divides surface and subsurface flow
LSUR	Length of overland flow	feet	200	500	100	700	Topography	Estimate from high resolution topo maps or GIS
SLSUR	Slope of overland flow plane	ft/ft	0.01	0.15	0.001	0.30	Topography	Estimate from high resolution topo maps or GIS
KVARY	Variable groundwater recession	1/inches	0.0	3.0	0.0	5.0	Baseflow recession variation	Used when recession rate varies with GW levels
AGWRC	Base groundwater recession	none	0.92	0.99	0.85	0.999	Baseflow recession	**Calibration**
PWAT - PARM3								
PETMAX	Temp below which ET is reduced	deg. F	35.0	45.0	32.0	48.0	Climate, vegetation	Reduces ET near freezing, when SNOW is active
PETMIN	Temp below which ET is set to zero	deg. F	30.0	35.0	30.0	40.0	Climate, vegetation	Reduces ET near freezing, when SNOW is active
INFEXP	Exponent in infiltration equation	none	2.0	2.0	1.0	3.0	Soils variability	Usually default to 2.0
INFILD	Ratio of max/mean infiltration capacities	none	2.0	2.0	1.0	3.0	Soils variability	Usually default to 2.0
DEEPFR	Fraction of GW inflow to deep recharge	none	0.0	0.20	0.0	0.50	Geology, GW recharge	Accounts for subsurface losses
BASETP	Fraction of remaining ET from baseflow	none	0.0	0.05	0.0	0.20	Riparian vegetation	Direct ET from riparian vegetation
AGWETP	Fraction of remaining ET from active GW	none	0.0	0.05	0.0	0.20	Marsh/wetlands extent	Direct ET from shallow GW
PWAT - PARM4								
CEPSC	Interception storage capacity	inches	0.03	0.20	0.01	0.40	Vegetation type/density, land use	Monthly values usually used
UZSN	Upper zone nominal soil moisture storage	inches	0.10	1.0	0.05	2.0	Surface soil conditions, land use	Accounts for near surface retention
NSUR	Manning's n (roughness) for overland flow	none	0.15	0.35	0.05	0.50	Surface conditions, residue, etc.	Monthly values often used for croplands
INTFW	Interflow inflow parameter	none	1.0	3.0	1.0	10.0	Soils, topography, land use	**Calibration,** based on hydrograph separation
IRC	Interflow recession parameter	none	0.5	0.7	0.3	0.85	Soils, topography, land use	Often start with a value of 0.7, and then adjust
LZETP	Lower zone ET parameter	none	0.2	0.7	0.1	0.9	Vegetation type/density, root depth	**Calibration**

HSPF IMPERVIOUS HYDROLOGY PARAMETERS AND VALUE RANGES

NAME	DEFINITION	UNITS	RANGE OF VALUES				FUNCTION OF ...	COMMENT
			TYPICAL		POSSIBLE			
			MIN	MAX	MIN	MAX		
IWAT - PARM2								
LSUR	Length of overland flow	feet	50	150	50	250	Topography, drainage system	Estimate from maps, GIS, or field survey
SLSUR	Slope of overland flow plane	ft/ft	0.01	0.05	0.001	0.15	Topography, drainage	Estimate from maps, GIS, or field survey
NSUR	Manning's n (roughness) for overland flow	none	0.03	0.10	0.01	0.15	Impervious surface conditions	Typical range is 0.05 to 0.10 for roads/parking lots
RETSC	Retention storage capacity	inches	0.03	0.10	0.01	0.30	Impervious surface conditions	Typical range is 0.03 to 0.10 for roads/parking lots
IWAT - PARM3								
PETMAX	Temp below which ET is reduced by half	deg. F	35.0	45.0	32.0	48.0	Climate, vegetation	Reduces ET near freezing, when SNOW is active
PETMIN	Temp below which ET is set to zero	deg. F	30.0	35.0	30.0	40.0	Climate, vegetation	Reduces ET near freezing, when SNOW is active

HSPF HYDRAULIC PARAMETERS AND VALUE RANGES

NAME	DEFINITION	UNITS	RANGE OF VALUES				FUNCTION OF ...	COMMENT
			TYPICAL		POSSIBLE			
			MIN	MAX	MIN	MAX		
HYDR - PARM2								
FTBDSN	WDM data set number for FTABLE	none	none	none	1	999	WDM File	Used only if FTABLE is in WDM file
FTABNO	FTABLE number in UCI file	none	none	none	1	999	RCHRES block/ reach numbering	Used only if FTABLE is in UCI file
LEN	Stream reach (RCHRES) length	miles	0.1	1.0	0.01	100	Topography, stream morphology	Used only in computing auxiliary parameters
DELTH	Stream reach length change in elevation	feet	10	100	0.1	1000	Topography, stream morphology	Used only for water quality and sediment
STCOR	Stage correction factor	feet	0.0	none	0.0	none	Topography	Dependent on elevation datum used
KS	Routing weighting factor	none	0.0	0.5	0.0	0.99	Channel slope, flow obstructions	Use KS = 0.5
DB50	Bed sediment diameter	inches	0.01	0.02	0.001	1.00	Channel bed properties	Used only in sediment calculations
ADCALC - DATA								
CRRAT	Ratio of maximum to mean flow velocity	none	1.5	2.0	1.0	3.5	Climate, vegetation	Only used with water quality
VOL	Initial stream channel water volume	acre-feet	0.0	none	0.0	none	Season, channel geometry, climate	Initial volume in reach channel