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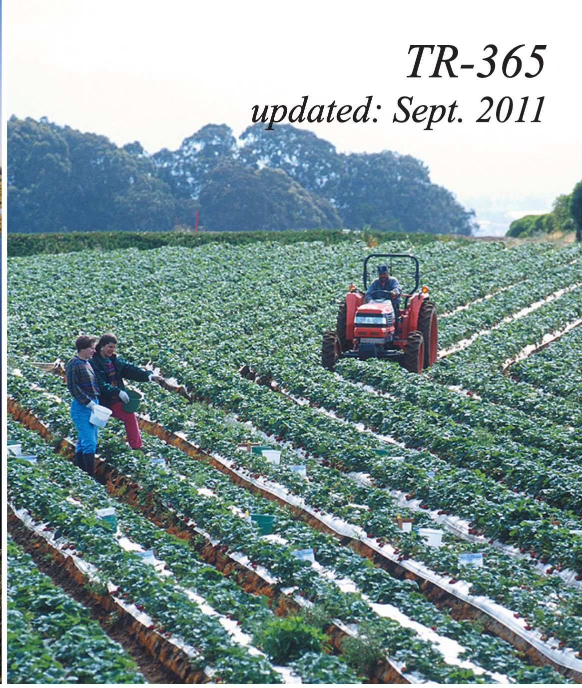

Soil and Water Assessment Tool

Input/Output File Documentation

Version 2009

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make every drop count

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CHAPTER 1

SWAT INPUT DATA: OVERVIEW

SWAT is a comprehensive model that requires a diversity of information in order to run. Novice users may feel a little overwhelmed by the variety and number of inputs when they first begin to use the model. However, many of the inputs are used to simulate special features that are not common to all watersheds.

This chapter provides an overview of model inputs. The inputs are organized by topic and emphasis is given to differentiating required inputs from optional inputs. This chapter focuses on assisting the user in identifying inputs that must be defined for their particular dataset. The remaining chapters list variables by file and discuss methods used to measure or calculate values for the input parameters.

1.1 WATERSHED CONFIGURATION

The first step in setting up a watershed simulation is to partition the watershed into subunits. SWAT allows several different subunits to be defined within a watershed.

- Subbasins
  - unlimited number of HRUs (1 per subbasin required)
  - one pond (optional)
  - one wetland (optional)
- Reach/main channel segments (1 per subbasin)
- Impoundments on main channel network (optional)
- Point sources (optional)

1.1.1 SUBBASINS

The first level of subdivision is the subbasin. Subbasins possess a geographic position in the watershed and are spatially related to one another, e.g. outflow from subbasin #5 enters subbasin #7. The subbasin delineation may be obtained from subwatershed boundaries that are defined by surface topography so that the entire area within a subbasin flows to the subbasin outlet. Alternatively, the subbasin delineation may be obtained from grid cell boundaries. Since most spatial input is grid-based (i.e. DEM, NEXRAD, LULC), grid cells are an appealing approach for subbasin delineation. However unlike the subwatershed discretization, grid cells do not preserve routing reaches and topographic flow paths.

A subbasin will contain at least one HRU, a tributary channel and a main channel or reach. Two types of impoundments, a pond and/or wetland, may also be defined within a subbasin. These features are reviewed in the following sections.

1.1.2 HYDROLOGIC RESPONSE UNITS

The land area in a subbasin may be divided into hydrologic response units (HRUs). Hydrologic response units are portions of a subbasin that possess unique landuse/management/soil attributes. HRUs were incorporated into SWAT as part of the HUMUS (Hydrologic Unit Model for the United States) project. Prior to the HUMUS project, only one landuse/management/soil combination could be defined per subbasin in SWAT. HUMUS used U.S.G.S. 2-digit hydrologic boundaries to divide the contiguous United States into watersheds while 8-digit hydrologic boundaries were used to define subbasins within the watersheds. Only percentages of soil and landuse were known within the 8-digit hydrologic units—the geographic location of the landuse and soils within each subbasin was unknown. To capture the diversity of land use and soils that could be encompassed in an 8-digit hydrologic unit, a method was needed to account for the complexity of the landscape within the boundaries of the subbasins. The inclusion of HRUs allowed SWAT to account for this diversity.

An HRU is not synonymous to a field. Rather it is the total area in the subbasin with a particular landuse, management and soil. While individual fields with a specific landuse, management and soil may be scattered throughout a subbasin, these areas are lumped together to form one HRU. HRUs are used in most SWAT runs since they simplify a run by lumping all similar soil and land use areas into a single response unit. It is often not practical to simulate individual fields.

Implicit in the concept of the HRU is the assumption that there is no interaction between HRUs in one subbasin. Loadings (runoff with sediment, nutrients, etc. transported by the runoff) from each HRU are calculated separately and then summed together to determine the total loadings from the subbasin. If the interaction of one landuse area with another is important, rather than defining those landuse areas as HRUs they should be defined as subbasins. It is only at the subbasin level that spatial relationships can be specified.

The benefit of HRUs is the increase in accuracy it adds to the prediction of loadings from the subbasin. The growth and development of plants can differ greatly among species. When the diversity in plant cover within a subbasin is accounted for, the net amount of runoff entering the main channel from the subbasin will be much more accurate.

As a general rule, a given subbasin should have 1-10 HRUs. For those wishing to incorporate more complexity into a dataset, we would recommend that the user define a greater number of subbasins in the watershed rather than many HRUs within a few subbasins. Of course, there are exceptions to this rule. An example of such an exception would be the requirement that the project uses a particular subbasin delineation that doesn't allow the user to capture landuse diversity without the incorporation of many HRUs.

1.1.3 REACH/MAIN CHANNELS

One reach or main channel is associated with each subbasin in a watershed. Loadings from the subbasin enter the channel network of the watershed in the associated reach segment. Outflow from the upstream reach segment(s) will also enter the reach segment. Processes involved in routing water, sediment and other constituents through the reach are reviewed in Section 7 of the Theoretical Documentation.

1.1.4 TRIBUTARY CHANNELS

The term tributary channel is used to differentiate inputs for channelized flow of surface runoff generated in a subbasin. Tributary channel inputs are used to calculate the time of concentration for channelized flow of runoff generated within the subbasin and transmission losses from runoff as it flows to the main channel.

Tributary channel inputs define the longest flow path in the subbasin. For some subbasins, the main channel may be the longest flow path. If so, tributary channel dimensions will be the same as those for the main channel. In other subbasins, the tributary channel dimensions will be significantly different than the main channel.

1.1.5 PONDS/WETLANDS/RESERVOIRS

In order to process USGS landuse maps, the GIS interfaces will allow HRUs to be created with water as the land use. If at all possible this should be avoided. Water bodies within a watershed should be modeled as ponds, wetlands or reservoirs.

Water bodies located on the stream network of the watershed are modeled as reservoirs. While the term ―reservoir” is commonly used for man-made structures and ―lake” for naturally occurring water bodies, the use of the term ―reservoir” in SWAT is not meant to imply that the water body is man-made. With the terms ―reservoir” and ―pond” we are differentiating impoundments by location. Because impoundments on the main channel network tend to be larger than impoundments off the main channel network, a difference in size is also implied with the use of these terms. It would probably be more appropriate to refer to the different types of water bodies as main channel impoundments and subbasin impoundments, but the need for different file extensions to store inputs makes the use of these two terms convenient.

Two water bodies (pond/wetlands) may be defined within each subbasin. Water entering these impoundments is generated in the subbasin—they cannot receive water originating in other subbasins. In contrast, reservoirs receive water contributed to the channel network from all upstream subbasins.

1.1.6 POINT SOURCES

SWAT directly models the loading of water, sediment and nutrients from land areas in a watershed. However, some watersheds will have loadings to the stream network from sources not associated with a land area. These are referred to as point sources. The most common point source is a sewage treatment plant.

In order to account for the loadings from a point source, SWAT allows users to add daily or average daily loading data for point sources to the main channel network. These loadings are then routed through the channel network along with the loadings generated by the land areas.

In the GIS interfaces, a subbasin map is produced which allows the user to easily see the spatial relationship between subbasins. In the Windows (non-GIS) interface, the user can set up the spatial positioning of subbasins with drag and drop objects and connecting arrows to show direction of flow. The core SWAT program is not able to access maps or displays. Instead, it uses the information provided in the watershed configuration file (.fig) to link the individual subbasins together in the watershed. The watershed file is an ASCII or text file. The file format is described in Chapter 2 and example watershed configurations are provided in Appendix B.

1.2 OVERVIEW OF INPUT FILES

Input for SWAT is defined at one of several different levels of detail: watershed, subbasin, or HRU. Unique features such as reservoirs or point sources must have input data provided for each individual feature included in the watershed simulation.

Watershed level inputs are used to model processes throughout the watershed. For example, the method selected to model potential evapotranspiration will be used in all HRUs in the watershed. Subbasin level inputs are inputs set at the same value for all HRUs in the subbasin if the input pertains to a process modeled in the HRU. Because there is one reach per subbasin, input data for main channels is defined at the subbasin level also. An example of subbasin level data is rainfall and temperature information. The same rainfall and maximum and minimum temperature are used for all HRUs, the main channel and any ponds or wetlands located within the subbasin. HRU level inputs are inputs that can be set to unique values for each HRU in the watershed. An example of an HRU input is the management scenario simulated in an HRU.

An attempt was been made to organize input information according to the type of input. However, there are a few files that have had to serve as ―catch-alls". These files contain input data for various processes modeled in the watershed that do not fit into any of the specialized files.

Input files for SWAT include:

file.cio (watershed level file)	Master watershed file. This required file contains the names of watershed level files and parameters related to printing.
.fig (watershed level file)	Watershed configuration file. This required file defines the routing network in the watershed and lists input file names for the different objects in the watershed.
.bsn (watershed level file)	Basin input file. This required file defines values or options used to model physical processes uniformly over the entire watershed.
.pcp (watershed level file)	Precipitation input file. This optional file contains daily measured precipitation for a measuring gage(s). Up to 18 precipitation files may be used in each simulation and each file can hold data for up to 300 stations. The data for a particular station is assigned to a subbasin in the subbasin input file (.sub).
.tmp (watershed level file)	Temperature input file. This optional file contains daily measured maximum and minimum temperatures for a measuring gage(s). Up to 18 temperature files may be used in each simulation and each file can hold data for up to 150 stations. The data for a particular station is assigned to a subbasin in the subbasin input file (.sub).
.slr (watershed level file)	Solar radiation input file. This optional file contains daily solar radiation for a measuring gage(s). The solar radiation file can hold data for up to 300 stations. The data for a particular station is assigned to a subbasin in the subbasin input file (.sub).
.wnd (watershed level file)	Wind speed input file. This optional file contains daily average wind speed for a measuring gage(s). The wind speed file can hold data for up to 300 stations. The data for a particular station is assigned to a subbasin in the subbasin input file (.sub).
.hmd (watershed level file)	Relative humidity input file. This optional file contains daily relative humidity values for a measuring gage(s). The relative humidity file can hold data for up to 300 stations. The data for a particular station is assigned to a subbasin in the subbasin input file (.sub).
.pet (watershed level file)	Potential evapotranspiration input file. This optional file contains daily PET values for the watershed.

.cst (watershed level file)	Weather forecast input file. This optional file contains the statistical data needed to generate representative daily climatic data for the subbasins during the forecast period.
.cal (watershed level file)	Auto-calibration input file. This optional file contains the data needed to operate the auto-calibration algorithms.
crop.dat (watershed level file)	Land cover/plant growth database file. This required file contains plant growth parameters for all land covers simulated in the watershed.
till.dat (watershed level file)	Tillage database file. This required file contains information on the amount and depth of mixing caused by tillage operations simulated in the watershed.
pest.dat (watershed level file)	Pesticide database file. This required file contains information on mobility and degradation for all pesticides simulated in the watershed.
fert.dat (watershed level file)	Fertilizer database file. This required file contains information on the nutrient content of all fertilizers and manures simulated in the watershed.
urban.dat (watershed level file)	Urban database file. This required file contains information on the build-up/wash-off of solids in urban areas simulated in the watershed.
septic.dat (watershed level file)	Septic database file. This file contains information on septic systems.
.sub (subbasin level file)	Subbasin input file. This required file for each subbasin defines climatic inputs, tributary channel attributes, and the number and types of HRUs in the subbasin.
.wgn (subbasin level file)	Weather generator input file. This required file contains the statistical data needed to generate representative daily climatic data for a subbasin.
.pnd (subbasin level file)	Pond/wetland input file. This optional file contains information for impoundments located within a subbasin.
.wus (subbasin level file)	Water use input file. This optional file contains information for consumptive water use in a subbasin.
.rte (subbasin level file)	Main channel input file. This required file contains parameters governing water and sediment movement in the main channel of a subbasin.
.sep (subbasin level file)	Septic input file. This optional file contains information for septic systems.

.wwq (watershed level file)	Watershed water quality input file. This optional file contains parameters used to model QUAL2E transformations in the main channels.
.swq (subbasin level file)	Stream water quality input file. This optional file contains parameters used to model pesticide and QUAL2E nutrient transformations in the main channel of the subbasin.
.hru (HRU level file)	HRU input file. Required file for HRU level parameters. Catch-all file.
.mgt (HRU level file)	Management input file. This required file contains management scenarios and specifies the land cover simulated in the HRU.
.sol (HRU level file)	Soil input file. This required file contains information about the physical characteristics of the soil in the HRU.
.chm (HRU level file)	Soil chemical input file. This optional file contains information about initial nutrient and pesticide levels of the soil in the HRU.
.gw (HRU level file)	Groundwater input file. This required file contains information about the shallow and deep aquifer in the subbasin. Because land covers differ in their interaction with the shallow aquifer, information in this input file is allowed to be varied at the HRU level.
.res (reservoir file)	Reservoir input file. This optional file contains parameters used to model the movement of water and sediment through a reservoir.
.lwq (reservoir file)	Lake water quality input file. This optional file contains parameters used to model the movement of nutrients and pesticides through a reservoir.
rechour.dat recday.dat recmon.dat recyear.dat reccnst.dat (point source file)	Point source input files. These optional files contain information about loadings to the channel network from a point source. The type of file used to store the data depends on how the data is summarized (hourly, daily, monthly, yearly, or average annual).

1.3 MODEL INPUTS BY TYPE

The following tables group inputs by type. Detailed explanations of the variables are given in the input file chapter. Please keep in mind that in the GIS interfaces, some of these variables are automatically set by the interface and users will not be allowed to edit them.

WATERSHED DIMENSIONS

SWAT calculates total watershed dimensions from the watershed configuration given in the .fig file and variables located in various files. The variables listed here are the ones used in the calculation.

Variable		**File**
SUB_KM	.sub	Chapter 5
HRUTOT	.sub	Chapter 5
HRU_FR	.hru	Chapter 19

Length of Simulation

Variable		**File**
NBYR	file.cio	Chapter 3
IYR	file.cio	Chapter 3
IDAF	file.cio	Chapter 3
IDAL	file.cio	Chapter 3

Output Print Options/Output Summary Options

Variable		**File**
IPRINT	file.cio	Chapter 3
NYSKIP	file.cio	Chapter 3
ILOG	file.cio	Chapter 3
IPRP	file.cio	Chapter 3
IPRS	file.cio	Chapter 3
IPDVAR(1-20)	file.cio	Chapter 3
IPDVAB(1-20)	file.cio	Chapter 3
IPDVAS(1-20)	file.cio	Chapter 3
IPDHRU(1-20)	file.cio	Chapter 3
TITLE	file.cio	Chapter 3
save command	.fig	Chapter 2
saveconc command	.fig	Chapter 2

Random Number Generator

Variable		**File**
IGEN	file.cio	Chapter 3

Special Project Flag

Variable		**File**
ISPROJ	file.cio	Chapter 3

CLIMATE

Precipitation

Variable	File	
PCPSIM	file.cio	Chapter 3
IDT	file.cio	Chapter 3
IDIST	file.cio	Chapter 3
REXP	file.cio	Chapter 3
NRGAGE	file.cio	Chapter 3
NRTOT	file.cio	Chapter 3
NRGFIL	file.cio	Chapter 3
RFILE(1-18)	file.cio	Chapter 3
IEVENT	.bsn	Chapter 4
ISED_DET	.bsn	Chapter 4
RAIN_YRS	.wgn	Chapter 12
PCPMM(1-12)	.wgn	Chapter 12
PCPSTD(1-12)	.wgn	Chapter 12
PCPSKW(1-12)	.wgn	Chapter 12
PR_W(1,1-12)	.wgn	Chapter 12
PR_W(2,1-12)	.wgn	Chapter 12
PCPD(1-12)	.wgn	Chapter 12
RAINHHMX(1-12)	.wgn	Chapter 12
FPCPMM(1-12)	.cst	Chapter 13
FPCPSTD(1-12)	.cst	Chapter 13
FPCPSKW(1-12)	.cst	Chapter 13
FPR_W(1,1-12)	.cst	Chapter 13
FPR_W(2,1-12)	.cst	Chapter 13
FPCPD(1-12)	.cst	Chapter 13
PRECIPITATION	.pcp	Chapter 6
IRGAGE	.sub	Chapter 5
PLAPS	.sub	Chapter 5
RFINC(1-12)	.sub	Chapter 5

Snow Processes

Variable	File	
SFTMP	.bsn	Chapter 4
SMTMP	.bsn	Chapter 4
SMFMX	.bsn	Chapter 4
SMFMN	.bsn	Chapter 4
TIMP	.bsn	Chapter 4
SNOCOVMX	.bsn	Chapter 4
SNO50COV	.bsn	Chapter 4
SNO_SUB	.sub	Chapter 5

Snow Processes, cont.

Variable	File	
SNOEB(1-10)	.sub	Chapter 5

Temperature

Variable	File	
TMPSIM	file.cio	Chapter 3
NTGAGE	file.cio	Chapter 3
NTTOT	file.cio	Chapter 3
NTGFIL	file.cio	Chapter 3
TFILE(1-18)	file.cio	Chapter 3
TMPMX(1-12)	.wgn	Chapter 12
TMPMN(1-12)	.wgn	Chapter 12
TMPSTDMX(1-12)	.wgn	Chapter 12
TMPSTDMN(1-12)	.wgn	Chapter 12
FTMPMX(1-12)	.cst	Chapter 13
FTMPMN(1-12)	.cst	Chapter 13
FTMPSTDMX(1-12)	.cst	Chapter 13
FTMPSTDMN(1-12)	.cst	Chapter 13
MAX TEMP	.tmp	Chapter 7
MIN TEMP	.tmp	Chapter 7
ITGAGE	.sub	Chapter 5
TLAPS	.sub	Chapter 5
TMPINC	.sub	Chapter 5

Solar Radiation

Variable	File	
SLRSIM	file.cio	Chapter 3
NSTOT	file.cio	Chapter 3
SLRFILE	file.cio	Chapter 3
WLATITUDE	.wgn	Chapter 12
SOLARAV(1-12)	.wgn	Chapter 12
SOL_RAD	.slr	Chapter 8
ISGAGE	.sub	Chapter 5
SUB_LAT	.sub	Chapter 5
RADINC(1-12)	.sub	Chapter 5

Relative Humidity Input

Variable	File	
RHSIM	file.cio	Chapter 3
NHTOT	file.cio	Chapter 3
RHFILE	file.cio	Chapter 3
DEWPT(1-12)	.wgn	Chapter 12
RHD	.hmd	Chapter 10
IHGAGE	.sub	Chapter 5
HUMINC(1-12)	.sub	Chapter 5

Wind Speed Input

Variable	File	
WNDSIM	file.cio	Chapter 3
NWTOT	file.cio	Chapter 3
WNDFILE	file.cio	Chapter 3
IWGAGE	.sub	Chapter 5
WNDAV(1-12)	.wgn	Chapter 12
WND_SP	.wnd	Chapter 9

Elevation Bands

Variable	File	
WELEV	.wgn	Chapter 12
ELEVATION	.pcp	Chapter 6
ELEVATION	.tmp	Chapter 7
ELEVB(1-10)	.sub	Chapter 5
ELEV_FR(1-10)	.sub	Chapter 5
SNOEB(1-10)	.sub	Chapter 5
PLAPS	.sub	Chapter 5
TLAPS	.sub	Chapter 5

Climate Change

Variable	File	
CO2	.sub	Chapter 5
RFINC(1-12)	.sub	Chapter 5
TMPINC(1-12)	.sub	Chapter 5
RADINC(1-12)	.sub	Chapter 5
HUMINC(1-12)	.sub	Chapter 5
CO2HI	crop.dat	Chapter 14
BIOEHI	crop.dat	Chapter 14

Weather Forecast

Variable	File	
FCSTYR	file.cio	Chapter 3
FCSTDAY	file.cio	Chapter 3
FCSTCYCLES	file.cio	Chapter 3
FCSTFILE	file.cio	Chapter 3
FCSTREG	.sub	Chapter 5
FCST_REG	.cst	Chapter 13
FTMPMX(1-12)	.cst	Chapter 13
FTMPMN(1-12)	.cst	Chapter 13
FTMPSTDMX(1-12)	.cst	Chapter 13
FTMPSTDMN(1-12)	.cst	Chapter 13
FPCPMM(1-12)	.cst	Chapter 13
FPCPSTD(1-12)	.cst	Chapter 13
FPCPSKW(1-12)	.cst	Chapter 13
FPR_W(1,1-12)	.cst	Chapter 13
FPR_W(2,1-12)	.cst	Chapter 13
FPCPD(1-12)	.cst	Chapter 13

HYDROLOGIC CYCLE

Potential and Actual Evapotranspiration

Variable	File	
IPET	.bsn	Chapter 4
PETFILE	.bsn	Chapter 4
ESCO	.bsn, .hru	Chapter 4, 19
EPCO	.bsn, .hru	Chapter 4, 19
PET_MEAS	.pet	Chapter 11
SUB_ELEV	.sub	Chapter 5
CANMX	.hru	Chapter 19
SOL_ALB	.sol	Chapter 22
GW_REVAP	.gw	Chapter 24
REVAPMN	.gw	Chapter 24

Surface Runoff

Variable	File	
IEVENT	.bsn	Chapter 4
ICN	.bsn	Chapter 4
CNCOEF	.bsn	Chapter 4
SURLAG	.bsn	Chapter 4

Surface Runoff, cont.

Variable		File
CN2	.mgt	Chapter 20
CNOP (***plant operation***)	.mgt	Chapter 20
CNOP (***harv & kill op***)	.mgt	Chapter 20
CNOP (***tillage operation***)	.mgt	Chapter 20
URBCN2	urban.dat	Chapter 18

Time of Concentration

Variable		File
CH_L(1)	.sub	Chapter 5
CH_S(1)	.sub	Chapter 5
CH_N(1)	.sub	Chapter 5
SLSUBBSN	.hru	Chapter 19
OV_N	.hru	Chapter 19

Crack Flow

Variable		File
ICRK	.bsn	Chapter 4
SOL_CRK	.sol	Chapter 22

Transmission Losses from Surface Runoff

Variable		File
CH_L(1)	.sub	Chapter 5
CH_W(1)	.sub	Chapter 5
CH_K(1)	.sub	Chapter 5

Soil Water

Variable		File
FFCB	.bsn	Chapter 4
SOL_Z	.sol	Chapter 22
SOL_BD	.sol	Chapter 22
SOL_AWC	.sol	Chapter 22
SOL_K	.sol	Chapter 22
irrigation operation	.mgt	Chapter 20
auto-irrigation operation	.mgt	Chapter 20
FLOW_OVN, ***route command***	.fig	Chapter 2

Lateral Flow

Variable	File	
HRU_SLP	.hru	Chapter 19
LAT_TTIME	.hru	Chapter 19
SLSOIL	.hru	Chapter 19

High Water Table

Variable	File	
IWATABLE	.hru	Chapter 19

Groundwater

Variable	File	
SHALLST	.gw	Chapter 24
DEEPST	.gw	Chapter 24
GW_DELAY	.gw	Chapter 24
ALPHA_BF	.gw	Chapter 24
GWQMN	.gw	Chapter 24
GW_REVAP	.gw	Chapter 24
REVAPMN	.gw	Chapter 24
RCHRG_DP	.gw	Chapter 24
WUSHAL(1-12)	.wus	Chapter 21
WUDEEP(1-12)	.wus	Chapter 21

SEDIMENT

Sediment Erosion

Variable	File	
ADJ_PKR	.bsn	Chapter 4
SLSUBBSN	.hru	Chapter 19
HRU_SLP	.hru	Chapter 19
LAT_SED	.hru	Chapter 19
FILTERW	.mgt	Chapter 20
CLAY	.sol	Chapter 22
SILT	.sol	Chapter 22
SAND	.sol	Chapter 22
ROCK	.sol	Chapter 22
USLE_K	.sol	Chapter 22
USLE_P	.mgt	Chapter 20
USLE_C	crop.dat	Chapter 14

NUTRIENTS

Nitrogen Cycle/Runoff

Variable	File	
RCN	.bsn	Chapter 4
CMN	.bsn	Chapter 4
CDN	.bsn	Chapter 4
SDNCO	.bsn	Chapter 4
N_UPDIS	.bsn	Chapter 4
NPERCO	.bsn	Chapter 4
RSDCO	.bsn	Chapter 4
ANION_EXCL	.sol	Chapter 22
SOL_NO3	.chm	Chapter 23
SOL_ORGN	.chm	Chapter 23
SOL_CBN	.sol	Chapter 22
ERORGN	.hru	Chapter 19
FILTERW	.mgt	Chapter 20
BIOMIX	.mgt	Chapter 20
fertilizer application	.mgt	Chapter 20
FMINN	fert.dat	Chapter 17
FORGN	fert.dat	Chapter 17
FNH3N	fert.dat	Chapter 17
tillage operation	.mgt	Chapter 20
EFFMIX	till.dat	Chapter 15
DEPTIL	till.dat	Chapter 15
grazing operation	.mgt	Chapter 20
auto-fertilization operation	.mgt	Chapter 20
continuous fertilization operatio	.mgt	Chapter 20
CNYLD	crop.dat	Chapter 14
PLTNFR(1)	crop.dat	Chapter 14
PLTNFR(2)	crop.dat	Chapter 14
PLTNFR(3)	crop.dat	Chapter 14
GWNO3	.gw	Chapter 24

Phosphorus Cycle/Runoff

Variable	File	
P_UPDIS	.bsn	Chapter 4
PPERCO	.bsn	Chapter 4
PHOSKD	.bsn	Chapter 4
PSP	.bsn	Chapter 4
RSDCO	.bsn	Chapter 4
SOL_SOLP	.chm	Chapter 23
SOL_ORGP	.chm	Chapter 23
ERORGP	.hru	Chapter 19

Phosphorus Cycle/Runoff, cont.

Variable	File	
FILTERW	.mgt	Chapter 20
BIOMIX	.mgt	Chapter 20
fertilizer application	.mgt	Chapter 20
FMINP	fert.dat	Chapter 17
FORGP	fert.dat	Chapter 17
tillage operation	.mgt	Chapter 20
EFFMIX	till.dat	Chapter 15
DEPTIL	till.dat	Chapter 15
grazing operation	.mgt	Chapter 20
auto-fertilization operation	.mgt	Chapter 20
continuous fertilization operation	.mgt	Chapter 20
CPYLD	crop.dat	Chapter 14
PLTPFR(1)	crop.dat	Chapter 14
PLTPFR(2)	crop.dat	Chapter 14
PLTPFR(3)	crop.dat	Chapter 14
GWSOLP	.gw	Chapter 24

PESTICIDE

Pesticide in Soil/Runoff

Variable	File	
PERCOP	.bsn	Chapter 4
PESTNUM	.chm	Chapter 23
PLTPST	.chm	Chapter 23
SOLPST	.chm	Chapter 23
FILTERW	.mgt	Chapter 20
PSTENR	.chm	Chapter 23
BIOMIX	.mgt	Chapter 20
pesticide application	.mgt	Chapter 20
SKOC	pest.dat	Chapter 16
WOF	pest.dat	Chapter 16
HLIFE_F	pest.dat	Chapter 16
HLIFE_S	pest.dat	Chapter 16
AP_EF	pest.dat	Chapter 16
WSOL	pest.dat	Chapter 16
tillage operation	.mgt	Chapter 20
EFFMIX	till.dat	Chapter 15
DEPTIL	till.dat	Chapter 15

BACTERIA

Bacteria in Soil/Runoff

Variable	File	
WDPQ	.bsn	Chapter 4
WGPQ	.bsn	Chapter 4
WDLPQ	.bsn	Chapter 4
WGLPQ	.bsn	Chapter 4
WDPS	.bsn	Chapter 4
WGPS	.bsn	Chapter 4
WDLPS	.bsn	Chapter 4
WGLPS	.bsn	Chapter 4
BACTKDQ	.bsn	Chapter 4
THBACT	.bsn	Chapter 4
WOF_P	.bsn	Chapter 4
WOF_LP	.bsn	Chapter 4
WDPF	.bsn	Chapter 4
WGPF	.bsn	Chapter 4
WDLPF	.bsn	Chapter 4
WGLPF	.bsn	Chapter 4
BACT_SWF	.bsn	Chapter 4
BACTMIX	.bsn	Chapter 4
BACTMIN	.bsn	Chapter 4
FILTERW	.mgt	Chapter 20
BIOMIX	.mgt	Chapter 20
tillage operation	.mgt	Chapter 20
EFFMIX	till.dat	Chapter 15
DEPTIL	till.dat	Chapter 15
fertilizer application	.mgt	Chapter 20
BACTPDB	fert.dat	Chapter 17
BACTLPDB	fert.dat	Chapter 17
BACTKDDB	fert.dat	Chapter 17
grazing operation	.mgt	Chapter 20
auto-fertilization operation	.mgt	Chapter 20
continuous fertilization operation	.mgt	Chapter 20

WATER QUALITY

Subbasin Water Quality Indices

Variable	File	
ISUBWQ	.bsn	Chapter 4

PLANTS

Plant Growth

Variable	File	
SOL_ZMX	.sol	Chapter 22
PHU_PLT/HEAT UNITS	.mgt	Chapter 20
BIO_MIN	.mgt	Chapter 20
plant operation	.mgt	Chapter 20
harvest & kill operation	.mgt	Chapter 20
harvest operation	.mgt	Chapter 20
kill operation	.mgt	Chapter 20
grazing operation	.mgt	Chapter 20
CO2	.sub	Chapter 5
IDC	crop.dat	Chapter 14
BIO_E	crop.dat	Chapter 14
HVSTI	crop.dat	Chapter 14
BLAI	crop.dat	Chapter 14
FRGRW1	crop.dat	Chapter 14
LAIMX1	crop.dat	Chapter 14
FRGRW2	crop.dat	Chapter 14
LAIMX2	crop.dat	Chapter 14
DLAI	crop.dat	Chapter 14
CHTMX	crop.dat	Chapter 14
RDMX	crop.dat	Chapter 14
T_OPT	crop.dat	Chapter 14
T_BASE	crop.dat	Chapter 14
CNYLD	crop.dat	Chapter 14
CPYLD	crop.dat	Chapter 14
PLTNFR(1)	crop.dat	Chapter 14
PLTNFR(2)	crop.dat	Chapter 14
PLTNFR(3)	crop.dat	Chapter 14
PLTPFR(1)	crop.dat	Chapter 14
PLTPFR(2)	crop.dat	Chapter 14
PLTPFR(3)	crop.dat	Chapter 14
WSYF	crop.dat	Chapter 14
GSI	crop.dat	Chapter 14
VPDFR	crop.dat	Chapter 14
FRGMAX	crop.dat	Chapter 14
WAVP	crop.dat	Chapter 14
CO2HI	crop.dat	Chapter 14
BIOEHI	crop.dat	Chapter 14

Plant Growth, cont.

Variable		File
ALAI_MIN	crop.dat	Chapter 14
BIO_LEAF	crop.dat	Chapter 14

Residue

Variable		File
RSDIN	.hru	Chapter 19
RSDCO	.bsn	Chapter 4
harvest & kill operation	.mgt	Chapter 20
harvest operation	.mgt	Chapter 20
kill operation	.mgt	Chapter 20
grazing operation	.mgt	Chapter 20
RSDCO_PL	crop.dat	Chapter 14
BIO_LEAF	crop.dat	Chapter 14

MANAGEMENT

Management-Land Cover

Variable		File
IGRO	.mgt	Chapter 20
NROT	.mgt	Chapter 20
PLANT_ID	.mgt	Chapter 20
LAI_INIT	.mgt	Chapter 20
BIO_INIT	.mgt	Chapter 20
PHU_PLT	.mgt	Chapter 20
BIO_MIN	.mgt	Chapter 20
plant operation	.mgt	Chapter 20
HEAT UNITS	.mgt	Chapter 20
PLANT_ID	.mgt	Chapter 20
HI_TARG	.mgt	Chapter 20
BIO_TARG	.mgt	Chapter 20
LAI_INIT	.mgt	Chapter 20
BIO_INIT	.mgt	Chapter 20
harvest & kill operation	.mgt	Chapter 20
harvest operation	.mgt	Chapter 20
HI_OVR	.mgt	Chapter 20
HARVEFF	.mgt	Chapter 20
kill operation	.mgt	Chapter 20

Management-Land Cover, cont.

Variable		File
grazing operation	.mgt	Chapter 20
BIO_EAT	.mgt	Chapter 20
GRZ_DAYS	.mgt	Chapter 20
BIO_TRMP	.mgt	Chapter 20

Management-Nutrients

Variable		File
BIOMIX	.mgt	Chapter 20
fertilizer application	.mgt	Chapter 20
FRT_SURFACE	.mgt	Chapter 20
FERT_ID	.mgt	Chapter 20
FERT_KG	.mgt	Chapter 20
tillage operation	.mgt	Chapter 20
TILLAGE_ID	.mgt	Chapter 20
grazing operation	.mgt	Chapter 20
MANURE_KG	.mgt	Chapter 20
MANURE_ID	.mgt	Chapter 20
auto-fertilization operation	.mgt	Chapter 20
AUTO_NSTRS	.mgt	Chapter 20
AFERT_ID	.mgt	Chapter 20
AUTO_NAPP	.mgt	Chapter 20
AUTO_NYR	.mgt	Chapter 20
AUTO_EFF	.mgt	Chapter 20
AFRT_SURFACE	.mgt	Chapter 20
continuous fertilization op	.mgt	Chapter 20
FERT_DAYS	.mgt	Chapter 20
CFRT_ID	.mgt	Chapter 20
IFRT_FREQ	.mgt	Chapter 20
CFRT_KG	.mgt	Chapter 20

Management-Pesticide

Variable		File
BIOMIX	.mgt	Chapter 20
pesticide application	.mgt	Chapter 20
PEST_ID	.mgt	Chapter 20
FERT_KG	.mgt	Chapter 20
tillage operation	.mgt	Chapter 20
TILLAGE_ID	.mgt	Chapter 20

Management-Water

Variable		File
IRRSC	.mgt	Chapter 20
IRRNO	.mgt	Chapter 20
FLOWMIN	.mgt	Chapter 20
DIVMAX	.mgt	Chapter 20
FLOWFR	.mgt	Chapter 20
DDRAIN	.mgt	Chapter 20
TDRAIN	.mgt	Chapter 20
GDRAIN	.mgt	Chapter 20
POT_FR	.hru	Chapter 19
POT_TILE	.hru	Chapter 19
POT_VOLX	.hru	Chapter 19
POT_VOL	.hru	Chapter 19
EVLAI	.bsn	Chapter 4
irrigation operation	.mgt	Chapter 20
IRR_AMT	.mgt	Chapter 20
auto-irrigation operation	.mgt	Chapter 20
WSTRS_ID	.mgt	Chapter 20
AUTO_WSTR	.mgt	Chapter 20
release/impound operation	.mgt	Chapter 20
IMP_TRIG	.mgt	Chapter 20

Management-Urban

Variable		File
IURBAN	.mgt	Chapter 20
URBLU	.mgt	Chapter 20
street sweeping operation	.mgt	Chapter 20
SWEEPEFF	.mgt	Chapter 20
FR_CURB	.mgt	Chapter 20
FIMP	urban.dat	Chapter 18
FCIMP	urban.dat	Chapter 18
CURBDEN	urban.dat	Chapter 18
URBCOEF	urban.dat	Chapter 18
DIRTMX	urban.dat	Chapter 18
THALF	urban.dat	Chapter 18
TNCONC	urban.dat	Chapter 18
TPCONC	urban.dat	Chapter 18
TNO3CONC	urban.dat	Chapter 18
URBCN2	urban.dat	Chapter 18

CHANNEL PROCESSES

Channel Water Routing

Variable		File
IEVENT	.bsn	Chapter 4
IRTE	.bsn	Chapter 4
TRNSRCH	.bsn	Chapter 4
EVRCH	.bsn	Chapter 4
MSK_CO1	.bsn	Chapter 4
MSK_CO2	.bsn	Chapter 4
MSK_X	.bsn	Chapter 4
CH_W(2)	.rte	Chapter 25
CH_D	.rte	Chapter 25
CH_S(2)	.rte	Chapter 25
CH_L(2)	.rte	Chapter 25
CH_N(2)	.rte	Chapter 25
CH_K(2)	.rte	Chapter 25
ALPHA_BNK	.rte	Chapter 25
FLOWMIN	.mgt	Chapter 20
DIVMAX	.mgt	Chapter 20
FLOWFR	.mgt	Chapter 20
WURCH(1-12)	.wus	Chapter 21
transfer command	.fig	Chapter 2
FLOW_OVN, ***route command***	.fig	Chapter 2

Channel Sediment Routing

Variable		File
IDEG	.bsn	Chapter 4
PRF	.bsn	Chapter 4
SPCON	.bsn	Chapter 4
SPEXP	.bsn	Chapter 4
CH_W(2)	.rte	Chapter 25
CH_D	.rte	Chapter 25
CH_S(2)	.rte	Chapter 25
CH_EROD	.rte	Chapter 25
CH_COV	.rte	Chapter 25
CH_WDR	.rte	Chapter 25

Channel Nutrient Routing

Variable	File	
IWQ	.bsn	Chapter 4
AI1	.wwq	Chapter 26
AI2	.wwq	Chapter 26
P_N	.wwq	Chapter 26
RS2	.swq	Chapter 27
RS3	.swq	Chapter 27
RS4	.swq	Chapter 27
RS5	.swq	Chapter 27
BC1	.swq	Chapter 27
BC2	.swq	Chapter 27
BC3	.swq	Chapter 27
BC4	.swq	Chapter 27

Channel Water Quality Indices

Variable	File	
IWQ	.bsn	Chapter 4
LAO	.wwq	Chapter 26
IGROPT	.wwq	Chapter 26
AI0	.wwq	Chapter 26
AI1	.wwq	Chapter 26
AI2	.wwq	Chapter 26
AI3	.wwq	Chapter 26
AI4	.wwq	Chapter 26
AI5	.wwq	Chapter 26
AI6	.wwq	Chapter 26
MUMAX	.wwq	Chapter 26
RHOQ	.wwq	Chapter 26
TFACT	.wwq	Chapter 26
K_L	.wwq	Chapter 26
K_N	.wwq	Chapter 26
K_P	.wwq	Chapter 26
LAMBDA0	.wwq	Chapter 26
LAMBDA1	.wwq	Chapter 26
LAMBDA2	.wwq	Chapter 26
P_N	.wwq	Chapter 26
RS1	.swq	Chapter 27
RK1	.swq	Chapter 27
RK2	.swq	Chapter 27
RK3	.swq	Chapter 27
RK4	.swq	Chapter 27
structure command	.fig	Chapter 2

Channel Pesticide Routing Input

Variable		File
IWQ	.bsn	Chapter 4
IRTPEST	.bsn	Chapter 4
CHPST_REA	.swq	Chapter 27
CHPST_VOL	.swq	Chapter 27
CHPST_KOC	.swq	Chapter 27
CHPST_STL	.swq	Chapter 27
CHPST_RSP	.swq	Chapter 27
CHPST_MIX	.swq	Chapter 27
SEDPST_CONC	.swq	Chapter 27
SEDPST_REA	.swq	Chapter 27
SEDPST_BRY	.swq	Chapter 27
SEDPST_ACT	.swq	Chapter 27

IMPOUNDMENT PROCESSES

Impoundment Water Routing—Pond

Variable		File
PND_FR	.pnd	Chapter 28
PND_PSA	.pnd	Chapter 28
PND_PVOL	.pnd	Chapter 28
PND_ESA	.pnd	Chapter 28
PND_EVOL	.pnd	Chapter 28
PND_VOL	.pnd	Chapter 28
PND_K	.pnd	Chapter 28
IFLOD1	.pnd	Chapter 28
IFLOD2	.pnd	Chapter 28
NDTARG	.pnd	Chapter 28
WUPND(1-12)	.wus	Chapter 21

Impoundment Water Routing—Wetland

Variable		File
WET_FR	.pnd	Chapter 28
WET_NSA	.pnd	Chapter 28
WET_NVOL	.pnd	Chapter 28
WET_MXSA	.pnd	Chapter 28
WET_MXVOL	.pnd	Chapter 28
WET_VOL	.pnd	Chapter 28
WET_K	.pnd	Chapter 28

Impoundment Water Routing—Pothole

Variable	File	
POT_FR	.hru	Chapter 19
POT_TILE	.hru	Chapter 19
POT_VOLX	.hru	Chapter 19
POT_VOL	.hru	Chapter 19
EVLAI	.bsn	Chapter 4
release/impound operation	.mgt	Chapter 20

Impoundment Water Routing—Reservoir

Variable	File	
RES_SUB	.res	Chapter 29
MORES	.res	Chapter 29
IYRES	.res	Chapter 29
RES_ESA	.res	Chapter 29
RES_EVOL	.res	Chapter 29
RES_PSA	.res	Chapter 29
RES_PVOL	.res	Chapter 29
RES_VOL	.res	Chapter 29
RES_K	.res	Chapter 29
IRESCO	.res	Chapter 29
OFLOWMX(1-12)	.res	Chapter 29
OFLOWMN(1-12)	.res	Chapter 29
RES_RR	.res	Chapter 29
RESMONO	.res	Chapter 29
IFLOD1R	.res	Chapter 29
IFLOD2R	.res	Chapter 29
NDTARGR	.res	Chapter 29
STARG(1-12)	.res	Chapter 29
RESDAYO	.res	Chapter 29
WURESN(1-12)	.res	Chapter 29
WURTNF	.res	Chapter 29
RES_OUTFLOW	resdayo.dat	Chapter 29
RESOUT	resmono.dat	Chapter 29

Impoundment Sediment Routing

Variable	File	
PND_SED	.pnd	Chapter 28
PND_NSED	.pnd	Chapter 28
WET_SED	.pnd	Chapter 28
WET_NSED	.pnd	Chapter 28
POT_NSED	.hru	Chapter 19

Impoundment Sediment Routing

Variable	File	
RES_SED	.res	Chapter 29
RES_NSED	.res	Chapter 29
RES_D50	.res	Chapter 29

Impoundment Nutrient Routing—Pond

Variable	File	
PSETLP1	.pnd	Chapter 28
PSETLP2	.pnd	Chapter 28
NSETLP1	.pnd	Chapter 28
NSETLP2	.pnd	Chapter 28
PND_NO3	.pnd	Chapter 28
PND_SOLP	.pnd	Chapter 28
PND_ORGN	.pnd	Chapter 28
PND_ORGP	.pnd	Chapter 28
IPND1	.pnd	Chapter 28
IPND2	.pnd	Chapter 28

Impoundment Nutrient Routing—Wetland

Variable	File	
PSETLW1	.pnd	Chapter 28
PSETLW2	.pnd	Chapter 28
NSETLW1	.pnd	Chapter 28
NSETLW2	.pnd	Chapter 28
WET_NO3	.pnd	Chapter 28
WET_SOLP	.pnd	Chapter 28
WET_ORGN	.pnd	Chapter 28
WET_ORGP	.pnd	Chapter 28
IPND1	.pnd	Chapter 28
IPND2	.pnd	Chapter 28

Impoundment Nutrient Routing—Reservoir

Variable	File	
IRES1	.lwq	Chapter 30
IRES2	.lwq	Chapter 30
PSETLR1	.lwq	Chapter 30
PSETLR2	.lwq	Chapter 30
NSETLR1	.lwq	Chapter 30
NSETLR2	.lwq	Chapter 30

Impoundment Nutrient Routing—Reservoir, cont.

Variable	File	
RES_ORGP	.lwq	Chapter 30
RES_SOLP	.lwq	Chapter 30
RES_ORGN	.lwq	Chapter 30
RES_NO3	.lwq	Chapter 30
RES_NH3	.lwq	Chapter 30
RES_NO2	.lwq	Chapter 30

Impoundment Water Quality Indices

Variable	File	
CHLAP	.pnd	Chapter 28
SECCIP	.pnd	Chapter 28
CHLAW	.pnd	Chapter 28
SECCIW	.pnd	Chapter 28
CHLAR	.lwq	Chapter 30
SECCIR	.lwq	Chapter 30

Impoundment Pesticide Routing—Reservoir

Variable	File	
IRTPEST	.bsn	Chapter 4
LKPST_CONC	.lwq	Chapter 30
LKPST_REA	.lwq	Chapter 30
LKPST_VOL	.lwq	Chapter 30
LKPST_KOC	.lwq	Chapter 30
LKPST_STL	.lwq	Chapter 30
LKPST_RSP	.lwq	Chapter 30
LKPST_MIX	.lwq	Chapter 30
LKSPST_CONC	.lwq	Chapter 30
LKSPST_REA	.lwq	Chapter 30
LKSPST_BRY	.lwq	Chapter 30
LKSPST_ACT	.lwq	Chapter 30

CHAPTER 2

SWAT INPUT DATA: WATERSHED CONFIGURATION

The first step in setting up a watershed simulation is to define the relative arrangement of the parts or elements, i.e. the configuration, of the watershed. If the watershed has only one primary channel and there is little variation in topography and climate across the watershed, there may not be a need to partition the watershed into smaller units. However, the majority of watersheds will exhibit enough complexity in the stream network, topography or climate to warrant subdivision for modeling purposes.

There are several techniques used to discretize a watershed. In the past, models could only apply one type of discretization scheme to a watershed. This resulted in the development of several models that differ only in the watershed discretization scheme used.

2.1 DISCRETIZATION SCHEMES

The three most common techniques used to discretize a watershed are:

- ♦ Grid cell. This configuration allows the user to incorporate significant spatial detail into a simulation. Models which use this technique include AGNPS (Young et al., 1987), ANSWERS (Beasley et al., 1980) and the WEPP grid version (Foster, 1987).
- ♦ Representative hillslope. This configuration is useful for modeling hillslope processes. This technique is used in APEX (Williams, et al., 1998) and the WEPP hillslope version (Lane and Nearing, 1989).
- ♦ Subwatershed. This configuration preserves the natural channels and flow paths of the watershed. This technique is used in the WEPP watershed version (Foster, 1987), HYMO (Williams and Hann, 1973) and SWRRB (Arnold et al., 1990).

All of these schemes have strengths, weaknesses and applications for which they are most appropriate. SWAT uses the subwatershed configuration as the primary discretization scheme for a watershed. However, because of the routing command language utilized in SWAT, it is possible to use any of these three, alone or in combination, to model a watershed.

2.2 WATERSHED CONFIGURATION FILE (.FIG)

The watershed configuration file contains information used by SWAT to simulate processes occurring within the HRU/subbasin and to route the stream loadings through the channel network of the watershed. A reach routing command structure, similar to that developed for HYMO (Williams and Hann, 1973), is utilized to route and add flows through the watershed. The following sections review the different features of the watershed configuration file.

2.2.1 INCORPORATION OF COMMENTS

To assist the user in interpreting the watershed configuration file, an unlimited number of comment lines are allowed. These comments can be used to isolate the routing commands for different reaches, etc. To included comments in the watershed configuration file, a line must have an asterisk (*) in the 1st space on the line. When SWAT reads the asterisk, it will skip to the next line.

2.2.2 COMMAND LINES

Fifteen different commands may be used in the watershed configuration file. The commands, along with their numeric codes, are:

finish	0
subbasin	1
route	2
routres	3
transfer	4
add	5
rechour	6
recmon	7
recyear	8
save	9
recday	10
reccnst	11
structure	12
apex	13
saveconc	14
autocal	16

The format of the commands is illustrated in Figure 2-1.

The most commonly used commands are: subbasin, route, add, and finish. These commands simulate the land phase of the hydrologic cycle and determine the loadings to the main channel (subbasin), model the movement and transformations occurring in the main channel (route), allow the output from different subbasins to be summed together (add), and identify the end of the routing command sequence (finish).

The remaining commands are utilized to model more unique configurations. This set of commands can be divided into several subgroups: routing of water through a reservoir (routres), humanly contrived movement of water (transfer), aeration of water resulting from flow through structures along the channel (structure), incorporation of point source data (rechour, recday, recmon, recyear, reccnst), formatting of watershed outflow for input into a different SWAT simulation (save), formatting of water quality simulation results at specified points in the reach network (saveconc), and identification of auto-calibration points in the watershed (autocal).

The watershed configuration file is a fixed format file. With fixed format, the model looks for data only in a particular location on a command line. Spaces not allocated to variable inputs for a specific command are not processed by the model. The interfaces commonly use the extra space to write other data or they insert zeros in the unused columns. Appendix B steps through the set up of example watershed configuration files and will be very helpful to users trying to familiarize themselves with the logic of this file.

Watershed Configuration: SWAT2003

Command formats:

	icode	ihout	inum1	inum2	inum3	rnum1	inum4
	column 1	**column 2**	**column 3**	**column 4**	**column 5**	**column 6**	**column 7**
	space 11-16	space 17-22	space 23-28	space 29-34	space 35-40	space 41-46	space 47-55
subbasin	1	HYD_STOR	SUB_NUM				GIS_CODE
	SUBFILE						
route	2	HYD_STOR	RCH_NUM	HYD_NUM		FLOW_OVN	
	RTEFILE		SWQFILE				
routres	3	HYD_STOR	RES_NUM	HYD_NUM			
	RESFILE		LWQFILE				
transfer	4	DEP_TYPE	DEP_NUM	DEST_TYPE	DEST_NUM	TRANS_AMT	TRANS_CODE
add	5	HYD_STOR	HYD_NUM1	HYD_NUM2			
rechour	6	HYD_STOR	FILEHR_NUM				
	FILE_HR						
recmon	7	HYD_STOR	FILEMON_NUM			DRAINAGE_AREA	
	FILE_MON						
recyear	8	HYD_STOR	FILEYR_NUM			DRAINAGE_AREA	
	FILE_YEAR						
save	9	HYD_NUM	FILEMASS_NUM	PRINT_FREQ	PRINT_FMT		
	FILE_MASS						
recday	10	HYD_STOR	FILEDAY_NUM			DRAINAGE_AREA	
	FILE_DAY						
reccnst	11	HYD_STOR	FILECNST_NUM			DRAINAGE_AREA	
	FILE_CNST						
structur	12	HYD_STOR	HYD_NUM			AERATION_COEF	
	13						
saveconc	14	HYD_NUM	FILECONC_NUM	PRINT_FREQ			
	FILE_CONC						
	15						
autocal	16	HYD_NUM	FILECAL_NUM	PRINT_FREQ			
	FILE_ACAL						
finish	0						

Figure 2-1: Commands included in watershed configuration file

2.2.2.1 FINISH COMMAND (0)

The last command line in the .fig file must be a finish command line. The finish command notifies the model that the end of the command lines in the watershed configuration file has been reached. Variables required on the finish command line are:

Variable name	Definition
COMMAND	The command code = 0 for the finish command. Required.

The format of the finish command line is:

Variable name	Position	Format	F90 Format
COMMAND	space 11-16	6-digit integer	i6

2.2.2.2 SUBBASIN COMMAND (1)

The subbasin command simulates all processes involved in the land phase of the hydrologic cycle and computes runoff, sediment, and chemical loadings from each HRU within the subbasin. The subbasin command requires 2 lines. Variables required on the subbasin command lines are:

Variable name	Definition
COMMAND	The command code = 1 for the subbasin command. Required.
HYD_STOR	The hydrograph storage location number. After a command is executed, the results are stored in an array at the position defined by this number. It is crucial that all hydrograph storage location numbers are unique. If the same number is used twice, output from one command line will be overwritten by that from another and simulation results will be incorrect. Required.
SUB_NUM	Subbasin number. Every subbasin in the watershed has a different number. Required.
GIS_CODE	GIS code printed to output files. Optional.
SUBFILE	Name of subbasin general input data file (.sub). This file contains parameters for the subbasin which are reviewed in Chapter 5. Required.

The format of the subbasin command lines is:

Variable name	Line #	Position	Format	F90 Format
COMMAND	1	space 11-16	6-digit integer	i6
HYD_STOR	1	space 17-22	6-digit integer	i6
SUB_NUM	1	space 23-28	6-digit integer	i6
GIS_CODE	1	space 47-55	9-digit integer	i9
SUBFILE	2	space 11-23	character	a13

2.2.2.3 ROUTE COMMAND (2)

The route command routes the water, sediment, and chemical loadings through a main channel or reach. The route command requires two lines. Variables required on the route command lines are:

Variable name	Definition
COMMAND	The command code = 2 for the route command. Required.
HYD_STOR	The hydrograph storage location number. After a command is executed, the results are stored in an array at the position defined by this number. It is crucial that all hydrograph storage location numbers are unique. If the same number is used twice, output from one command line will be overwritten by that from another and simulation results will be incorrect. Required.
RCH_NUM	Reach number. The reach number is the same as the number of the subbasin in which the reach is located. Required.
HYD_NUM	Inflow hydrograph storage location number. The storage location containing the data to be routed through the reach. Required.
FLOW_OVN	Fraction of overland flow (0.000 to 1.000). If flow leaving a subbasin is completely channelized, FLOW_OVN = 0.000. In cases where a hillslope is being simulated, overland flow from one subbasin to another occurs and the value of FLOW_OVN can be increased to account for the amount of non-channelized overland flow taking place between the subbasins. The overland flow to the next subbasin is added to the rainfall of the receiving subbasin and allowed to infiltrate or run off. The sediment and chemical loadings associated with the overland flow are assumed to be deposited on the upper soil layer of the receiving subbasin. The fraction of the flow in the channel is routed directly to the reach of the receiving subbasin. Required.

Variable name	Definition
RTEFILE	Name of routing input data file (.rte). This file contains parameters for the main channel which are reviewed in Chapter 25. Required.
SWQFILE	Name of stream water quality data file (.swq). This file contains parameters for water quality simulation in the reach which are reviewed in Chapter 27. Required.

The format of the route command lines is:

Variable name	Line #	Position	Format	F90 Format
COMMAND	1	space 11-16	6-digit integer	i6
HYD_STOR	1	space 17-22	6-digit integer	i6
RCH_NUM	1	space 23-28	6-digit integer	i6
HYD_NUM	1	space 29-34	6-digit integer	i6
FLOW_OVN	1	space 41-46	decimal (xx.xxx)	f6.3
RTEFILE	2	space 11-23	character	a13
SWQFILE	2	space 24-36	character	a13

2.2.2.4 ROUTRES COMMAND (3)

The routres command routes water, sediment, and chemical loadings through a reservoir. The routres command requires two lines. Variables required on the routres command lines are:

Variable name	Definition
COMMAND	The command code = 3 for the routres command. Required.
HYD_STOR	The hydrograph storage location number for results. Required.
RES_NUM	Reservoir number. Each reservoir modeled in the watershed must be assigned a unique consecutive number beginning at 1. Required.
HYD_NUM	Inflow hydrograph storage location number. The storage location of the data to be routed through the reservoir. Required.
RESFILE	Name of reservoir input file (.res). This file contains parameters for the reservoir which are reviewed in Chapter 29. Required.
LWQFILE	Name of reservoir water quality input file (.lwq). This file contains parameters to model water quality in the reservoir which are reviewed in Chapter 30. Optional.

The format of the routres command lines is:

Variable name	Line #	Position	Format	F90 Format
COMMAND	1	space 11-16	6-digit integer	i6
HYD_STOR	1	space 17-22	6-digit integer	i6
RES_NUM	1	space 23-28	6-digit integer	i6
HYD_NUM	1	space 29-34	6-digit integer	i6
RESFILE	2	space 11-23	character	a13
LWQFILE	2	space 24-36	character	a13

2.2.2.5 TRANSFER COMMAND (4)

While water is most typically removed from a water body for irrigation purposes, SWAT also allows water to be transferred from one water body to another. This is performed with a transfer command in the watershed configuration file.

The transfer command can be used to move water from any reservoir or reach in the watershed to any other reservoir or reach in the watershed. The user must input the type of water source, the location of the source, the type of water body receiving the transfer, the location of the receiving water body, and the amount of water transferred.

Three options are provided to specify the amount of water transferred: a fraction of the volume of water in the source; a volume of water left in the source; or the volume of water transferred. The transfer is performed every day of the simulation.

Originally, the transfer command was the only method available to irrigate an HRU. While the irrigation scenarios are now handled primarily in the management files, the transfer command was retained for flexibility. This command should not be used with hourly stream routing. Variables required on the transfer command line are:

Variable name	Definition
COMMAND	The command code = 4 for the transfer command. Required.
DEP_TYPE	Water source type: 1 reach 2 reservoir Required.
DEP_NUM	Water source number. The number of the reach or reservoir from which the flow will be diverted. Required.

Variable name	Definition
DEST_TYPE	Destination type. Defines the receiving body. 1 reach 2 reservoir Required.
DEST_NUM	Destination number. Number of reach or reservoir receiving the water. Required.
TRANS_AMT	The flow amount transferred. (defined by TRANS_CODE). Required.
TRANS_CODE	The rule code governing the transfer of water: 1 A fraction of the flow or volume to be transferred out of the reach or reservoir is specified 2 A minimum flow (reach) or volume (reservoir) to leave in the reach or reservoir is specified (m^3/day) 3 An exact amount of water to be transferred is specified (m^3/day) Required.

The format of the transfer command line is:

Variable name	Position	Format	F90 Format
COMMAND	space 11-16	6-digit integer	i6
DEP_TYPE	space 17-22	6-digit integer	i6
DEP_NUM	space 23-28	6-digit integer	i6
DEST_TYPE	space 29-34	6-digit integer	i6
DEST_NUM	space 35-40	6-digit integer	i6
TRANS_AMT	space 41-46	decimal (xx.xxx)	f6.3
TRANS_CODE	space 47-55	9-digit integer	i9

2.2.2.6 ADD COMMAND (5)

The add command is used to sum the water, sediment, and chemical loadings of any two hydrographs. Variables required on the add command line are:

Variable name	Definition
COMMAND	The command code = 5 for the add command. Required.
HYD_STOR	The hydrograph storage location number to hold the results. Required.
HYD_NUM1	The hydrograph storage location number of the 1st set of data to be added. Required.
HYD_NUM2	The hydrograph storage location number of the 2nd set of data to be added. Required.

The format of the add command line is:

Variable name	Position	Format	F90 Format
COMMAND	space 11-16	6-digit integer	i6
HYD_STOR	space 17-22	6-digit integer	i6
HYD_NUM1	space 23-28	6-digit integer	i6
HYD_NUM2	space 29-34	6-digit integer	i6

2.2.2.7 RECHOUR COMMAND (6)

The rechour command is one of five routing commands that reads in flow, sediment and chemical loading records from a file for routing through the watershed. This command is useful for reading in point source data or data from simulations of upstream areas. The rechour command is used to read in data summarized on an hourly basis. The rechour command requires two lines. Variables required on the rechour command lines are:

Variable name	Definition
COMMAND	The command code = 6 for the rechour command. Required.
HYD_STOR	The hydrograph storage location number for the records. Required.
FILEHR_NUM	The file number. Unique file numbers should be used for each rechour command. Required.
DRAINAGE_AREA	Drainage area associated with records (km^2). Optional.
FILE_HR	Name of file containing hourly records. Parameters included in the file are reviewed in Chapter 31. Required.

The format of the rechour command lines is:

Variable name	Line #	Position	Format	F90 Format
COMMAND	1	space 11-16	6-digit integer	i6
HYD_STOR	1	space 17-22	6-digit integer	i6
FILEHR_NUM	1	space 23-28	6-digit integer	i6
DRAINAGE_AREA	1	space 41-46	decimal (xx.xxx)	f6.3
FILE_HR	2	space 11-23	character	a13

2.2.2.8 RECMON COMMAND (7)

The recmon command is one of five routing commands that reads in flow, sediment and chemical loading records from a file for routing through the watershed. The recmon command is used to read in data summarized by month. The recmon command requires two lines. Variables required on the recmon command lines are:

Variable name	Definition
COMMAND	The command code = 7 for the recmon command. Required.
HYD_STOR	The hydrograph storage location number for the records. Required.
FILEMON_NUM	The file number. Unique file numbers should be used for each recmon command. Required.
DRAINAGE_AREA	Drainage area associated with records (km^2). Optional.
FILE_MON	Name of the file containing the monthly records. Parameters included in the file are reviewed in Chapter 31. Required.

The format of the recmon command lines is:

Variable name	Line #	Position	Format	F90 Format
COMMAND	1	space 11-16	6-digit integer	i6
HYD_STOR	1	space 17-22	6-digit integer	i6
FILEMON_NUM	1	space 23-28	6-digit integer	i6
DRAINAGE_AREA	1	space 41-46	decimal (xx.xxx)	f6.3
FILE_MON	2	space 11-23	character	a13

2.2.2.9 RECYEAR COMMAND (8)

The recyear command is one of five routing commands that reads in flow, sediment and chemical loading records from a file for routing through the watershed. The recyear command is used to read in annual output. The recyear command requires two lines. Variables required on the recyear command lines are:

Variable name	Definition
COMMAND	The command code = 8 for the recyear command. Required.
HYD_STOR	The hydrograph storage location number for the records. Required.
FILEYR_NUM	The file number. Unique file numbers should be used for each recyear command. Required.
DRAINAGE_AREA	Drainage area associated with records (km^2). Optional.
FILE_YR	Name of file containing annual records. Parameters included in the file are reviewed in Chapter 31. Required.

The format of the recyear command lines is:

Variable name	Line #	Position	Format	F90 Format
COMMAND	1	space 11-16	6-digit integer	i6
HYD_STOR	1	space 17-22	6-digit integer	i6
FILEYR_NUM	1	space 23-28	6-digit integer	i6
DRAINAGE_AREA	1	space 41-46	decimal(xx.xxx)	f6.3
FILE_YR	2	space 11-23	character	a13

2.2.2.10 SAVE COMMAND (9)

The save command allows the user to print daily SWAT output to the output file specified. This output file can then be read into another SWAT run using the recday command. Up to 10 save commands are allowed in a given watershed configuration file. Variables required on the save command line are:

Variable name	Definition
COMMAND	The command code = 9 for save command. Required.
HYD_NUM	The hydrograph storage location number of the data to be printed to file. Required.
FILESAVE_NUM	The file number. Unique file numbers should be used for each save command. Required.
PRINT_FREQ	Printing frequency. For simulations using a sub-daily time step, water quality information may be summarized and printed for every hour or every day. Simulations using a daily time step will always print daily average values. 0 report daily averages 1 report hourly averages The default printing frequency is to print daily averages. Required.
PRINT_FMT	Printing format. This variable allows users to output data in two different formats. 0 SWAT code format 1 SWAT/ArcView Interface format If the SWAT/ArcView Interface is being used to set up datasets, this variable will format the output from the save command to be imported by the interface. Required.
FILE_MASS	Name of file to which the water quality information is written. Required.

The format of the save command line is:

Variable name	Line #	Position	Format	F90 Format
COMMAND	1	space 11-16	6-digit integer	i6
HYD_NUM	1	space 17-22	6-digit integer	i6
FILESAVE_NUM	1	space 23-28	6-digit integer	i6
PRINT_FREQ	1	space 29-34	6-digit integer	i6
PRINT_FMT	1	space 35-40	6-digit integer	i6
FILE_MASS	2	space 11-23	character	a13

2.2.2.11 RECDAY COMMAND (10)

The recday command is one of five routing commands that reads in flow, sediment and chemical loading records from a file for routing through the watershed. This command is useful for reading in point source data or data from simulations of upstream areas. The recday command is used to read in data summarized on a daily basis. The recday command requires two lines. Variables required on the recday command lines are:

Variable name	Definition
COMMAND	The command code = 10 for the recday command. Required.
HYD_STOR	The hydrograph storage location number for the records. Required.
FILEDAY_NUM	The file number. Unique file numbers should be used for each recday command. Required.
DRAINAGE_AREA	Drainage area associated with records (km^2). Optional.
FILE_DAY	Name of file containing daily records. Parameters in this file are reviewed in Chapter 31. Required.

The format of the recday command lines is:

Variable name	Line #	Position	Format	F90 Format
COMMAND	1	space 11-16	6-digit integer	i6
HYD_STOR	1	space 17-22	6-digit integer	i6
FILEDAY_NUM	1	space 23-28	6-digit integer	i6
DRAINAGE_AREA	1	space 41-46	decimal (xx.xxx)	f6.3
FILE_DAY	2	space 11-23	character	a13

2.2.2.12 RECCNST COMMAND (11)

The reccnst command is one of five routing commands that reads in flow, sediment and chemical loading records from a file for routing through the watershed. This command is useful for reading in point source data. The reccnst command is used to read in average annual data. The reccnst command requires two lines. Variables required on the reccnst command lines are:

Variable name	Definition
COMMAND	The command code = 11 for the reccnst command. Required.
HYD_STOR	The hydrograph storage location number for the records. Required.
FILECNST_NUM	The file number. Unique file numbers should be used for each reccnst command. Required.
DRAINAGE_AREA	Drainage area associated with records (km^2). Optional.
FILE_CNST	Name of file containing average annual records. Parameters in this file are reviewed in Chapter 31. Required.

The format of the reccnst command lines is:

Variable name	Line #	Position	Format	F90 Format
COMMAND	1	space 11-16	6-digit integer	i6
HYD_STOR	1	space 17-22	6-digit integer	i6
FILECNST_NUM	1	space 23-28	6-digit integer	i6
DRAINAGE_AREA	1	space 41-46	decimal(xx.xxx)	f6.3
FILE_CNST	2	space 11-23	character	a13

2.2.2.13 STRUCTURE COMMAND (12)

The structure command simulates aeration caused by the tumbling of water as it moves over weirs or other structures along the stream network. In highly polluted streams, the aeration of the stream by this method is a significant source of oxygen. The structure command alters the dissolved oxygen content based on the aeration coefficient input by the user. Variables required on the structure command line are:

Variable name	Definition
COMMAND	The command code = 12 for the structure command. Required.
HYD_STOR	The hydrograph storage location number for results. Required.
HYD_NUM	Inflow hydrograph storage location number. The data that is to be adjusted to reflect aeration. (Dissolved oxygen content is the only value that is altered with this command.) Required.
AERATION_COEF	Aeration coefficient. Butts and Evans (1983) documents the following relationship that can be used to estimate the reaeration coefficient: $rea = 1 + 0.38 \cdot coef_a \cdot coef_b \cdot h_{fall} \cdot (1 - 0.11 \cdot h_{fall}) \cdot (1 + 0.046 \cdot \overline{T}_{water})$ where rea is the reaeration coefficient, $coef_a$ is an empirical water quality factor, $coef_b$ is an empirical dam aeration coefficient, h_{fall} is the height through which water falls (m), and $\overline{T}_{water}$ is the average water temperature (°C).

Variable name	Definition
AERATION_COEF, cont.	The empirical water quality factor is assigned a value based on the condition of the stream: $coef_a$ = 1.80 in clean water $coef_a$ = 1.60 in slightly polluted water $coef_a$ = 1.00 in moderately polluted water $coef_a$ = 1.00 in moderately polluted water $coef_a$ = 0.65 in grossly polluted water The empirical dam aeration coefficient is assigned a value based on the type of structure: $coef_b$ = 0.70 to 0.90 for flat broad crested weir $coef_b$ = 1.05 for sharp crested weir with straight slope face $coef_b$ = 0.80 for sharp crested weir with vertical face $coef_b$ = 0.05 for sluice gates with submerged discharge Required.

The format of the structure command is:

Variable name	Position	Format	F90 Format
COMMAND	space 11-16	6-digit integer	i6
HYD_STOR	space 17-22	6-digit integer	i6
HYD_NUM	space 23-28	6-digit integer	i6
AERATION_COEF	space 41-46	decimal (xx.xxx)	f6.3

2.2.2.14 APEX COMMAND (13)

The apex command allows the model to read from a daily APEX output file.

The apex command requires two lines. Variables required on the apex command lines are:

Variable name	Definition
COMMAND	The command code = 13 for the apex command. Required.
HYD_STOR	The hydrograph storage location number of the data get from the subbasin command. Required.
FILECONC_NUM	The file number. Unique file numbers should be used for each APEX command. Required.
APEX_IN	Name of APEX output file to be read into SWAT. Required.

The format of the apex command lines is:

Variable name	Line #	Position	Format	F90 Format
COMMAND	1	space 11-16	6-digit integer	i6
HYD_STOR	1	space 17-22	6-digit integer	i6
FILECONC_NUM	1	space 23-28	6-digit integer	i6
APEX_IN	2	space 11-23	character	a13

2.2.2.15 SAVECONC COMMAND (14)

The saveconc command saves flow, sediment and water quality indicator information from a specified point on the reach network to a file. The water quality information is reported as concentrations. This command is useful for isolating reach information at a particular point on the channel network. Up to 50 saveconc commands can be specified in the watershed configuration file.

The saveconc command requires two lines. Variables required on the saveconc command lines are:

Variable name	Definition
COMMAND	The command code = 14 for the saveconc command. Required.
HYD_NUM	The hydrograph storage location number of the data to be printed to file. Required.
FILECONC_NUM	The file number. Unique file numbers should be used for each saveconc command. Required.
PRINT_FREQ	Printing frequency. For simulations using a sub-daily time step, water quality information may be summarized and printed for every hour or every day. Simulations using a daily time step will always print daily average values. 0 report daily averages 1 report hourly averages If no printing frequency is specified, the model will print daily averages. Required.
FILE_CONC	Name of file to which the water quality information is written. Required.

The format of the saveconc command lines is:

Variable name	Line #	Position	Format	F90 Format
COMMAND	1	space 11-16	6-digit integer	i6
HYD_NUM	1	space 17-22	6-digit integer	i6
FILECONC_NUM	1	space 23-28	6-digit integer	i6
PRINT_FREQ	1	space 29-34	6-digit integer	i6
FILE_CONC	2	space 11-23	character	a13

2.2.2.16 AUTOCAL COMMAND (16)

The autocal command identifies the location on the stream network that will be targeted in the automated method (calibration/sensitivity analysis). Measured data used to calibrate the simulation must be provided in the file specified in this command. Up to 10 autocal commands can be specified in a watershed configuration file.

The autocal command requires two lines. Variables required on the autocal command lines are:

Variable name	Definition
COMMAND	The command code = 16 for the autocal command. Required.
HYD_NUM	The hydrograph storage location number of the simulated data to be used in the calibration process. Required.
FILECAL_NUM	The file number. Unique file numbers should be used for each autocal command. Required.
PRINT_FREQ	Printing frequency. For simulations using a sub-daily time step, measured data to be used in the calibration process may be summarized on an hourly or daily basis. Simulations using a daily time step will always require daily measured data. 0 measured data summarized on a daily basis 1 measured data summarized on an hourly basis Required.
FILE_ACAL	Name of file containing the measured data to be used to calibrate the dataset at the specified point. Required.

The format of the autocal command lines is:

Variable name	Line #	Position	Format	F90 Format
COMMAND	1	space 11-16	6-digit integer	i6
HYD_NUM	1	space 17-22	6-digit integer	i6
FILECAL_NUM	1	space 23-28	6-digit integer	i6
PRINT_FREQ	1	space 29-34	6-digit integer	i6
FILE_ACAL	2	space 11-23	character	a13

2.3 REFERENCES

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CHAPTER 3

SWAT INPUT DATA: FILE.CIO

File management is performed with the master watershed file (file.cio). The master watershed file contains information related to modeling options, climate inputs, databases, and output specifications.

The master watershed file can be divided into several sections. A brief description of the variables in the master watershed file follows. They are grouped by section and listed in the order they appear within the file.

3.1 TITLE SECTION

Variable name	Definition
TITLE	Three lines of 'file.cio' are reserved for a description of the simulation run. The description may take up to 80 spaces per line. The title given in file.cio is printed to every output file. Optional.

3.2 GENERAL INFORMATION/ WATERSHED CONFIGURATION

Variable name	Definition
FIGFILE	Name of watershed configuration file (**.fig**). Contains the commands to add and route loadings through the watershed. This file is reviewed in Chapter 2. Required.
NBYR	Number of calendar years simulated. The number of years simulated in a SWAT run is unlimited. If a simulation is begun on August 1st of the year 1995 and ends July 30th of the year 1997, the model will be simulating 3 calendar years (1995, 1996 and 1997). If a forecast period is simulated, NBYR should include the forecast period as well as the period of normal simulation. Required.
IYR	Beginning year of simulation (for example, 1980). The value entered for this variable is not important unless measured data (e.g. weather) is used in the run. When measured data is used, the model uses IYR to locate the beginning year within the data file. Required.
IDAF	Beginning Julian day of simulation. With this variable, SWAT is able to begin a simulation at any time of the year. If the variable is left blank or set to zero, the model starts the simulation on January 1st. Required.

Variable name	Definition
IDAL	Ending Julian day of simulation. With this variable, SWAT will end the simulation on the date specified. If the variable is left blank or set to zero, the model ends the simulation on December 31st. If a forecast period is simulated, IDAL should be set to the last day of the forecast period. Required.

3.3 CLIMATE

Variable name	Definition
IGEN	Random generator seed code. A set of random numbers is needed by SWAT to generate weather data. SWAT has a set of default random numbers embedded in the code. To use the default random numbers, the user should set IGN = 0. This is the default value for IGN. In some situations, a user may wish to vary the weather sequence between runs. One method to do this is to set IGN to a different number every time the model is run. This code will activate a random number generator, which will replace the default set of random numbers with a new set. The value to which IGN is set determines the number of times the random number generator is cycled before the simulation begins. The seeds produced by the random number generator are then utilized by the weather generator instead of the default values. Measured weather data read into the model is not affected by this variable. However, if the measured data contains missing values, the weather generator is activated to produce data to replace the missing values. The data produced to replace missing values will be affected by this variable. Required.

Variable name	Definition
PCPSIM	Rainfall input code. This variable identifies the method the model will use to process rainfall data. There are two options: 1 measured data read for each subbasin 2 rainfall generated for each subbasin If observed rainfall data is available for a watershed, the user should read in the measured data. Required.
IDT	Time step used to report measured rainfall data (minutes). Required if IEVENT = 2 or 3 (see Chapter 4 for a description of IEVENT). One of the following should be chosen: 1 min, 2 min, 3 min, 4 min, 5 min, 6 min, 10 min, 12 min, 15 min, 20 min, 30 min.
IDIST	Rainfall distribution code used to generate daily precipitation values. There are two options: 0 skewed distribution 1 mixed exponential distribution Required.
REXP	Value of exponent for mixed exponential rainfall distribution. A value for REXP is needed only if IDIST = 1. The model will set REXP = 1.3 if no value is entered.
NRGAGE	Number of precipitation gage (.pcp) files used in the simulation. Up to 18 files may be used. Required if measured precipitation data are used.
NRTOT	Total number of precipitation gage records used in the simulation. If each .pcp file contains only one precipitation gage record, NRTOT = NRGAGE. Otherwise, NRTOT > NRGAGE. A maximum of 5400 precipitation gage records may be used in a simulation. Required if measured precipitation data are used.

Variable name	Definition
NRGFIL	Number of precipitation gage records within each .pcp file. A maximum of 300 precipitation gage records may be placed in each .pcp file. Required if measured precipitation data are used.
TMPSIM	Temperature input code. This variable identifies the method the model will use to process temperature data. There are two options: 1 measured date read for each subbasin 2 daily max/min generated for each subbasin If observed temperature data is available for the watershed, the user should read in the measured data. Required.
NTGAGE	Number of temperature gage (.tmp) files used in the simulation. Up to 18 files may be used. Required if measured temperature data are used.
NTTOT	Total number of temperature gage records used in the simulation. If each .tmp file contains only one temperature gage record, NTTOT = NTGAGE. Otherwise, NTTOT > NTGAGE. A maximum of 2700 temperature gage records may be used in a simulation. Required if measured temperature data are used.
NTGFIL	Number of temperature gage records within each .tmp file. A maximum of 150 temperature gage records may be placed in each .tmp file. Required if measured temperature data are used.

Variable name	Definition
SLRSIM	Solar radiation input code. This variable identifies the method the model will use to process solar radiation data. There are two options: 1 measured data read for each subbasin 2 solar radiation generated for each subbasin Option 1 allows users to use recorded data or import values generated with an independent weather generator. The default or recommended option is #2—allow SWAT to generate solar radiation values. Required.
NSTOT	Number of solar radiation records within the .slr file. A maximum of 300 solar radiation records may be placed in the .slr file. Required if measured solar radiation data are used.
RHSIM	Relative humidity input code. This variable identifies the method the model will use to process relative humidity data. There are two options: 1 measured data read for each subbasin 2 relative humidity generated for each subbasin Option 1 allows users to use recorded data or import values generated with an independent weather generator. The default or recommended option is #2—allow SWAT to generate relative humidity values. Required.
NHTOT	Number of relative humidity records within the .hmd file. A maximum of 300 relative humidity records may be placed in the .hmd file. Required if measured relative humidity data are used.

Variable name	Definition
WNDSIM	Wind speed input code. This variable identifies the method the model will use to process wind speed data. There are two options: 1 measured data read for each subbasin 2 wind speed generated for each subbasin Option 1 allows users to use recorded data or import values generated with an independent weather generator. The default or recommended option is #2—allow SWAT to generate wind speed values. Required.
NWTOT	Number of wind speed records within the .wnd file. A maximum of 300 wind speed records may be placed in the .wnd file. Required if measured wind speed data are used.
FCSTYR	Year that forecast period begins. Required only if forecast data is being used for a portion of the simulation
FCSTDAY	Day that forecast period begins. Julian date. Required only if forecast data is being used for a portion of the simulation.
FCSTCYCLES	Number of times that the forecast period is simulated Required only if forecast data is being used for a portion of the simulation. The forecast period should be simulated a minimum of 20 times to obtain a representative distribution of possible weather scenarios given the predicted probabilities.
RFILE(1)	Name of measured precipitation input file #1 (**.pcp**). This file is reviewed in Chapter 6. Required only if measured precipitation data are used.
RFILE(2)	Name of measured precipitation input file #2 (**.pcp**). Optional.
RFILE(3)	Name of measured precipitation input file #3 (**.pcp**). Optional.

Variable name	Definition
RFILE(4)	Name of measured precipitation input file #4 (**.pcp**). Optional.
RFILE(5)	Name of measured precipitation input file #5 (**.pcp**). Optional.
RFILE(6)	Name of measured precipitation input file #6 (**.pcp**). Optional.
RFILE(7)	Name of measured precipitation input file #7 (**.pcp**). Optional.
RFILE(8)	Name of measured precipitation input file #8 (**.pcp**). Optional.
RFILE(9)	Name of measured precipitation input file #9 (**.pcp**). Optional.
RFILE(10)	Name of measured precipitation input file #10 (**.pcp**). Optional.
RFILE(11)	Name of measured precipitation input file #11 (**.pcp**). Optional.
RFILE(12)	Name of measured precipitation input file #12 (**.pcp**). Optional.
RFILE(13)	Name of measured precipitation input file #13 (**.pcp**). Optional.
RFILE(14)	Name of measured precipitation input file #14 (**.pcp**). Optional.
RFILE(15)	Name of measured precipitation input file #15 (**.pcp**). Optional.
RFILE(16)	Name of measured precipitation input file #16 (**.pcp**). Optional.
RFILE(17)	Name of measured precipitation input file #17 (**.pcp**). Optional.
RFILE(18)	Name of measured precipitation input file #18 (**.pcp**) Optional.

Variable name	Definition
TFILE(1)	Name of measured temperature input file #1 (**.tmp**). This file is reviewed in Chapter 7. Required if measured temperature data are used.
TFILE(2)	Name of measured temperature input file #2 (**.tmp**). Optional.
TFILE(3)	Name of measured temperature input file #3 (**.tmp**). Optional.
TFILE(4)	Name of measured temperature input file #4 (**.tmp**). Optional.
TFILE(5)	Name of measured temperature input file #5 (**.tmp**). Optional.
TFILE(6)	Name of measured temperature input file #6 (**.tmp**). Optional.
TFILE(7)	Name of measured temperature input file #7 (**.tmp**). Optional.
TFILE(8)	Name of measured temperature input file #8 (**.tmp**). Optional.
TFILE(9)	Name of measured temperature input file #9 (**.tmp**). Optional.
TFILE(10)	Name of measured temperature input file #10 (**.tmp**). Optional.
TFILE(11)	Name of measured temperature input file #11 (**.tmp**). Optional.
TFILE(12)	Name of measured temperature input file #12 (**.tmp**). Optional.
TFILE(13)	Name of measured temperature input file #13 (**.tmp**). Optional.
TFILE(14)	Name of measured temperature input file #14 (**.tmp**). Optional.
TFILE(15)	Name of measured temperature input file #15 (**.tmp**). Optional.

Variable name	Definition
TFILE(16)	Name of measured temperature input file #16 (**.tmp**). Optional.
TFILE(17)	Name of measured temperature input file #17 (**.tmp**). Optional.
TFILE(18)	Name of measured temperature input file #18 (**.tmp**). Optional.
SLRFILE	Name of measured solar radiation input file (**.slr**). This file is reviewed in Chapter 8. Required if measured solar radiation data are used.
RHFILE	Name of measured relative humidity input file (**.hmd**). This file is reviewed in Chapter 10. Required if measured relative humidity data are used.
WNDFILE	Name of measured wind speed input file (**.wnd**). This file is reviewed in Chapter 9. Required if measured wind speed data are used.
FCSTFILE	Name of weather forecast input file (**.cst**). This file is reviewed in Chapter 13. Required if a forecast period is simulated.

3.4 WATERSHED MODELING OPTIONS

Variable name	Definition
BSNFILE	Name of basin input file (**.bsn**). Contains inputs for physical processes modeled or defined at the watershed level. This file is reviewed in Chapter 4. Required.

3.5 DATABASE FILES

Variable name	Definition
PLANTDB	Name of land cover/plant growth database file (**crop.dat**). This file contains growth parameters for the different land covers. This file is reviewed in Chapter 14. Required.
TILLDB	Name of tillage database file (**till.dat**). This file contains mixing efficiencies for different tillage implements. This file is reviewed in Chapter 15. Required.
PESTDB	Name of pesticide database file (**pest.dat**). This file contains parameters governing movement and degradation of pesticides. This file is reviewed in Chapter 16. Required.
FERTDB	Name of fertilizer/manure database file (**fert.dat**). This file contains nutrient content data for fertilizers. This file is reviewed in Chapter 17. Required.
URBANDB	Name of urban land type database file (**urban.dat**). This file contains data required to model build-up/wash-off in urban areas. This file is reviewed in Chapter 18. Required.

3.6 SPECIAL PROJECTS

Variable name	Definition
ISPROJ	Special project flag. SWAT includes sections of code specific to particular projects. This variable flags the code used in the particular simulation. There are two options: 0 not a special project 1 Repeat simulation (test variable initialization) A user will set this variable to something other than zero only if the SWAT programmers have told him to do so. Required.
ICLB	Automated method flag. This variable defines the automated method used in a SWAT simulation. 0 no automated method performed 1 sensitivity analysis 2 uncertainty analysis/ autocalibration 3 sensitivity and uncertainty analysis/ autocalibration This variable should be set to a value other than 0 only after an initial manual calibration has been performed. Optional.
CALFILE	Name of file containing auto-calibration parameters. Required only if ICLB is set to a value other than 0. This file is reviewed in the SWAT User's Manual.

3.7 OUTPUT INFORMATION

Variable name	Definition
IPRINT	Print code. This variable governs the frequency that model results are printed to output files. There are three options: 0 Monthly 1 Daily 2 Annually If you choose to print results on a daily basis, the number of years simulated should be limited and/or the variables printed to the output file should be restricted. If these precautions are not taken, the output files will be too large to view. Required.
NYSKIP	Number of years to ***not*** print output. The options are 0 print output for all years of the simulation 1 print output after the first year of simulation 2 print output after the second year of simulation ⇣ nbyr no output will be printed Some simulations will need a warm-up or equilibration period. The use of an equilibration period becomes more important as the simulation period of interest shortens. For 30-year simulations, an equilibrium period is optional. For a simulation covering 5 years or less, an equilibrium period is recommended. An equilibration period of one year is usually adequate to get the hydrologic cycle fully operational.

Variable name	Definition
NYSKIP, cont.	NYSKIP allows the user to exclude data generated during the equilibration period from output summaries. In addition to not writing data to the output files, annual averages are not computed for the skipped years. Averages for the entire simulation period will also exclude data from the skipped years. The default value for NYSKIP is 0. Required.
ILOG	Streamflow print code. This variable allows the user to take the $\log_{10}$ of the flow prior to printing streamflow values to the .rch file. There are two options: 0 print streamflow in .rch file 1 print log of streamflow in .rch file In large basins (for example, the Mississippi River basin), streamflow values printed to the .rch file may exceed the range allowed by the file format statements. This variable will eliminate print errors caused by very large values. This variable should be set to 0 unless the output files have *** symbols instead of numbers (this happens if the numbers are too big to fit in the allotted spaces). Required.
IPRP	Print code for output.pst file. There are two options: 0 do not print pesticide output (output.pst will be empty) 1 print pesticide output Required.
IPRS	Print code for soil chemical output files. There are two options: 0 do not print final soil chemical information (output.chm will be empty) 1 print final soil chemical information for every HRU in .chm format *Not operational—future feature.*

For long runs, the output files can get so large that the user may have difficulty in opening the files to look at output. The user has the option of customizing the output printed to the output files. Lines of file.cio are used to specify the variables to be printed to the reach output file (output.rch), the subbasin output file (output.sub), and the HRU output file (output.hru). If these lines contain only zeros, the model will print all the output variables to the file.

Variable name	Definition
IPDVAR(:)	Output variables printed to the *output.rch* file. (up to 20 variables may be chosen in customized output.) Optional. The codes for the output variables are: 1 FLOW_IN: Average daily streamflow into reach (m^3/s) 2 FLOW_OUT: Average daily streamflow out of reach (m^3/s) 3 EVAP: Average daily loss of water from reach by evaporation (m^3/s) 4 TLOSS: Average daily loss of water from reach by transmission (m^3/s) 5 SED_IN: Sediment transported with water into reach (metric tons) 6 SED_OUT: Sediment transported with water out of reach (metric tons) 7 SEDCONC: Concentration of sediment in reach (mg/L) 8 ORGN_IN: Organic nitrogen transported with water into reach (kg N) 9 ORGN_OUT: Organic nitrogen transported with water out of reach (kg N) 10 ORGP_IN: Organic phosphorus transported with water into reach (kg P) 11 ORGP_OUT: Organic phosphorus transported with water out of reach (kg P) 12 NO3_IN: Nitrate transported with water into reach (kg N) 13 NO3_OUT: Nitrate transported with water out of reach (kg N) 14 NH4_IN: Ammonium transported with water into reach (kg N) 15 NH4_OUT: Ammonium transported with water out of reach (kg N) 16 NO2_IN: Nitrite transported with water into reach (kg N) 17 NO2_OUT: Nitrite transported with water out of reach (kg N) 18 MINP_IN: Mineral phosphorus transported with water into reach (kg P) 19 MINP_OUT: Mineral phosphorus transported with water out of reach (kg P) 20 CHLA_IN: Chlorophyll-a transported with water into reach (kg) 21 CHLA_OUT: Chlorophyll-a transported with water out of reach (kg) 22 CBOD_IN: Carbonaceous biochemical oxygen demand transported into reach (kg O_2) 23 CBOD_OUT: Carbonaceous biochemical oxygen demand transported out of reach (kg O_2) 24 DISOX_IN: Dissolved oxygen transported into reach (kg O_2) 25 DISOX_OUT: Dissolved oxygen transported out of reach (kg O_2) 26 SOLPST_IN: Soluble pesticide transported with water into reach (mg a.i.) 27 SOLPST_OUT: Soluble pesticide transported with water out of reach (mg a.i.) 28 SORPST_IN: Pesticide sorbed to sediment transported with water into reach (mg a.i.) 29 SORPST_OUT: Pesticide sorbed to sediment transported with water out of reach (mg a.i.) 30 REACTPST: Loss of pesticide from water by reaction (mg a.i.)

Variable name	Definition
	continued from previous page: 31 VOLPST: Loss of pesticide from water by volatilization (mg a.i.) 32 SETTLPST: Transfer of pesticide from water to river bed sediment by settling (mg a.i.) 33 RESUSP_PST: Transfer of pesticide from river bed sediment to water by resuspension (mg a.i.) 34 DIFFUSEPST: Transfer of pesticide from water to river bed sediment by diffusion (mg a.i.) 35 REACBEDPST: Loss of pesticide from river bed sediment by reaction (mg a.i.) 36 BURYPST: Loss of pesticide from river bed sediment by burial (mg a.i.) 37 BED_PST: Pesticide in river bed sediment (mg a.i.) 38 BACTP_OUT: Number of persistent bacteria transported out of reach (# cfu/ 100 mL) 39 BACTLP_OUT: Number of less persistent bacteria transported out of reach (# cfu/ 100 mL) 40 CMETAL#1: Conservative metal #1 transported out of reach (kg) 41 CMETAL#2: Conservative metal #2 transported out of reach (kg) 42 CMETAL#3: Conservative metal #3 transported out of reach (kg)
IPDVAB(:)	Output variables printed to the *output.sub* file (up to 15 variables may be chosen in customized output.) Optional. The codes for the output variables are: 1 PRECIP: Average total precipitation on subbasin (mm H_2O) 2 SNOMELT: Snow melt (mm H_2O) 3 PET: Potential evapotranspiration (mm H_2O) 4 ET: Actual evapotranspiration (mm H_2O) 5 SW: Soil water content (mm H_2O) 6 PERC: Amount of water percolating out of root zone (mm H_2O) 7 SURQ: Surface runoff (mm H_2O) 8 GW_Q: Groundwater discharge into reach (mm H_2O) 9 WYLD: Net water yield to reach (mm H_2O) 10 SYLD: Sediment yield (metric tons/ha) 11 ORGN: Organic N released into reach (kg/ha) 12 ORGP: Organic P released into reach (kg/ha) 13 NSURQ: Nitrate released into reach (kg/ha) 14 SOLP: Soluble P released into reach (kg/ha) 15 SEDP: Mineral P attached to sediment released into reach (kg/ha)
IPDVAS(:)	Output variables printed to the *output.hru* file (up to 20 variables may be chosen in customized output.) Optional. The codes for the output variables are: 1 PRECIP: Total precipitation on HRU (mm H_2O) 2 SNOFALL: Precipitation falling as snow, sleet, or freezing rain (mm H_2O)

Variable name	Definition
	continued from previous page: 3 SNOMELT: Amount of snow or ice melting (mm H_2O) 4 IRR: Amount of irrigation water applied to HRU (mm H_2O) 5 PET: Potential evapotranspiration (mm H_2O) 6 ET: Amount of water removed by evapotranspiration (mm H_2O) 7 SW_INIT: Soil water content at beginning of time period (mm H_2O) 8 SW_END: Soil water content at end of time period (mm H_2O) 9 PERC: Amount of water percolating out of the root zone (mm H_2O) 10 GW_RCHG: Amount of water entering both aquifers (mm H_2O) 11 DA_RCHG: Amount of water entering deep aquifer from root zone (mm H_2O) 12 REVAP: Water in shallow aquifer returning to root zone (mm H_2O) 13 SA_IRR: Amount of water removed from shallow aquifer for irrigation (mm H_2O) 14 DA_IRR: Amount of water removed from deep aquifer for irrigation (mm H_2O) 15 SA_ST: Amount of water in shallow aquifer storage at end of time period (mm H_2O) 16 DA_ST: Amount of water in deep aquifer storage at end of time period (mm H_2O) 17 SURQ_GEN: Surface runoff generated during time step (mm H_2O) 18 SURQ_CNT: Surface runoff contribution to reach (mm H_2O) 19 TLOSS: Amount of water removed from tributary channels by transmission (mm H_2O) 20 LATQ: Lateral flow contribution to reach (mm H_2O) 21 GW_Q: Groundwater discharge into reach (mm H_2O) 22 WYLD: Net amount of water contributed by the HRU to the reach (mm H_2O) 23 DAILYCN: Average curve number for time period. 24 TMP_AV: Average air temperature for time period (°C) 25 TMP_MX: Average of daily maximum air temperatures for time period (°C). 26 TMP_MN: Average of daily minimum air temperatures for time period (°C). 27 SOL_TMP: Average soil temperature in time period (°C). 28 SOLAR: Average daily solar radiation for time period (MJ/m^2). 29 SYLD: Amount of sediment contributed by the HRU to the reach (metric tons/ha) 30 USLE: USLE soil loss (metric tons/ha) 31 N_APP: Amount of N fertilizer applied in regular fertilizer operation (kg N/ha) 32 P_APP: Amount of P fertilizer applied in regular fertilizer operation (kg P/ha) 33 NAUTO: Amount of N fertilizer applied automatically (kg N/ha) 34 PAUTO: Amount of P fertilizer applied automatically (kg P/ha) 35 NGRZ: Nitrogen applied to HRU in grazing operation during time step (kg N/ha) 36 PGRZ: Phosphorus applied to HRU in grazing operation during time step (kg P/ha) 37 CFERTN: Nitrogen applied to HRU in continuous fertilizer operation during time step (kg N/ha)

Variable name	Definition
	continued from previous page: 38 CFERTP: Phosphorus applied to HRU in continuous fertilizer operation during time step (kg P/ha) 39 NRAIN: Nitrate added in rainfall (kg N/ha) 40 NFIX: Amount of N fixed by legumes (kg N/ha) 41 F-MN: Transformation of N from fresh organic to mineral pool (kg N/ha) 42 A-MN: Transformation of N from active organic to mineral pool (kg N/ha) 43 A-SN: Transformation of N from active organic to stable organic pool (kg N/ha) 44 F-MP: Transformation of P from fresh organic to mineral (solution) pool (kg P/ha) 45 AO-LP: Transformation of P from organic to labile pool (kg P/ha) 46 L-AP: Transformation of P from labile to active mineral pool (kg P/ha) 47 A-SP: Transformation of P from active mineral to stable mineral pool (kg P/ha) 48 DNIT: Amount of N removed from soil by denitrification (kg N/ha) 49 NUP: Nitrogen uptake by plants (kg N/ha) 50 PUP: Phosphorus uptake by plants (kg P/ha) 51 ORGN: Organic N contributed by HRU to reach (kg N/ha) 52 ORGP: Organic P contributed by HRU to reach (kg P/ha) 53 SEDP: Mineral P attached to sediment contributed by HRU to reach (kg P/ha) 54 NSURQ: NO_3 contributed by HRU in surface runoff to reach (kg N/ha) 55 NLATQ: NO_3 contributed by HRU in lateral flow to reach (kg N/ha) 56 NO3L: NO_3 leached below the soil profile (kg N/ha) 57 NO3GW: NO_3 contributed by HRU in groundwater flow to reach (kg N/ha) 58 SOLP: Soluble phosphorus contributed by HRU in surface runoff to reach (kg P/ha) 59 P_GW: Soluble phosphorus contributed by HRU in groundwater flow to reach (kg P/ha) 60 W_STRS: Number of water stress days. 61 TMP_STRS: Number of temperature stress days 62 N_STRS: Number of nitrogen stress days. 63 P_STRS: Number of phosphorus stress days. 64 BIOM: Total plant biomass (metric tons/ha) 65 LAI: Leaf area index 66 YLD: Harvested yield (metric tons/ha) 67 BACTP: Persistent bacteria in surface runoff (# cfu/m^2) 68 BACTLP: Number of less persistent bacteria in surface runoff (# cfu/m^2)
IPDHRU(:)	Numbers of HRUs whose data will be printed to the HRU output files (up to 20 HRUs may be specified in customized output.) If all IPDHRU values are set to zero, the model will print output data for all HRUs in the watershed.
ATMOFILE	Atmospheric deposition filename.

IPHR	Code for printing hourly output file (hourq.dat) 0 = no print 1 = print file
ISTO	Code for printing soil storage values by soil layer (soilst.out) 0 = no print 1 = print file
ISOL	Code for printing phosphorus/nitrogen in soil profile (output.sol) 0 = no print 1 = print file
I_SUBW	Code for routing headwaters. 0 = do not route 1 = route
SEPTDB	Septic database filename (septwq.dat). Optional.
IA_B	Code for binary output of files (.rch, .sub, .hru files only) 0 = do not print binary files 1 = print binary files
IHUMUS	Code for output file for humus 0 = do not print watqual.out file 1 = print watqual.out
ITEMP	Code for channel velocity and water depth output files (input code affects both files) 0 = do not print chanvel.out/watrdep.out 1 = print chanvel.out/watrdep.out
ISNOW	Code for printing snowband.out file: 0 = do not print snowband.out file 1 = print snowband.out file
IMGT	Code for printing output.mgt file 0 = do not print output.mgt 1 = print output.mgt

The format of file.cio is:

Variable name	Line #	Position	Format	F90 Format
Comment lines	1-2	space 1-80	character	a80
TITLE	3-5	space 1-80	character	a80
Comment line	6	space 1-80	character	a80
FIGFILE	7	space 1-13	character	a13
NBYR	8	none	integer	free
IYR	9	none	integer	free
IDAF	10	none	integer	free
IDAL	11	none	integer	free

Variable name	Line #	Position	Format	F90 Format
Comment line	12	space 1-80	character	a80
IGEN	13	none	integer	free
PCPSIM	14	none	integer	free
IDT	15	none	integer	free
IDIST	16	none	integer	free
REXP	17	none	real	free
NRGAGE	18	none	integer	free
NRTOT	19	none	integer	free
NRGFIL	20	none	integer	free
TMPSIM	21	none	integer	free
NTGAGE	22	none	integer	free
NTTOT	23	none	integer	free
NTGFIL	24	none	integer	free
SLRSIM	25	none	integer	free
NSTOT	26	none	integer	free
RHSIM	27	none	integer	free
NHTOT	28	none	integer	free
WNDSIM	29	none	integer	free
NWTOT	30	none	integer	free
FCSTYR	31	none	integer	free
FCSTDAY	32	none	integer	free
FCSTCYCLES	33	none	integer	free
Comment line	34	space 1-80	character	a80
RFILE(1)	35	space 1-13	character	a13
RFILE(2)	35	space 14-26	character	a13
RFILE(3)	35	space 27-39	character	a13
RFILE(4)	35	space 40-52	character	a13
RFILE(5)	35	space 53-65	character	a13
RFILE(6)	35	space 66-78	character	a13
RFILE(7)	36	space 1-13	character	a13
RFILE(8)	36	space 14-26	character	a13
RFILE(9)	36	space 27-39	character	a13
RFILE(10)	36	space 40-52	character	a13
RFILE(11)	36	space 53-65	character	a13
RFILE(12)	36	space 66-78	character	a13

Variable name	Line #	Position	Format	F90 Format
RFILE(13)	37	space 1-13	character	a13
RFILE(14)	37	space 14-26	character	a13
RFILE(15)	37	space 27-39	character	a13
RFILE(16)	37	space 40-52	character	a13
RFILE(17)	37	space 53-65	character	a13
RFILE(18)	37	space 66-78	character	a13
Comment line	38	space 1-80	character	a80
TFILE(1)	39	space 1-13	character	a13
TFILE(2)	39	space 14-26	character	a13
TFILE(3)	39	space 27-39	character	a13
TFILE(4)	39	space 40-52	character	a13
TFILE(5)	39	space 53-65	character	a13
TFILE(6)	39	space 66-78	character	a13
TFILE(7)	40	space 1-13	character	a13
TFILE(8)	40	space 14-26	character	a13
TFILE(9)	40	space 27-39	character	a13
TFILE(10)	40	space 40-52	character	a13
TFILE(11)	40	space 53-65	character	a13
TFILE(12)	40	space 66-78	character	a13
TFILE(13)	41	space 1-13	character	a13
TFILE(14)	41	space 14-26	character	a13
TFILE(15)	41	space 27-39	character	a13
TFILE(16)	41	space 40-52	character	a13
TFILE(17)	41	space 53-65	character	a13
TFILE(18)	41	space 66-78	character	a13
SLRFILE	42	space 1-13	character	a13
RHFILE	43	space 1-13	character	a13
WNDFILE	44	space 1-13	character	a13
FCSTFILE	45	space 1-13	character	a13
Comment line	46	space 1-80	character	a80
BSNFILE	47	space 1-13	character	a13
Comment line	48	space 1-80	character	a80
PLANTDB	49	space 1-13	character	a13
TILLDB	50	space 1-13	character	a13
PESTDB	51	space 1-13	character	a13

Variable name	Line #	Position	Format	F90 Format
FERTDB	52	space 1-13	character	a13
URBANDB	53	space 1-13	character	a13
Comment line	54	space 1-80	character	a80
ISPROJ	55	none	integer	free
ICLB	56	none	integer	free
CALFILE	57	space 1-13	character	a13
Comment line	58	space 1-80	character	a80
IPRINT	59	none	integer	free
NYSKIP	60	none	integer	free
ILOG	61	none	integer	free
IPRP	62	none	integer	free
IPRS	63	none	integer	free
Comment line	64	space 1-80	character	a80
IPDVAR(1)	65	none	integer	free
IPDVAR(2)	65	none	integer	free
IPDVAR(3)	65	none	integer	free
IPDVAR(4)	65	none	integer	free
IPDVAR(5)	65	none	integer	free
IPDVAR(6)	65	none	integer	free
IPDVAR(7)	65	none	integer	free
IPDVAR(8)	65	none	integer	free
IPDVAR(9)	65	none	integer	free
IPDVAR(10)	65	none	integer	free
IPDVAR(11)	65	none	integer	free
IPDVAR(12)	65	none	integer	free
IPDVAR(13)	65	none	integer	free
IPDVAR(14)	65	none	integer	free
IPDVAR(15)	65	none	integer	free
IPDVAR(16)	65	none	integer	free
IPDVAR(17)	65	none	integer	free
IPDVAR(18)	65	none	integer	free
IPDVAR(19)	65	none	integer	free
IPDVAR(20)	65	none	integer	free
Comment line	66	space 1-80	character	a80
IPDVAB(1)	67	none	integer	free

Variable name	Line #	Position	Format	F90 Format
IPDVAB(2)	67	none	integer	free
IPDVAB(3)	67	none	integer	free
IPDVAB(4)	67	none	integer	free
IPDVAB(5)	67	none	integer	free
IPDVAB(6)	67	none	integer	free
IPDVAB(7)	67	none	integer	free
IPDVAB(8)	67	none	integer	free
IPDVAB(9)	67	none	integer	free
IPDVAB(10)	67	none	integer	free
IPDVAB(11)	67	none	integer	free
IPDVAB(12)	67	none	integer	free
IPDVAB(13)	67	none	integer	free
IPDVAB(14)	67	none	integer	free
IPDVAB(15)	67	none	integer	free
Comment line	68	space 1-80	character	a80
IPDVAS(1)	69	none	integer	free
IPDVAS(2)	69	none	integer	free
IPDVAS(3)	69	none	integer	free
IPDVAS(4)	69	none	integer	free
IPDVAS(5)	69	none	integer	free
IPDVAS(6)	69	none	integer	free
IPDVAS(7)	69	none	integer	free
IPDVAS(8)	69	none	integer	free
IPDVAS(9)	69	none	integer	free
IPDVAS(10)	69	none	integer	free
IPDVAS(11)	69	none	integer	free
IPDVAS(12)	69	none	integer	free
IPDVAS(13)	69	none	integer	free
IPDVAS(14)	69	none	integer	free
IPDVAS(15)	69	none	integer	free
IPDVAS(16)	69	none	integer	free
IPDVAS(17)	69	none	integer	free
IPDVAS(18)	69	none	integer	free
IPDVAS(19)	69	none	integer	free
IPDVAS(20)	69	none	integer	free

Variable name	Line #	Position	Format	F90 Format
Comment line	70	space 1-80	character	a80
IPDHRU(1)	71	none	integer	free
IPDHRU(2)	71	none	integer	free
IPDHRU(3)	71	none	integer	free
IPDHRU(4)	71	none	integer	free
IPDHRU(5)	71	none	integer	free
IPDHRU(6)	71	none	integer	free
IPDHRU(7)	71	none	integer	free
IPDHRU(8)	71	none	integer	free
IPDHRU(9)	71	none	integer	free
IPDHRU(10)	71	none	integer	free
IPDHRU(11)	71	none	integer	free
IPDHRU(12)	71	none	integer	free
IPDHRU(13)	71	none	integer	free
IPDHRU(14)	71	none	integer	free
IPDHRU(15)	71	none	integer	free
IPDHRU(16)	71	none	integer	free
IPDHRU(17)	71	none	integer	free
IPDHRU(18)	71	none	integer	free
IPDHRU(19)	71	none	integer	free
IPDHRU(20)	71	none	integer	free
COMMENT LINE	72	space 1-80	character	a80
ATMOFILE	73	space 1-80	character	a80
IPHR	74	none	integer	free
ISTO	75	none	integer	free
ISOL	76	none	integer	free
I_SUBW	77	none	integer	free
SEPTDB	78	space 1-80	character	a80
IA_B	79	none	integer	free
IHUMUS	80	none	integer	free
ITEMP	81	none	integer	free
ISNOW	82	none	integer	free
IMGT	83	none	integer	free

CHAPTER 4

SWAT INPUT DATA: .BSN

General watershed attributes are defined in the basin input file. These attributes control a diversity of physical processes at the watershed level. The interfaces will automatically set these parameters to the –default" or recommended values listed in the variable documentation. Users can use the default values or change them to better reflect what is happening in a given watershed. Variables governing bacteria or pesticide transport need to be initialized only if these processes are being modeled in the watershed. Even if nutrients are not being studied in a watershed, some attention must be paid to these variables because nutrient cycling impacts plant growth which in turn affects the hydrologic cycle.

Following is a brief description of the variables in the basin input file. They are listed by topic.

4.1 TITLE

Variable name	Definition
TITLE	The first line is reserved for a description. The description may take up to 80 spaces. The title line is not processed by the model and may be left blank. Optional.

4.2 MODELING OPTIONS: LAND AREA

WATER BALANCE

Variable name	Definition
SFTMP	Snowfall temperature (ºC). Mean air temperature at which precipitation is equally likely to be rain as snow/freezing rain. The snowfall temperature should be between –5 ºC and 5 ºC. A default recommended for this variable is SFTMP = 1.0. Required in watersheds where snowfall is significant.
SMTMP	Snow melt base temperature (ºC). The snow pack will not melt until the snow pack temperature exceeds a threshold value, T_{mlt}. The snow melt base temperature should be between –5 ºC and 5 ºC. A default recommended for this variable is SMTMP = 0.50. Required in watersheds where snowfall is significant.

Variable name	Definition
SMFMX	Melt factor for snow on June 21 (mm H_2O/ºC-day). If the watershed is in the Northern Hemisphere, SMFMX will be the maximum melt factor. If the watershed is in the Southern Hemisphere, SMFMX will be the minimum melt factor. SMFMX and SMFMN allow the rate of snow melt to vary through the year. The variables account for the impact of snow pack density on snow melt. In rural areas, the melt factor will vary from 1.4 to 6.9 mm H_2O/day-°C (Huber and Dickinson, 1988). In urban areas, values will fall in the higher end of the range due to compression of the snow pack by vehicles, pedestrians, etc. Urban snow melt studies in Sweden (Bengston, 1981; Westerstrom, 1981) reported melt factors ranging from 3.0 to 8.0 mm H_2O/day-°C. Studies of snow melt on asphalt (Westerstrom, 1984) gave melt factors of 1.7 to 6.5 mm H_2O/day-°C. If no value for SMFMX is entered, the model will set SMFMX = 4.5. Required in watersheds where snowfall is significant.
SMFMN	Melt factor for snow on December 21 (mm H_2O/ºC-day). If the watershed is in the Northern Hemisphere, SMFMN will be the minimum melt factor. If the watershed is in the Southern Hemisphere, SMFMN will be the maximum melt factor. SMFMX and SMFMN allow the rate of snow melt to vary through the year. The variables account for the impact of snow pack density on snow melt. In rural areas, the melt factor will vary from 1.4 to 6.9 mm H_2O/day-°C (Huber and Dickinson, 1988). In urban areas, values will fall in the higher end of the range due to compression of the snow pack by vehicles, pedestrians, etc. Urban snow melt studies in Sweden (Bengston, 1981; Westerstrom, 1981) reported melt factors ranging from 3.0 to 8.0 mm H_2O/day-°C. Studies of snow melt on asphalt (Westerstrom, 1984) gave melt factors of 1.7 to 6.5 mm H_2O/day-°C. If no value for SMFMN is entered, the model will set SMFMN = 4.5. Required in watersheds where snowfall is significant.

Variable name	Definition
TIMP	Snow pack temperature lag factor. The influence of the previous day's snow pack temperature on the current day's snow pack temperature is controlled by a lagging factor, ℓ_{sno}. The lagging factor inherently accounts for snow pack density, snow pack depth, exposure and other factors affecting snow pack temperature. TIMP can vary between 0.01 and 1.0. As ℓ_{sno} approaches 1.0, the mean air temperature on the current day exerts an increasingly greater influence on the snow pack temperature and the snow pack temperature from the previous day exerts less and less influence. As TIMP goes to zero, the snow pack's temperature will be less influenced by the current day's air temperature. If no value for TIMP is entered, the model will set TIMP = 1.0. Required in watersheds where snowfall is significant.
SNOCOVMX	Minimum snow water content that corresponds to 100% snow cover, SNO_{100}, (mm H_2O). Due to variables such as drifting, shading and topography, the snow pack in a subbasin will rarely be uniformly distributed over the total area. This results in a fraction of the subbasin area that is bare of snow. This fraction must be quantified to accurately compute snow melt in the subbasin. The factors that contribute to variable snow coverage are usually similar from year to year, making it possible to correlate the areal coverage of snow with the amount of snow present in the subbasin at a given time. This correlation is expressed as an areal depletion curve, which is used to describe the seasonal growth and recession of the snow pack as a function of the amount of snow present in the subbasin (Anderson, 1976). The areal depletion curve requires a threshold depth of snow, SNO_{100}, to be defined above which there will always be 100% cover. The threshold depth will depend on factors such as vegetation distribution, wind loading of snow, wind scouring of snow, interception and aspect, and will be unique to the watershed of interest.

Variable name	Definition
SNOCOVMX, cont.	If the snow water content is less than SNOCOVMX, then a certain percentage of ground cover will be bare. It is important to remember that once the volume of water held in the snow pack exceeds SNO_{100} the depth of snow over the HRU is assumed to be uniform, i.e. sno_{cov} = 1.0. The areal depletion curve affects snow melt only when the snow pack water content is between 0.0 and SNO_{100}. Consequently if SNO_{100} is set to a very small value, the impact of the areal depletion curve on snow melt will be minimal. As the value for SNO_{100} increases, the influence of the areal depletion curve will assume more importance in snow melt processes. If no value for SNOCOVMX is entered, the model will set SNOCOVMX = 1.00. Required in watersheds where snowfall is significant.
SNO50COV	Fraction of snow volume represented by SNOCOVMX that corresponds to 50% snow cover. SWAT assumes a nonlinear relationship between snow water and snow cover. SNO50COV can vary between 0.01 and 0.99. Example areal depletion curves for various fractions of SNO_{100} at 50% coverage are shown in the following figures. If no value for SNO50COV is entered, the model will set SNO50COV = 0.50, i.e. 50% of SNOCOVMX. Required in watersheds where snowfall is significant.

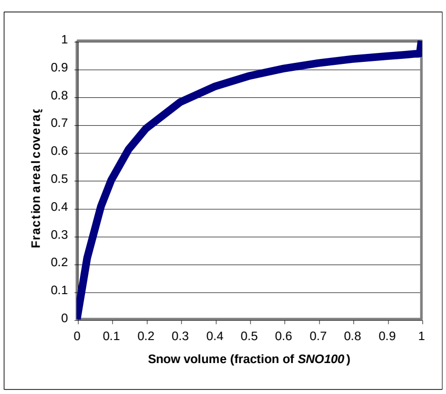

Figure 4-1: 10% SNO_{100} = 50% coverage

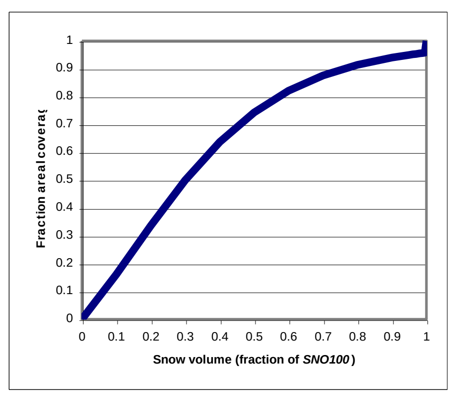

Figure 4-2: 30% SNO_{100} = 50% coverage

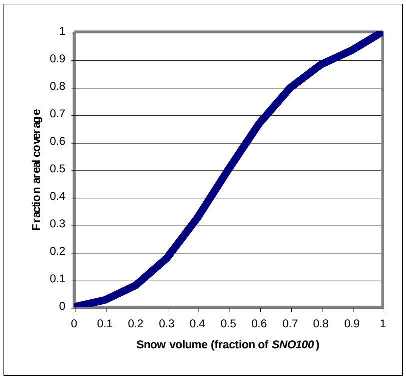

Figure 4-3: 50% SNO_{100} = 50% coverage

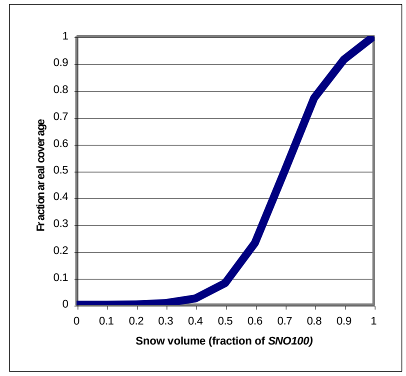

Figure 4-4: 70% SNO_{100} = 50% coverage

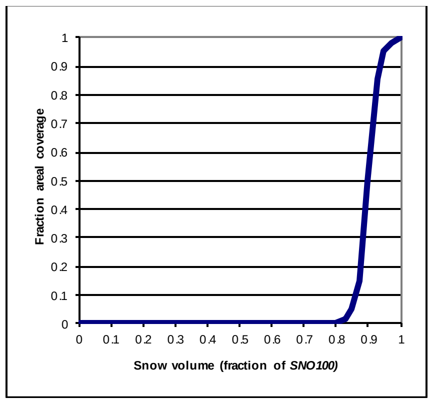

Figure 4-5: 90% SNO_{100} = 50% coverage

Variable name	Definition
IPET	Potential evapotranspiration (PET) method. There are four options for potential ET calculations: 0 Priestley-Taylor method 1 Penman/Monteith method 2 Hargreaves method 3 read in potential ET values Numerous methods exist to calculate potential evapotranspiration. Three of the most popular or widely-used are included in SWAT. However, if a method other than Priestley-Taylor, Penman/Monteith, or Hargreaves is recommended for the area in which the watershed is located, the user can calculate daily PET values with the recommended method and import them into SWAT. A discussion of Priestley-Taylor, Penman-Monteith and Hargreaves PET methods is found in Chapter 2:2 of the theoretical documentation. Required.

Variable name	Definition
PETFILE	Name of potential evapotranspiration input file (**.pet**). This file is described in Chapter 11. Required only if IPET = 3.
ESCO	Soil evaporation compensation factor. This coefficient has been incorporated to allow the user to modify the depth distribution used to meet the soil evaporative demand to account for the effect of capillary action, crusting and cracks. ESCO must be between 0.01 and 1.0. As the value for ESCO is reduced, the model is able to extract more of the evaporative demand from lower levels. The change in depth distribution resulting from different values of *esco* are graphed in Figure 4-6.

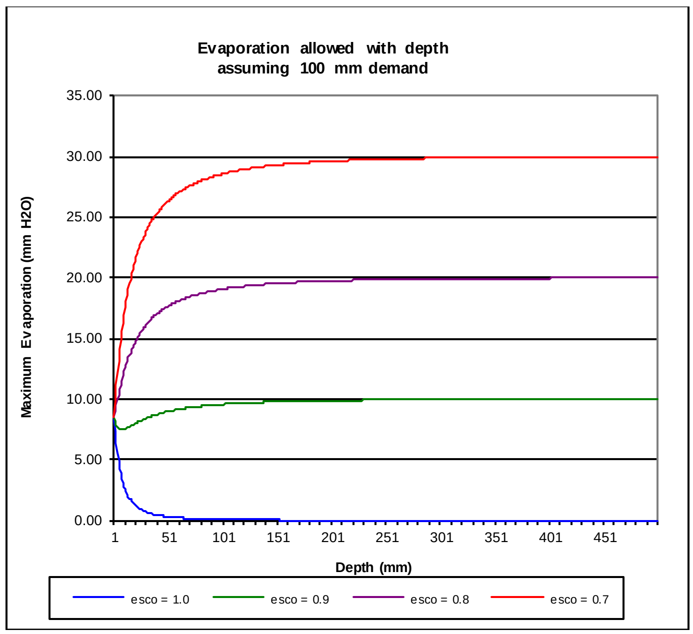

Figure 4-6: Soil evaporative demand distribution with depth

If no value for ESCO is entered, the model will set ESCO = 0.95. The value for ESCO may be set at the watershed or HRU level (ESCO in .hru file, see Chapter 19).

Required.

Variable name	Definition
EPCO	Plant uptake compensation factor. The amount of water uptake that occurs on a given day is a function of the amount of water required by the plant for transpiration, E_t, and the amount of water available in the soil, SW. If upper layers in the soil profile do not contain enough water to meet the potential water uptake, users may allow lower layers to compensate. The plant uptake compensation factor can range from 0.01 to 1.00. As *epco* approaches 1.0, the model allows more of the water uptake demand to be met by lower layers in the soil. As *epco* approaches 0.0, the model allows less variation from the original depth distribution to take place. If no value for EPCO is entered, the model will set EPCO = 1.0. The value for EPCO may be set at the watershed or HRU level (EPCO in .hru file, see Chapter 19). Required.
EVLAI	Leaf area index at which no evaporation occurs from water surface. EVLAI is used in HRUs where a plant is growing in a ponded environment (e.g. rice). Currently, this is simulated only in HRUs defined as depressional areas/potholes. Evaporation from the water surface is allowed until the leaf area of the plant reaches the value specified for EVLAI. Chapter 8:1 in the Theoretical Documentation provides more detail on the use of this parameter. EVLAI should be set between 0.0 and 10.0. If no value for EVLAI is entered, the model will set EVLAI = 3.0. Required if depressional areas/potholes are modeled in the watershed.

Variable name	Definition
FFCB	Initial soil water storage expressed as a fraction of field capacity water content. All soils in the watershed will be initialized to the same fraction. FFCB should be between 0.0 and 1.0. If FFCB is not set to a value, the model will calculate it as a function of average annual precipitation. The default method is to allow the model to calculate FFCB (set FFCB = 0.0). We recommend using a 1 year equilibration period for the model where the watershed simulation is set to start 1 year prior to the period of interest. This allows the model to get the water cycling properly before any comparisons between measured and simulated data are made. When an equilibration period is incorporated, the value for FFCB is not going to impact model results. Required.

SURFACE RUNOFF

Variable name	Definition
IEVENT	Rainfall/runoff/routing option: 0 daily rainfall/curve number runoff/daily routing 1 daily rainfall/Green & Ampt infiltration/daily routing (sub-hourly rainfall required for Green & Ampt is generated from daily) 2 sub-hourly rainfall/Green & Ampt infiltration/daily routing 3 sub-hourly rainfall/Green & Ampt infiltration/hourly routing Option 0 is the default option. Required.

Variable name	Definition
ICN	Daily curve number calculation method: 0 calculate daily CN value as a function of soil moisture 1 calculate daily CN value as a function of plant evapotranspiration Option 0 was the only method used to calculate the daily CN value in versions of SWAT prior to SWAT2009. Calculation of the daily CN value as a function of plant evapotranspiration was added because the soil moisture method was predicting too much runoff in shallow soils. By calculating daily CN as a function of plant evapotranspiration, the value is less dependent on soil storage and more dependent on antecedent climate. Required.
CNCOEF	Plant ET curve number coefficient. ET weighting coefficient used to calculate the retention coefficient for daily curve number calculations dependent on plant evapotranspiration. This value can vary between 0.5 and 2.0. If no value is entered for CNCOEF, the model will set CNCOEF = 1.0. Required if ICN = 1.
ICRK	Crack flow code. There are two options: 0 do not model crack flow in soil 1 model crack flow in soil Crack, or bypass, flow is a newer feature in SWAT and has been tested on a limited basis in simulations of some areas in Texas. This type of flow should be modeled only on soils classified as Vertisols. The default option is to model the watershed without crack flow. Required.

Variable name	Definition
SURLAG	Surface runoff lag coefficient. In large subbasins with a time of concentration greater than 1 day, only a portion of the surface runoff will reach the main channel on the day it is generated. SWAT incorporates a surface runoff storage feature to lag a portion of the surface runoff release to the main channel. SURLAG controls the fraction of the total available water that will be allowed to enter the reach on any one day. Figure 4-7 plots the fraction of total available water entering the reach at different values for *surlag* and t_{conc}. Note that for a given time of concentration, as *surlag* decreases in value more water is held in storage. The delay in release of surface runoff will smooth the streamflow hydrograph simulated in the reach. If no value for SURLAG is entered, the model will set SURLAG = 4.0. Required.

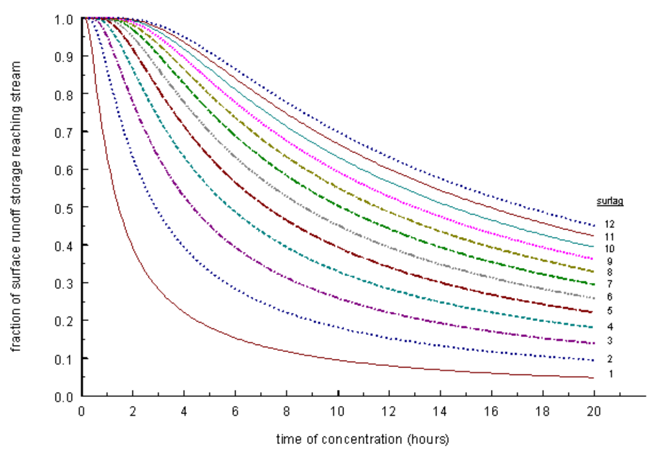

Figure 4-7: Influence of *surlag* and t_{conc} on fraction of surface runoff released.

Variable name	Definition
ISED_DET	Code governing calculation of daily maximum half-hour rainfall value: 0 generate daily value using triangular distribution 1 use monthly maximum half-hour rainfall value for all days in month The user has the option of using the monthly maximum half-hour rainfall for all days in the month. The randomness of the triangular distribution used to generated daily values causes the maximum half-hour rainfall value to jump around. For small plots or microwatersheds in particular, the variability of the triangular distribution is unrealistic. Required.
ADJ_PKR	Peak rate adjustment factor for sediment routing in the *subbasin (tributary channels).* Sediment routing is a function of peak flow rate and mean daily flow. Because SWAT originally could not directly calculate the sub-daily hydrograph due to the use of precipitation summarized on a daily basis, this variable was incorporated to allow adjustment for the effect of the peak flow rate on sediment routing. This factor is used in the MUSLE equation and impacts the amount of erosion generated in the HRUs. If no value for ADJ_PKR is entered, the model will set ADJ_PKR=1.0. Required.
TB_ADJ	*New variable in testing.* *Adjustment factor for subdaily unit hydrograph basetime.*

NUTRIENT CYCLING

Variable name	Definition
RCN	Concentration of nitrogen in rainfall (mg N/L). If no value for RCN is entered, the model will set RCN = 1.0. Required.

Variable name	Definition
CMN	Rate factor for humus mineralization of active organic nutrients (N and P). Chapters 3:1 and 3:2 of the Theoretical Documentation describe the use of this parameter in the mineralization calculations. If no value for CMN is specified, the model will set CMN = 0.0003. Required.
CDN	Denitrification exponential rate coefficient. This coefficient allows the user to control the rate of denitrification. Acceptable values for CDN range from 0.0 to 3.0. If no value for CDN is specified, the model will set CDN = 1.4. Required.

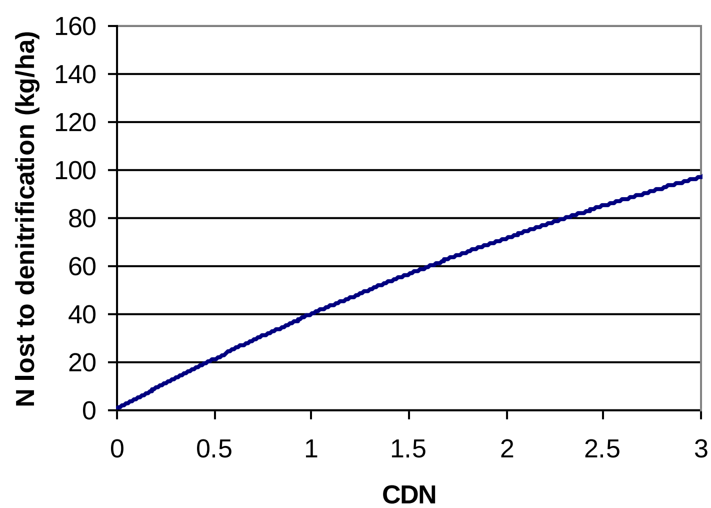

Fig 4-8: Impact of CDN value on amount of nitrogen lost to denitrification assuming initial nitrate content in layer is 200 kg/ha, temperature of layer is 10 °C, and organic carbon content of layer is 2%.

Variable name	Definition
SDNCO	Denitrification threshold water content. Fraction of field capacity water content above which denitrification takes place. Denitrification is the bacterial reduction of nitrate, NO_3^-, to N_2 or N_2O gases under anaerobic (reduced) conditions. Because SWAT does not track the redox status of the soil layers, the presence of anaerobic conditions in a soil layer is defined by this variable. If the soil water content calculated as fraction of field capacity is ≥ SDNCO, then anaerobic conditions are assumed to be present and denitrification is modeled. If the soil water content calculated as a fraction of field capacity is < SDNCO, then aerobic conditions are assumed to be present and denitrification is not modeled. If no value for SDNCO is specified, the model will set SDNCO = 1.10. Required.
N_UPDIS	Nitrogen uptake distribution parameter. Root density is greatest near the surface, and plant nitrogen uptake in the upper portion of the soil will be greater than in the lower portion. The depth distribution of nitrogen uptake is controlled by β_n, the nitrogen uptake distribution parameter. The importance of the nitrogen uptake distribution parameter lies in its control over the maximum amount of nitrate removed from the upper layers. Because the top 10 mm of the soil profile interacts with surface runoff, the nitrogen uptake distribution parameter will influence the amount of nitrate available for transport in surface runoff. The model allows lower layers in the root zone to fully compensate for lack of nitrate in the upper layers, so there should not be significant changes in nitrogen stress with variation in the value used for β_n. If no value for N_UPDIS is entered, the model will set N_UPDIS = 20.0. Figure 4-9 illustrates nitrogen uptake as a function of depth for four different uptake distribution parameter values. Required.

Variable name	Definition
N_UPDIS, cont.	

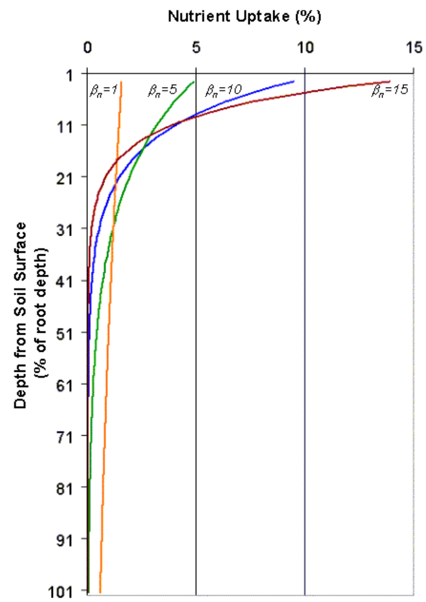

Figure 4-9: Depth distribution of nitrogen uptake

Variable name	Definition
P_UPDIS	Phosphorus uptake distribution parameter. This parameter controls plant uptake of phosphorus from the different soil horizons in the same way that UBN controls nitrogen uptake. The illustration of nitrogen uptake as a function of depth for four different uptake distribution parameter values in Figure 4-9 is valid for phosphorus uptake as well. Phosphorus removed from the soil by plants is taken from the solution phosphorus pool. The importance of the phosphorus uptake distribution parameter lies in its control over the maximum amount of solution P removed from the upper layers. Because the top 10 mm of the soil profile interacts with surface runoff, the phosphorus uptake distribution parameter will influence the amount of labile phosphorus available for transport in surface runoff. The model allows lower layers in the root zone to fully compensate for lack of solution P in the upper layers, so there should not be significant changes in phosphorus stress with variation in the value used for β_p.

Variable name	Definition
P_UPDIS, cont.	If no value for P_UPDIS is entered, the model will set P_UPDIS = 20.0. Required.
NPERCO	Nitrate percolation coefficient. NPERCO controls the amount of nitrate removed from the surface layer in runoff relative to the amount removed via percolation. The value of NPERCO can range from 0.01 to 1.0. As NPERCO → 0.0, the concentration of nitrate in the runoff approaches 0. As NPERCO → 1.0, surface runoff has the same concentration of nitrate as the percolate. If no value for NPERCO is entered, the model will set NPERCO = 0.20. Required.
PPERCO	Phosphorus percolation coefficient (10 m^3/Mg). The phosphorus percolation coefficient is the ratio of the solution phosphorus concentration in the surface 10 mm of soil to the concentration of phosphorus in percolate. The value of PPERCO can range from 10.0 to 17.5 If no value for PPERCO is entered, the model will set PPERCO = 10.0. Required.
PHOSKD	Phosphorus soil partitioning coefficient (m3/Mg). The phosphorus soil partitioning coefficient is the ratio of the soluble phosphorus concentration in the surface 10 mm of soil to the concentration of soluble phosphorus in surface runoff. The primary mechanism of phosphorus movement in the soil is by diffusion. Diffusion is the migration of ions over small distances (1-2 mm) in the soil solution in response to a concentration gradient. Due to the low mobility of solution phosphorus, surface runoff will only partially interact with the solution P stored in the top 10 mm of soil. If no value for PHOSKD is entered, the model will set PHOSKD = 175.0. Required.

Variable name	Definition
PSP	Phosphorus availability index.
	Many studies have shown that after an application of soluble P fertilizer, solution P concentration decreases rapidly with time due to reaction with the soil. This initial "fast" reaction is followed by a much slower decrease in solution P that may continue for several years (Barrow and Shaw, 1975; Munns and Fox, 1976; Rajan and Fox, 1972; Sharpley, 1982). In order to account for the initial rapid decrease in solution P, SWAT assumes a rapid equilibrium exists between solution P and an "active" mineral pool. The subsequent slow reaction is simulated by the slow equilibrium assumed to exist between the "active" and "stable" mineral pools. The algorithms governing movement of inorganic phosphorus between these three pools are taken from Jones et al. (1984).
	Equilibration between the solution and active mineral pool is governed by the phosphorus availability index. This index specifies the fraction of fertilizer P which is in solution after an incubation period, i.e. after the rapid reaction period.
	A number of methods have been developed to measure the phosphorus availability index. Jones et al. (1984) recommends a method outlined by Sharpley et al. (1984) in which various amounts of phosphorus are added in solution to the soil as K_2HPO_4. The soil is wetted to field capacity and then dried slowly at 25°C. When dry, the soil is rewetted with deionized water. The soil is exposed to several wetting and drying cycles over a 6-month incubation period. At the end of the incubation period, solution phosphorus is determined by extraction with anion exchange resin.
	The P availability index is then calculated: $$pai = \frac{P_{solution,f} - P_{solution,i}}{fert_{minP}}$$ where pai is the phosphorus availability index, $P_{solution,f}$ is the amount of phosphorus in solution after fertilization and incubation, $P_{solution,i}$ is the amount of phosphorus in solution before fertilization, and $fert_{minP}$ is the amount of soluble P fertilizer added to the sample.
	If no value for PSP is entered, the model will set PSP = 0.40.
	Required.

Variable name	Definition
RSDCO	Residue decomposition coefficient. The fraction of residue which will decompose in a day assuming optimal moisture, temperature, C:N ratio and C:P ratio. If no value for RSDCO is entered, the model will set RSDCO = 0.05. Required.

PESTICIDE CYCLING

Variable name	Definition
PERCOP	Pesticide percolation coefficient. PERCOP controls the amount of pesticide removed from the surface layer in runoff and lateral flow relative to the amount removed via percolation. The value of PERCOP can range from 0.01 to 1.0. As PERCOP → 0.0, the concentration of pesticide in the runoff and lateral flow approaches 0. As PERCOP → 1.0, surface runoff and lateral flow has the same concentration of pesticide as the percolate. If no value for PERCOP is entered, the model will set PERCOP = 0.50. Required if pesticide transport is of interest.

ALGAE/CBOD/DISSOLVED OXYGEN

Variable name	Definition
ISUBWQ	Subbasin water quality code. The algorithms used to calculate loadings of algae, organic carbonaceous biological oxygen demand and dissolved oxygen to the stream network (see Chapter 4:4 in Theoretical Documentation) were derived from results of limited studies and are still in the testing phase. ISUBWQ allows the user to choose to apply or not apply the algorithms. 0 do not calculate algae/CBOD loadings and set dissolved oxygen to saturated oxygen concentration 1 calculate algae/CBOD/dissolved oxygen loadings using algorithms documented in Theoretical Documentation The default option is ISUBWQ=0. Required.

BACTERIA

Variable name	Definition
WDPQ	Die-off factor for persistent bacteria in soil solution at 20°C. (1/day) SWAT allows two different bacteria types to be modeled in a given simulation. In the input/output files these two types are referred to as ‗persistent' and ‗less persistent'. These terms are purely descriptive and are used solely to differentiate between the two types. The bacteria input variables in the .bsn file govern the actual persistence of the two bacteria types. The user may choose to model no, one, or two types of bacteria. Required if bacteria processes are of interest.
WGPQ	Growth factor for persistent bacteria in soil solution at 20°C. (1/day) Required if bacteria processes are of interest.
WDLPQ	Die-off factor for less persistent bacteria in soil solution at 20°C. (1/day) Required if bacteria processes are of interest.
WGLPQ	Growth factor for less persistent bacteria in soil solution at 20°C. (1/day) Required if bacteria processes are of interest.
WDPS	Die-off factor for persistent bacteria adsorbed to soil particles at 20°C. (1/day) Required if bacteria processes are of interest.
WGPS	Growth factor for persistent bacteria adsorbed to soil particles at 20°C. (1/day) Required if bacteria processes are of interest.
WDLPS	Die-off factor for less persistent bacteria adsorbed to soil particles at 20°C. (1/day) Required if bacteria processes are of interest.
WGLPS	Growth factor for less persistent bacteria adsorbed to soil particles at 20°C. (1/day) Required if bacteria processes are of interest.

Variable name	Definition
WDPF	Die-off factor for persistent bacteria on foliage at 20°C. (1/day) Required if bacteria processes are of interest.
WGPF	Growth factor for persistent bacteria on foliage at 20°C. (1/day) Required if bacteria processes are of interest.
WDLPF	Die-off factor for less persistent bacteria on foliage at 20°C. (1/day) Required if bacteria processes are of interest.
WGLPF	Growth factor for less persistent bacteria on foliage at 20°C. (1/day) Required if bacteria processes are of interest.
BACT_SWF	Fraction of manure applied to land areas that has active colony forming units. If no value for BACT_SWF is specified, the model will set BACT_SWF = 0.15. Required if bacteria processes are of interest.
WOF_P	Wash-off fraction for persistent bacteria. Fraction of persistent bacteria on foliage that washes off during a rainfall event. Required if bacteria processes are of interest.
WOF_LP	Wash-off fraction for less persistent bacteria. Fraction of less persistent bacteria on foliage that washes off during a rainfall event. Required if bacteria processes are of interest.

Variable name	Definition
BACTKDQ	Bacteria soil partitioning coefficient (m^3/Mg). The bacteria soil partitioning coefficient is the ratio of the solution bacteria concentration in the surface 10 mm of soil to the concentration of solution bacteria in surface runoff. Due to the low mobility of bacteria, surface runoff will only partially interact with the solution bacteria stored in the top 10 mm of soil. If no value for BACTKDQ is entered, the model will set BACTKDQ = 175.0. Required if bacteria processes are of interest.
BACTMIX	Bacteria percolation coefficient (10 m^3/Mg). The bacteria percolation coefficient is the ratio of the solution bacteria concentration in the surface 10 mm of soil to the concentration of bacteria in percolate. The value of BACTMIX can range from 7.0 to 20.0. If no value for BACTMIX is entered, the model will set BACTMIX = 10.0. Required if bacteria processes are of interest.
THBACT	Temperature adjustment factor for bacteria die-off/growth. If no value for THBACT is entered, the model will set THBACT = 1.07. Required if bacteria processes are of interest.
BACTMINLP	Minimum daily bacteria loss for less persistent bacteria (# cfu/m^2). This is the minimum daily bacteria loss from each of the different bacteria pools. Also, when bacteria levels fall below BACTMIN the model considers the remaining bacteria in the soil to be insignificant and zeros out, i.e. kills, the remaining bacteria. If no value for BACTMIN is entered, the model will set BACTMIN = 0.0.

BACTMINP	Minimum daily bacteria loss for persistent bacteria (# cfu/m^2). This is the minimum daily bacteria loss from each of the different bacteria pools. Also, when bacteria levels fall below BACTMIN the model considers the remaining bacteria in the soil to be insignificant and zeros out, i.e. kills, the remaining bacteria. If no value for BACTMIN is entered, the model will set BACTMIN = 0.0.
WDLPRCH	Die-off factor for less persistent bacteria in streams (moving water) at 20°C. (1/day) Required if bacteria processes are of interest.
WDPRCH	Die-off factor for persistent bacteria in streams (moving water) at 20°C. (1/day) Required if bacteria processes are of interest.
WDLPRES	Die-off factor for less persistent bacteria in water bodies (still water) at 20°C. (1/day) Required if bacteria processes are of interest.
WDPRES	Die-off factor for persistent bacteria in water bodies (still water) at 20°C. (1/day) Required if bacteria processes are of interest.

4.3 MODELING OPTIONS: REACHES

Variable name	**Definition**
IRTE	Channel water routing method: 0 variable storage method 1 Muskingum method The user must be careful to define MSK_CO1, MSK_CO2 and MSK_X when the Muskingum method is chosen. The default option is IRTE=0. Required.

Variable name	Definition
MSK_CO1	Calibration coefficient used to control impact of the storage time constant (K_m) for normal flow (where normal flow is when river is at bankfull depth) upon the K_m value calculated for the reach. Required only if IRTE = 1.
MSK_CO2	Calibration coefficient used to control impact of the storage time constant (K_m) for low flow (where low flow is when river is at 0.1 bankfull depth) upon the K_m value calculated for the reach. Required only if IRTE = 1.
MSK_X	MSK_X is a weighting factor that controls the relative importance of inflow and outflow in determining the storage in a reach. The weighting factor has a lower limit of 0.0 and an upper limit of 0.5. This factor is a function of the wedge storage. For reservoir-type storage, there is no wedge and X = 0.0. For a full-wedge, X = 0.5. For rivers, X will fall between 0.0 and 0.3 with a mean value near 0.2. If no value for MSK_X is entered, the model will set MSK_X = 0.2. Required only if IRTE = 1.
TRNSRCH	Fraction of transmission losses from main channel that enter deep aquifer. The remainder if the transmission losses enter bank storage. In arid watersheds, transmission losses from the main channel network may be permanently lost due to transmission to aquifers that do not contribute flow back to the stream network. This variable allows the user to specify the fraction of transmission losses from the channel network that is permanently lost. TRNSRCH varies between 0.00 and 1.00. The default value for TRNSRCH is 0.00. Required.

Variable name	Definition
EVRCH	Reach evaporation adjustment factor. The evaporation coefficient is a calibration parameter for the user and is allowed to vary between 0.0 and 1.0. This coefficient was created to allow reach evaporation to be dampened in arid regions. The original equation tends to overestimate evaporation in these areas. If no value for EVRCH is entered, the model will set EVRCH = 1.00. Required.
IDEG	Channel degradation code. There are two options: 0 channel dimensions are not updated as a result of degradation (the dimensions remain constant for the entire simulation) 1 channel dimensions are updated as a result of degradation Traditionally, channel dimensions remain fixed, or constant, throughout the simulation. The change in channel dimensions with time is a new feature in SWAT that is still in the testing phase. The recommended option is to keep the channel dimensions constant. Required.
PRF	Peak rate adjustment factor for sediment routing in the main channel. Sediment routing is a function of peak flow rate and mean daily flow. Because SWAT originally could not directly calculate the sub-daily hydrograph, this variable was incorporated to allow adjustment for the effect of the peak flow rate on sediment routing. This variable impacts channel degradation. If no value for PRF is entered, the model will set PRF = 1.0. Required.

Variable name	Definition
SPCON	Linear parameter for calculating the maximum amount of sediment that can be reentrained during channel sediment routing. The maximum amount of sediment that can be transported from a reach segment is calculated $conc_{sed,ch,mx} = c_{sp} \cdot v_{ch,pk}^{spexp}$ where concsed,ch,mx is the maximum concentration of sediment that can be transported by the water (ton/m3 or kg/L), csp is a coefficient defined by the user, vch,pk is the peak channel velocity (m/s), and spexp is an exponent defined by the user. SPCON should be between 0.0001 and 0.01. If no value for SPCON is entered, the model will set SPCON = 0.0001. Required.
SPEXP	Exponent parameter for calculating sediment reentrained in channel sediment routing The maximum amount of sediment that can be transported from a reach segment is calculated $conc_{sed,ch,mx} = c_{sp} \cdot v_{ch,pk}^{spexp}$ where concsed,ch,mx is the maximum concentration of sediment that can be transported by the water (ton/m3 or kg/L), csp is a coefficient defined by the user, vch,pk is the peak channel velocity (m/s), and spexp is an exponent defined by the user. The exponent, spexp, normally varies between 1.0 and 2.0 and was set at 1.5 in the original Bagnold stream power equation (Arnold et al., 1995). If no value for SPEXP is entered, the model will set SPEXP = 1.0. Required.
IWQ	In-stream water quality code. The variable identifies whether in-stream transformation of nutrients using the QUAL2E algorithms and in-stream transformation of pesticides is allowed to occur. 0 do not model in-stream nutrient and pesticide transformations 1 model in-stream nutrient and pesticide transformations The default option is IWQ=0. Required.

Variable name	Definition
WWQFILE	Name of watershed water quality input file (**.wwq**). This file is described in Chapter 26. Required.
IRTPEST	Identification number of pesticide to be routed through the watershed channel network. This is the pesticide ID number from the pesticide database. While more than one type of pesticide may be applied to the HRUs, the model will monitor the movement of only one pesticide through the channel network. Required only if pesticide transport processes are of interest.
DEPIMP_BSN	Depth to impervious layer for modeling perched water tables (mm). This variable is included for convenience. A value for DEPIMP_BSN can be defined that will be used to set the value of DEP_IMP (.hru) for every HRU in the watershed. If the user sets a value for DEPIMP_BSN and also sets values for DEP_IMP in some HRUs, the customized values for DEP_IMP will not be overwritten by the basin level value (DEPIMP_BSN). For watersheds where there are no perched water tables, DEPIMP_BSN should be set to 0. For watersheds where perched water tables occur in only a portion of the watershed, DEPIM_BSN should be set to 0 and the DEP_IMP variable (.hru) should be used to set the depth to the impervious layer for those areas that have perched water tables. See DEP_IMP (.hru) for more information. Optional.
DDRAIN_BSN	Depth to the sub-surface drain (mm) Optional.
TDRAIN_BSN	Time to drain soil to field capacity (hours). Optional.
GDRAIN_BSN	Drain tile lag time (hours). Optional.

CNFROZ_BSN	Parameter for frozen soil adjustment on infiltration/runoff. If no value for CNFROZ_BSN is entered, the model will set CNFROZ_BSN = 0.000862. Optional.
DORM_HR	Time threshold used to define dormancy (hours). The maximum day length minus DORM_HR is equal to when dormancy occurs. Optional.
SMXCO	Adjustment factor for maximum curve number S factor. Coefficient curve number method that uses antecedent climate. Optional.
FIXCO	Nitrogen fixation coefficient. (0.0 – 1.0) 1.0 = fixes 100% of nitrogen demand. 0.0 = fixes none of nitrogen demand.
NFIXMX	Maximum daily-n fixation (kg/ha). (1.0 – 20.0)
ANION_EXCL_BSN	Fraction of porosity from which anions are excluded. (.01 – 1.00)
CH_ONCO_BSN	Channel organic nitrogen concentration in basin (ppm). (0.0 – 100.0)
CH_OPCO_BSN	Channel organic phosphorus concentration in basin (ppm). (0.0 – 100)
HLIFE_NGW_BSN	Half-life of nitrogen in groundwater (days) (0.0 – 500.0)
RCN_SUB_BSN	Concentration of nitrate in precipitation (ppm). (0.0 – 2.0)
BC1_BSN	Rate constant for biological oxidation of NH3 (1/day). (0.10 – 1.0)
BC2_BSN	Rate constant for biological oxidation NO2 to NO3 (1/day) (0.2 – 2.0)
BC3_BSN	Rate constant for hydrolosis of organic nitrogen to ammonia (1/day). (0.02 – 0.40)
BC4_BSN	Rate constant for decay of organic phosphorus to dissolved phosphorus (1/day) (0.01 – 0.70)
DECR_MIN	Minimum daily residue decay (fraction 0.0 – 0.05)

ICFAC	ICFAC = 0 for C-factor calculation using Cmin. ICFAC = 1 for new C-factor calculation. (0-1)
RSD_COVCO	Residue cover factor for computing fraction of cover. (0.1 – 0.5)
VCRIT	Critical velocity
CSWAT	Code for new carbon routines: 0 = original routines 1 = new carbon routines
RES_STLR_CO	Reservoir sediment settling coefficient (0.09 – 0.27)

The basin input file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line.

Variable name	Line #	Format	F90 Format
TITLE	1	character	a80
Comment line	2	character	a80
Comment line	3	character	a80
SFTMP	4	real	free
SMTMP	5	real	free
SMFMX	6	real	free
SMFMN	7	real	free
TIMP	8	real	free

Variable name	Line #	Format	F90 Format
SNOCOVMX	9	real	free
SNO50COV	10	real	free
IPET	11	integer	free
PETFILE	12	character	a13 (space 1-13)
ESCO	13	real	free
EPCO	14	real	free
EVLAI	15	real	free
FFCB	16	real	free
Comment line	17	character	a80
IEVENT	18	integer	free
ICRK	19	integer	free

Variable name	Line #	Format	F90 Format
SURLAG	20	real	free
ADJ_PKR	21	real	free
PRF	22	real	free
SPCON	23	real	free
SPEXP	24	real	free
Comment line	25	character	a80
RCN	26	real	free
CMN	27	real	free
N_UPDIS	28	real	free
P_UPDIS	29	real	free
NPERCO	30	real	free
PPERCO	31	real	free
PHOSKD	32	real	free
PSP	33	real	free
RSDCO	34	real	free
Comment line	35	character	a80
PERCOP	36	real	free
Comment line	37	character	a80
ISUBWQ	38	integer	free
Comment line	39	character	a80
WDPQ	40	real	free
WGPQ	41	real	free
WDLPQ	42	real	free
WGLPQ	43	real	free
WDPS	44	real	free
WGPS	45	real	free
WDLPS	46	real	free
WGLPS	47	real	free
BACTKDQ	48	real	free
THBACT	49	real	free
WOF_P	50	real	free
WOF_LP	51	real	free
WDPF	52	real	free
WGPF	53	real	free
WDLPF	54	real	free
WGLPF	55	real	free

Variable name	Line #	Format	F90 Format
ISED_DET	56	integer	free
Comment line	57	character	a80
IRTE	58	integer	free
MSK_CO1	59	real	free
MSK_CO2	60	real	free
MSK_X	61	real	free
IDEG	62	integer	free
IWQ	63	integer	free
WWQFILE	64	character	a13 (space 1-13)
TRNSRCH	65	real	free
EVRCH	66	real	free
IRTPEST	67	integer	free
ICN	68	real	free
CNCOEF	69	real	free
CDN	70	real	free
SDNCO	71	real	free
BACT_SWF	72	real	free
BACTMX	73	real	free
BACTMINLP	74	real	free
BACTMINP	75	real	free
WDLPRCH	76	real	free
QWDPRCH	77	real	free
WDLPRES	78	real	free
WDPRES	79	real	free
TB_ADJ	80	real	free
DEPIMP_BSN	81	real	free
DDRAIN_BSN	82	real	free
TDRAIN_BSN	83	real	free
GDRAIN_BSN	84	real	free
CN_FROZ	85	real	free
DORM_HR	86	real	free
SMXCO	87	real	free
FIXCO	88	real	free
NFIXMX	89	real	free
ANION_EXCL_BSN	90	real	free
CH_ONCO_BSN	91	real	free

Variable name	Line #	Format	F90 Format
CH_OPCO_BSN	92	real	free
HLIFE_NGW_BSN	93	real	free
RCN_SUB_BSN	94	real	free
BC1_BSN	95	real	free
BC2_BSN	96	real	free
BC3_BSN	97	real	free
BC4_BSN	98	real	free
DECR_MIN	99	real	free
ICFAC	100	real	free
RSD_COVCO	101	real	free
VCRIT	102	real	free
CSWAT	103	integer	free
RES_STLR_CO	104	real	free

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CHAPTER 5

SWAT INPUT DATA: .SUB

The subbasin general input file contains information related to a diversity of features within the subbasin. Data contained in the subbasin input file can be grouped into the following categories: subbasin size and location, specification of climatic data used within the subbasin, the amount of topographic relief within the subbasin and its impact on the climate, properties of tributary channels within the subbasin, variables related to climate change, the number of HRUs in the subbasin and the names of HRU input files.

Following is a brief description of the variables in the subbasin general input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the .sub file is reserved for user comments. The comments may take up to 80 spaces. The title line is not processed by the model and may be left blank. Optional.
SUB_KM	Area of subbasin (km^2). Required.
SUB_LAT	Latitude of subbasin (degrees). The latitude is expressed as a real number with minutes and seconds converted to fractions of a degree. Required.
SUB_ELEV	Elevation of subbasin (m). Required.
IRGAGE	Number of the measured precipitation record used within subbasin. Required if measured precipitation data is to be used in simulation.
ITGAGE	Number of the measured temperature record used within the subbasin. Required if measured temperature data is to be used in simulation.
ISGAGE	Number of the solar radiation record used within the subbasin. Required if measured solar radiation data is to be used in simulation.
IHGAGE	Number of the relative humidity record used within the subbasin. Required if measured relative humidity data is to be used in simulation.
IWGAGE	Number of the wind speed record used within the subbasin. Required if measured wind speed data is to be used in simulation.

Variable name	Definition
WGNFILE	Name of subbasin weather generator data file (**.wgn**). This file is described in Chapter 12. Required.
FCST_REG	Weather forecast region number assigned to subbasin. Weather generator parameters for the forecast region are used to simulate climatic processes during the forecast period of a simulation. Required only if weather forecasting is being incorporated into the simulation.
ELEVB(band)	Elevation at the center of the elevation band (m). Orographic precipitation is a significant phenomenon in certain areas of the world. To account for orographic effects on both precipitation and temperature, SWAT allows up to 10 elevation bands to be defined in each subbasin. The only processes modeled separately for each individual elevation band are the accumulation, sublimation and melting of snow. As with the initial precipitation and temperature data, after amounts of sublimation and snow melt are determined for each elevation band, subbasin average values are calculated. These average values are the values that are used in the remainder of the simulation and reported in the output files. Required if elevation bands are simulated in the subbasin.
ELEVB_FR(band)	Fraction of subbasin area within the elevation band. Values for ELEVB_FR should be between 0.0 and 1.0. Required if elevation bands are simulated in the subbasin.
SNOEB(BAND)	Initial snow water content in elevation band (mm H2O). The amount of snow in the elevation band is expressed as depth of water instead of depth of snow because the density of snow is highly variable. Optional.

Variable name	Definition
PLAPS	Precipitation lapse rate (mm H_2O/km). A positive value denotes an increase in precipitation with an increase in elevation while a negative value denotes a decrease in precipitation with an increase in elevation. The lapse rate is used to adjust precipitation for elevation bands in the subbasin. To adjust the precipitation, the elevation of the recording station or the weather station is compared to the elevation specified for the elevation band. If no elevation bands are defined, the precipitation generated or read in from the .pcp file is used for the subbasin with no adjustment Required if elevation bands are simulated in the subbasin
TLAPS	Temperature lapse rate (ºC/km). A positive value denotes an increase in temperature with an increase in elevation while a negative value denotes a decrease in temperature with an increase in elevation. The lapse rate is used to adjust temperature for elevation bands in the subbasin. To adjust the temperature, the elevation of the recording station or the weather station is compared to the elevation specified for the elevation band. If no elevation bands are defined, the temperature generated or read in from the .tmp file is used for the subbasin with no adjustment. If no value is entered for TLAPS, the model sets TLAPS = -6 ºC/km. Required if elevation bands are simulated in the subbasin.
SNO_SUB	Initial snow water content (mm H2O). The amount of snow in the subbasin is expressed as depth of water instead of depth of snow because the density of snow is highly variable. This value is not used if the subbasin is divided into elevation bands (see variables ELEVB, ELEVB_FR and SNOEB in this file). Optional.

Variable name	Definition
CH_L(1)	Longest "tributary" channel length in subbasin (km). The channel length is the distance along the channel from the subbasin outlet to the most distant point in the subbasin. Required.
CH_S(1)	Average slope of tributary channels (m/m). The average channel slope is computed by taking the difference in elevation between the subbasin outlet and the most distant point in the subbasin and dividing by CH_L. Required.
CH_W(1)	Average width of tributary channels (m). Required.
CH_K(1)	Effective hydraulic conductivity in tributary channel alluvium (mm/hr). This parameter controls transmission losses from surface runoff as it flows to the main channel in the subbasin. Required.
CH_N(1)	Manning's "n" value for the tributary channels Required.

Table 6-1: Values of Manning's roughness coefficient, *n*, for channel flow (Chow, 1959).[1]

Characteristics of Channel	Median	Range
Excavated or dredged		
Earth, straight and uniform	0.025	0.016-0.033
Earth, winding and sluggish	0.035	0.023-0.050
Not maintained, weeds and brush	0.075	0.040-0.140
Natural streams		
Few trees, stones or brush	0.050	0.025-0.065
Heavy timber and brush	0.100	0.050-0.150

[1] Chow (1959) has a very extensive list of Manning's roughness coefficients. These values represent only a small portion of those he lists in his book.

Variable name	Definition
PNDFILE	Name of subbasin pond input data file (**.pnd**). This file is described in Chapter 28. Required.

Variable name	Definition
WUSFILE	Name of subbasin water use management data file (**.wus**). This file is described in Chapter 21. Required.
CO2	Carbon dioxide concentration (ppmv). If no value for CO2 is entered the model will set CO2 = 330 ppmv (ambient CO_2 concentration). Optional. Used only in climate change studies.
RFINC(mon)	Rainfall adjustment (% change). Daily rainfall within the month is adjusted by the specified percentage. For example, setting RFINC = 10 will make rainfall equal to 110% of the original value. Optional. Used only in climate change studies.
TMPINC(mon)	Temperature adjustment (ºC). Daily maximum and minimum temperatures within the month are raised or lowered by the specified amount. Optional. Used only in climate change studies.
RADINC(mon)	Radiation adjustment (MJ/m^2-day). Daily radiation within the month is raised or lowered by the specified amount. Optional. Used only in climate change studies.
HUMINC(mon)	Humidity adjustment. Daily values for relative humidity within the month are raised or lowered by the specified amount. The relative humidity in SWAT is reported as a fraction. Optional. Used only in climate change studies.
HRUTOT	Total number of HRUs modeled in the subbasin. Each subbasin must contain at least one HRU. HRUTOT includes special (pothole, floodplain, riparian) as well as generic HRUs. Required.
POT_HRUFILE	Name of pothole HRU general input data file (**.hru**). This file is described in Chapter 19. Optional.

Variable name	Definition
POT_MGFILE	Name of pothole HRU land use management data file (**.mgt**). This file is described in Chapter 20. Optional.
POT_SOLFILE	Name of pothole HRU soil data file (**.sol**). This file is described in Chapter 22. Optional.
POT_CHMFILE	Name of pothole HRU soil chemical data file (**.chm**). This file is described in Chapter 23. Optional.
POT_GWFILE	Name of pothole HRU groundwater data file (**.gw**). This file is described in Chapter 24. Optional.
FLD_HRUFILE	Name of floodplain HRU general input data file (**.hru**). *Not operational-future feature.*
FLD_MGTFILE	Name of floodplain HRU land use management data file (**.mgt**). *Not operational-future feature.*
FLD_SOLFILE	Name of floodplain HRU soil data file (**.sol**). *Not operational-future feature.*
FLD_CHMFILE	Name of floodplain HRU soil chemical data file (**.chm**). *Not operational-future feature.*
FLD_GWFILE	Name of floodplain HRU groundwater data file (**.gw**). *Not operational-future feature.*
RIP_HRUFILE	Name of riparian zone HRU general input data file (**.hru**). *Not operational-future feature.*
RIP_MGTFILE	Name of riparian zone HRU land use management data file (**.mgt**). *Not operational-future feature.*
RIP_SOLFILE	Name of riparian zone HRU soil data file (**.sol**). *Not operational-future feature.*

Variable name	Definition
RIP_CHMFILE	Name of riparian zone HRU soil chemical data file (**.chm**). *Not operational-future feature.*
RIP_GWFILE	Name of riparian zone HRU groundwater data file (**.gw**). *Not operational-future feature.*
HRUFILE	Name of generic HRU general input data file (**.hru**). This file is described in Chapter 19. Required.
MGTFILE	Name of generic HRU land use management data file (**.mgt**). This file is described in Chapter 20. Required.
SOLFILE	Name of generic HRU soil data file (**.sol**). This file is described in Chapter 22. Required.
CHMFILE	Name of generic HRU soil chemical data file (**.chm**). This file is described in Chapter 23. Required.
GWFILE	Name of generic HRU groundwater data file (**.gw**). This file is described in Chapter 24. Required.
OPSFILE	Name of generic HRU operation scheduling data file (**.ops**). This file is described in Chapter 33.
SEPTFILE	Name of generic HRU septic data file (**.sep**). This file is described in Chapter 34.
PFLAG	Pothole trigger. Identifies HRU as a pothole.

The subbasin general input file is partially free format and partially fixed format. The variables that are free format will have *free* listed in the **F90Format** column and will not have a position defined. The variables that are fixed format will have a FORTRAN format and position specified.

The free format variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line.

The fixed format variables must be entered using the specified format and positioning on the line in order for the model to read them properly.

The format for the subbasin general input file is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1	space 1-80	character	a80
SUB_KM	2		integer	free
Comment line	3	space 1-80	character	a80
Comment line	4	space 1-80	character	a80
SUB_LAT	5		real	free
SUB_ELEV	6		real	free
IRGAGE	7		integer	free
ITGAGE	8		integer	free
ISGAGE	9		integer	free
IHGAGE	10		integer	free
IWGAGE	11		integer	free
WGNFILE	12	space 1-13	character	a13
FCST_REG	13	space 1-13	character	a13
Comment line	14	space 1-80	character	a80
Comment line	15	space 1-80	character	a80
ELEVB(1)	16	space 1-8	decimal (xxxx.xxx)	f8.3
ELEVB(2)	16	space 9-16	decimal (xxxx.xxx)	f8.3
ELEVB(3)	16	space 17-24	decimal (xxxx.xxx)	f8.3
ELEVB(4)	16	space 25-32	decimal (xxxx.xxx)	f8.3
ELEVB(5)	16	space 33-40	decimal (xxxx.xxx)	f8.3
ELEVB(6)	16	space 41-48	decimal (xxxx.xxx)	f8.3
ELEVB(7)	16	space 49-56	decimal (xxxx.xxx)	f8.3
ELEVB(8)	16	space 57-64	decimal (xxxx.xxx)	f8.3
ELEVB(9)	16	space 65-72	decimal (xxxx.xxx)	f8.3
ELEVB(10)	16	space 73-80	decimal (xxxx.xxx)	f8.3
Comment line	17	space 1-80	character	a80
ELEVB_FR(1)	18	space 1-8	decimal (xxxx.xxx)	f8.3
ELEVB_FR(2)	18	space 9-16	decimal (xxxx.xxx)	f8.3

Variable name	Line #	Position	Format	F90 Format
ELEVB_FR(3)	18	space 17-24	decimal (xxxx.xxx)	f8.3
ELEVB_FR(4)	18	space 25-32	decimal (xxxx.xxx)	f8.3
ELEVB_FR(5)	18	space 33-40	decimal (xxxx.xxx)	f8.3
ELEVB_FR(6)	18	space 41-48	decimal (xxxx.xxx)	f8.3
ELEVB_FR(7)	18	space 49-56	decimal (xxxx.xxx)	f8.3
ELEVB_FR(8)	18	space 57-64	decimal (xxxx.xxx)	f8.3
ELEVB_FR(9)	18	space 65-72	decimal (xxxx.xxx)	f8.3
ELEVB_FR(10)	18	space 73-80	decimal (xxxx.xxx)	f8.3
Comment line	19	space 1-80	character	a80
SNOEB(1)	20	space 1-8	decimal (xxxx.xxx)	f8.3
SNOEB(2)	20	space 9-16	decimal (xxxx.xxx)	f8.3
SNOEB(3)	20	space 17-24	decimal (xxxx.xxx)	f8.3
SNOEB(4)	20	space 25-32	decimal (xxxx.xxx)	f8.3
SNOEB(5)	20	space 33-40	decimal (xxxx.xxx)	f8.3
SNOEB(6)	20	space 41-48	decimal (xxxx.xxx)	f8.3
SNOEB(7)	20	space 49-56	decimal (xxxx.xxx)	f8.3
SNOEB(8)	20	space 57-64	decimal (xxxx.xxx)	f8.3
SNOEB(9)	20	space 65-72	decimal (xxxx.xxx)	f8.3
SNOEB(10)	20	space 73-80	decimal (xxxx.xxx)	f8.3
PLAPS	21		real	free
TLAPS	22		real	free
SNO_SUB	23		real	free
Comment line	24	space 1-80	character	a80
CH_L(1)	25		real	free
CH_S(1)	26		real	free
CH_W(1)	27		real	free
CH_K(1)	28		real	free
CH_N(1)	29		real	free
Comment line	30	space 1-80	character	a80
PNDFILE	31	space 1-13	character	a13
Comment line	32	space 1-80	character	a80
WUSFILE	33	space 1-13	character	a13
Comment line	34	space 1-80	character	a80
CO2	35		real	free
Comment line	36	space 1-80	character	a80
RFINC(1)	37	space 1-8	decimal (xxxx.xxx)	f8.3

Variable name	Line #	Position	Format	F90 Format
RFINC(2)	37	space 9-16	decimal (xxxx.xxx)	f8.3
RFINC(3)	37	space 17-24	decimal (xxxx.xxx)	f8.3
RFINC(4)	37	space 25-32	decimal (xxxx.xxx)	f8.3
RFINC(5)	37	space 33-40	decimal (xxxx.xxx)	f8.3
RFINC(6)	37	space 41-48	decimal (xxxx.xxx)	f8.3
Comment line	38	space 1-80	character	a80
RFINC(7)	39	space 1-8	decimal (xxxx.xxx)	f8.3
RFINC(8)	39	space 9-16	decimal (xxxx.xxx)	f8.3
RFINC(9)	39	space 17-24	decimal (xxxx.xxx)	f8.3
RFINC(10)	39	space 25-32	decimal (xxxx.xxx)	f8.3
RFINC(11)	39	space 33-40	decimal (xxxx.xxx)	f8.3
RFINC(12)	39	space 41-48	decimal (xxxx.xxx)	f8.3
Comment line	40	space 1-80	character	a80
TMPINC(1)	41	space 1-8	decimal (xxxx.xxx)	f8.3
TMPINC(2)	41	space 9-16	decimal (xxxx.xxx)	f8.3
TMPINC(3)	41	space 17-24	decimal (xxxx.xxx)	f8.3
TMPINC(4)	41	space 25-32	decimal (xxxx.xxx)	f8.3
TMPINC(5)	41	space 33-40	decimal (xxxx.xxx)	f8.3
TMPINC(6)	41	space 41-48	decimal (xxxx.xxx)	f8.3
Comment line	42	space 1-80	character	a80
TMPINC(7)	43	space 1-8	decimal (xxxx.xxx)	f8.3
TMPINC(8)	43	space 9-16	decimal (xxxx.xxx)	f8.3
TMPINC(9)	43	space 17-24	decimal (xxxx.xxx)	f8.3
TMPINC(10)	43	space 25-32	decimal (xxxx.xxx)	f8.3
TMPINC(11)	43	space 33-40	decimal (xxxx.xxx)	f8.3
TMPINC(12)	43	space 41-48	decimal (xxxx.xxx)	f8.3
Comment line	44	space 1-80	character	a80
RADINC(1)	45	space 1-8	decimal (xxxx.xxx)	f8.3
RADINC(2)	45	space 9-16	decimal (xxxx.xxx)	f8.3
RADINC(3)	45	space 17-24	decimal (xxxx.xxx)	f8.3
RADINC(4)	45	space 25-32	decimal (xxxx.xxx)	f8.3
RADINC(5)	45	space 33-40	decimal (xxxx.xxx)	f8.3
RADINC(6)	45	space 41-48	decimal (xxxx.xxx)	f8.3
Comment line	46	space 1-80	character	a80
RADINC(7)	47	space 1-8	decimal (xxxx.xxx)	f8.3
RADINC(8)	47	space 9-16	decimal (xxxx.xxx)	f8.3

Variable name	Line #	Position	Format	F90 Format
RADINC(9)	47	space 17-24	decimal (xxxx.xxx)	f8.3
RADINC(10)	47	space 25-32	decimal (xxxx.xxx)	f8.3
RADINC(11)	47	space 33-40	decimal (xxxx.xxx)	f8.3
RADINC(12)	47	space 41-48	decimal (xxxx.xxx)	f8.3
Comment line	48	space 1-80	character	a80
HUMINC(1)	49	space 1-8	decimal (xxxx.xxx)	f8.3
HUMINC(2)	49	space 9-16	decimal (xxxx.xxx)	f8.3
HUMINC(3)	49	space 17-24	decimal (xxxx.xxx)	f8.3
HUMINC(4)	49	space 25-32	decimal (xxxx.xxx)	f8.3
HUMINC(5)	49	space 33-40	decimal (xxxx.xxx)	f8.3
HUMINC(6)	49	space 41-48	decimal (xxxx.xxx)	f8.3
Comment line	50	space 1-80	character	a80
HUMINC(7)	51	space 1-8	decimal (xxxx.xxx)	f8.3
HUMINC(8)	51	space 9-16	decimal (xxxx.xxx)	f8.3
HUMINC(9)	51	space 17-24	decimal (xxxx.xxx)	f8.3
HUMINC(10)	51	space 25-32	decimal (xxxx.xxx)	f8.3
HUMINC(11)	51	space 33-40	decimal (xxxx.xxx)	f8.3
HUMINC(12)	51	space 41-48	decimal (xxxx.xxx)	f8.3
Comment line	52	space 1-80	character	a80
HRUTOT	53		integer	free
Comment line	54	space 1-80	character	a80
Comment line	55	space 1-80	character	a80
POT_HRUFILE	56	space 1-13	character	a13
POT_MGTFILE	56	space 14-26	character	a13
POT_SOLFILE	56	space 27-39	character	a13
POT_CHMFILE	56	space 40-52	character	a13
POT_GWFILE	56	space 53-65	character	a13
Comment line	57	space 1-80	character	a80
FLD_HRUFILE	58	space 1-13	character	a13
FLD_MGTFILE	58	space 14-26	character	a13
FLD_SOLFILE	58	space 27-39	character	a13
FLD_CHMFILE	58	space 40-52	character	a13
FLD_GWFILE	58	space 53-65	character	a13
Comment line	59	space 1-80	character	a80
RIP_HRUFILE	60	space 1-13	character	a13
RIP_MGTFILE	60	space 14-26	character	a13

Variable name	Line #	Position	Format	F90 Format
RIP_SOLFILE	60	space 27-39	character	a13
RIP_CHMFILE	60	space 40-52	character	a13
RIP_GWFILE	60	space 53-65	character	a13
Comment line	61	space 1-80	character	a80
HRUFILE	62-END	space 1-13	character	a13
MGTFILE	62-END	space 14-26	character	a13
SOLFILE	62-END	space 27-39	character	a13
CHMFILE	62-END	space 40-52	character	a13
GWFILE	62-END	space 53-65	character	a13
OPSFILE	62-END	space 66-78	character	a13
SEPTFILE	62-END	space 79-91	character	a13
PFLAG	62-END	space 92-95	integer	i4

REFERENCES

Chow, V.T. 1959. Open-channel hydraulics. McGraw-Hill, New York.

CHAPTER 6

SWAT INPUT DATA: .PCP

SWAT requires daily precipitation. Values for precipitation may be read from records of observed data or they may be generated. This chapter describes the format of the file used to read in measured precipitation data.

Up to 18 precipitation files may be utilized in a simulation. The precipitation files are able to hold records for more than one gage, so there is not a limitation on the number of gages that can be used in a simulation.

The precipitation data may be read into the model in daily or sub-daily time increments. The following sections describe the format for a daily and a subdaily precipitation file.

6.1 DAILY PRECIPITATION DATA

Daily precipitation data is used when the SCS curve number method is chosen to model surface runoff (Set by IEVENT in the .bsn file, see Chapter 4).

While the input file must contain data for the entire period of simulation, the record does not have to begin with the first day of simulation. SWAT is able to search for the beginning date in the file, saving editing time on the user's part. Once SWAT locates the record for the beginning day of simulation, it no longer processes the year and date. Because it does not check the subsequent dates, it is very important that the data for the remaining days in the simulation are listed sequentially. (If no year and date are entered for any of the records, the model assumes the first line of data corresponds to the first day of simulation.)

Following is a brief description of the variables in the precipitation input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the precipitation file is reserved for comments. The title line is not processed by the model and may be left blank. Optional.
LATITUDE	Latitude of precipitation recording gage location. This value is not used by the model and may be left blank. Optional.
LONGITUDE	Longitude of precipitation recording gage location. This value is not used by the model and may be left blank. Optional.
ELEVATION	Elevation of precipitation recording gage (m). The elevation of the recording gage is used to adjust precipitation values for elevation in subbasins where elevation bands and a precipitation lapse rate are defined. Required if elevation bands are modeled in watershed.
YEAR	Year (4-digit). Required.

Variable name	Definition
DATE	Julian date. Required.
PRECIPITATION	Amount of precipitation falling during the day (mm). A negative 99.0 (-99.0) should be inserted for missing data. This value tells SWAT to generate precipitation for that day. Required.

The format of the daily precipitation file with one record is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1	unrestricted	character	unrestricted
LATITUDE	2	space 8-12	free	unrestricted
LONGITUDE	3	space 8-12	free	unrestricted
ELEVATION	4	space 8-12	integer	i5
YEAR	5-END	space 1-4	integer	i4
DATE	5-END	space 5-7	integer	i3
PRECIPITATION	5-END	space 8-12	decimal(xxx.x)	f5.1

To place more than one data record within the .pcp file, repeat the original formatting for the recorded data to the right of the existing data. Simulations have been run with 200 records placed in the precipitation files.

For example, assume there are records for six different rain gages stored in the daily .pcp. The formatting of the .pcp file is

Gage	Variable name	Line #	Position	Format	F90 Format
ALL	TITLE	1	unrestricted	character	unrestricted
1	LATITUDE	2	space 8-12	free	unrestricted
2	LATITUDE	2	space 13-17	free	unrestricted
3	LATITUDE	2	space 18-22	free	unrestricted
4	LATITUDE	2	space 23-27	free	unrestricted
5	LATITUDE	2	space 28-32	free	unrestricted
6	LATITUDE	2	space 33-37	free	unrestricted
1	LONGITUDE	3	space 8-12	free	unrestricted
2	LONGITUDE	3	space 13-17	free	unrestricted

Gage	Variable name	Line #	Position	Format	F90 Format
3	LONGITUDE	3	space 18-22	free	unrestricted
4	LONGITUDE	3	space 23-27	free	unrestricted
5	LONGITUDE	3	space 28-32	free	unrestricted
6	LONGITUDE	3	space 33-37	free	unrestricted
1	ELEVATION	4	space 8-12	integer	i5
2	ELEVATION	4	space 13-17	integer	i5
3	ELEVATION	4	space 18-22	integer	i5
4	ELEVATION	4	space 23-27	integer	i5
5	ELEVATION	4	space 28-32	integer	i5
6	ELEVATION	4	space 33-37	integer	i5
ALL	YEAR	5-END	space 1-4	4-digit integer	i4
ALL	DATE	5-END	space 5-7	3-digit integer	i3
1	PRECIPITATION	5-END	space 8-12	decimal(xxx.x)	f5.1
2	PRECIPITATION	5-END	space 13-17	decimal(xxx.x)	f5.1
3	PRECIPITATION	5-END	space 18-22	decimal(xxx.x)	f5.1
4	PRECIPITATION	5-END	space 23-27	decimal(xxx.x)	f5.1
5	PRECIPITATION	5-END	space 28-32	decimal(xxx.x)	f5.1
6	PRECIPITATION	5-END	space 33-37	decimal(xxx.x)	f5.1

6.2 SUB-DAILY PRECIPITATION DATA

Sub-daily precipitation data is required if the Green & Ampt infiltration method is being used (Set by IEVENT in the .bsn file, see Chapter 4).

While the input file must contain data for the entire period of simulation, the record does not have to begin with the first day of simulation. SWAT is able to search for the beginning date in the file, saving editing time on the user's part. Unlike the daily precipitation data, SWAT verifies that the date is correct on all lines. If the model reads in an incorrect date, it will print an error message to the *input.std* file stating the day and year in the precipitation record where the inconsistency is located and the program will stop.

The number of lines of precipitation data per day is governed by the time step used (IDT in file.cio, see Chapter 3). To save space, only one line is required for days with no rain at all. When SWAT reads a blank for the delimiter (see variable list below), it knows that all time steps on the day have no precipitation and that there are no more lines of precipitation data for that day.

Following is a brief description of the variables in the sub-daily precipitation input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the precipitation file is reserved for comments. The title line is not processed by the model and may be left blank. Optional.
LATITUDE	Latitude of precipitation recording gage location. This value is not used by the model and may be left blank. Optional.
LONGITUDE	Longitude of precipitation recording gage location. This value is not used by the model and may be left blank. Optional.
ELEVATION	Elevation of precipitation recording gage (m). The elevation of the recording gage is used to adjust precipitation values for elevation in subbasins where elevation bands and a precipitation lapse rate are defined. Required if elevation bands modeled in watershed.
YEAR	Year (4-digit). Required.
DATE	Julian date. Required.
HOUR	Hour of day (0-23). The hour and minute are at the end of the time step. Required.
DELIMITER	Space is allowed on the line for a colon to separate the hour and minute readings. The delimiter is used by the model to identify days where there is no rain and only one line is present for the day in the .pcp file. If a blank space is inserted instead of the colon, the model will assign zero precipitation to all time steps on the day. Required.

Variable name	Definition
MINUTE	Minute of hour (0-59). The hour and minute are at the end of the time step. Required.
PRECIPITATION	Amount of precipitation falling in the time period (mm). A negative 99.0 (-99.0) should be inserted for missing data. This value tells SWAT to generate precipitation for that day. Precipitation values will be generated for the entire day. If the record for a given day has missing values for only part of the day, all provided values are ignored and the weather generator sets values for the entire day. Required.

The format of the sub-daily precipitation file with one record is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1	unrestricted	character	unrestricted
LATITUDE	2	space 13-17	free	unrestricted
LONGITUDE	3	space 13-17	free	unrestricted
ELEVATION	4	space 13-17	integer	i5
YEAR	5-END	space 1-4	integer	i4
DATE	5-END	space 5-7	integer	i3
HOUR	5-END	space 8-9	integer	i2
DELIMITER	5-END	space 10	character	a1
MINUTE	5-END	space 11-12	integer	i2
PRECIPITATION	5-END	space 13-17	decimal(xxx.x)	f5.1

To place more than one data record within the .pcp file, repeat the original formatting for the recorded data to the right of the existing data. Simulations have been run with 200 records placed in the precipitation files.

For example, assume there are records for six different rain gages stored in the sub-daily .pcp. The formatting of the .pcp file is

Gage	Variable name	Line #	Position	Format	F90 Format
ALL	TITLE	1	unrestricted	character	unrestricted
1	LATITUDE	2	space 13-17	free	unrestricted
2	LATITUDE	2	space 18-22	free	unrestricted

Gage	Variable name	Line #	Position	Format	F90 Format
3	LATITUDE	2	space 23-27	free	unrestricted
4	LATITUDE	2	space 28-32	free	unrestricted
5	LATITUDE	2	space 33-37	free	unrestricted
6	LATITUDE	2	space 38-42	free	unrestricted
1	LONGITUDE	3	space 13-17	free	unrestricted
2	LONGITUDE	3	space 18-22	free	unrestricted
3	LONGITUDE	3	space 23-27	free	unrestricted
4	LONGITUDE	3	space 28-32	free	unrestricted
5	LONGITUDE	3	space 33-37	free	unrestricted
6	LONGITUDE	3	space 38-42	free	unrestricted
1	ELEVATION	4	space 13-17	integer	i5
2	ELEVATION	4	space 18-22	integer	i5
3	ELEVATION	4	space 23-27	integer	i5
4	ELEVATION	4	space 28-32	integer	i5
5	ELEVATION	4	space 33-37	integer	i5
6	ELEVATION	4	space 38-42	integer	i5
ALL	YEAR	5-END	space 1-4	4-digit integer	i4
ALL	DATE	5-END	space 5-7	3-digit integer	i3
ALL	HOUR	5-END	space 8-9	integer	i2
ALL	DELIMITER	5-END	space 10	character	a1
ALL	MINUTE	5-END	space 11-12	integer	i2
1	PRECIPITATION	5-END	space 13-17	decimal(xxx.x)	f5.1
2	PRECIPITATION	5-END	space 18-22	decimal(xxx.x)	f5.1
3	PRECIPITATION	5-END	space 23-27	decimal(xxx.x)	f5.1
4	PRECIPITATION	5-END	space 28-32	decimal(xxx.x)	f5.1
5	PRECIPITATION	5-END	space 33-37	decimal(xxx.x)	f5.1
6	PRECIPITATION	5-END	space 38-42	decimal(xxx.x)	f5.1

CHAPTER 7

SWAT INPUT DATA: .TMP

SWAT requires daily maximum and minimum air temperature. Temperature data may be read from records of observed data or they may be generated. This chapter reviews the file used to store measured temperature data.

Up to 18 temperature files may be utilized in a simulation. The temperature files are able to hold records for more than one gage, so there is not a limitation on the number of gages that can be used in a simulation.

As with the precipitation file, the record in the temperature input file does not have to begin with the first day of simulation. SWAT is able to search for the beginning date in the temperature file and all the comments made for this feature in the discussion of the precipitation file pertain to the temperature file as well.

Following is a brief description of the variables in the temperature input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the temperature file is reserved for comments. The title line is not processed by the model and may be left blank. Optional.
LATITUDE	Latitude of temperature recording gage location. This value is not used by the model and may be left blank. Optional.
LONGITUDE	Longitude of temperature recording gage location. This value is not used by the model and may be left blank. Optional.
ELEVATION	Elevation of temperature recording gage (m). The elevation of the recording gage is used to adjust temperature values for elevation in subbasins where elevation bands are defined. Required if elevation bands are modeled in watershed.
YEAR	Year (4-digit). Required.
DATE	Julian date. Required.
MAX TEMP	Daily maximum temperature (ºC). A negative 99.0 (-99.0) should be inserted for missing maximum temperatures. This value tells SWAT to generate the missing value(s). Required.
MIN TEMP	Daily minimum temperature (ºC). A negative 99.0 (-99.0) should be inserted for missing minimum temperatures. This value tells SWAT to generate the missing value(s). Required.

The format of the temperature file with one record is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1	unrestricted	character	unrestricted
LATITUDE	2	space 8-17	free	
LONGITUDE	3	space 8-17	free	
ELEVATION	4	space 8-17	integer	i10
YEAR	5-END	space 1-4	4-digit integer	i4
DATE	5-END	space 5-7	3-digit integer	i3
MAX TEMP	5-END	space 8-12	decimal(xxx.x)	f5.1
MIN TEMP	5-END	space 13-17	decimal(xxx.x)	f5.1

To place more than one data record within the .tmp file, repeat the original formatting for the recorded data to the right of the existing data. Simulations have been run with 150 records placed in the temperature files.

For example, assume there are records for three different temperature gages stored in the .tmp. The formatting of the .tmp file is

Gage	Variable name	Line #	Position	Format	F90 Format
ALL	TITLE	1	unrestricted	character	unrestricted
1	LATITUDE	2	space 8-17	free	unrestricted
2	LATITUDE	2	space 18-27	free	unrestricted
3	LATITUDE	2	space 28-37	free	unrestricted
1	LONGITUDE	3	space 8-17	free	unrestricted
2	LONGITUDE	3	space 18-27	free	unrestricted
3	LONGITUDE	3	space 28-37	free	unrestricted
1	ELEVATION	4	space 8-17	integer	i10
2	ELEVATION	4	space 18-27	integer	i10
3	ELEVATION	4	space 28-37	integer	i10
ALL	YEAR	5-END	space 1-4	4-digit integer	i4
ALL	DATE	5-END	space 5-7	3-digit integer	i3
1	MAX TEMP	5-END	space 8-12	decimal(xxx.x)	f5.1
1	MIN TEMP	5-END	space 13-17	decimal(xxx.x)	f5.1
2	MAX TEMP	5-END	space 18-22	decimal(xxx.x)	f5.1
2	MIN TEMP	5-END	space 23-27	decimal(xxx.x)	f5.1
3	MAX TEMP	5-END	space 28-32	decimal(xxx.x)	f5.1
3	MIN TEMP	5-END	space 33-37	decimal(xxx.x)	f5.1

CHAPTER 8

SWAT INPUT DATA: .SLR

SWAT requires daily solar radiation values. These values may be read from records of observed data or they may be generated. This chapter reviews the file used to read in measured solar radiation data.

One solar radiation file may be used in a simulation. This file is able to hold records for more than one gage, so there is not a limitation on the number of gages that can be used in a simulation.

As with the precipitation file, the record in the solar radiation input file does not have to begin with the first day of simulation. SWAT is able to search for the beginning date in the solar radiation file and all the comments made for this feature in the discussion of the precipitation file pertain to the solar radiation file as well.

Following is a brief description of the variables in the solar radiation input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the solar radiation file is reserved for comments. The title line is not processed by the model and may be left blank. Optional.
YEAR	Year (4-digit). Required.
DATE	Julian date. Required.
SOL_RAD	Daily total solar radiation (MJ/m^2). A negative 99.0 (-99.0) should be inserted for missing radiation values. This value tells SWAT to generate the missing value(s). Required.

The format of the solar radiation input file with one record is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1	unrestricted	character	unrestricted
YEAR	2-END	space 1-4	4-digit integer	i4
DATE	2-END	space 5-7	3-digit integer	i3
SOL_RAD	2-END	space 8-15	decimal(xxxx.xxx)	f8.3

To place more than one data record within the .slr file, repeat the original formatting for the recorded data to the right of the existing data.

For example, assume there are records for six different solar radiation gages stored in the .slr. The formatting of the .slr file is

Gage	Variable name	Line #	Position	Format	F90 Format
ALL	TITLE	1	unrestricted	character	unrestricted
ALL	YEAR	2-END	space 1-4	4-digit integer	i4
ALL	DATE	2-END	space 5-7	3-digit integer	i3
1	SOL_RAD	2-END	space 8-15	decimal(xxxx.xxx)	f8.3
2	SOL_RAD	2-END	space 16-23	decimal(xxxx.xxx)	f8.3
3	SOL_RAD	2-END	space 24-31	decimal(xxxx.xxx)	f8.3
4	SOL_RAD	2-END	space 32-39	decimal(xxxx.xxx)	f8.3
5	SOL_RAD	2-END	space 40-47	decimal(xxxx.xxx)	f8.3
6	SOL_RAD	2-END	space 48-55	decimal(xxxx.xxx)	f8.3

CHAPTER 9

SWAT INPUT DATA: .WND

SWAT requires daily wind speed values when the Penman-Monteith method is selected to calculate potential evapotranspiration. Values for all these parameters may be read from records of observed data or they may be generated. This chapter reviews the input file used to read in measured daily wind speed values.

One wind speed input file may be used in a simulation. This file is able to hold records for more than one gage, so there is not a limitation on the number of gages that can be used in a simulation.

As with the precipitation file, the record in the wind speed input file does not have to begin with the first day of simulation. SWAT is able to search for the beginning date in the wind speed file and all the comments made for this feature in the discussion of the precipitation file pertain to the wind speed file as well.

Following is a brief description of the variables in the wind speed input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the wind speed file is reserved for comments. The title line is not processed by the model and may be left blank. Optional.
YEAR	Year (4-digit). Required.
DATE	Julian date. Required.
WND_SP	Daily average wind speed (m/s). A negative 99.0 (-99.0) should be inserted for missing wind speed values. This value tells SWAT to generate the missing value(s). Required.

The format of the wind speed input file with one record is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1	unrestricted	character	unrestricted
YEAR	2-END	space 1-4	4-digit integer	i4
DATE	2-END	space 5-7	3-digit integer	i3
WND_SP	2-END	space 8-15	decimal(xxxx.xxx)	f8.3

To place more than one data record within the .wnd file, repeat the original formatting for the recorded data to the right of the existing data.

For example, assume there are records for ten different wind speed gages stored in the .wnd. The formatting of the .wnd file is

Gage	Variable name	Line #	Position	Format	F90 Format
ALL	TITLE	1	unrestricted	character	unrestricted
ALL	YEAR	2-END	space 1-4	4-digit integer	i4
ALL	DATE	2-END	space 5-7	3-digit integer	i3
1	WND_SP	2-END	space 8-15	decimal(xxxx.xxx)	f8.3
2	WND_SP	2-END	space 16-23	decimal(xxxx.xxx)	f8.3
3	WND_SP	2-END	space 24-31	decimal(xxxx.xxx)	f8.3
4	WND_SP	2-END	space 32-39	decimal(xxxx.xxx)	f8.3
5	WND_SP	2-END	space 40-47	decimal(xxxx.xxx)	f8.3
6	WND_SP	2-END	space 48-55	decimal(xxxx.xxx)	f8.3
7	WND_SP	2-END	space 56-63	decimal(xxxx.xxx)	f8.3
8	WND_SP	2-END	space 64-71	decimal(xxxx.xxx)	f8.3
9	WND_SP	2-END	space 72-79	decimal(xxxx.xxx)	f8.3
10	WND_SP	2-END	space 80-87	decimal(xxxx.xxx)	f8.3

CHAPTER 10

SWAT INPUT DATA: .HMD

SWAT requires daily relative humidity values when the Penman-Monteith or Priestley-Taylor method is used to calculate potential evapotranspiration and for the calculation of vapor stress on plant growth. Values for relative humidity may be read from records of observed data or they may be generated. This chapter reviews the input file used to read relative humidity values into the model.

One relative humidity input file may be used in a simulation. This file is able to hold records for more than one gage, so there is not a limitation on the number of gages that can be used in a simulation.

As with the precipitation file, the record in the relative humidity input file does not have to begin with the first day of simulation. SWAT is able to search for the beginning date in the relative humidity file and all the comments made for this feature in the discussion of the precipitation file pertain to the relative humidity file as well.

Following is a brief description of the variables in the relative humidity input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the relative humidity file is reserved for comments. The title line is not processed by the model and may be left blank. Optional.
YEAR	Year (4-digit). Required.
DATE	Julian date. Required.
RHD	Daily average relative humidity expressed as a fraction. A negative 99.0 (-99.0) should be inserted for missing relative humidity values. This value tells SWAT to generate the missing value(s). Required.

The format of the relative humidity input file with one record is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1	unrestricted	character	unrestricted
YEAR	2-END	space 1-4	4-digit integer	i4
DATE	2-END	space 5-7	3-digit integer	i3
RHD	2-END	space 8-15	decimal(xxxx.xxx)	f8.3

To place more than one data record within the .hmd file, repeat the original formatting for the recorded data to the right of the existing data.

For example, assume there are records for five different relative humidity gages stored in the .hmd file. The formatting of the .hmd file is

Gage	Variable name	Line #	Position	Format	F90 Format
ALL	TITLE	1	unrestricted	character	unrestricted
ALL	YEAR	2-END	space 1-4	4-digit integer	i4
ALL	DATE	2-END	space 5-7	3-digit integer	i3
1	RHD	2-END	space 8-15	decimal(xxxx.xxx)	f8.3
2	RHD	2-END	space 16-23	decimal(xxxx.xxx)	f8.3
3	RHD	2-END	space 24-31	decimal(xxxx.xxx)	f8.3
4	RHD	2-END	space 32-39	decimal(xxxx.xxx)	f8.3
5	RHD	2-END	space 40-47	decimal(xxxx.xxx)	f8.3

CHAPTER 11

SWAT INPUT DATA: .PET

SWAT requires daily potential evapotranspiration values. If the user wishes to calculate potential evapotranspiration using a method other than Penman-Monteith, Priestley-Taylor, or Hargreaves, the potential evapotranspiration values can be read in using the .pet file. The potential evapotranspiration file holds only one record that is used for the entire watershed.

As with the precipitation file, the record in the potential evapotranspiration input file does not have to begin with the first day of simulation. SWAT is able to search for the beginning date in the potential evapotranspiration input file and all the comments made for this feature in the discussion of the precipitation file pertain to the potential evapotranspiration file as well.

Following is a brief description of the variables in the potential evapotranspiration input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the potential evapotranspiration file is reserved for comments. The title line is not processed by the model and may be left blank. Optional.
YEAR	Year (4-digit). Required.
DATE	Julian date. Required.
PETMEAS	Daily potential evapotranspiration for watershed (mm H_2O). Required.

The format of the potential evapotranspiration input file is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1	unrestricted	character	unrestricted
YEAR	2-END	space 1-4	4-digit integer	i4
DATE	2-END	space 5-7	3-digit integer	i3
PETMEAS	2-END	space 8-12	decimal(xxx.x)	f5.1

CHAPTER 12

SWAT INPUT DATA: .WGN

SWAT requires daily precipitation, maximum/minimum air temperature, solar radiation, wind speed and relative humidity. Values for all these parameters may be read from records of observed data or they may be generated.

The weather generator input file contains the statistical data needed to generate representative daily climate data for the subbasins. Ideally, at least 20 years of records are used to calculate parameters in the .wgn file. Climatic data will be generated in two instances: when the user specifies that simulated weather will be used or when measured data is missing.

Following is a brief description of the variables in the weather generator input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the .wgn file is reserved for user comments. The comments may take up to 80 spaces. The title line is not processed by the model and may be left blank. Optional.
WLATITUDE	Latitude of weather station used to create statistical parameters (degrees). The latitude is expressed as a real number with minutes and seconds converted to fractions of a degree. Required.
WLONGITUDE	Longitude of weather station (degrees). This variable is not used by the model and may be left blank. Optional.
WELEV	Elevation of weather station (m). Required if elevation bands are modeled in watershed.
RAIN_YRS	The number of years of maximum monthly 0.5 h rainfall data used to define values for RAIN_HHMX(1) - RAIN_HHMX(12). If no value is input for RAIN_YRS, SWAT will set RAIN_YRS = 10. Required.
TMPMX(mon)	Average or mean daily maximum air temperature for month (ºC). This value is calculated by summing the maximum air temperature for every day in the month for all years of record and dividing by the number of days summed:

Variable name	Definition
TMPMX(mon), cont.	$$\mu mx_{mon} = \frac{\sum_{d=1}^{N} T_{mx,mon}}{N}$$ where μmx_{mon} is the mean daily maximum temperature for the month (°C), $T_{mx,mon}$ is the daily maximum temperature on record d in month mon (°C), and N is the total number of daily maximum temperature records for month mon. Required.
TMPMN(mon)	Average or mean daily minimum air temperature for month (ºC). This value is calculated by summing the minimum air temperature for every day in the month for all years of record and dividing by the number of days summed: $$\mu mn_{mon} = \frac{\sum_{d=1}^{N} T_{mn,mon}}{N}$$ where μmn_{mon} is the mean daily minimum temperature for the month (°C), $T_{mn,mon}$ is the daily minimum temperature on record d in month mon (°C), and N is the total number of daily minimum temperature records for month mon. Required.
TMPSTDMX(mon)	Standard deviation for daily maximum air temperature in month (ºC). This parameter quantifies the variability in maximum temperature for each month. The standard deviation is calculated: $$\sigma mx_{mon} = \sqrt{\left(\frac{\sum_{d=1}^{N} \left(T_{mx,mon} - \mu mx_{mon}\right)^2}{N-1}\right)}$$

Variable name	Definition
TMPSTDMX(mon), cont.	where σmx_{mon} is the standard deviation for daily maximum temperature in month mon (ºC), $T_{mx,mon}$ is the daily maximum temperature on record d in month mon (°C), μmx_{mon} is the average daily maximum temperature for the month (°C), and N is the total number of daily maximum temperature records for month mon. Required.
TMPSTDMN(mon)	Standard deviation for daily minimum air temperature in month (ºC). This parameter quantifies the variability in minimum temperature for each month. The standard deviation is calculated: $$\sigma mn_{mon} = \sqrt{\left(\frac{\sum_{d=1}^{N} \left(T_{mn,mon} - \mu mn_{mon} \right)^2}{N-1} \right)}$$ where σmn_{mon} is the standard deviation for daily minimum temperature in month mon (ºC), $T_{mn,mon}$ is the daily minimum temperature on record d in month mon (°C), μmn_{mon} is the average daily minimum temperature for the month (°C), and N is the total number of daily minimum temperature records for month mon. Required.
PCPMM(mon)	Average or mean total monthly precipitation (mm H_2O). $$\bar{R}_{mon} = \frac{\sum_{d=1}^{N} R_{day,mon}}{yrs}$$ where $\bar{R}_{mon}$ is the mean monthly precipitation (mm H_2O), $R_{day,mon}$ is the daily precipiation for record d in month mon (mm H_2O), N is the total number of records in month mon used to calculate the average, and yrs is the number of years of daily precipitation records used in calculation. Required.

Variable name	Definition
PCPSTD(mon)	Standard deviation for daily precipitation in month (mm H_2O/day). This parameter quantifies the variability in precipitation for each month. The standard deviation is calculated: $$\sigma_{mon} = \sqrt{\left(\frac{\sum_{d=1}^{N}\left(R_{day,mon} - \bar{R}_{mon}\right)^2}{N-1}\right)}$$ where σ_{mon} is the standard deviation for daily precipitation in month mon (mm H_2O), $R_{day,mon}$ is the amount of precipitation for record d in month mon (mm H_2O), $\bar{R}_{mon}$ is the average precipitation for the month (mm H_2O), and N is the total number of daily precipitation records for month mon. (Note: daily precipitation values of 0 mm are included in the standard deviation calculation). Required.
PCPSKW(mon)	Skew coefficient for daily precipitation in month. This parameter quantifies the symmetry of the precipitation distribution about the monthly mean. The skew coefficient is calculated: $$g_{mon} = \frac{N \cdot \sum_{d=1}^{N}\left(R_{day,mon} - \bar{R}_{mon}\right)^3}{(N-1)\cdot(N-2)\cdot\left(\sigma_{mon}\right)^3}$$ where g_{mon} is the skew coefficient for precipitation in the month, N is the total number of daily precipitation records for month mon, $R_{day,mon}$ is the amount of precipitation for record d in month mon (mm H_2O), $\bar{R}_{mon}$ is the average precipitation for the month (mm H_2O), and σ_{mon} is the standard deviation for daily precipitation in month mon (mm H_2O). (Note: daily precipitation values of 0 mm are included in the skew coefficient calculation). Required.

Variable name	Definition
PR_W(1,mon)	Probability of a wet day following a dry day in the month. This probability is calculated: $$P_i(W/D) = \frac{days_{W/D,i}}{days_{dry,i}}$$ where $P_i(W/D)$ is the probability of a wet day following a dry day in month i, $days_{W/D,i}$ is the number of times a wet day followed a dry day in month i for the entire period of record, and $days_{dry,i}$ is the number of dry days in month i during the entire period of record. A dry day is a day with 0 mm of precipitation. A wet day is a day with > 0 mm precipitation. Required.
PR_W(2,mon)	Probability of a wet day following a wet day in the month. This probability is calculated: $$P_i(W/W) = \frac{days_{W/W,i}}{days_{wet,i}}$$ where $P_i(W/W)$ is the probability of a wet day following a wet day in month i, $days_{W/W,i}$ is the number of times a wet day followed a wet day in month i for the entire period of record, and $days_{wet,i}$ is the number of wet days in month i during the entire period of record. A dry day is a day with 0 mm of precipitation. A wet day is a day with > 0 mm precipitation. Required.
PCPD(mon)	Average number of days of precipitation in month. This parameter is calculated: $$\bar{d}_{wet,i} = \frac{days_{wet,i}}{yrs}$$ where $\bar{d}_{wet,i}$ is the average number of days of precipitation in month i, $days_{wet,i}$ is the number of wet days in month i during the entire period of record, and yrs is the number of years of record. Required.

Variable name	Definition
RAINHHMX(mon)	Maximum 0.5 hour rainfall in entire period of record for month (mm H_2O). This value represents the most extreme 30-minute rainfall intensity recorded in the entire period of record. Required.
SOLARAV(mon)	Average daily solar radiation for month ($MJ/m^2/day$). This value is calculated by summing the total solar radiation for every day in the month for all years of record and dividing by the number of days summed: $$\mu rad_{mon} = \frac{\sum_{d=1}^{N} H_{day,mon}}{N}$$ where μrad_{mon} is the mean daily solar radiation for the month ($MJ/m^2/day$), $H_{day,mon}$ is the total solar radiation reaching the earth's surface for day d in month mon ($MJ/m^2/day$), and N is the total number of daily solar radiation records for month mon. Required.

Variable name	Definition
DEWPT(mon)	Average daily dew point temperature for each month (ºC) or relative humidity (fraction) can be input. If all twelve months are less than one, the model assumes relative humidity is input. Relative humidity is defined in equation 1:3.5.1 in the SWAT Theoretical documentation as the amount of water vapor in the air as a fraction of saturation humidity. If any month has a value greater than 1.0, the model assumes dewpoint temperature is input. Dew point temperature is the temperature at which the actual vapor pressure present in the atmosphere is equal to the saturation vapor pressure. This value is calculated by summing the dew point temperature for every day in the month for all years of record and dividing by the number of days summed: $$\mu dew_{mon} = \frac{\sum_{d=1}^{N} T_{dew,mon}}{N}$$ where μdew_{mon} is the mean daily dew point temperature for the month (ºC), $T_{dew,mon}$ is the dew point temperature for day d in month mon (ºC), and N is the total number of daily dew point records for month mon. Dew point is converted to relative humidity using equations 1:3.5.1 and 1:3.5.2 in the Theoretical Documentation. Required for Penman-Monteith potential evaporation equation.
WNDAV(mon)	Average daily wind speed in month (m/s). This value is calculated by summing the average or mean wind speed values for every day in the month for all years of record and dividing by the number of days summed: $$\mu wnd_{mon} = \frac{\sum_{d=1}^{N} \mu_{wnd,mon}}{N}$$ where μwnd_{mon} is the mean daily wind speed for the month (m/s), $\mu_{wnd,mon}$ is the average wind speed for day d in month mon (m/s), and N is the total number of daily wind speed records for month mon. Required.

The format of the weather generator input file is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1	space 1-80	character	a80
WLATITUDE	2	space 13-19	decimal(xxxx.xx)	f7.2
WLONGITUDE	2	space 32-38	decimal(xxxx.xx)	f7.2
WELEV	3	space 13-19	decimal(xxxx.xx)	f7.2
RAIN_YRS	4	space 13-19	decimal(xxxx.xx)	f7.2
TMPMX(1)	5	space 1-6	decimal(xxx.xx)	f6.2
TMPMX(2)	5	space 7-12	decimal(xxx.xx)	f6.2
TMPMX(3)	5	space 13-18	decimal(xxx.xx)	f6.2
TMPMX(4)	5	space 19-24	decimal(xxx.xx)	f6.2
TMPMX(5)	5	space 25-30	decimal(xxx.xx)	f6.2
TMPMX(6)	5	space 31-36	decimal(xxx.xx)	f6.2
TMPMX(7)	5	space 37-42	decimal(xxx.xx)	f6.2
TMPMX(8)	5	space 43-48	decimal(xxx.xx)	f6.2
TMPMX(9)	5	space 49-54	decimal(xxx.xx)	f6.2
TMPMX(10)	5	space 55-60	decimal(xxx.xx)	f6.2
TMPMX(11)	5	space 61-66	decimal(xxx.xx)	f6.2
TMPMX(12)	5	space 67-72	decimal(xxx.xx)	f6.2
TMPMN(1)	6	space 1-6	decimal(xxx.xx)	f6.2
TMPMN(2)	6	space 7-12	decimal(xxx.xx)	f6.2
TMPMN(3)	6	space 13-18	decimal(xxx.xx)	f6.2
TMPMN(4)	6	space 19-24	decimal(xxx.xx)	f6.2
TMPMN(5)	6	space 25-30	decimal(xxx.xx)	f6.2
TMPMN(6)	6	space 31-36	decimal(xxx.xx)	f6.2
TMPMN(7)	6	space 37-42	decimal(xxx.xx)	f6.2
TMPMN(8)	6	space 43-48	decimal(xxx.xx)	f6.2
TMPMN(9)	6	space 49-54	decimal(xxx.xx)	f6.2
TMPMN(10)	6	space 55-60	decimal(xxx.xx)	f6.2
TMPMN(11)	6	space 61-66	decimal(xxx.xx)	f6.2
TMPMN(12)	6	space 67-72	decimal(xxx.xx)	f6.2
TMPSTDMX(1)	7	space 1-6	decimal(xxx.xx)	f6.2
TMPSTDMX(2)	7	space 7-12	decimal(xxx.xx)	f6.2
TMPSTDMX(3)	7	space 13-18	decimal(xxx.xx)	f6.2

Variable name	**Line #**	**Position**	**Format**	**F90 Format**
TMPSTDMX(4)	7	space 19-24	decimal(xxx.xx)	f6.2
TMPSTDMX(5)	7	space 25-30	decimal(xxx.xx)	f6.2
TMPSTDMX(6)	7	space 31-36	decimal(xxx.xx)	f6.2
TMPSTDMX(7)	7	space 37-42	decimal(xxx.xx)	f6.2
TMPSTDMX(8)	7	space 43-48	decimal(xxx.xx)	f6.2
TMPSTDMX(9)	7	space 49-54	decimal(xxx.xx)	f6.2
TMPSTDMX(10)	7	space 55-60	decimal(xxx.xx)	f6.2
TMPSTDMX(11)	7	space 61-66	decimal(xxx.xx)	f6.2
TMPSTDMX(12)	7	space 67-72	decimal(xxx.xx)	f6.2
TMPSTDMN(1)	8	space 1-6	decimal(xxx.xx)	f6.2
TMPSTDMN(2)	8	space 7-12	decimal(xxx.xx)	f6.2
TMPSTDMN(3)	8	space 13-18	decimal(xxx.xx)	f6.2
TMPSTDMN(4)	8	space 19-24	decimal(xxx.xx)	f6.2
TMPSTDMN(5)	8	space 25-30	decimal(xxx.xx)	f6.2
TMPSTDMN(6)	8	space 31-36	decimal(xxx.xx)	f6.2
TMPSTDMN(7)	8	space 37-42	decimal(xxx.xx)	f6.2
TMPSTDMN(8)	8	space 43-48	decimal(xxx.xx)	f6.2
TMPSTDMN(9)	8	space 49-54	decimal(xxx.xx)	f6.2
TMPSTDMN(10)	8	space 55-60	decimal(xxx.xx)	f6.2
TMPSTDMN(11)	8	space 61-66	decimal(xxx.xx)	f6.2
TMPMN(3)	6	space 13-18	decimal(xxx.xx)	f6.2
TMPSTDMN(12)	8	space 67-72	decimal(xxx.xx)	f6.2
PCPMM(1)	9	space 1-6	decimal(xxx.xx)	f6.2
PCPMM(2)	9	space 7-12	decimal(xxx.xx)	f6.2
PCPMM(3)	9	space 13-18	decimal(xxx.xx)	f6.2
PCPMM(4)	9	space 19-24	decimal(xxx.xx)	f6.2
PCPMM(5)	9	space 25-30	decimal(xxx.xx)	f6.2
PCPMM(6)	9	space 31-36	decimal(xxx.xx)	f6.2
PCPMM(7)	9	space 37-42	decimal(xxx.xx)	f6.2
PCPMM(8)	9	space 43-48	decimal(xxx.xx)	f6.2
PCPMM(9)	9	space 49-54	decimal(xxx.xx)	f6.2
PCPMM(10)	9	space 55-60	decimal(xxx.xx)	f6.2
PCPMM(11)	9	space 61-66	decimal(xxx.xx)	f6.2
PCPMM(12)	9	space 67-72	decimal(xxx.xx)	f6.2

Variable name	Line #	Position	Format	F90 Format
PCPSTD(1)	10	space 1-6	decimal(xxx.xx)	f6.2
PCPSTD(2)	10	space 7-12	decimal(xxx.xx)	f6.2
PCPSTD(3)	10	space 13-18	decimal(xxx.xx)	f6.2
PCPSTD(4)	10	space 19-24	decimal(xxx.xx)	f6.2
PCPSTD(5)	10	space 25-30	decimal(xxx.xx)	f6.2
PCPSTD(6)	10	space 31-36	decimal(xxx.xx)	f6.2
PCPSTD(7)	10	space 37-42	decimal(xxx.xx)	f6.2
PCPSTD(8)	10	space 43-48	decimal(xxx.xx)	f6.2
PCPSTD(9)	10	space 49-54	decimal(xxx.xx)	f6.2
PCPSTD(10)	10	space 55-60	decimal(xxx.xx)	f6.2
PCPSTD(11)	10	space 61-66	decimal(xxx.xx)	f6.2
PCPSTD(12)	10	space 67-72	decimal(xxx.xx)	f6.2
PCPSKW(1)	11	space 1-6	decimal(xxx.xx)	f6.2
PCPSKW(2)	11	space 7-12	decimal(xxx.xx)	f6.2
PCPSKW(3)	11	space 13-18	decimal(xxx.xx)	f6.2
PCPSKW(4)	11	space 19-24	decimal(xxx.xx)	f6.2
PCPSKW(5)	11	space 25-30	decimal(xxx.xx)	f6.2
PCPSKW(6)	11	space 31-36	decimal(xxx.xx)	f6.2
PCPSKW(7)	11	space 37-42	decimal(xxx.xx)	f6.2
PCPSKW(8)	11	space 43-48	decimal(xxx.xx)	f6.2
PCPSKW(9)	11	space 49-54	decimal(xxx.xx)	f6.2
PCPSKW(10)	11	space 55-60	decimal(xxx.xx)	f6.2
PCPSKW(11)	11	space 61-66	decimal(xxx.xx)	f6.2
PCPSKW(12)	11	space 67-72	decimal(xxx.xx)	f6.2
PR_W(1,1)	12	space 1-6	decimal(xxx.xx)	f6.2
PR_W(1,2)	12	space 7-12	decimal(xxx.xx)	f6.2
PR_W(1,3)	12	space 13-18	decimal(xxx.xx)	f6.2
PR_W(1,4)	12	space 19-24	decimal(xxx.xx)	f6.2
PR_W(1,5)	12	space 25-30	decimal(xxx.xx)	f6.2
PR_W(1,6)	12	space 31-36	decimal(xxx.xx)	f6.2
PR_W(1,7)	12	space 37-42	decimal(xxx.xx)	f6.2
PR_W(1,8)	12	space 43-48	decimal(xxx.xx)	f6.2
PR_W(1,9)	12	space 49-54	decimal(xxx.xx)	f6.2
PR_W(1,10)	12	space 55-60	decimal(xxx.xx)	f6.2
PR_W(1,11)	12	space 61-66	decimal(xxx.xx)	f6.2

Variable name	Line #	Position	Format	F90 Format
PR_W(1,12)	12	space 67-72	decimal(xxx.xx)	f6.2
PR_W(2,1)	13	space 1-6	decimal(xxx.xx)	f6.2
PR_W(2,2)	13	space 7-12	decimal(xxx.xx)	f6.2
PR_W(2,3)	13	space 13-18	decimal(xxx.xx)	f6.2
PR_W(2,4)	13	space 19-24	decimal(xxx.xx)	f6.2
PR_W(2,5)	13	space 25-30	decimal(xxx.xx)	f6.2
PR_W(2,6)	13	space 31-36	decimal(xxx.xx)	f6.2
PR_W(2,7)	13	space 37-42	decimal(xxx.xx)	f6.2
PR_W(2,8)	13	space 43-48	decimal(xxx.xx)	f6.2
PR_W(2,9)	13	space 49-54	decimal(xxx.xx)	f6.2
PR_W(2,10)	13	space 55-60	decimal(xxx.xx)	f6.2
PR_W(2,11)	13	space 61-66	decimal(xxx.xx)	f6.2
PR_W(2,12)	13	space 67-72	decimal(xxx.xx)	f6.2
PCPD(1)	14	space 1-6	decimal(xxx.xx)	f6.2
PCPD(2)	14	space 7-12	decimal(xxx.xx)	f6.2
PCPD(3)	14	space 13-18	decimal(xxx.xx)	f6.2
PCPD(4)	14	space 19-24	decimal(xxx.xx)	f6.2
PCPD(5)	14	space 25-30	decimal(xxx.xx)	f6.2
PCPD(6)	14	space 31-36	decimal(xxx.xx)	f6.2
PCPD(7)	14	space 37-42	decimal(xxx.xx)	f6.2
PCPD(8)	14	space 43-48	decimal(xxx.xx)	f6.2
PCPD(9)	14	space 49-54	decimal(xxx.xx)	f6.2
PCPD(10)	14	space 55-60	decimal(xxx.xx)	f6.2
PCPD(11)	14	space 61-66	decimal(xxx.xx)	f6.2
PCPD(12)	14	space 67-72	decimal(xxx.xx)	f6.2
RAINHHMX(1)	15	space 1-6	decimal(xxx.xx)	f6.2
RAINHHMX(2)	15	space 7-12	decimal(xxx.xx)	f6.2
RAINHHMX(3)	15	space 13-18	decimal(xxx.xx)	f6.2
RAINHHMX(4)	15	space 19-24	decimal(xxx.xx)	f6.2
RAINHHMX(5)	15	space 25-30	decimal(xxx.xx)	f6.2
RAINHHMX(6)	15	space 31-36	decimal(xxx.xx)	f6.2
RAINHHMX(7)	15	space 37-42	decimal(xxx.xx)	f6.2
RAINHHMX(8)	15	space 43-48	decimal(xxx.xx)	f6.2
RAINHHMX(9)	15	space 49-54	decimal(xxx.xx)	f6.2
RAINHHMX(10)	15	space 55-60	decimal(xxx.xx)	f6.2

Variable name	Line #	Position	Format	F90 Format
RAINHHMX(11)	15	space 61-66	decimal(xxx.xx)	f6.2
RAINHHMX(12)	15	space 67-72	decimal(xxx.xx)	f6.2
SOLARAV(1)	16	space 1-6	decimal(xxx.xx)	f6.2
SOLARAV(2)	16	space 7-12	decimal(xxx.xx)	f6.2
SOLARAV(3)	16	space 13-18	decimal(xxx.xx)	f6.2
SOLARAV(4)	16	space 19-24	decimal(xxx.xx)	f6.2
SOLARAV(5)	16	space 25-30	decimal(xxx.xx)	f6.2
SOLARAV(6)	16	space 31-36	decimal(xxx.xx)	f6.2
SOLARAV(7)	16	space 37-42	decimal(xxx.xx)	f6.2
SOLARAV(8)	16	space 43-48	decimal(xxx.xx)	f6.2
SOLARAV(9)	16	space 49-54	decimal(xxx.xx)	f6.2
SOLARAV(10)	16	space 55-60	decimal(xxx.xx)	f6.2
SOLARAV(11)	16	space 61-66	decimal(xxx.xx)	f6.2
SOLARAV(12)	16	space 67-72	decimal(xxx.xx)	f6.2
DEWPT(1)	17	space 1-6	decimal(xxx.xx)	f6.2
DEWPT(2)	17	space 7-12	decimal(xxx.xx)	f6.2
DEWPT(3)	17	space 13-18	decimal(xxx.xx)	f6.2
DEWPT(4)	17	space 19-24	decimal(xxx.xx)	f6.2
DEWPT(5)	17	space 25-30	decimal(xxx.xx)	f6.2
DEWPT(6)	17	space 31-36	decimal(xxx.xx)	f6.2
DEWPT(7)	17	space 37-42	decimal(xxx.xx)	f6.2
DEWPT(8)	17	space 43-48	decimal(xxx.xx)	f6.2
DEWPT(9)	17	space 49-54	decimal(xxx.xx)	f6.2
DEWPT(10)	17	space 55-60	decimal(xxx.xx)	f6.2
DEWPT(11)	17	space 61-66	decimal(xxx.xx)	f6.2
DEWPT(12)	17	space 67-72	decimal(xxx.xx)	f6.2
WNDAV(1)	18	space 1-6	decimal(xxx.xx)	f6.2
WNDAV(2)	18	space 7-12	decimal(xxx.xx)	f6.2
WNDAV(3)	18	space 13-18	decimal(xxx.xx)	f6.2
WNDAV(4)	18	space 19-24	decimal(xxx.xx)	f6.2
WNDAV(5)	18	space 25-30	decimal(xxx.xx)	f6.2
WNDAV(6)	18	space 31-36	decimal(xxx.xx)	f6.2
WNDAV(7)	18	space 37-42	decimal(xxx.xx)	f6.2
WNDAV(8)	18	space 43-48	decimal(xxx.xx)	f6.2
WNDAV(9)	18	space 49-54	decimal(xxx.xx)	f6.2

Variable name	Line #	Position	Format	F90 Format
WNDAV(10)	18	space 55-60	decimal(xxx.xx)	f6.2
WNDAV(11)	18	space 61-66	decimal(xxx.xx)	f6.2
WNDAV(12)	18	space 67-72	decimal(xxx.xx)	f6.2

CHAPTER 13

SWAT INPUT DATA: .CST

SWAT allows a user to simulate forecast scenarios if desired. The forecast input file contains the statistical data needed to generate daily climate data for the subbasins during the forecast period.

In a forecast simulation, a non-forecast and forecast period are defined. The forecast period begins on the day specified by FCSTDAY and FCSTYR in the master watershed file (file.cio, see Chapter 3) and ends on the last day of the simulation. During the non-forecast period, the parameters used to generate weather are taken from the weather generator file (.wgn, Chapter 12). When the forecast period is simulated, the monthly weather generator parameters for precipitation and temperature are replaced with parameter values stored in the forecast input file (.cst).

The forecast period must be simulated a number of times to obtain a distribution of possible weather scenarios. The user defines the number of model runs made (FCSTCYCLES, file.cio, see Chapter 3). A minimum of 20 cycles is recommended. The only difference between forecast scenarios is the value of the random number seeds used to generate daily weather values.

An unlimited number of forecast regions can be defined in a watershed. The forecast region number assigned to a subbasin in the subbasin input file (.sub, Chapter 5) must correspond to a forecast region number given for a specific dataset in the forecast input file (.cst).

Following is a brief description of the variables in the forecast input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the .cst file is reserved for user comments. The comments may take up to 80 spaces. The title line is not processed by the model and may be left blank. Optional.
FCST_REGTOT	The total number of forecast regions in the watershed. Data for all the regions is listed in the .cst file. Required if forecast period simulated.
The following input data must be given for each forecast region in the watershed.	
REGION TITLE	Title line for a given forecast region. This line is not used by the model, but makes a convenient location to write the name of the region or any other information the user wishes to record. Optional.
FCST_REG	Forecast region number. This number is used to link forecast data to the desired subbasin(s). Required if forecast period simulated.
FTMPMX(mon)	Average or mean daily maximum air temperature for month in forecast period (ºC). Required if forecast period simulated.

Variable name	Definition
FTMPMN(mon)	Average or mean daily minimum air temperature for month in forecast period (ºC). Required if forecast period simulated.
FTMPSTDMX(mon)	Standard deviation for daily maximum air temperature in month in forecast period (ºC). This parameter quantifies the variability in maximum temperature for each month. Required if forecast period simulated.
FTMPSTDMN(mon)	Standard deviation for daily minimum air temperature in month in forecast period (ºC). This parameter quantifies the variability in minimum temperature for each month. Required if forecast period simulated.
FPCPMM(mon)	Average or mean total monthly precipitation in forecast period (mm H_2O). Required if forecast period simulated.
FPCPSTD(mon)	Standard deviation for daily precipitation in month in forecast period (mm H_2O/day). This parameter quantifies the variability in precipitation for each month. (Note: daily precipitation values of 0 mm are included in the standard deviation calculation). Required if forecast period simulated.
FPCPSKW(mon)	Skew coefficient for daily precipitation in month in forecast period. This parameter quantifies the symmetry of the precipitation distribution about the monthly mean. (Note: daily precipitation values of 0 mm are included in the skew coefficient calculation). Required if forecast period simulated.
FPR_W(1,mon)	Probability of a wet day following a dry day in the month in forecast period. Required if forecast period simulated.
FPR_W(2,mon)	Probability of a wet day following a wet day in the month in forecast period. Required if forecast period simulated.

Variable name	Definition
FPCPD(mon)	Average number of days of precipitation in month in forecast period. Required if forecast period simulated.

The format of the forecast input file is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1	space 1-80	Character	a80
FCSTREGTOT	2	space 1-6	Integer	i6
The remainder of lines repeat for the number of forecast regions defined by FCSTREGTOT.				
REGION TITLE	2 + 1*i*	space 1-80	Character	a80
FCST_REG	2 + 2*i*	space 1-6	Integer	i6
FTMPMX(1)	2 + 3*i*	space 1-6	decimal(xxx.xx)	f6.2
FTMPMX(2)	2 + 3*i*	space 7-12	decimal(xxx.xx)	f6.2
FTMPMX(3)	2 + 3*i*	space 13-18	decimal(xxx.xx)	f6.2
FTMPMX(4)	2 + 3*i*	space 19-24	decimal(xxx.xx)	f6.2
FTMPMX(5)	2 + 3*i*	space 25-30	decimal(xxx.xx)	f6.2
FTMPMX(6)	2 + 3*i*	space 31-36	decimal(xxx.xx)	f6.2
FTMPMX(7)	2 + 3*i*	space 37-42	decimal(xxx.xx)	f6.2
FTMPMX(8)	2 + 3*i*	space 43-48	decimal(xxx.xx)	f6.2
FTMPMX(9)	2 + 3*i*	space 49-54	decimal(xxx.xx)	f6.2
FTMPMX(10)	2 + 3*i*	space 55-60	decimal(xxx.xx)	f6.2
FTMPMX(11)	2 + 3*i*	space 61-66	decimal(xxx.xx)	f6.2
FTMPMX(12)	2 + 3*i*	space 67-72	decimal(xxx.xx)	f6.2
FTMPMN(1)	2 + 4*i*	space 1-6	decimal(xxx.xx)	f6.2
FTMPMN(2)	2 + 4*i*	space 7-12	decimal(xxx.xx)	f6.2
FTMPMN(3)	2 + 4*i*	space 13-18	decimal(xxx.xx)	f6.2
FTMPMN(4)	2 + 4*i*	space 19-24	decimal(xxx.xx)	f6.2
FTMPMN(5)	2 + 4*i*	space 25-30	decimal(xxx.xx)	f6.2
FTMPMN(6)	2 + 4*i*	space 31-36	decimal(xxx.xx)	f6.2
FTMPMN(7)	2 + 4*i*	space 37-42	decimal(xxx.xx)	f6.2
FTMPMN(8)	2 + 4*i*	space 43-48	decimal(xxx.xx)	f6.2
FTMPMN(9)	2 + 4*i*	space 49-54	decimal(xxx.xx)	f6.2
FTMPMN(10)	2 + 4*i*	space 55-60	decimal(xxx.xx)	f6.2
FTMPMN(11)	2 + 4*i*	space 61-66	decimal(xxx.xx)	f6.2

Variable name	Line #	Position	Format	F90 Format
FTMPMN(12)	2 + 4*i*	space 67-72	decimal(xxx.xx)	f6.2
FTMPSTDMX(1)	2 + 5*i*	space 1-6	decimal(xxx.xx)	f6.2
FTMPSTDMX(2)	2 + 5*i*	space 7-12	decimal(xxx.xx)	f6.2
FTMPSTDMX(3)	2 + 5*i*	space 13-18	decimal(xxx.xx)	f6.2
FTMPSTDMX(4)	2 + 5*i*	space 19-24	decimal(xxx.xx)	f6.2
FTMPSTDMX(5)	2 + 5*i*	space 25-30	decimal(xxx.xx)	f6.2
FTMPSTDMX(6)	2 + 5*i*	space 31-36	decimal(xxx.xx)	f6.2
FTMPSTDMX(7)	2 + 5*i*	space 37-42	decimal(xxx.xx)	f6.2
FTMPSTDMX(8)	2 + 5*i*	space 43-48	decimal(xxx.xx)	f6.2
FTMPSTDMX(9)	2 + 5*i*	space 49-54	decimal(xxx.xx)	f6.2
FTMPSTDMX(10)	2 + 5*i*	space 55-60	decimal(xxx.xx)	f6.2
FTMPSTDMX(11)	2 + 5*i*	space 61-66	decimal(xxx.xx)	f6.2
FTMPSTDMX(12)	2 + 5*i*	space 67-72	decimal(xxx.xx)	f6.2
FTMPSTDMN(1)	2 + 6*i*	space 1-6	decimal(xxx.xx)	f6.2
FTMPSTDMN(2)	2 + 6*i*	space 7-12	decimal(xxx.xx)	f6.2
FTMPSTDMN(3)	2 + 6*i*	space 13-18	decimal(xxx.xx)	f6.2
FTMPSTDMN(4)	2 + 6*i*	space 19-24	decimal(xxx.xx)	f6.2
FTMPSTDMN(5)	2 + 6*i*	space 25-30	decimal(xxx.xx)	f6.2
FTMPSTDMN(6)	2 + 6*i*	space 31-36	decimal(xxx.xx)	f6.2
FTMPSTDMN(7)	2 + 6*i*	space 37-42	decimal(xxx.xx)	f6.2
FTMPSTDMN(8)	2 + 6*i*	space 43-48	decimal(xxx.xx)	f6.2
FTMPSTDMN(9)	2 + 6*i*	space 49-54	decimal(xxx.xx)	f6.2
FTMPSTDMN(10)	2 + 6*i*	space 55-60	decimal(xxx.xx)	f6.2
FTMPSTDMN(11)	2 + 6*i*	space 61-66	decimal(xxx.xx)	f6.2
FTMPSTDMN(12)	2 + 6*i*	space 67-72	decimal(xxx.xx)	f6.2
FPCPMM(1)	2 + 7*i*	space 1-6	decimal(xxx.xx)	f6.2
FPCPMM(2)	2 + 7*i*	space 7-12	decimal(xxx.xx)	f6.2
FPCPMM(3)	2 + 7*i*	space 13-18	decimal(xxx.xx)	f6.2
FPCPMM(4)	2 + 7*i*	space 19-24	decimal(xxx.xx)	f6.2
FPCPMM(5)	2 + 7*i*	space 25-30	decimal(xxx.xx)	f6.2
FPCPMM(6)	2 + 7*i*	space 31-36	decimal(xxx.xx)	f6.2
FPCPMM(7)	2 + 7*i*	space 37-42	decimal(xxx.xx)	f6.2
FPCPMM(8)	2 + 7*i*	space 43-48	decimal(xxx.xx)	f6.2
FPCPMM(9)	2 + 7*i*	space 49-54	decimal(xxx.xx)	f6.2
FPCPMM(10)	2 + 7*i*	space 55-60	decimal(xxx.xx)	f6.2

Variable name	Line #	Position	Format	F90 Format
FPCPMM(11)	2 + 7*i*	space 61-66	decimal(xxx.xx)	f6.2
FPCPMM(12)	2 + 7*i*	space 67-72	decimal(xxx.xx)	f6.2
FPCPSTD(1)	2 + 8*i*	space 1-6	decimal(xxx.xx)	f6.2
FPCPSTD(2)	2 + 8*i*	space 7-12	decimal(xxx.xx)	f6.2
FPCPSTD(3)	2 + 8*i*	space 13-18	decimal(xxx.xx)	f6.2
FPCPSTD(4)	2 + 8*i*	space 19-24	decimal(xxx.xx)	f6.2
FPCPSTD(5)	2 + 8*i*	space 25-30	decimal(xxx.xx)	f6.2
FPCPSTD(6)	2 + 8*i*	space 31-36	decimal(xxx.xx)	f6.2
FPCPSTD(7)	2 + 8*i*	space 37-42	decimal(xxx.xx)	f6.2
FPCPSTD(8)	2 + 8*i*	space 43-48	decimal(xxx.xx)	f6.2
FPCPSTD(9)	2 + 8*i*	space 49-54	decimal(xxx.xx)	f6.2
FPCPSTD(10)	2 + 8*i*	space 55-60	decimal(xxx.xx)	f6.2
FPCPSTD(11)	2 + 8*i*	space 61-66	decimal(xxx.xx)	f6.2
FPCPSTD(12)	2 + 8*i*	space 67-72	decimal(xxx.xx)	f6.2
FPCPSKW(1)	2 + 9*i*	space 1-6	decimal(xxx.xx)	f6.2
FPCPSKW(2)	2 + 9*i*	space 7-12	decimal(xxx.xx)	f6.2
FPCPSKW(3)	2 + 9*i*	space 13-18	decimal(xxx.xx)	f6.2
FPCPSKW(4)	2 + 9*i*	space 19-24	decimal(xxx.xx)	f6.2
FPCPSKW(5)	2 + 9*i*	space 25-30	decimal(xxx.xx)	f6.2
FPCPSKW(6)	2 + 9*i*	space 31-36	decimal(xxx.xx)	f6.2
FPCPSKW(7)	2 + 9*i*	space 37-42	decimal(xxx.xx)	f6.2
FPCPSKW(8)	2 + 9*i*	space 43-48	decimal(xxx.xx)	f6.2
FPCPSKW(9)	2 + 9*i*	space 49-54	decimal(xxx.xx)	f6.2
FPCPSKW(10)	2 + 9*i*	space 55-60	decimal(xxx.xx)	f6.2
FPCPSKW(11)	2 + 9*i*	space 61-66	decimal(xxx.xx)	f6.2
FPCPSKW(12)	2 + 9*i*	space 67-72	decimal(xxx.xx)	f6.2
FPR_W(1,1)	2 + 10*i*	space 1-6	decimal(xxx.xx)	f6.2
FPR_W(1,2)	2 + 10*i*	space 7-12	decimal(xxx.xx)	f6.2
FPR_W(1,3)	2 + 10*i*	space 13-18	decimal(xxx.xx)	f6.2
FPR_W(1,4)	2 + 10*i*	space 19-24	decimal(xxx.xx)	f6.2
FPR_W(1,5)	2 + 10*i*	space 25-30	decimal(xxx.xx)	f6.2
FPR_W(1,6)	2 + 10*i*	space 31-36	decimal(xxx.xx)	f6.2
FPR_W(1,7)	2 + 10*i*	space 37-42	decimal(xxx.xx)	f6.2
FPR_W(1,8)	2 + 10*i*	space 43-48	decimal(xxx.xx)	f6.2
FPR_W(1,9)	2 + 10*i*	space 49-54	decimal(xxx.xx)	f6.2

Variable name	Line #	Position	Format	F90 Format
FPR_W(1,10)	2 + 10*i*	space 55-60	decimal(xxx.xx)	f6.2
FPR_W(1,11)	2 + 10*i*	space 61-66	decimal(xxx.xx)	f6.2
FPR_W(1,12)	2 + 10*i*	space 67-72	decimal(xxx.xx)	f6.2
FPR_W(2,1)	2 + 11*i*	space 1-6	decimal(xxx.xx)	f6.2
FPR_W(2,2)	2 + 11*i*	space 7-12	decimal(xxx.xx)	f6.2
FPR_W(2,3)	2 + 11*i*	space 13-18	decimal(xxx.xx)	f6.2
FPR_W(2,4)	2 + 11*i*	space 19-24	decimal(xxx.xx)	f6.2
FPR_W(2,5)	2 + 11*i*	space 25-30	decimal(xxx.xx)	f6.2
FPR_W(2,6)	2 + 11*i*	space 31-36	decimal(xxx.xx)	f6.2
FPR_W(2,7)	2 + 11*i*	space 37-42	decimal(xxx.xx)	f6.2
FPR_W(2,8)	2 + 11*i*	space 43-48	decimal(xxx.xx)	f6.2
FPR_W(2,9)	2 + 11*i*	space 49-54	decimal(xxx.xx)	f6.2
FPR_W(2,10)	2 + 11*i*	space 55-60	decimal(xxx.xx)	f6.2
FPR_W(2,11)	2 + 11*i*	space 61-66	decimal(xxx.xx)	f6.2
FPR_W(2,12)	2 + 11*i*	space 67-72	decimal(xxx.xx)	f6.2
FPCPD(1)	2 + 12*i*	space 1-6	decimal(xxx.xx)	f6.2
FPCPD(2)	2 + 12*i*	space 7-12	decimal(xxx.xx)	f6.2
FPCPD(3)	2 + 12*i*	space 13-18	decimal(xxx.xx)	f6.2
FPCPD(4)	2 + 12*i*	space 19-24	decimal(xxx.xx)	f6.2
FPCPD(5)	2 + 12*i*	space 25-30	decimal(xxx.xx)	f6.2
FPCPD(6)	2 + 12*i*	space 31-36	decimal(xxx.xx)	f6.2
FPCPD(7)	2 + 12*i*	space 37-42	decimal(xxx.xx)	f6.2
FPCPD(8)	2 + 12*i*	space 43-48	decimal(xxx.xx)	f6.2
FPCPD(9)	2 + 12*i*	space 49-54	decimal(xxx.xx)	f6.2
FPCPD(10)	2 + 12*i*	space 55-60	decimal(xxx.xx)	f6.2
FPCPD(11)	2 + 12*i*	space 61-66	decimal(xxx.xx)	f6.2
FPCPD(12)	2 + 12*i*	space 67-72	decimal(xxx.xx)	f6.2

CHAPTER 14

SWAT INPUT DATA: PLANT.DAT

Information required to simulate plant growth is stored by plant species in the plant growth database file. This database file is supplied with the model. The plant growth database distributed with SWAT includes parameters for most of the common plant species. If a user needs to model a land use or plant not included in the database, please feel free to contact the SWAT development team for assistance in determining plant parameters. Appendix A documents the source of parameter values in the distributed database file.

Following is a brief description of the variables in the land cover/plant growth database file. They are listed in the order they appear within the file.

Variable name	Definition
ICNUM	Land cover/plant code. The different plants listed in the plant growth database must have unique values for ICNUM. ICNUM is the numeric code used in the management file to identify the land cover to be modeled. Required.
CPNM	A four character code to represent the land cover/plant name. The 4-letter codes in the plant growth and urban databases are used by the GIS interfaces to link land use/land cover maps to SWAT plant types. This code is printed to the output files. When adding a new plant species or land cover category, the four letter code for the new plant must be unique. Required.
IDC	Land cover/plant classification: 1 warm season annual legume 2 cold season annual legume 3 perennial legume 4 warm season annual 5 cold season annual 6 perennial 7 trees Processes modeled differently for the 7 groups are: 1 warm season annual legume • simulate nitrogen fixation • root depth varies during growing season due to root growth 2 cold season annual legume • simulate nitrogen fixation • root depth varies during growing season due to root growth • fall-planted land covers will go dormant when daylength is less than the threshold daylength

Variable name	Definition
IDC, cont.	3 perennial legume • simulate nitrogen fixation • root depth always equal to the maximum allowed for the plant species and soil • plant goes dormant when daylength is less than the threshold daylength 4 warm season annual • root depth varies during growing season due to root growth 5 cold season annual • root depth varies during growing season due to root growth • fall-planted land covers will go dormant when daylength is less than the threshold daylength 6 perennial • root depth always equal to the maximum allowed for the plant species and soil • plant goes dormant when daylength is less than the threshold daylength 7 trees • root depth always equal to the maximum allowed for the plant species and soil • partitions new growth between leaves/needles (20%) and woody growth (80%). At the end of each growing season, a fraction of the biomass is converted to residue Required.
DESCRIPTION	Full land cover/plant name. This description is not used by the model and is present to assist the user in differentiating between plant species. Optional.
BIO_E	Radiation-use efficiency or biomass-energy ratio ((kg/ha)/(MJ/m^2)). Radiation-use efficiency (RUE) is the amount of dry biomass produced per unit intercepted solar radiation. The radiation-use efficiency is assumed to be independent of the plant's growth stage. BIO_E represents the potential or unstressed growth rate (including roots) per unit of intercepted photosynthetically active radiation.

Variable name	Definition
BIO_E, cont.	Determination of RUE is commonly performed and a literature review will provide those setting up experiments with numerous examples. The following overview of the methodology used to measure RUE was summarized from Kiniry et al (1998) and Kiniry et al (1999). To calculate RUE, the amount of photosynthetically active radiation (PAR) intercepted and the mass of aboveground biomass is measured several times throughout a plant's growing season. The frequency of the measurements taken will vary but in general 4 to 7 measurements per growing season are considered to be adequate. As with leaf area determinations, the measurements should be performed on non-stressed plants. Intercepted radiation is measured with a light meter. Whole spectrum and PAR sensors are available and calculations of RUE will be performed differently depending on the sensor used. A brief discussion of the difference between whole spectrum and PAR sensors and the difference in calculations is given in Kiniry (1999). The use of a PAR sensor in RUE studies is strongly encouraged. When measuring radiation, three to five sets of measurements are taken rapidly for each plant plot. A set of measurements consists of 10 measurements above the leaf canopy, 10 below, and 10 more above. The light measurements should be taken between 10:00 am and 2:00 pm local time. The measurements above and below the leaf canopy are averaged and the fraction of intercepted PAR is calculated for the day from the two values. Daily estimates of the fraction of intercepted PAR are determined by linearly interpolating the measured values.

Variable name	Definition
BIO_E, cont.	The *fraction* of intercepted PAR is converted to an *amount* of intercepted PAR using daily values of incident total solar radiation measured with a standard weather station. To convert total incident radiation to total incident PAR, the daily solar radiation values are multiplied by the percent of total radiation that has a wavelength between 400 and 700 mm. This percent usually falls in the range 45 to 55% and is a function of cloud cover. 50% is considered to be a default value. Once daily intercepted PAR values are determined, the total amount of PAR intercepted by the plant is calculated for each date on which biomass was harvested. This is calculated by summing daily intercepted PAR values from the date of seedling emergence to the date of biomass harvest. To determine biomass production, aboveground biomass is harvested from a known area of land within the plot. The plant material should be dried at least 2 days at 65°C and then weighed. RUE is determined by fitting a linear regression for aboveground biomass as a function of intercepted PAR. The slope of the line is the RUE. Figure 14-1 shows the plots of aboveground biomass and summed intercepted photosynthetically active radiation for Eastern gamagrass. (Note that the units for RUE values in the graph, as well as values typically reported in literature, are different from those used by SWAT. To obtain the value used in SWAT, multiply by 10.) This parameter can greatly change the rate of growth, incidence of stress during the season and the resultant yield. This parameter should be one of the last to be adjusted. Adjustments should be based on research results. Care should be taken to make adjustments based only on data with no drought, nutrient or temperature stress. Required.

Variable name	Definition

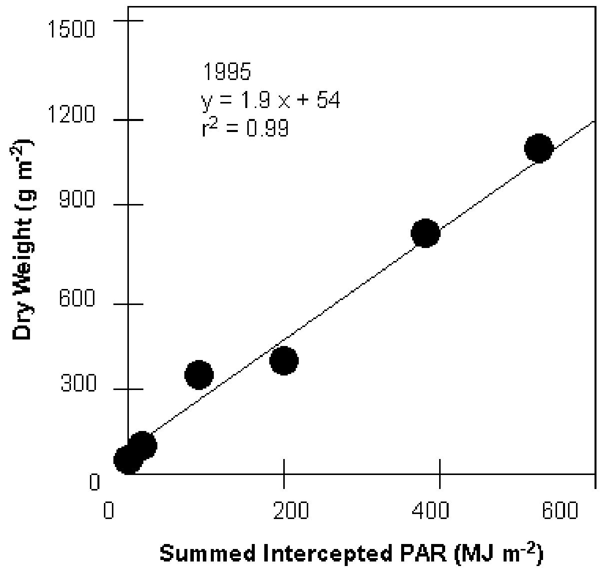

Figure 14-1: Aboveground biomass and summed intercepted photosynthetically active radiation for Eastern gamagrass (after Kiniry et al.,1999).

HVSTI	Harvest index for optimal growing conditions. The harvest index defines the fraction of the aboveground biomass that is removed in a harvest operation. This value defines the fraction of plant biomass that is "lost" from the system and unavailable for conversion to residue and subsequent decomposition. For crops where the harvested portion of the plant is aboveground, the harvest index is always a fraction less than 1. For crops where the harvested portion is belowground, the harvest index may be greater than 1. Two harvest indices are provided in the database, the harvest index for optimal growing conditions (HVSTI) and the harvest index under highly stressed growing conditions (WSYF).

Variable name	Definition
HVSTI, cont.	To determine the harvest index, the plant biomass removed during the harvest operation is dried at least 2 days at 65°C and weighed. The total aboveground plant biomass in the field should also be dried and weighed. The harvest index is then calculated by dividing the weight of the harvested portion of the plant biomass by the weight of the total aboveground plant biomass. Plants will need to be grown in two different plots where optimal climatic conditions and stressed conditions are produced to obtain values for both harvest indices. Required.
BLAI	Maximum potential leaf area index. BLAI is one of six parameters use to quantify leaf area development of a plant species during the growing season. Figure 14-2 illustrates the relationship of the database parameters to the leaf area development modeled by SWAT.

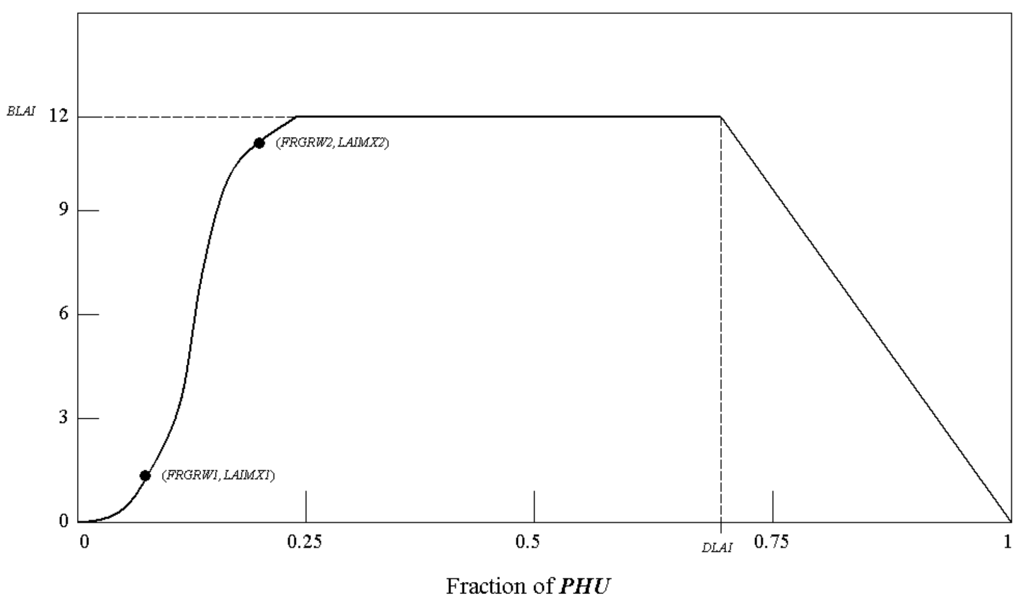

Figure 14-2: Leaf area index as a function of fraction of growing season for Alamo switchgrass

Variable name	Definition
BLAI, cont.	To identify the leaf area development parameters, record the leaf area index and number of accumulated heat units for the plant species throughout the growing season and then plot the results. For best results, several years worth of field data should be collected. At the very minimum, data for two years is recommended. It is important that the plants undergo no water or nutrient stress during the years in which data is collected.
	The leaf area index incorporates information about the plant density, so field experiments should either be set up to reproduce actual plant densities or the maximum LAI value for the plant determined from field experiments should be adjusted to reflect plant densities desired in the simulation. Maximum LAI values in the default database correspond to plant densities associated with rainfed agriculture.
	The leaf area index is calculated by dividing the green leaf area by the land area. Because the entire plant must be harvested to determine the leaf area, the field experiment needs to be designed to include enough plants to accommodate all leaf area measurements made during the year.
	Although measuring leaf area can be laborious for large samples, there is no intrinsic difficulty in the process. The most common method is to obtain an electronic scanner and feed the harvested green leaves and stems into the scanner. Older methods for estimating leaf area include tracing of the leaves (or weighed subsamples) onto paper, the use of planimeters, the punch disk method of Watson (1958) and the linear dimension method of Duncan and Hesketh (1968).
	Chapter 5:1 in the Theoretical Documentation reviews the methodology used to calculate accumulated heat units for a plant at different times of the year as well as determination of the fraction of total, or potential, heat units that is required for the plant database.

Variable name	Definition
BLAI, cont.	The values for BLAI in the plant growth database are based on average plant densities in dryland (rainfed) agriculture. BLAI may need to be adjusted for drought-prone regions where planting densities are much smaller or irrigated conditions where densities are much greater. Required.
FRGRW1	Fraction of the plant growing season or fraction of total potential heat units corresponding to the 1st point on the optimal leaf area development curve. Please see Figure 14-2 and the explanation given for parameter BLAI to obtain additional information about this parameter and methods used to measure it. Required.
LAIMX1	Fraction of the maximum leaf area index corresponding to the 1st point on the optimal leaf area development curve. Please see Figure 14-2 and the explanation given for parameter BLAI to obtain additional information about this parameter and methods used to measure it. Required.
FRGRW2	Fraction of the plant growing season or fraction of total potential heat units corresponding to the 2nd point on the optimal leaf area development curve. Please see Figure 14-2 and the explanation given for parameter BLAI to obtain additional information about this parameter and methods used to measure it. Required.
LAIMX2	Fraction of the maximum leaf area index corresponding to the 2nd point on the optimal leaf area development curve. Please see Figure 14-2 and the explanation given for parameter BLAI to obtain additional information about this parameter and methods used to measure it. Required.

Variable name	Definition
DLAI	Fraction of growing season when leaf area begins to decline. Please see Figure 14-2 and the explanation given for parameter BLAI to obtain additional information about this parameter and methods used to measure it. Required.
CHTMX	Maximum canopy height (m). Maximum canopy height is a straightforward measurement. The canopy height of non-stressed plants should be recorded at intervals throughout the growing season. The maximum value recorded is used in the database. Required.
RDMX	Maximum root depth (m). To determine maximum rooting depth, plant samples need to be grown on soils without an impermeable layer. Once the plants have reached maturity, soil cores are taken for the entire depth of the soil. Each 0.25 meter increment is washed and the live plant material collected. Live roots can be differentiated from dead roots by the fact that live roots are whiter and more elastic and have an intact cortex. The deepest increment of the soil core in which live roots are found defines the maximum rooting depth. Required.
T_OPT	Optimal temperature for plant growth (ºC). Both optimal and base temperatures are very stable for cultivars within a species. Optimal temperature for plant growth is difficult to measure directly. Looking at Figure 14-3, one might be tempted to select the temperature corresponding to the peak of the plot as the optimal temperature. This would not be correct.

Variable name	Definition
T_OPT, cont.	The peak of the plot defines the optimal temperature for leaf development—not for plant growth. If an optimal temperature cannot be obtained through a review of literature, use the optimal temperature listed for a plant already in the database with similar growth habits. Review of temperatures for many different plants have provided generic values for base and optimal temperatures as a function of growing season. In situations, where temperature information is unavailable, these values may be used. For warm season plants, the generic base temperature is ~8ºC and the generic optimal temperature is ~25ºC. For cool season plants, the generic base temperature is ~0ºC and the generic optimal temperature is ~13ºC. Required.
T_BASE	Minimum (base) temperature for plant growth (ºC). SWAT uses the base temperature to calculate the number of heat units accrued every day. The minimum or base temperature for plant growth varies with growth stage of the plant. However, this variation is ignored by the model—SWAT uses the same base temperature throughout the growing season. Base temperature is measured by growing plants in growth chambers at several different temperatures. The rate of leaf tip appearance as a function of temperature is plotted. Extrapolating the line to the leaf tip appearance rate of 0.0 leaves/day gives the base or minimum temperature for plant growth. Figure 14-3 plots data for corn. (Note that the line intersects the x-axis at 8°C.) Required.

Variable name	Definition
T_BASE, cont.	

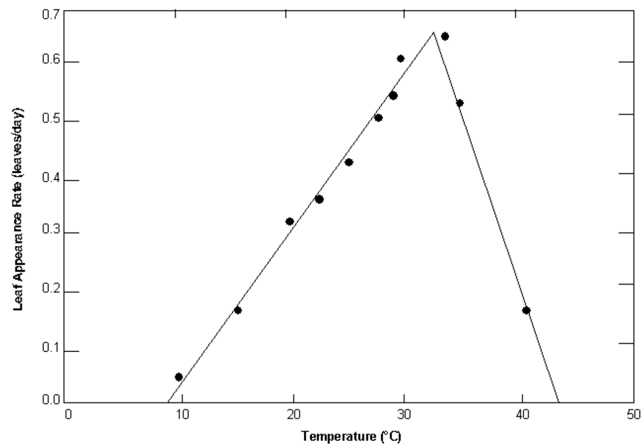

Figure 14-3: Rate of leaf tip appearance as a function of temperature for corn (after Kiniry et al, 1991)

CNYLD	Normal fraction of nitrogen in yield (kg N/kg yield). In addition to the amount of plant biomass removed in the yield, SWAT needs to know the amount of nitrogen and phosphorus removed in the yield. The harvested portion of the plant biomass is sent to a testing laboratory to determine the fraction of nitrogen and phosphorus in the biomass. This value is estimated on a dry weight basis. Required.
CPYLD	Normal fraction of phosphorus in yield (kg P/kg yield). In addition to the amount of plant biomass removed in the yield, SWAT needs to know the amount of nitrogen and phosphorus removed in the yield. The harvested portion of the plant biomass is sent to a testing laboratory to determine the fraction of nitrogen and phosphorus in the biomass. This value is estimated on a dry weight basis. Required.

Variable name	Definition
PLTNFR(1)	Nitrogen uptake parameter #1: normal fraction of nitrogen in plant biomass at emergence (kg N/kg biomass) In order to calculate the plant nutrient demand throughout a plant's growing cycle, SWAT needs to know the fraction of nutrient in the total plant biomass (on a dry weight basis) at different stages of crop growth. Six variables in the plant database provide this information: PLTNFR(1), PLTNFR(2), PLTNFR(3), PLTPFR(1), PLTPFR(2), and PLTPFR(3). Plant samples are analyzed for nitrogen and phosphorus content at three times during the growing season: shortly after emergence, near the middle of the season, and at maturity. The plant samples can be sent to testing laboratories to obtain the fraction of nitrogen and phosphorus in the biomass. Ideally, the plant samples tested for nutrient content should include the roots as well as the aboveground biomass. Differences in partitioning of nutrients to roots and shoots can cause erroneous conclusions when comparing productivity among species if only the aboveground biomass is measured. Required.
PLTNFR(2)	Nitrogen uptake parameter #2: normal fraction of nitrogen in plant biomass at 50% maturity (kg N/kg biomass) Please read the explanation for parameter PLTNFR(1) to obtain additional information about this parameter and methods used to measure it. Required.
PLTNFR(3)	Nitrogen uptake parameter #3: normal fraction of nitrogen in plant biomass at maturity (kg N/kg biomass) Please read the explanation for parameter PLTNFR(1) to obtain additional information about this parameter and methods used to measure it. Required.

Variable name	Definition
PLTPFR(1)	Phosphorus uptake parameter #1: normal fraction of phosphorus in plant biomass at emergence (kg P/kg biomass) Please read the explanation for parameter PLTNFR(1) to obtain additional information about this parameter and methods used to measure it. Required.
PLTPFR(2)	Phosphorus uptake parameter #2: normal fraction of phosphorus in plant biomass at 50% maturity (kg P/kg biomass) Please read the explanation for parameter PLTNFR(1) to obtain additional information about this parameter and methods used to measure it. Required.
PLTPFR(3)	Phosphorus uptake parameter #3: normal fraction of phosphorus in plant biomass at maturity (kg P/kg biomass) Please read the explanation for parameter PLTNFR(1) to obtain additional information about this parameter and methods used to measure it. Required.
WSYF	Lower limit of harvest index ((kg/ha)/(kg/ha)). The value between 0.0 and HVSTI which represents the lowest harvest index expected due to water stress. Please read the explanation for parameter HVSTI to obtain additional information about this parameter and methods used to measure it. Required.

Variable name	Definition
USLE_C	Minimum value of USLE C factor for water erosion applicable to the land cover/plant. The minimum C factor can be estimated from a known average annual C factor using the following equation (Arnold and Williams, 1995): $C_{USLE,mn} = 1.463 \ln\left[C_{USLE,aa}\right] + 0.1034$ where $C_{USLE,mn}$ is the minimum C factor for the land cover and $C_{USLE,aa}$ is the average annual C factor for the land cover. Required.
GSI	Maximum stomatal conductance at high solar radiation and low vapor pressure deficit (m·s-1). Stomatal conductance of water vapor is used in the Penman-Monteith calculations of maximum plant evapotranspiration. The plant database contains three variables pertaining to stomatal conductance that are required only if the Penman-Monteith equations are chosen to model evapotranspiration: maximum stomatal conductance (GSI), and two variables that define the impact of vapor pressure deficit on stomatal conductance (FRGMAX, VPDFR). Körner et al (1979) defines maximum leaf diffusive conductance as the largest value of conductance observed in fully developed leaves of well-watered plants under optimal climatic conditions, natural outdoor CO2 concentrations and sufficient nutrient supply. Leaf diffusive conductance of water vapor cannot be measured directly but can be calculated from measurements of transpiration under known climatic conditions. A number of different methods are used to determine diffusive conductance: transpiration measurements in photosynthesis cuvettes, energy balance measurements or weighing experiments, ventilated diffusion porometers and non-ventilated porometers. Körner (1977) measured diffusive conductance using a ventilated diffusion porometer.

Variable name	Definition
GSI, cont.	To obtain maximum leaf conductance values, leaf conductance is determined between sunrise and late morning until a clear decline or no further increase is observed. Depending on phenology, measurements are taken on at least three bright days in late spring and summer, preferably just after a rainy period. The means of maximum leaf conductance of 5 to 10 samples each day are averaged, yielding the maximum diffusive conductance for the species. Due to the variation of the location of stomata on plant leaves for different plant species, conductance values should be calculated for the total leaf surface area. Required.
VPDFR	Vapor pressure deficit (kPa) corresponding to the second point on the stomatal conductance curve. (The first point on the stomatal conductance curve is comprised of a vapor pressure deficit of 1 kPa and the fraction of maximum stomatal conductance equal to 1.00.) As with radiation-use efficiency, stomatal conductance is sensitive to vapor pressure deficit. Stockle et al (1992) compiled a short list of stomatal conductance response to vapor pressure deficit for a few plant species. Due to the paucity of data, default values for the second point on the stomatal conductance vs. vapor pressure deficit curve are used for all plant species in the database. The fraction of maximum stomatal conductance (FRGMAX) is set to 0.75 and the vapor pressure deficit corresponding to the fraction given by FRGMAX (VPDFR) is set to 4.00 kPa. If the user has actual data, they should use those values, otherwise the default values are adequate. Required.

Variable name	Definition
FRGMAX	Fraction of maximum stomatal conductance corresponding to the second point on the stomatal conductance curve. (The first point on the stomatal conductance curve is comprised of a vapor pressure deficit of 1 kPa and the fraction of maximum stomatal conductance equal to 1.00.) Please read the explanation for parameter VPDFR to obtain additional information about this parameter and methods used to measure it. Required.
WAVP	Rate of decline in radiation use efficiency per unit increase in vapor pressure deficit. Stockle and Kiniry (1990) first noticed a relationship between RUE and vapor pressure deficit and were able to explain a large portion of within-species variability in RUE values for sorghum and corn by plotting RUE values as a function of average daily vapor pressure deficit values. Since this first article, a number of other studies have been conducted that support the dependence of RUE on vapor pressure deficit. However, there is still some debate in the scientific community on the validity of this relationship. If the user does not wish to simulate a change in RUE with vapor pressure deficit, the variable WAVP can be set to 0.0 for the plant. To define the impact of vapor pressure deficit on RUE, vapor pressure deficit values must be recorded during the growing seasons that RUE determinations are being made. It is important that the plants are exposed to no other stress than vapor pressure deficit, i.e. plant growth should not be limited by lack of soil water and nutrients. Vapor pressure deficits can be calculated from relative humidity (see Chapter 1:2 in Theoretical Documentation) or from daily maximum and minimum temperatures using the technique of Diaz and Campbell (1988) as described by Stockle and Kiniry (1990). The change in RUE with vapor pressure deficit is determined by fitting a linear regression for RUE as a function of vapor pressure deficit. Figure 14-4 shows a plot of RUE as a function of vapor pressure deficit for grain sorghum.

Variable name	Definition
WAVP, cont.	

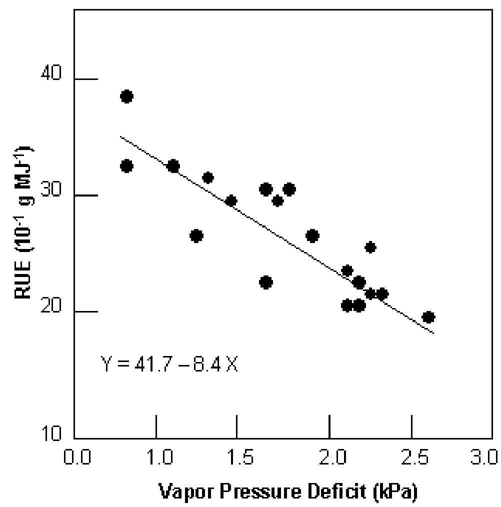

Figure 14-4: Response of radiation-use efficiency to mean daily vapor pressure deficit for grain sorghum (after Kiniry, 1999).

From Figure 14-4, the rate of decline in radiation-use efficiency per unit increase in vapor pressure deficit, Δrue_{dcl}, for sorghum is 8.4×10^{-1} $g\cdot MJ^{-1}\cdot kPa^{-1}$. When RUE is adjusted for vapor pressure deficit, the model assumes the RUE value reported for BIO_E is the radiation-use efficiency at a vapor pressure deficit of 1 kPa.

The value of WAVP varies among species, but a value of 6 to 8 is suggested as an approximation for most plants.

Required.

CO2HI	Elevated CO_2 atmospheric concentration (μL CO_2/L air) corresponding the 2^{nd} point on the radiation use efficiency curve. (The 1^{st} point on the radiation use efficiency curve is comprised of the ambient CO_2 concentration, 330 μL CO_2/L air, and the biomass-energy ratio reported for BIO_E)

Variable name	Definition
CO2HI, cont.	In order to assess the impact of climate change on agricultural productivity, SWAT incorporates equations that adjust RUE for elevated atmospheric CO_2 concentrations. Values must be entered for CO2HI and BIOEHI in the plant database whether or not the user plans to simulate climate change. For simulations in which elevated CO_2 levels are not modeled, CO2HI should be set to some number greater than 330 ppmv and BIOEHI should be set to some number greater than BIO_E. To obtain radiation-use efficiency values at elevated CO_2 levels for plant species not currently in the database, plants should be established in growth chambers set up in the field or laboratory where CO_2 levels can be controlled. RUE values are determined using the same methodology described in the explanation of BIO_E. Required.
BIOEHI	Biomass-energy ratio corresponding to the 2nd point on the radiation use efficiency curve. (The 1st point on the radiation use efficiency curve is comprised of the ambient CO_2 concentration, 330 μL CO_2/L air, and the biomass-energy ratio reported for BIO_E.) Please read the explanation for parameter CO2HI and BIO_E to obtain additional information about this parameter and methods used to measure it. Required.
RSDCO_PL	Plant residue decomposition coefficient. The plant residue decomposition coefficient is the fraction of residue that will decompose in a day assuming optimal moisture, temperature, C:N ratio, and C:P ratio. This variable was originally in the basin input file (.bsn), but was added to the crop database so that users could vary decomposition by plant species. A default value of 0.05 is used for all plant species in the database. Required.

Variable name	Definition
ALAI_MIN	Minimum leaf area index for plant during dormant period (m^2/m^2). This variable pertains to perennials and trees only. (The value is never used for other types of plants.) In versions of SWAT prior to SWAT2009, the minimum leaf area index for plants during the dormant period was always set to 0.75. Because this value was not ideal for all plants (trees in particular), users are now allowed to vary the minimum LAI for dormancy. Please see the explanation given for parameter BLAI to obtain additional information about this parameter and methods used to measure it. Required.
BIO_LEAF	Fraction of tree biomass accumulated each year that is converted to residue during dormancy. This variable pertains to trees only. (The value is never used for other types of plants.) BIO_LEAF governs the amount of biomass that falls off the tree and is converted to residue when the plant goes dormant in the winter. In versions of SWAT prior to SWAT2009, the fraction of biomass converted to residue at the beginning of dormancy was always defined as 0.30. Required if land cover is classified as a tree (see IDC).
MAT_YRS	Number of years required for tree species to reach full development (years). This variable pertains to trees only. (The value is never used for other types of plants.) Required if land cover is classified as a tree (see IDC).
BMX_TREES	Maximum biomass for a forest (metric tons/ha). This variable pertains to trees only. (The value is never used for other types of plants.) The maximum biomass for a mature forest stand generally falls in the range of 30-50 metric tons/ha. Required if land cover is classified as a tree (see IDC).
BMDIEOFF	Biomass dieoff fraction. This coefficient is the fraction above ground biomass that dies off at dormancy. Default value = 0.10.

RSR1C	Initial root to shoot ration at the beginning of the growing season. Default = 0.40.
RSR2C	Root to shoot ration at the end of the growing season. Default = 0.20.
EXT_COEF	Light extinction coefficient. This coefficient is used to calculate the amount of intercepted photosynthetically active radiation. In versions of SWAT prior to SWAT2009, the light extinction coefficient was always defined as 0.65.

EXT_COEF, cont

Differences in canopy structure for a species are described by the number of leaves present (leaf area index) and the leaf orientation. Leaf orientation has a significant impact on light interception and consequently on radiation-use efficiency. More erect leaf types spread the incoming light over a greater leaf area, decreasing the average light intensity intercepted by individual leaves (Figure 14-5). A reduction in light intensity interception by an individual leaf favors a more complete conversion of total canopy-intercepted light energy into biomass.

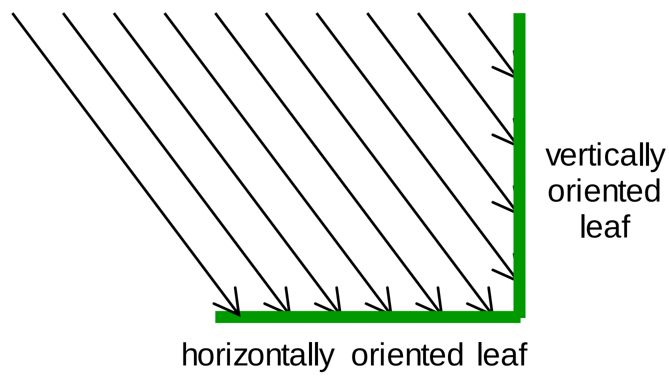

Figure 14-5: Light intensity interception as a function of leaf orientation. The vertically oriented leaf intercepts 4 units of light while a horizontally oriented leaf of the same length intercepts 6 units of light.

Using the light extinction coefficient value (k_ℓ) in the Beer-Lambert formula (equation 5:2.1.1) to quantify efficiency of light interception per unit leaf area index, more erect leaf types have a smaller k_ℓ.

To calculate the light extinction coefficient, the amount of photosynthetically active radiation (PAR) intercepted and the mass of aboveground biomass (LAI) is measured several times throughout a plant's growing season using the methodology described in the previous sections. The light extinction coefficient is then calculated using the Beer-Lambert equation:

$$\frac{TPAR}{PAR} = \left(1 - \exp\left(-k_\ell \cdot LAI\right)\right) \text{ or } k_\ell = -\ln\left(\frac{TPAR}{PAR}\right) \cdot \frac{1}{LAI}$$

where $TPAR$ is the transmitted photosynthetically active radiation, and PAR is the incoming photosynthetically active radiation.

Five lines are required to store the plant growth parameters for a land cover/plant in the database (plant.dat) file. The plant growth database file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line.

Variable name	Line #	Format	F90 Format
ICNUM	1	integer	free
CPNM	1	character	a4
IDC	1	integer	free
BIO_E	2	real	free
HVSTI	2	real	free
BLAI	2	real	Free
FRGRW1	2	real	Free
LAIMX1	2	real	Free
FRGRW2	2	real	Free
LAIMX2	2	real	Free
DLAI	2	real	Free
CHTMX	2	real	free
RDMX	2	real	free
T_OPT	3	real	free
T_BASE	3	real	free
CNYLD	3	real	free
CPYLD	3	real	free
PLTNFR(1)	3	real	free
PLTNFR(2)	3	real	free
PLTNFR(3)	3	real	free
PLTPFR(1)	3	real	free
PLTPFR(2)	3	real	free
PLTPFR(3)	3	real	free
WSYF	4	real	free
USLE_C	4	real	free
GSI	4	real	free
VPDFR	4	real	free
FRGMAX	4	real	free
WAVP	4	real	free

Variable name	Line #	Format	F90 Format
CO2HI	4	real	free
BIOEHI	4	real	free
RSDCO_PL	4	real	free
ALAI_MIN	4	real	free
BIO_LEAF	5	real	free
MAT_YRS	5	integer	free
BMX_TREES	5	real	free
EXT_COEF	5	real	free
BMDIEOFF	5	real	free
RSR1C	5	real	free
RSR2C	5	real	free

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CHAPTER **15**

SWAT INPUT DATA: TILL.DAT

SWAT uses five databases to store information related to plant growth, urban land characteristics, tillage implements, fertilizer components and pesticide properties. The tillage database distributed with SWAT contains mixing depth and mixing efficiency data for the most common tillage implements.

Tillage operations redistribute nutrients, pesticide and residue in the soil profile. Appendix A documents the source of parameter values in the database file provided with the model.

Following is a brief description of the variables in the tillage database file. They are listed in the order they appear within the file.

Variable name	Definition
ITNUM	Tillage number. ITNUM is the numeric code used in the management file to identify the tillage practice to be modeled. The different tillage operations in the tillage database must have unique values for ITNUM. Required.
TILLNM	An eight-character code representing the tillage operation name. Optional.
EFFMIX	Mixing efficiency of tillage operation. The mixing efficiency specifies the fraction of materials (residue, nutrients and pesticides) on the soil surface which are mixed uniformly throughout the soil depth specified by DEPTIL. The remaining fraction of residue and nutrients is left in the original location (soil surface or layer). Required.
DEPTIL	Depth of mixing caused by the tillage operation (mm). Required.

The format of the tillage database file is:

Variable name	Line #	Position	Format	F90 Format
ITNUM	ALL	space 1-4	4-digit integer	i4
TILLNM	ALL	space 9-16	character	a8
EFFMIX	ALL	space 25-32	decimal(xxxx.xxx)	f8.3
DEPTIL	ALL	space 41-48	decimal(xxxx.xxx)	f8.3

CHAPTER 16

SWAT INPUT DATA: PEST.DAT

SWAT uses five databases to store information related to plant growth, urban land characteristics, tillage implements, fertilizer components and pesticide properties. The pesticide database contains parameters that govern pesticide fate and transport in the HRUs. Appendix A documents the source of parameter values in the database file provided with the model.

Following is a brief description of the variables in the pesticide/toxin database file. They are listed in the order they appear within the file.

Variable name	Definition
IPNUM	Pesticide/toxin number. IPNUM is the numeric code used in the management file to identify the pesticide/toxin to be applied. The different toxins in the pesticide database must have unique values for IPNUM. Required.
PNAME	Name of pesticide/toxin. (up to 17 characters allowed) Required.
SKOC	Soil adsorption coefficient normalized for soil organic carbon content (mg/kg)/(mg/L). Pesticide in the soil environment can be transported in solution or attached to sediment. The partitioning of a pesticide between the solution and soil phases is defined by the soil adsorption coefficient for the pesticide. The soil adsorption coefficient is the ratio of the pesticide concentration in the soil or solid phase to the pesticide concentration in the solution or liquid phase: $K_p = \frac{C_{solidphase}}{C_{solution}}$ where K_p is the soil adsorption coefficient ((mg/kg)/(mg/L) or m^3/ton), $C_{solidphase}$ is the concentration of the pesticide sorbed to the solid phase (mg chemical/kg solid material or g/ton), and $C_{solution}$ is the concentration of the pesticide in solution (mg chemical/L solution or g/ton). The definition of the soil adsorption coefficient in this equation assumes that the pesticide sorption process is linear with concentration and instantaneously reversible. Because the partitioning of pesticide is dependent upon the amount of organic material in the soil, the soil adsorption coefficient input to the model is normalized for soil organic carbon content. The relationship between the soil adsorption coefficient and the soil adsorption coefficient normalized for soil organic carbon content is: $K_p = K_{oc} \cdot \frac{orgC}{100}$

Variable name	Definition
SKOC, cont.	where K_p is the soil adsorption coefficient ((mg/kg)/(mg/L)), K_{oc} is the soil adsorption coefficient normalized for soil organic carbon content ((mg/kg)/(mg/L) or m^3/ton), and *orgC* is the percent organic carbon present in the soil. Required.
WOF	Wash-off fraction. The wash-off fraction quantifies the fraction of pesticide on the plant canopy that may be dislodged. The wash-off fraction is a function of the nature of the leaf surface, plant morphology, pesticide solubility, polarity of the pesticide molecule, formulation of the commercial product and timing and volume of the rainfall event. Required.
HLIFE_F	Degradation half-life of the chemical on the foliage (days). The half-life for a pesticide defines the number of days required for a given pesticide concentration to be reduced by one-half. The half-life entered for a pesticide is a lumped parameter that includes the net effect of volatilization, photolysis, hydrolysis, biological degradation and chemical reactions. For most pesticides, the foliar half-life is much less than the soil half-life due to enhanced volatilization and photodecomposition. If the foliar half-life is available for the pesticide this value should be used. If the foliar half-life is not available, the foliar half-life can be estimated using the following rules: 1) Foliar half-life is assumed to be less than the soil half-life by a factor of 0.5 to 0.25, depending on vapor pressure and sensitivity to photodegradation. 2) Foliar half-life is adjusted downward for pesticides with vapor pressures less than 10^{-5} mm Hg. 3) The maximum foliar half-life assigned is 30 days. Required.

Variable name	Definition
HLIFE_S	Degradation half-life of the chemical in the soil (days). The half-life for a pesticide defines the number of days required for a given pesticide concentration to be reduced by one-half. The soil half-life entered for a pesticide is a lumped parameter that includes the net effect of volatilization, photolysis, hydrolysis, biological degradation and chemical reactions. Required.
AP_EF	Application efficiency. The fraction of pesticide applied which is deposited on the foliage and soil surface (0.1-1.0). The remainder is lost. The application efficiency for all pesticides listed in the database is defaulted to 0.75. This variable is a calibration parameter. Required.
WSOL	Solubility of the chemical in water (mg/L or ppm) The water solubility value defines the highest concentration of pesticide that can be reached in the runoff and soil pore water. While this is an important characteristic, researchers have found that the soil adsorption coefficient, K_{oc}, tends to limit the amount of pesticide entering solution so that the maximum possible concentration of pesticide in solution is seldom reached. Reported solubility values are determined under laboratory conditions at a constant temperature, typically between 20°C and 30°C. Required.

The format of the pesticide/toxin database file is:

Variable name	Line #	Position	Format	F90 Format
IPNUM	ALL	space 1-3	integer	i3
PNAME	ALL	space 4-20	character	a17
SKOC	ALL	space 21-30	decimal(xxxxxxxx.x)	f10.1
WOF	ALL	space 31-35	decimal(xx.xx)	f5.2
HLIFE_F	ALL	space 36-43	decimal(xxxxxx.x)	f8.1
HLIFE_S	ALL	space 44-51	decimal(xxxxxx.x)	f8.1
AP_EF	ALL	space 52-56	decimal(xx.xx)	f5.2
WSOL	ALL	space 57-67	decimal(xxxxxxx.xxx)	f11.3

CHAPTER 17

SWAT INPUT DATA: FERT.DAT

SWAT uses five databases to store information related to plant growth, urban land characteristics, tillage implements, fertilizer components and pesticide properties. The fertilizer database summarizes the relative fractions of nitrogen and phosphorus pools in the different fertilizers. Information on levels of bacteria in manure is also stored in this file. Appendix A documents the source of parameter values in the database file provided with the model.

Following is a brief description of the variables in the fertilizer database file. They are listed in the order they appear within the file.

Variable name	Definition
IFNUM	Fertilizer identification number. IFNUM is the reference number used in the management file to identify the fertilizer type being applied. The different fertilizers/manures in the fertilizer database must have unique values for IFNUM. Required.
FERTNM	Name of fertilizer/manure (up to 8 characters allowed). Required.
FMINN	Fraction of mineral N (NO_3 and NH_4) in fertilizer (kg min-N/kg fertilizer). Value should be between 0.0 and 1.0. Required.
FMINP	Fraction of mineral P in fertilizer (kg min-P/kg fertilizer). Value should be between 0.0 and 1.0. Required.
FORGN	Fraction of organic N in fertilizer (kg org-N/kg fertilizer). Value should be between 0.0 and 1.0. Required.
FORGP	Fraction of organic P in fertilizer (kg org-P/kg fertilizer). Value should be between 0.0 and 1.0. Required.
FNH3N	Fraction of mineral N in fertilizer applied as ammonia (kg NH_3-N/kg min-N). Value should be between 0.0 and 1.0. Required.
BACTPDB	Concentration of persistent bacteria in manure/fertilizer (# cfu/g manure). Optional.

Variable name	Definition
BACTLPDB	Concentration of less-persistent bacteria in manure/fertilizer (# cfu/g manure). Optional.
BACTKDDB	Bacteria partition coefficient. Value should be between 0.0 and 1.0. As the bacteria partition coefficient approaches 0.0, bacteria is primarily sorbed to soil particles. As the bacteria partition coefficient approaches 1.0, bacteria is primarily in solution. Optional.

The format of the fertilizer database file is:

Variable name	Line #	Position	Format	F90 Format
IFNUM	ALL	space 1-4	integer	i4
FERTNM	ALL	space 6-13	character	a8
FMINN	ALL	space 14-21	decimal(xxxx.xxx)	f8.3
FMINP	ALL	space 22-29	decimal(xxxx.xxx)	f8.3
FORGN	ALL	space 30-37	decimal(xxxx.xxx)	f8.3
FORGP	ALL	space 38-45	decimal(xxxx.xxx)	f8.3
FNH3N	ALL	space 46-53	decimal(xxxx.xxx)	f8.3
BACTPDB	ALL	space 54-61	decimal(xxxx.xxx)	f8.3
BACTLPDB	ALL	space 62-71	decimal(xxxxxxx.xx)	f10.2
BACTKDDB	ALL	space 72-81	decimal(xxxxxxx.xx)	f10.2

CHAPTER 18

SWAT INPUT DATA: URBAN.DAT

SWAT uses five databases to store information related to plant growth, urban land characteristics, tillage implements, fertilizer components and pesticide properties. The urban database summarizes parameters used by the model to simulate different types of urban areas. Appendix A documents the source of parameter values in the database file provided with the model.

Following is a brief description of the variables in the urban database file. They are listed in the order they appear within the file.

Variable name	Definition
IUNUM	Urban land type identification number. IUNUM is the numeric code used in the management file to identify the urban land type present in an HRU. The different land types in the urban database must have unique values for IUNUM. Required.
URBNAME	4-character code for urban land type. The 4-letter codes in the plant growth and urban databases are used by the GIS interfaces to link land use/land cover maps to SWAT plant types. This code is printed to the output files. When adding a new urban category, the four letter code for the new urban land type must be unique. Required.
URBFLNM	Full description for urban land type—may take up to 54 characters. (not used by SWAT) Optional.
FIMP	Fraction total impervious area in urban land type. This includes directly and indirectly connected impervious areas. Urban areas differ from rural areas in the fraction of total area that is impervious. Construction of buildings, parking lots and paved roads increases the impervious cover in a watershed and reduces infiltration. With development, the spatial flow pattern of water is altered and the hydraulic efficiency of flow is increased through artificial channels, curbing, and storm drainage and collection systems. Required.
FCIMP	Fraction directly connected impervious area in urban land type.

Variable name	Definition
FCIMP, cont.	Impervious areas can be differentiated into two groups—the area that is hydraulically connected to the drainage system and the area that is not directly connected. As an example, assume there is a house surrounded by a yard where runoff from the roof flows into the yard and is able to infiltrate into the soil. The rooftop is impervious but it is not hydraulically connected to the drainage system. In contrast, a parking lot whose runoff enters a storm water drain is hydraulically connected. When modeling urban areas the connectedness of the drainage system must be quantified. The best methods for determining the fraction total and directly connected impervious areas is to conduct a field survey or analyze aerial photographs. Required.
CURBDEN	Curb length density in urban land type (km/ha). Curb length may be measured directly by scaling the total length of streets off of maps and multiplying by two. To calculate the density, the curb length is divided by the area represented by the map. Required.
URBCOEF	Wash-off coefficient for removal of constituents from impervious area (mm^{-1}). Wash off is the process of erosion or solution of constituents from an impervious surface during a runoff event. The original default value for urb_{coef} was calculated as 0.18 mm^{-1} by assuming that 13 mm of total runoff in one hour would wash off 90% of the initial surface load (Huber and Heaney, 1982). Using sediment transport theory, Sonnen (1980) estimated values for the wash-off coefficient ranging from 0.002-0.26 mm^{-1}. Huber and Dickinson (1988) noted that values between 0.039 and 0.390 mm^{-1} for the wash-off coefficient give sediment concentrations in the range of most observed values. This variable is used to calibrate the model to observed data. Required.
DIRTMX	Maximum amount of solids allowed to build up on impervious areas (kg/curb km). Required.

Variable name	Definition
THALF	Number of days for amount of solids on impervious areas to build up from 0 kg/curb km to half the maximum allowed, i.e. 1/2 DIRTMX (days). Required.
TNCONC	Concentration of total nitrogen in suspended solid load from impervious areas (mg N/kg sed). Required.
TPCONC	Concentration of total phosphorus in suspended solid load from impervious areas (mg P/kg sed). Required.
TNO3CONC	Concentration of nitrate in suspended solid load from impervious areas (mg NO_3-N/kg sed). Required.
URBCN2	Curve number for moisture condition II in impervious areas of urban land type. Required.

Every urban land type uses two lines in the urban.dat file to store input values. The format of every set of two lines is described below.

Variable name	Line #	Position	Format	F90 Format
IUNUM	1	space 1-3	integer	i3
URBNAME	1	space 5-8	character	a4
URBFLNM	1	space 10-64	character	a55
FIMP	1	space 65-72	decimal(xxxx.xxx)	f8.3
FCIMP	1	space 73-80	decimal(xxxx.xxx)	f8.3
CURBDEN	2	space 5-12	decimal(xxxx.xxx)	f8.3
URBCOEF	2	space 13-20	decimal(xxxx.xxx)	f8.3
DIRTMX	2	space 21-28	decimal(xxxx.xxx)	f8.3
THALF	2	space 29-36	decimal(xxxx.xxx)	f8.3
TNCONC	2	space 37-44	decimal(xxxx.xxx)	f8.3
TPCONC	2	space 45-52	decimal(xxxx.xxx)	f8.3
TNO3CONC	2	space 53-60	decimal(xxxx.xxx)	f8.3
URBCN2	2	space 61-66	decimal(xxxx.x)	f6.1

REFERENCES

Huber, W.C. and R.E. Dickinson. 1988. Storm water management model, version 4: user's manual. U.S. Environmental Protection Agency, Athens, GA.

Huber, W.C. and J.P. Heaney. 1982. Chapter 3: Analyzing residual discharge and generation from urban and non-urban land surfaces. p. 121-243. *In* D.J. Basta and B.T. Bower (eds). Analyzing natural systems, analysis for regional residuals—environmental quality management. John Hopkins University Press, Baltimore, MD.

Sonnen, M.B. 1980. Urban runoff quality: information needs. ASCE Journal of the Technical Councils 106(TC1): 29-40.

CHAPTER 19

SWAT INPUT DATA: .HRU

The HRU general input file contains information related to a diversity of features within the HRU. Data contained in the HRU input file can be grouped into the following categories: topographic characteristics, water flow, erosion, land cover, and depressional storage areas.

Following is a brief description of the variables in the HRU general input file. They are listed in the order they appear within the file.

19.1 TITLE

Variable name	Definition
TITLE	The first line of the .hru file is reserved for user comments. The comments may take up to 80 spaces. The title line is not processed by the model and may be left blank. Optional.

19.2 TOPOGRAPHIC CHARACTERISTICS

Variable name	Definition
HRU_FR	Fraction of subbasin area contained in HRU (km^2/km^2). If no value for HRU_FR is entered, the model will set HRU_FR = 0.0000001. Required.
SLSUBBSN	Average slope length (m). This is the distance that sheet flow is the dominant surface runoff flow process. Slope length should be measured to the point that flow begins to concentrate. This length is easily observable after a heavy rain on a fallow field when the rills are well developed. In this situation, the slope length is the distance from the microwatershed divide to the origin of the rill. This value can also be determined from topographic maps. Terraces divide the slope of the hill into segments equal to the horizontal terrace interval. With terracing, the slope length is the terrace interval. For broadbase terraces, the horizontal terrace interval is the distance from the center of the ridge to the center of the channel for the terrace below. The horizontal terrace interval for steep backslope terraces is the distance from the point where cultivation begins at the base of the ridge to the base of the frontslope of the terrace below.

Variable name	Definition
SLSUBBSN, cont.	Slope length is a parameter that is commonly overestimated. As a rule of thumb, 90 meters (300 ft) is considered to be a very long slope length. If no value for SLSUBBSN is entered, the model will set SLSUBBSN = 50. The GIS interfaces will assign the same value to this variable for all HRUs within a subbasin. However, some users like to vary this value by soil type and land cover. Required.
SLSOIL	Slope length for lateral subsurface flow (m). If no value is entered for SLSOIL, the model sets SLSOIL = SLSUBBSN. The GIS interfaces will assign the same value to this variable for all HRUs within a subbasin. However, some users like to vary this value by soil type and land cover. Required.
HRU_SLP	Average slope steepness (m/m). The GIS interfaces will assign the same value to this variable for all HRUs within a subbasin. However, some users like to vary this value by soil type and land cover. Required.

19.3 LAND COVER CHARACTERISTICS

Variable name	Definition
CANMX	Maximum canopy storage (mm H_2O). The plant canopy can significantly affect infiltration, surface runoff and evapotranspiration. As rain falls, canopy interception reduces the erosive energy of droplets and traps a portion of the rainfall within the canopy. The influence the canopy exerts on these processes is a function of the density of plant cover and the morphology of the plant species.

Variable name	Definition
CANMX, cont.	When calculating surface runoff, the SCS curve number method lumps canopy interception in the term for initial abstractions. This variable also includes surface storage and infiltration prior to runoff and is estimated as 20% of the retention parameter value for a given day (see Chapter 2:1). When the Green and Ampt infiltration equation is used to calculate infiltration, the interception of rainfall by the canopy must be calculated separately. SWAT allows the maximum amount of water that can be held in canopy storage to vary from day to day as a function of the leaf area index. CANMX is the maximum amount of water that can be trapped in the canopy when the canopy is fully developed (mm H_2O). Required.
RSDIN	Initial residue cover (kg/ha). Optional.
OV_N	Manning's "n" value for overland flow. Required.

Table 19-1: Values of Manning's roughness coefficient, *n*, for overland flow (Engman, 1983).

Characteristics of Land Surface	Median	Range
Fallow, no residue	0.010	0.008-0.012
Conventional tillage, no residue	0.090	0.060-0.120
Conventional tillage, residue	0.190	0.160-0.220
Chisel plow, no residue	0.090	0.060-0.120
Chisel plow, residue	0.130	0.100-0.160
Fall disking, residue	0.400	0.300-0.500
No till, no residue	0.070	0.040-0.100
No till, 0.5-1 t/ha residue	0.120	0.070-0.170
No till, 2-9 t/ha residue	0.300	0.170-0.470
Rangeland, 20% cover	0.600	
Short grass prairie	0.150	0.100-0.200
Dense grass	0.240	0.170-0.300
Bermudagrass	0.410	0.300-0.480

19.4 WATER CYCLING

Variable name	Definition
LAT_TTIME	Lateral flow travel time (days). Setting LAT_TTIME = 0.0 will allow the model to calculate the travel time based on soil hydraulic properties. This variable should be set to a specific value only by hydrologists familiar with the base flow characteristics of the watershed. Required.
POT_FR	Fraction of HRU area that drains into pothole. Required only if depressional storage area/pothole is defined in subbasin.
FLD_FR	Fraction of HRU area that drains into floodplain. Required only if floodplain is defined in subbasin.
RIP_FR	Fraction of HRU area that drains into riparian area. Required only if riparian area is defined in subbasin.
DEP_IMP	Depth to impervious layer in soil profile (mm). Perched water tables are created when water percolating through the soil profile reaches a layer of low hydraulic conductivity that causes water to pond at the upper boundary of the impervous layer. This variable defines the depth to the impervious layer in the soil profile and is required if perched water tables, depressional storage areas/potholes, or tile drainage is being modeled in the HRU (or subbasin for depressional storage areas). If perched water tables do not occur in the HRU leave this variable set to 0. If a generic depth is defined using DEPIMP_BSN (.bsn), set DEP_IMP = 0 to use the basin-level value.
EV_POT	Pothole evaporation coefficient. Default = 0.50.
DIS_STREAM	Average distance to the stream (m). Default = 35.0.
CF	This parameter controls the response of decomposition to the combined effect of soil temperature and moisture. You can get a more accurate definition and the range of values from the table below.
CFH	Maximum humification rate

Variable name	Definition
CFDEC	The undisturbed soil turnover rate under optimum soil water and temperature. Increasing it will increase carbon and organic N decomposition.

Upper and lower bounds of the parameters varied within the Monte Carlo framework

Parameter [unit]	Lower bound	Upper bound
Power controlling decomposition, f_p [dimensionless]	0.5	1.0
Maximum humification rate, h_R [day^{-1}]	x0.8	x1.2
Maximum decomposition rate, k_S [year^{-1}]	0.045	0.065

Unless the user has measured data and the model is decomposing soil carbon or organic N too fast or too slow, the user should simply leave these parameters set to the default values.

19.5 EROSION

Variable name	Definition
LAT_SED	Sediment concentration in lateral and groundwater flow (mg/L). Sediment concentration in lateral and groundwater flow is usually very low and does not contribute significantly to total sediment yields unless return flow is very high. Optional.
EPCO	Plant uptake compensation factor. The amount of water uptake that occurs on a given day is a function of the amount of water required by the plant for transpiration, E_t, and the amount of water available in the soil, *SW*. If upper layers in the soil profile do not contain enough water to meet the potential water uptake, users may allow lower layers to compensate. The plant uptake compensation factor can range from 0.01 to 1.00. As *epco* approaches 1.0, the model allows more of the water uptake demand to be met by lower layers in the soil. As *epco* approaches 0.0, the model allows less variation from the original depth distribution to take place.

Variable name	Definition
EPCO, cont.	If no value for EPCO is entered, the model will set EPCO = 1.0. The value for EPCO may be set at the watershed or HRU level (EPCO in .bsn, see Chapter 4). Required.
ESCO	Soil evaporation compensation factor. This coefficient has been incorporated to allow the user to modify the depth distribution used to meet the soil evaporative demand to account for the effect of capillary action, crusting and cracks. ESCO must be between 0.01 and 1.0. As the value for ESCO is reduced, the model is able to extract more of the evaporative demand from lower levels. The change in depth distribution resulting from different values of *esco* are graphed in Figure 19-1. If no value for ESCO is entered, the model will set ESCO = 0.95. The value for ESCO may be set at the watershed or HRU level (ESCO in .bsn, see Chapter 4). Required.

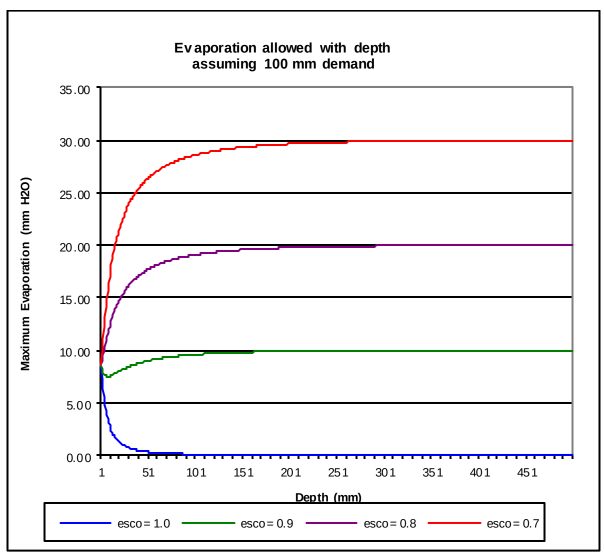

Figure 19-1: Soil evaporative demand distribution with depth

Variable name	Definition
ERORGN	Organic N enrichment ratio for loading with sediment. As surface runoff flows over the soil surface, part of the water's energy is used to pick up and transport soil particles. The smaller particles weigh less and are more easily transported than coarser particles. When the particle size distribution of the transported sediment is compared to that of the soil surface layer, the sediment load to the main channel has a greater proportion of clay sized particles. In other words, the sediment load is enriched in clay particles. Organic nitrogen in the soil is attached primarily to colloidal (clay) particles, so the sediment load will also contain a greater proportion or concentration of organic N than that found in the soil surface layer. The enrichment ratio is defined as the ratio of the concentration of organic nitrogen transported with the sediment to the concentration in the soil surface layer. SWAT will calculate an enrichment ratio for each storm event, or allow the user to define a particular enrichment ratio for organic nitrogen that is used for all storms during the simulation. To calculate the enrichment ratio, the value for ERORGN is set to zero. The default option is to allow the model to calculate the enrichment ratio. Required.
ERORGP	Phosphorus enrichment ratio for loading with sediment. The enrichment ratio is defined as the ratio of the concentration of phosphorus transported with the sediment to the concentration of phosphorus in the soil surface layer. SWAT will calculate an enrichment ratio for each storm event, or allow the user to define a particular enrichment ratio for phosphorus attached to sediment that is used for all storms during the simulation. If the value for ERORGP is set to zero, the model will calculate an enrichment ratio for every storm event. The default option is to allow the model to calculate the enrichment ratio. Required.

19.6 DEPRESSIONAL STORAGE AREA/POTHOLE

Variable name	Definition
POT_TILE	Average daily outflow to main channel from tile flow if drainage tiles are installed in the pothole (mm). Required only for the HRU that is defined as a depressional storage area/pothole.
POT_VOLX	Maximum volume of water stored in the pothole (mm). Required only for the HRU that is defined as a depressional storage area/pothole.
POT_VOL	Initial volume of water stored in the pothole (mm). Required only for the HRU that is defined as a depressional storage area/pothole.
POT_NSED	Equilibrium sediment concentration in pothole (mg/L). Required only for the HRU that is defined as a depressional storage area/pothole.
POT_NO3L	*Not currently active*. Nitrate decay rate in pothole (1/day). Required only for the HRU that is defined as a depressional storage area/pothole.

The HRU general input file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format for the HRU general input file is:

Variable name	Line #	Format	F90 Format
TITLE	1	character	a80
HRU_FR	2	real	free
SLSUBBSN	3	real	free
HRU_SLP	4	real	free
OV_N	5	real	free
LAT_TTIME	6	real	free

Variable name	Line #	Format	F90 Format
LAT_SED	7	real	free
SLSOIL	8	real	free
CANMX	9	real	free
ESCO	10	real	free
EPCO	11	real	free
RSDIN	12	real	free
ERORGN	13	real	free
ERORGP	14	real	free
POT_FR	15	real	free
FLD_FR	16	real	free
RIP_FR	17	real	free
Comment line	18	character	a80
POT_TILE	19	real	free
POT_VOLX	20	real	free
POT_VOL	21	real	free
POT_NSED	22	real	free
POT_NO3L	23	real	free
DEP_IMP	24	real	free
EVPOT	28	real	free
DIS_STREAM	29	real	free
CF	30	real	free
CFH	31	real	free
CFDEC	32	real	free

19.7 URBAN BPM REDUCTIONS

Variable name	Definition
SED_CON	Sediment concentration in runoff, after urban BMP is applied (0-5,000 ppm)
ORGN_CON	Organic nitrogen concentration in runoff, after urban BMP is applied (0-100 ppm)
ORGP_CON	Organic phosphorus concentration in runoff, after urban BMP is applied (0-50 ppm)
SOLN_CON	Soluble nitrogen concentration in runoff, after urban BMP is applied (0-10 ppm)
SOLP_CON	Soluble phosphorus concentration in runoff, after urban BMP is applied (0-3 ppm)

19.8 REFERENCES

Engman, E.T. 1983. Roughness coefficients for routing surface runoff. Proc. Spec. Conf. Frontiers of Hydraulic Engineering.

CHAPTER 20

SWAT INPUT DATA: .MGT

A primary goal of environmental modeling is to assess the impact of human activities on a given system. Central to this assessment is the itemization of the land and water management practices taking place within the system. The primary file used to summarize these practices is the HRU management file (.mgt). This file contains input data for planting, harvest, irrigation applications, nutrient applications, pesticide applications, and tillage operations. Information regarding tile drains and urban areas is also stored in this file.

The management file can be divided into two sections. The first section summarizes inputs for initial conditions or management practices that never change during the simulation. The second section lists the schedule of management operations occurring at specific times.

20.1 GENERAL MANAGEMENT VARIABLES

The general management variables are:

Variable name	Definition
TITLE	The first line of the .mgt file is reserved for user comments. The comments may take up to 80 spaces. The title line is not processed by the model and may be left blank. Optional.
NMGT	Management code. Used by SWAT/GRASS (GIS) interface. The model doesn't use this variable. Optional.

20.1.1 INITIAL PLANT GROWTH PARAMETERS

Variable name	Definition
IGRO	Land cover status code. This code informs the model whether or not a land cover is growing at the beginning of the simulation. 0 no land cover growing 1 land cover growing Required.
PLANT_ID	Land cover identification number. If a land cover is growing at the beginning of the simulation (IGRO = 1), this variable defines the type of land cover. The identification number is the numeric code for the land cover given in the plant growth database (Chapter 14). Required if IGRO = 1.
LAI_INIT	Initial leaf area index. If a land cover is growing at the beginning of the simulation (IGRO = 1), the leaf area index of the land cover must be defined. Required if IGRO = 1.

Variable name	Definition
BIO_INIT	Initial dry weight biomass (kg/ha). If a land cover is growing at the beginning of the simulation (IGRO = 1), the initial biomass must be defined. Required if IGRO = 1.
PHU_PLT	Total number of heat units or growing degree days needed to bring plant to maturity. This value is needed only if a land cover is growing at the beginning of the simulation (IGRO = 1). Calculation of PHU_PLT is reviewed in Chapter 5:1 of the Theoretical Documentation. Required if IGRO = 1.

20.1.2 GENERAL MANAGEMENT PARAMETERS

Variable name	Definition
BIOMIX	Biological mixing efficiency. Biological mixing is the redistribution of soil constituents as a result of the activity of biota in the soil (e.g. earthworms, etc.). Studies have shown that biological mixing can be significant in systems where the soil is only infrequently disturbed. In general, as a management system shifts from conventional tillage to conservation tillage to no-till there will be an increase in biological mixing. SWAT allows biological mixing to occur to a depth of 300 mm (or the bottom of the soil profile if it is shallower than 300 mm). The efficiency of biological mixing is defined by the user and is conceptually the same as the mixing efficiency of a tillage implement. The redistribution of nutrients by biological mixing is calculated using the same methodology as that used for a tillage operation. Biological mixing is performed at the end of every calendar year. If no value for BIOMIX is entered, the model will set BIOMIX = 0.20. Optional.

Variable name	Definition
CN2	Initial SCS runoff curve number for moisture condition II. The SCS curve number is a function of the soil's permeability, land use and antecedent soil water conditions. Typical curve numbers for moisture condition II are listed in the following tables for various land covers and soil types (SCS Engineering Division, 1986). These values are appropriate for a 5% slope. The curve number may be updated in plant, tillage, and harvest/ kill operations. If CNOP is never defined for these operations, the value set for CN2 will be used throughout the simulation. If CNOP is defined for an operation, the value for CN2 is used until the time of the operation containing the first CNOP value. From that point on, the model only uses operation CNOP values to define the curve number for moisture condition II. Values for CN2 and CNOP should be entered for pervious conditions. In HRUs with urban areas, the model will adjust the curve number to reflect the impact of the impervious areas. Required.

Table 20-1: Runoff curve numbers for cultivated agricultural lands

Cover			Hydrologic Soil Group			
Land Use	**Treatment or practice**	**Hydrologic condition**	**A**	**B**	**C**	**D**
Fallow	Bare soil	- - - -	77	86	91	94
	Crop residue cover*	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row	Poor	72	81	88	91
		Good	67	78	85	89
	Straight row w/ residue	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured w/ residue	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced	Poor	66	74	80	82
		Good	62	71	78	81
	Contoured & terraced w/ residue	Poor	65	73	79	81
		Good	61	70	77	80
Small grains	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Straight row w/ residue	Poor	64	75	83	86
		Good	60	72	80	84

* Crop residue cover applies only if residue is on at least 5% of the surface throughout the year.

Variable name	**Definition**

CN2, cont.

Cover			Hydrologic Soil Group			
Land Use	**Treatment or practice**	**Hydrologic condition**	**A**	**B**	**C**	**D**
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured w/ residue	Poor	62	73	81	84
		Good	60	72	80	83
	Contoured & terraced	Poor	61	72	79	82
		Good	59	70	78	81
	Contoured & terraced w/ residue	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation	Straight row	Poor	66	77	85	89
		Good	58	72	81	85
	Contoured	Poor	64	75	83	85
		Good	55	69	78	83
	Contoured & terraced	Poor	63	73	80	83
		Good	51	67	76	80

Table 20-2: Runoff curve numbers for other agricultural lands

Cover		Hydrologic Soil Group			
Cover Type	**Hydrologic condition**	**A**	**B**	**C**	**D**
Pasture, grassland, or range—continuous forage for grazing[1]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay	- - - -	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element[2]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30	48	65	73
Woods—grass combination (orchard or tree farm)	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods[3]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	- - - -	59	74	82	86

[1] *Poor:* < 50% ground cover or heavily grazed with no mulch; *Fair:* 50 to 75% ground cover and not heavily grazed; *Good*: > 75% ground cover and lightly or only occasionally grazed
[2] *Poor:* < 50% ground cover; *Fair:* 50 to 75% ground cover; Good: > 75% ground cover
[3] *Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning; *Fair:* Woods are grazed but not burned, and some forest litter covers the soil; *Good:* Woods are protected from grazing, and litter and brush adequately cover the soil.

Variable name	Definition

CN2, cont.

Table 20-3: Runoff curve numbers for urban areas[§]

Cover			Hydrologic Soil Group			
Cover Type	Hydrologic condition	Average % impervious area	A	B	C	D
Fully developed urban areas						
Open spaces (lawns, parks, golf courses, cemeteries, etc.)[†]	Poor		68	79	86	89
	Fair		49	69	79	84
	Good		39	61	74	80
Impervious areas:						
Paved parking lots, roofs, driveways, etc. (excl. right-of-way)	- - - -		98	98	98	98
Paved streets and roads; open ditches (incl. right-of-way)	- - - -		83	89	92	93
Gravel streets and roads (including right-of-way)	- - - -		76	85	89	91
Dirt streets and roads (including right-of way)	- - - -		72	82	87	89
Urban districts:						
Commercial and business		85%	89	92	94	95
Industrial		72%	81	88	91	93
Residential Districts by average lot size:						
1/8 acre (0.05 ha) or less (town houses)		65%	77	85	90	92
1/4 acre (0.10 ha)		38%	61	75	83	87
1/3 acre (0.13 ha)		30%	57	72	81	86
1/2 acre (0.20 ha)		25%	54	70	80	85
1 acre (0.40 ha)		20%	51	68	79	84
2 acres (0.81 ha)		12%	46	65	77	82
Developing urban areas:						
Newly graded areas (pervious areas only, no vegetation)			77	86	91	94

USLE_P

USLE equation support practice factor.

The support practice factor, P_{USLE}, is defined as the ratio of soil loss with a specific support practice to the corresponding loss with up-and-down slope culture. Support practices include contour tillage, stripcropping on the contour, and terrace systems. Stabilized waterways for the disposal of excess rainfall are a necessary part of each of these practices.

Contour tillage and planting provides almost complete protection against erosion from storms of low to moderate intensity, but little or no protection against occasional severe storms that cause extensive breakovers of contoured rows. Contouring is most effective on slopes of 3 to 8 percent. Values for P_{USLE} and slope-length limits for contour support practices are given in Table 20-4.

[§] SWAT will automatically adjust curve numbers for impervious areas when IURBAN and URBLU are defined in the .hru file. Curve numbers from Table 6-3 should ***not*** be used in this instance.

[†] *Poor:* grass cover < 50%; *Fair:* grass cover 50 to 75%; *Good:* grass cover > 75%

Variable name	Definition

USLE_P, cont.

Table 20-4: P factor values and slope-length limits for contouring (Wischmeier and Smith, 1978).

Land slope (%)	P_{USLE}	Maximum length (m)
1 to 2	0.60	122
3 to 5	0.50	91
6 to 8	0.50	61
9 to 12	0.60	37
13 to 16	0.70	24
17 to 20	0.80	18
21 to 25	0.90	15

Stripcropping is a practice in which contoured strips of sod are alternated with equal-width strips of row crop or small grain. Recommended values for contour stripcropping are given in Table 20-5.

Table 20-5: P factor values, maximum strip width and slope-length limits for contour stripcropping (Wischmeier and Smith, 1978).

Land slope (%)	P_{USLE} values[1] A	B	C	Strip width (m)	Maximum length (m)
1 to 2	0.30	0.45	0.60	40	244
3 to 5	0.25	0.38	0.50	30	183
6 to 8	0.25	0.38	0.50	30	122
9 to 12	0.30	0.45	0.60	24	73
13 to 16	0.35	0.52	0.70	24	49
17 to 20	0.40	0.60	0.80	18	37
21 to 25	0.45	0.68	0.90	15	30

[1]P values:

A: For 4-year rotation of row crop, small grain with meadow seeding, and 2 years of meadow. A second row crop can replace the small grain if meadow is established in it.

B: For 4-year rotation of 2 years row crop, winter grain with meadow seeding, and 1-year meadow.

C: For alternate strips of row crop and winter grain

Terraces are a series of horizontal ridges made in a hillside. There are several types of terraces. Broadbase terraces are constructed on gently sloping land and the channel and ridge are cropped the same as the interterrace area. The steep backslope terrace, where the backslope is in sod, is most common on steeper land. Impoundment terraces are terraces with underground outlets.

Variable name	Definition
USLE_P, cont.	Terraces divide the slope of the hill into segments equal to the horizontal terrace interval. With terracing, the slope length is the terrace interval. For broadbase terraces, the horizontal terrace interval is the distance from the center of the ridge to the center of the channel for the terrace below. The horizontal terrace interval for steep backslope terraces is the distance from the point where cultivation begins at the base of the ridge to the base of the frontslope of the terrace below.

Values for P_{USLE} for contour farming terraced fields are listed in Table 20-6. These values apply to broadbase, steep backslope and level terraces. Keep in mind that the values given in Table 20-6 do not account for all erosion control benefits of terraces. The shorter slope-length used in the calculation of the length-slope factor will produce additional reduction.

Required.

Table 20-6: P factor values for contour-farmed terraced fields[1]

Land slope (%)	Farm planning		Computing sediment yield[3]	
	Contour P factor[2]	Stripcrop P factor	Graded channels sod outlets	Steep backslope underground outlets
1 to 2	0.60	0.30	0.12	0.05
3 to 8	0.50	0.25	0.10	0.05
9 to 12	0.60	0.30	0.12	0.05
13 to 16	0.70	0.35	0.14	0.05
17 to 20	0.80	0.40	0.16	0.06
21 to 25	0.90	0.45	0.18	0.06

[1] Slope length is the horizontal terrace interval. The listed values are for contour farming. No additional contouring factor is used in the computation.
[2] Use these values for control of interterrace erosion within specified soil loss tolerances.
[3] These values include entrapment efficiency and are used for control of offsite sediment within limits and for estimating the field's contribution to watershed sediment yield.

BIO_MIN	Minimum plant biomass for grazing (kg/ha).

This variable was created so that the plant cover in an HRU would not be reduced to zero when grazing was included in the list of management operations. Grazing will not be simulated unless the biomass is at or above BIO_MIN.

Required if grazing occurs in HRU.

Variable name	Definition
FILTERW	Width of edge-of-field filter strip (m). Edge-of field filter strips may be defined in an HRU. Sediment, nutrient, pesticide and bacteria loads in surface runoff are reduced as the surface runoff passes through the filter strip. Optional.

20.1.3 URBAN MANAGEMENT PARAMETERS

Variable name	Definition
IURBAN	Urban simulation code: 0 no urban sections in HRU 1 urban sections in HRU, simulate using USGS regression equations 2 urban sections in HRU, simulate using build up/wash off algorithm Most large watersheds and river basins contain areas of urban land use. Estimates of the quantity and quality of runoff in urban areas are required for comprehensive management analysis. SWAT calculates runoff from urban areas with the SCS curve number method or the Green & Ampt equation. Loadings of sediment and nutrients are determined using one of two options. The first is a set of linear regression equations developed by the USGS (Driver and Tasker, 1988) for estimating storm runoff volumes and constituent loads. The other option is to simulate the buildup and washoff mechanisms, similar to SWMM - Storm Water Management Model (Huber and Dickinson, 1988). Required.
URBLU	Urban land type identification number from the urban database (see Chapter 18). Required if IURBAN > 0.

20.1.4 IRRIGATION MANAGEMENT PARAMETERS

Variable name	Definition
IRRSC	Irrigation code. Water applied to an HRU is obtained from one of five types of water sources: a reach, a reservoir, a shallow aquifer, a deep aquifer, or a source outside the watershed. In addition to the type of water source, the model must know the location of the water source (unless the source is outside the watershed). For the reach, shallow aquifer or deep aquifer, SWAT needs to know the subbasin number in which the source is located. If a reservoir is used to supply water, SWAT must know the reservoir number. This variable, along with IRRNO, specifies the source of irrigation water applied in the HRU. Irrigation water may be diverted from anywhere in the watershed or outside the watershed. IRRSC tells the model what type of water body the irrigation water is being diverted from. The options are: 0 no irrigation 1 divert water from reach 2 divert water from reservoir 3 divert water from shallow aquifer 4 divert water from deep aquifer 5 divert water from unlimited source outside watershed
IRRNO	Irrigation source location. Water applied to an HRU is obtained from one of five types of water sources: a reach, a reservoir, a shallow aquifer, a deep aquifer, or a source outside the watershed. In addition to the type of water source, the model must know the location of the water source (unless the source is outside the watershed). For the reach, shallow aquifer or deep aquifer, SWAT needs to know the subbasin number in which the source is located. If a reservoir is used to supply water, SWAT must know the reservoir number.

Variable name	Definition
IRRNO, cont.	The definition of this variable depends on the setting of IRRSC. IRRSC = 1: IRRNO is the number of the reach that water is removed from. IRRSC = 2: IRRNO is the number of the reservoir that water is removed from. IRRSC = 3 or 4: IRRNO is the number of the subbasin that water is removed from. IRRSC = 0 or 5: this variable is not used. Required if 1 ≤ IRRSC ≤ 4.
FLOWMIN	Minimum in-stream flow for irrigation diversions (m^3/s). If the source of the irrigation water is a reach, SWAT allows additional input parameters to be set. These parameters are used to prevent flow in the reach from being reduced to zero as a result of irrigation water removal. Users may define a minimum in-stream flow, a maximum irrigation water removal amount that cannot be exceeded on any given day, and/or a fraction of total flow in the reach that is available for removal on a given day. FLOWMIN may be set when IRRSC = 1. If FLOWMIN is defined by the user, irrigation water will be diverted from the reach only if flow in the reach is at or above FLOWMIN. Optional. Used only if IRRSC = 1.
DIVMAX	Maximum daily irrigation diversion from the reach (If value entered for DIVMAX is positive the units are mm, if the value entered for DIVMAX is negative the units are 104 m3) If the source of the irrigation water is a reach, SWAT allows additional input parameters to be set. These parameters are used to prevent flow in the reach from being reduced to zero as a result of irrigation water removal. Users may define a minimum in-stream flow, a maximum irrigation water removal amount that cannot be exceeded on any given day, and/or a fraction of total flow in the reach that is available for removal on a given day.

Variable name	Definition
DIVMAX, cont.	DIVMAX may be set when IRRSC = 1. If DIVMAX is defined by the user, the amount of water removed from the reach and applied to the HRU on any one day will never exceed the value assigned to DIVMAX. Optional. Used only if IRRSC = 1.
FLOWFR	Fraction of available flow that is allowed to be applied to the HRU. If the source of the irrigation water is a reach, SWAT allows additional input parameters to be set. These parameters are used to prevent flow in the reach from being reduced to zero as a result of irrigation water removal. Users may define a minimum in-stream flow, a maximum irrigation water removal amount that cannot be exceeded on any given day, and/or a fraction of total flow in the reach that is available for removal on a given day. Available flow is defined as the total flow in the reach minus FLOWMIN. If FLOWMIN is left at zero, the model assume all flow in the reach is available for application as irrigation water. FLOWFR may be set when IRRSC = 1. The value for FLOWFR should be between 0.01 and 1.00. The model will default FLOWFR = 1.0 if no value is entered or 0.00 is entered. Required if IRRSC = 1.

20.1.5 TILE DRAIN MANAGEMENT PARAMETERS

Variable name	Definition
DDRAIN	Depth to subsurface drain (mm). If drainage tiles are installed in the HRU, the depth to the tiles is needed. A common depth for drain installation is 90 mm. To simulate tile drainage in an HRU, the user must specify the depth from the soil surface to the drains, the amount of time required to drain the soil to field capacity, and the amount of lag between the time water enters the tile till it exits the tile and enters the main channel. Tile drainage occurs when the soil water content exceeds field capacity. Required if drainage tiles are modeled in HRU.

Variable name	Definition
TDRAIN	Time to drain soil to field capacity (hours). The time required to drain the soil from saturation to field capacity. Most tile drains are designed to reduce the water content to field capacity within 48 hours. To simulate tile drainage in an HRU, the user must specify the depth from the soil surface to the drains, the amount of time required to drain the soil to field capacity, and the amount of lag between the time water enters the tile until it exits the tile and enters the main channel. Tile drainage occurs when the soil water content exceeds field capacity. Required if drainage tiles are modeled in HRU.
GDRAIN	Drain tile lag time (hours). The amount of time between the transfer of water from the soil to the drain tile and the release of the water from the drain tile to the reach. To simulate tile drainage in an HRU, the user must specify the depth from the soil surface to the drains, the amount of time required to drain the soil to field capacity, and the amount of lag between the time water enters the tile till it exits the tile and enters the main channel. Tile drainage occurs when the soil water content exceeds field capacity. Required if drainage tiles are modeled in HRU.

20.1.6 MANAGEMENT OPERATIONS

Variable name	Definition
NROT	Number of years of rotation. This code identifies the number of years of management practices given in the .mgt file. If the management doesn't change from year to year, the management operations for only one year are needed. Two land covers/crops may not be grown simultaneously, but they may be grown in the same year. For two or more crops grown in the same year, NROT is equal to 1 for 1 year of management practices listed. NROT has nothing to do with the number of different crops grown. If NROT is set to 0, SWAT will model fallow conditions (bare soil) in the HRU throughout the simulation. Required.

The first section of the management file is free format. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the first section of the management file is:

Variable name	Line #	Format	F90 Format
TITLE	1	character	a80
NMGT	2	integer	Free
Comment line	3	character	a80
IGRO	4	integer	Free
PLANT_ID	5	integer	Free
LAI_INIT	6	real	free
BIO_INIT	7	real	free
PHU_PLT	8	real	free
COMMENT LINE	9	character	a80
BIOMIX	10	real	free
CN2	11	real	free
USLE_P	12	real	free

Variable name	Line #	Format	F90 Format
BIO_MIN	13	real	free
FILTERW	14	real	free
Comment line	15	character	a80
IURBAN	16	integer	free
URBLU	17	integer	free
Comment line	18	character	a80
IRRSC	19	integer	free
IRRNO	20	integer	free
FLOWMIN	21	real	free
DIVMAX	22	real	free
FLOWFR	23	real	free
Comment line	24	character	a80
DDRAIN	25	real	free
TDRAIN	26	real	free
GDRAIN	27	real	free
Comment line	28	character	a80
NROT	29	integer	free
Comment line	30	character	a80

20.2 SCHEDULED MANAGEMENT OPERATIONS

SWAT will simulate 15 different types of management operations. The first four variables on all management lines are identical while the remaining nine are operation specific. The variables for the different operations will be defined in separate sections. The type of operation simulated is identified by the code given for the variable MGT_OP.

The different codes for MGT_OP are:

1 **planting/beginning of growing season:** this operation initializes the growth of a specific land cover/plant type in the HRU

2 **irrigation operation:** this operation applies water to the HRU on the specified day

3 **fertilizer application:** this operation adds nutrients to the soil in the HRU on the specified day

4 **pesticide application:** this operation applies a pesticide to the plant and/or soil in the HRU on the specified day

5 **harvest and kill operation:** this operation harvests the portion of

the plant designated as yield, removes the yield from the HRU and converts the remaining plant biomass to residue on the soil surface.

6 **tillage operation:** this operation mixes the upper soil layers and redistributes the nutrients/chemicals/etc. within those layers

7 **harvest only operation:** this operation harvests the portion of the plant designated as yield and removes the yield from the HRU, but allows the plant to continue growing. This operation is used for hay cuttings.

8 **kill/end of growing season:** this operation stops all plant growth and converts all plant biomass to residue.

9 **grazing operation:** this operation removes plant biomass at a specified rate and allows simultaneous application of manure.

10 **auto irrigation initialization:** this operation initializes auto irrigation within the HRU. Auto irrigation applies water whenever the plant experiences a user-specified level of water stress.

11 **auto fertilization initialization:** this operation initializes auto fertilization within the HRU. Auto fertilization applies nutrients whenever the plant experiences a user-specified level of nitrogen stress.

12 **street sweeping operation:** this operation removes sediment and nutrient build-up on impervious areas in the HRU. This operation can only be used when the urban build up/wash off routines are activated for the HRU (see IURBAN).

13 **release/impound:** this operation releases/impounds water in HRUs growing rice or other plants

14 **continuous fertilization:** this operation applies fertilizer/manure to the soil surface on a continuous basis

15 **continuous pesticides:** this operation applies pesticides to the soil surface on a continuous basis

0 **end of year rotation flag:** this operation identifies the end of the operation scheduling for a year.

	mon	day	HU	mgt op	mgt1i	mgt2i	mgt3i	mgt4	mgt5	mgt6	mgt7	mgt8	mgt9
plant/begin growing season	*	*	*	1	PLANT_ID		CURYR_MAT	HEAT_UNITS	LAI_INIT	BIO_INIT	HI_TARG	BIO_TARG	CNOP
irrigate	*	*	*	2				IRR_AMT					
fertilizer application	*	*	*	3	FERT_ID			FRT_KG	FRT_SURFACE				
pesticide application	*	*	*	4	PEST_ID			PST_KG					
harvest/kill operation	*	*	*	5				CNOP					
tillage operation	*	*	*	6	TILL_ID			CNOP					
harvest operation	*	*	*	7				HARVEFF	HI_OVR				
kill/end growing season	*	*	*	8									
grazing	*	*	*	9	GRZ_DAYS	MANURE_ID		BIO_EAT	BIO_TRMP	MANURE_KG			
auto irrigation	*	*	*	10	WSTRS_ID			AUTO_WSTRS					
auto fertilization	*	*	*	11	AFERT_ID			AUTO_NSTRS	AUTO_NAPP	AUTO_NYR	AUTO_EFF	AFRT_SURFACE	
sweep operation	*	*		12				SWEEPEFF	FR_CURB				
release/impound	*	*		13	IMP_TRIG								
continuous fertilization	*	*	*	14	FERT_DAYS	CFRT_ID	IFRT_FREQ	CFRT_KG					
end of year flag				0									

Figure 20-1: Management operations.

For each year of management operations provided, the operations must be listed in chronological order starting in January.

20.2.1 PLANTING/BEGINNING OF GROWING SEASON

The plant operation initiates plant growth. This operation can be used to designate the time of planting for agricultural crops or the initiation of plant growth in the spring for a land cover that requires several years to reach maturity (forests, orchards, etc.).

The plant operation will be performed by SWAT only when no land cover is growing in an HRU. Before planting a new land cover, the previous land cover must be removed with a kill operation or a harvest and kill operation. If two plant operations are placed in the management file and the first land cover is not killed prior to the second plant operation, the second plant operation is ignored by the model.

Information required in the plant operation includes the timing of the operation (month and day or fraction of base zero potential heat units), the total number of heat units required for the land cover to reach maturity, and the specific land cover to be simulated in the HRU. If the land cover is being transplanted, the leaf area index and biomass for the land cover at the time of transplanting must be provided. Also, for transplanted land covers, the total number of heat units for the land cover to reach maturity should be from the period the land cover is transplanted to maturity (not from seed generation). Heat units are reviewed in Chapter 5:1 of the Theoretical Documentation. If the transplanted land cover is a type of tree, the age of the plants in years at the time of transplanting must be provided.

The user has the option of varying the curve number in the HRU throughout the year. New curve number values may be entered in a plant operation, tillage operation and harvest and kill operation. The curve number entered for these operations are for moisture condition II. SWAT adjusts the entered value daily to reflect change in water content.

For simulations where a certain amount of crop yield and biomass is required, the user can force the model to meet this amount by setting a harvest index target and a biomass target. These targets are effective only if a harvest and kill operation is used to harvest the crop.

The variables that may be entered on the planting line are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 1 for planting/beginning of growing season. Required.
PLANT_ID	Land cover/plant identification number from plant growth database (see Chapter 14). Required.
CURYR_MAT	Current age of trees (years). If the land cover planted/transplanted is a type of tree, the age of the seedlings in years is required. For other types of land covers, this input is not required.
HEAT UNITS	Total heat units for cover/plant to reach maturity. Calculation of HEAT UNITS is reviewed in Chapter 5:1 of the Theoretical Documentation. Required.
LAI_INIT	Initial leaf area index. This variable is used only for covers/plants which are transplanted rather than established from seeds. Optional.
HI_TARG	Harvest index target ((kg/ha)/(kg/ha)). This variable along with BIO_TARG allows the user to specify the harvest index and biomass produced by the plant every year. The model will then simulate plant growth to meet these specified values. If you are studying the effect of management practices on yields or you want the biomass to vary in response to different weather conditions, you would not want to use HI_TARG or BIO_TARG. Optional.

Variable name	Definition
BIO_INIT	Initial dry weight biomass (kg/ha). This variable is used only for covers/plants that are transplanted rather than established from seeds. Optional.
BIO_TARG	Biomass (dry weight) target (metric tons/ha). This variable along with HI_TARG allows the user to specify the harvest index and biomass produced by the plant every year. The model will then simulate plant growth to meet these specified values. If you are studying the effect of management practices on yields or you want the biomass to vary in response to different weather conditions, you would not want to use HI_TARG or BIO_TARG. Optional.
CNOP	SCS runoff curve number for moisture condition II Please read discussion for CN2 in Section 20.1 General Management Variables for more information on this variable. Optional.

The format of the planting operation line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
PLANT_ID	space 20-23	4-digit integer	i4
CURYR_MAT	space 29-30	2-digit integer	i2
HEAT UNITS	space 32-43	decimal (xxxxxx.xxxxx)	f12.5
LAI_INIT	space 45-50	decimal (xxx.xx)	f6.2
BIO_INIT	space 52-62	decimal (xxxxx.xxxxx)	f11.5
HI_TARG	space 64-67	decimal (x.xx)	f4.2
BIO_TARG	space 69-74	decimal (xxxxx.xx)	F6.2
CNOP	space 76-80	decimal (xx.xx)	f5.2

20.2.2 IRRIGATION OPERATION

Water applied to an HRU is obtained from one of five types of water sources: a reach, a reservoir, a shallow aquifer, a deep aquifer, or a source outside the watershed. In addition to the type of water source, the model must know the location of the water source (unless the source is outside the watershed). For the reach, shallow aquifer or deep aquifer, SWAT needs to know the subbasin number in which the source is located. If a reservoir is used to supply water, SWAT must know the reservoir number.

If the source of the irrigation water is a reach, SWAT allows additional input parameters to be set. These parameters are used to prevent flow in the reach from being reduced to zero as a result of irrigation water removal. Users may define a minimum in-stream flow, a maximum irrigation water removal amount that cannot be exceeded on any given day, and/or a fraction of total flow in the reach that is available for removal on a given day.

For a given irrigation event, SWAT determines the amount of water available in the source. The amount of water available is compared to the amount of water specified in the irrigation operation. If the amount available is less than the amount specified, SWAT will only apply the available water.

Water applied to an HRU is used to fill the soil layers up to field capacity beginning with the soil surface layer and working downward until all the water applied is used up or the bottom of the profile is reached. If the amount of water specified in an irrigation operation exceeds the amount needed to fill the soil layers up to field capacity water content, the excess water is returned to the source. For HRUs that are defined as potholes or depressional areas, the irrigation water is added to the ponded water overlying the soil surface.

The variables which may be entered on the irrigation line are listed and described below

Variable name	Definition
MONTH	Month operation takes place. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 2 for irrigation operation. Required.
IRR_SC	Irrigation source code. Water applied to an HRU is obtained from one of five types of water sources: a reach, a reservoir, a shallow aquifer, a deep aquifer, or a source outside the watershed. In addition to the type of water source, the model must know the location of the water source (unless the source is outside the watershed). For the reach, shallow aquifer or deep aquifer, SWAT needs to know the subbasin number in which the source is located. If a reservoir is used to supply water, SWAT must know the reservoir number. This variable, along with IRR_NO, specifies the source of irrigation water applied in the HRU. Irrigation water may be diverted from anywhere in the watershed or outside the watershed. IRR_SC tells the model what type of water body the irrigation water is being diverted from. The options are: 0 no irrigation 1 divert water from reach 2 divert water from reservoir 3 divert water from shallow aquifer 4 divert water from deep aquifer 6 divert water from unlimited source outside watershed

Variable name	Definition
IRR_NO	Irrigation source location. Water applied to an HRU is obtained from one of five types of water sources: a reach, a reservoir, a shallow aquifer, a deep aquifer, or a source outside the watershed. In addition to the type of water source, the model must know the location of the water source (unless the source is outside the watershed). For the reach, shallow aquifer or deep aquifer, SWAT needs to know the subbasin number in which the source is located. If a reservoir is used to supply water, SWAT must know the reservoir number. The definition of this variable depends on the setting of IRR_SC. IRRSC = 1: IRR_NO is the number of the reach that water is removed from. IRRSC = 2: IRR_NO is the number of the reservoir that water is removed from. IRRSC = 3 or 4: IRR_NO is the number of the subbasin that water is removed from. IRR_SC = 0 or 5: this variable is not used. Required if 1 ≤ IRR_SC ≤ 4.
IRR_AMT	Depth of irrigation water applied on HRU (mm). Required.
IRR_SALT	Concentration of salt in irrigation (mg/kg). Not currently operational.
IRR_EFM	Irrigation efficiency (0-1).
IRR_SQ	Surface runoff ratio (0-1). (.1 is 10% surface runoff) (fraction)

The format of the irrigation operation line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
IRR_SC	space 25-27	3-digit integer	i3
IRR_NO	space 29-30	2-digit integer	i2
IRR_AMT	space 32-43	decimal (xxxxxx.xxxxx)	f12.5
IRR_SALT	space 45-50	decimal (xxx.xx)	f6.2
IRR_EFM	space 52-62	decimal (xxxxx.xxxxx)	f11.5
IRR_SQ	space 64-67	decimal (x.xx)	f4.2

20.2.3 FERTILIZER APPLICATION

The fertilizer operation applies fertilizer or manure to the soil.

Information required in the fertilizer operation includes the timing of the operation (month and day or fraction of plant potential heat units), the type of fertilizer/manure applied, the amount of fertilizer/manure applied, and the depth distribution of fertilizer application.

SWAT assumes surface runoff interacts with the top 10 mm of soil. Nutrients contained in this surface layer are available for transport to the main channel in surface runoff. The fertilizer operation allows the user to specify the fraction of fertilizer that is applied to the top 10 mm. The remainder of the fertilizer is added to the first soil layer defined in the HRU .sol file. The weight fraction of different types of nutrients and bacteria are defined for the fertilizer in the fertilizer database.

The variables which may be entered on the fertilization line are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 3 for fertilizer application. Required.
FERT_ID	Fertilizer identification number from fertilizer database (see Chapter 17). Required.
FRT_KG	Amount of fertilizer applied to HRU (kg/ha). Required.
FRT_SURFACE	Fraction of fertilizer applied to top 10mm of soil. The remaining fraction is applied to the 1st soil layer below 10 mm. If FRT_SURFACE is set to 0, the model applies 20% of the fertilizer to the top 10mm and the remainder to the 1st soil layer. Required.

The format of the fertilizer application line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
FERT_ID	space 20-23	4-digit integer	i4
FRT_KG	space 32-43	decimal (xxxxxx.xxxxx)	f12.5
FRT_SURFACE	space 45-50	decimal (xxx.xx)	f6.2

20.2.4 PESTICIDE APPLICATION

The pesticide operation applies pesticide to the HRU.

Information required in the pesticide operation includes the timing of the operation (month and day or fraction of plant potential heat units), the type of pesticide applied, and the amount of pesticide applied.

Field studies have shown that even on days with little or no wind, a portion of pesticide applied to the field is lost. The fraction of pesticide that reaches the foliage or soil surface is defined by the pesticide's application efficiency.

The variables which may be entered on the pesticide application line are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 4 for pesticide application. Required.
PEST_ID	Pesticide identification code from pesticide database (see Chapter 16). Required.
PST_KG	Amount of pesticide applied to HRU (kg/ha). Required.

Variable name	Definition
PST_DEP	Depth of pesticide incorporation in the soil (mm) If = 0, assumes surface apply.

The format of the pesticide application line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
PEST_ID	space 20-23	4-digit integer	i4
PST_KG	space 32-43	decimal (xxxxxx.xxxxx)	f12.5
PST_DEP	space 45-50	decimal (xxx.xx)	f6.2

20.2.5 HARVEST AND KILL OPERATION

The harvest and kill operation stops plant growth in the HRU. The fraction of biomass specified in the land cover's harvest index (in the plant growth database, see Chapter 14) is removed from the HRU as yield. The remaining fraction of plant biomass is converted to residue on the soil surface.

The only information required by the harvest and kill operation is the timing of the operation (month and day or fraction of plant potential heat units). The user also has the option of updating the moisture condition II curve number in this operation.

The variables which may be entered on the harvest and kill line are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 5 for harvest and kill operation. Required.
CNOP	SCS runoff curve number for moisture condition II Please read discussion for CN2 in Section 20.1 General Management Variables for more information on this variable. Optional.

The format of the harvest and kill line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
CNOP	space 32-43	decimal (xxxxxx.xxxxx)	f12.5

20.2.6 TILLAGE OPERATION

The tillage operation redistributes residue, nutrients, pesticides and bacteria in the soil profile.

Information required in the tillage operation includes the timing of the operation (month and day or fraction of base zero potential heat units) and the type of tillage operation. The user also has the option of updating the moisture condition II curve number in this operation.

The variables for the tillage operation are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 6 for tillage operation. Required.
TILL_ID	Tillage implement code from tillage database (see Chapter 15). Required.
CNOP	SCS runoff curve number for moisture condition II Please read discussion for CN2 in Section 20.1 General Management Variables for more information on this variable. Optional.

The format of the tillage operation line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
TILL_ID	space 20-23	4-digit integer	i4
CNOP	space 32-43	decimal (xxxxx.xxxxx)	f12.5

20.2.7 HARVEST OPERATION

The harvest operation will remove grain or plant biomass without killing the plant. A code (IHV_GBM) is used to specify if the harvest is for grain or biomass. Grain harvest was developed so the user could harvest grain and then harvest biomass for biofuel or feed. Biomass harvest is most commonly used to cut hay or grass.

The only information required by the harvest operation is the date. However, a harvest index override and a harvest efficiency can be set.

For grain harvest, a harvest index in the plant growth database is set to the optimum fraction of the plant biomass partitioned into seed for agricultural crops. The harvest index override is not used for grain harvest (see harvest index target). A typical fraction of biomass removed in a cutting for hay is included in the plant growth database. If the user prefers a different fraction of biomass to be removed, the harvest index override should be set to the desired value.

A harvest efficiency may also be defined for the operation. When harvesting grain, the efficiency accounts for losses from the harvesting machine. For example, if an efficiency of 0.95 is used for grain, yield is cut by 5 percent and the nutrients and carbon in the lost grain is not returned to the soil. For biomass harvest, the efficiency specifies the fraction of harvested plant biomass removed from the HRU. The remaining fraction is converted to residue on the soil surface. If the harvest efficiency is left blank or set to zero, the model assumes this feature is not being used and removes 100% of the harvested biomass (no biomass is converted to residue). For grass mowing, an efficiency of one assumes that all clippings are removed from the HRU while an efficiency of zero leaves all clippings on the ground.

After biomass is removed in a harvest operation, the plant's leaf area index and accumulated heat units are set back by the fraction of biomass removed. Reducing the number of accumulated heat units shifts the plant's development to an earlier period in which growth is usually occurring at a faster rate.

The variables for the harvest-only operation are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 7 for the harvest only operation. Required.
IHV_GBM	Grain or biomass harvest code A value of 0 specifies a biomass harvest while a value of 1 specifies a grain harvest.

Variable name	Definition
HARVEFF	Harvest efficiency. For grain harvest, the harvest efficiency defines the fraction of yield biomass removed by the harvesting equipment, with the remaining yield lost. For biomass harvest, if HARVEFF is close to zero, the cutting or clipping are left on the ground and if HARVEFF is 1.0, all cut biomass (yield) is removed. If the harvest efficiency is not set or 0.00 is entered, the model assumes the user wants to ignore harvest efficiency and sets the fraction to 1.00 so that the entire yield is removed from the HRU. Optional.
HI_OVR	Harvest index override ((kg/ha)/(kg/ha)) This variable will force the ratio of yield to total aboveground biomass to the specified value. For grain harvest, the harvest index in the plant growth database (plant.dat) is used that assumes that only the seed is being harvested (HI_OVR is not used in grain harvest). If biomass is cut and removed (for example, in hay cuttings), HIOVR must be used to specify the amount of biomass cut. Optional.

The format of the harvest operation line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
IHV_GBM	space 25-27	3-digit integer	I3
HARVEFF	space 32-43	decimal (xxxxxx.xxxxx)	f12.5
HI_OVR	space 45-50	decimal (xxx.xx)	f6.2

20.2.8 KILL OPERATION

The kill operation stops plant growth in the HRU. All plant biomass is converted to residue.

The only information required by the kill operation is the timing of the operation (month and day or fraction of plant potential heat units).

The variables entered for the kill operation are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 8 for kill operation. Required.

The format of the kill line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2

20.2.9 GRAZING OPERATION

The grazing operation simulates plant biomass removal and manure deposition over a specified period of time. This operation is used to simulate pasture or range grazed by animals.

Information required in the grazing operation includes the time during the year at which grazing begins (month and day or fraction of plant potential heat units), the length of the grazing period, the amount of biomass removed daily, the amount of manure deposited daily, and the type of manure deposited. The amount of biomass trampled is an optional input.

Biomass removal in the grazing operation is similar to that in the harvest operation. However, instead of a fraction of biomass being specified, an absolute amount to be removed every day is given. In some conditions, this can result in a reduction of the plant biomass to a very low level that will result in increased erosion in the HRU. To prevent this, a minimum plant biomass for grazing may be specified (BIO_MIN in the first section of the management file). When the plant biomass falls below the amount specified for BIO_MIN, the model will not graze, trample, or apply manure in the HRU on that day.

If the user specifies an amount of biomass to be removed daily by trampling, this biomass is converted to residue.

Nutrient fractions of the manure applied during grazing are stored in the fertilizer database (see Chapter 17). The manure nutrient loadings are added to the topmost 10 mm of soil. This is the portion of the soil with which surface runoff interacts.

After biomass is removed by grazing and/or trampling, the plant's leaf area index and accumulated heat units are set back by the fraction of biomass removed.

The variables entered for the grazing operation are listed and described below.

Variable name	Definition
MONTH	Month grazing begins. Either MONTH/DAY or HUSC is required.
DAY	Day grazing begins. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 9 for grazing operation. Required.
GRZ_DAYS	Number of consecutive days grazing takes place in the HRU. Required.
MANURE_ID	Manure identification code from fertilizer database (see Chapter 17). Required.
BIO_EAT	Dry weight of biomass consumed daily ((kg/ha)/day). Required.
BIO_TRMP	Dry weight of biomass trampled daily ((kg/ha)/day) Trampling becomes significant as the number of animals grazing per hectare increases. This is a very subjective value which is typically set equal to BIO_EAT, i.e. the animals trample as much as they eat. Optional.
MANURE_KG	Dry weight of manure deposited daily ((kg/ha)/day). Required.

The format of the grazing operation line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
GRZ_DAYS	space 20-23	4-digit integer	i4
MANURE_ID	space 25-27	3-digit integer	i3
BIO_EAT	space 32-43	decimal (xxxxxx.xxxxx)	f12.5
BIO_TRMP	space 45-50	decimal (xxx.xx)	f6.2
MANURE_KG	space 52-62	decimal (xxxxx.xxxxx)	f11.5

20.2.10 AUTO IRRIGATION INITIALIZATION

Rather than specifying fixed amounts and time for irrigation, the user can allow the model to apply water as needed by the plant.

The variables entered for auto-irrigation initialization are listed and described below.

Variable name	Definition
MONTH	Month auto irrigation is initialized. Either MONTH/DAY or HUSC is required.
DAY	Day auto irrigation is initialized. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.

Variable name	Definition
MGT_OP	Management operation number. MGT_OP = 10 for auto irrigation initialization. Required.
WSTRS_ID	Water stress identifier. SWAT allows automatic irrigation to be triggered by plant water demand or by soil water content. WSTRS_ID identifies the process the user wishes to use to trigger automatic irrigation. WSTRS_ID may be set to: 1 plant water demand 2 soil water content Required.
IRR_SCA	Auto Irrigation source code. Water applied to an HRU is obtained from one of five types of water sources: a reach, a reservoir, a shallow aquifer, a deep aquifer, or a source outside the watershed. In addition to the type of water source, the model must know the location of the water source (unless the source is outside the watershed). For the reach, shallow aquifer or deep aquifer, SWAT needs to know the subbasin number in which the source is located. If a reservoir is used to supply water, SWAT must know the reservoir number. This variable, along with IRR_NOA, specifies the source of irrigation water applied in the HRU. Irrigation water may be diverted from anywhere in the watershed or outside the watershed. IRR_SCA tells the model what type of water body the irrigation water is being diverted from. The source options are: 0 no irrigation 1 divert water from reach 2 divert water from reservoir 3 divert water from shallow aquifer 4 divert water from deep aquifer 5 divert water from unlimited source outside watershed

IRR_NOA	Auto Irrigation source location. Water applied to an HRU is obtained from one of five types of water sources: a reach, a reservoir, a shallow aquifer, a deep aquifer, or a source outside the watershed. In addition to the type of water source, the model must know the location of the water source (unless the source is outside the watershed). For the reach, shallow aquifer or deep aquifer, SWAT needs to know the subbasin number in which the source is located. If a reservoir is used to supply water, SWAT must know the reservoir number. The definition of this variable depends on the setting of IRRSC. IRR_SCA = 1: IRR_NOA is the number of the reach that water is removed from. IRR_SCA = 2: IRR_NOA is the number of the reservoir that water is removed from. IRR_SCA = 3 or 4: IRR_NOA is the number of the subbasin that water is removed from. IRR_SCA = 0 or 5: this variable is not used. Required if 1 ≤ IRR_SCA ≤ 4.
AUTO_WSTRS	Water stress threshold that triggers irrigation. When the user selects auto-application of irrigation water in an HRU, a water stress threshold must be specified. When water stress is based on plant water demand (WSTRS_ID=1), the water stress threshold is a fraction of potential plant growth. Anytime actual plant growth falls below this threshold fraction due to water stress the model will automatically apply water to the HRU. If enough water is available from the irrigation source, the model will add water to the soil until it is at field capacity.

Variable name	Definition
AUTO_WSTRS, cont.	This factor ranges from 0.0 to 1.0 where 0.0 indicates there is no growth of the plant due to water stress and 1.0 indicates there is no reduction of plant growth due to water stress. The water stress threshold for plant water demand is usually set somewhere between 0.90 and 0.95. When water stress is based on soil water deficit (WSTRS_ID=2), the water stress threshold is the soil water deficit below field capacity (mm H_2O). Anytime the water content of the soil profile falls below *FC – AUTO_WSTR*, the model will automatically apply water to the HRU. If enough water is available from the irrigation source, the model will add water to the soil until it is at field capacity. Required.
IRR_EFF	Irrigation efficiency.
IRR_MX	Amount of irrigation water applied each time auto irrigation is triggered (mm).
IRR_ASQ	Surface runoff ratio (0-1) (.1 is 10% surface runoff) (fraction)

The format of the auto irrigation line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
WSTRS_ID	space 20-23	4-digit integer	i4
IRR_SCA	space 25-27	3-digit integer	i3
IRR_NOA	space 29-30	2-digit integer	i2
AUTO_WSTRS	space 32-43	decimal (xxxxxx.xxxxx)	f12.5
IRR_EFF	space 45-50	decimal (xxx.xx)	f6.2
IRR_MX	space 52-62	decimal (xxxxx.xxxxx)	f11.5
IRR_ASQ	space 64-67	decimal (x.xx)	f4.2

20.2.11 AUTO FERTILIZATION INITIALIZATION

Fertilization in an HRU may be scheduled by the user or automatically applied by SWAT. When the user selects auto-application of fertilizer in an HRU, a nitrogen stress threshold must be specified. The nitrogen stress threshold is a fraction of potential plant growth. Anytime actual plant growth falls below this threshold fraction due to nitrogen stress, the model will automatically apply fertilizer to the HRU. The user specifies the type of fertilizer, the fraction of total fertilizer applied to the soil surface, the maximum amount of fertilizer that can be applied during the year, the maximum amount of fertilizer that can be applied in any one application, and the application efficiency.

The variables entered for auto-fertilization initialization are listed and described below.

Variable name	Definition
MONTH	Month initialization takes place. Either MONTH/DAY or HUSC is required.
DAY	Day initialization takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 11 for auto fertilization initialization. Required.
AFERT_ID	Fertilizer identification number from the fertilizer database (see Chapter 17). Required.

Variable name	Definition
AUTO_NSTRS	Nitrogen stress factor of cover/plant that triggers fertilization. The nitrogen stress factor is calculated by dividing the growth of the plant undergoing nitrogen stress by the growth of the plant if there was no nitrogen stress. This factor ranges from 0.0 to 1.0 where 0.0 indicates there is no growth of the plant due to nitrogen stress and 1.0 indicates there is no reduction of plant growth due to nitrogen stress. The nitrogen stress threshold is usually set somewhere between 0.90 and 0.95. Required.
AUTO_NAPP	Maximum amount of mineral N allowed in any one application (kg N/ha). If this variable is left blank, the model will set AUTO_NMXS = 200. Required.
AUTO_NYR	Maximum amount of mineral N allowed to be applied in any one year (kg N/ha). If this variable is left blank, the model will set AUTO_NMXA = 300. Required.
AUTO_EFF	Application efficiency. The amount of fertilizer applied in auto fertilization is based on the amount of nitrogen removed at harvest. If you set AUTO_EFF = 1.0, the model will apply enough fertilizer to replace the amount of nitrogen removed at harvest. If AUTO_EFF > 1.0, the model will apply fertilizer to meet harvest removal plus an extra amount to make up for nitrogen losses due to surface runoff/leaching. If AUTO_EFF < 1.0, the model will apply fertilizer at the specified fraction below the amount removed at harvest. If this variable is left blank, the model will set AUTO_EFF = 1.3. Required.

Variable name	Definition
AFRT_SURFACE	Fraction of fertilizer applied to top 10mm of soil. The remaining fraction is applied to the 1st soil layer below 10mm. If this variable is left blank, the model will set AFRT_LY1 = 0.2. Required.

The format of the auto fertilization line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
AFERT_ID	space 20-23	4-digit integer	i4
AUTO_NSTRS	space 32-43	decimal (xxxxxx.xxxxx)	f12.5
AUTO_NAPP	space 45-50	decimal (xxx.xx)	f6.2
AUTO_NYR	space 52-62	decimal (xxxxx.xxxxx)	f11.5
AUTO_EFF	space 64-67	decimal (x.xx)	f4.2
AFRT_SURFACE	space 69-74	decimal (xxxxx.xx)	F6.2

20.2.12 STREET SWEEPING OPERATION

Street cleaning is performed in urban areas to control buildup of solids and trash. While it has long been thought that street cleaning has a beneficial effect on the quality of urban runoff, studies by EPA have found that street sweeping has little impact on runoff quality unless it is performed every day (U.S. Environmental Protection Agency, 1983).

SWAT performs street sweeping operations only when the build up/wash off algorithm is specified for urban loading calculations. Street sweeping is performed only on dry days, where a dry day is defined as a day with less than 0.1 mm of surface runoff.

The variables entered for the street sweeping operation are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 12 for street sweeping. Required.
SWEEPEFF	Removal efficiency of sweeping operation. The removal efficiency of street sweeping is a function of the type of sweeper, whether flushing is a part of the street

Variable name	Definition
SWEEPEFF, cont.	cleaning process, the quantity of total solids, the frequency of rainfall events and the constituents considered. Removal efficiency can vary depending on the constituent being considered, with efficiencies being greater for particulate constituents. The removal efficiencies for nitrogen and phosphorus are typically less than the solid removal efficiency (Pitt, 1979). Because SWAT assumes a set concentration of nutrient constituents in the solids, the same removal efficiency is in effect used for all constituents. Table 20-7 provides removal efficiencies for various street cleaning programs. SWEEPEFF is a fraction that ranges between 0.0 and 1.0. A value of 0.0 indicates that none of the built-up sediments are removed while a value of 1.0 indicates that all of the built-up sediments are removed. Required.

Table 20-7: Removal efficiencies (fraction removed) from street cleaner path (from Pitt, 1979)

Street Cleaning Program and Street Surface Loading Conditions	Total Solids	BOD_5	COD	KN	PO_4	Pesticides
Vacuum Street Cleaner *(5.5-55 kg/curb km)*						
1 pass	.31	.24	.16	.26	.08	.33
2 passes	.45	.35	.22	.37	.12	.50
3 passes	.53	.41	.27	.45	.14	.59
Vacuum Street Cleaner *(55-280 kg/curb km)*						
1 pass	.37	.29	.21	.31	.12	.40
2 passes	.51	.42	.29	.46	.17	.59
3 passes	.58	.47	.35	.51	.20	.67
Vacuum Street Cleaner *(280-2820 kg/curb km)*						
1 pass	.48	.38	.33	.43	.20	.57
2 passes	.60	.50	.42	.54	.25	.72
3 passes	.63	.52	.44	.57	.26	.75
Mechanical Street Cleaner *(50-500 kg/curb km)*						
1 pass	.54	.40	.31	.40	.20	.40
2 passes	.75	.58	.48	.58	.35	.60
3 passes	.85	.69	.59	.69	.46	.72
Flusher	.30	*a*	*a*	*a*	*a*	*a*
Mechanical Street Cleaner followed by a Flusher	.80	*b*	*b*	*b*	*b*	*b*

a: efficiency fraction estimated .15 to .40
b: efficiency fraction estimated .35 to 1.00

Variable name	Definition
FR_CURB	Fraction of curb length available for sweeping. The availability factor, fr_{av}, is the fraction of the curb length that is sweepable. The entire curb length is often not available for sweeping due to the presence of cars and other obstacles. FR_CURB can range from 0.01 to 1.00. If no value is entered for FR_CURB (FR_CURB left blank or set to 0.0, the model will assume 100% of the curb length is available for sweeping. Required.

The format of the street sweeping line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
SWEEPEFF	space 32-43	decimal (xxxxxx.xxxxx)	f12.5
FR_CURB	space 45-50	decimal (xxx.xx)	f6.2

20.2.13 RELEASE/IMPOUND OPERATION

In areas of low relief and/or young geologic development, the drainage network may be poorly developed. Watersheds in these areas may have many closed depressional areas, referred to as potholes. Runoff generated within these areas flows to the lowest portion of the pothole rather than contributing to flow in the main channel. Other systems that are hydrologically similar to potholes include playa lakes and fields that are artifically impounded for rice production. The algorithms reviewed in this section are used to model these types of systems.

One HRU in each subbasin can be defined as a pothole. To initiate water impoundment, a release/impound operation must be placed in the .mgt file. The release/impound operation can be used only in the HRU designated as a depressional/impounded area in the subbasin.

The variables entered for the release/impound operation are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 13 for release/impoundment of water. Required.
IMP_TRIG	Release/impound action code: 0 initiate water impoundment 1 initiate water release Required.

The format of the release/impound line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
IMP_TRIG	space 20-23	4-digit integer	i4

20.2.14 CONTINUOUS FERTILIZER OPERATION

When manure is being distributed across land areas as part of waste management for intensive animal operations, the continuous fertilizer operation provides the user with a convenient method to set up the multiple fertilizer applications.

The variables entered for the continuous fertilizer operation are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 14 for continuous fertilizer operation. Required.
FERT_DAYS	Duration or length of period (days) the continuous fertilizer operation takes place in the HRU. Required.
CFRT_ID	Fertilizer/manure identification number from fertilizer database (see Chapter 17). Required.

Variable name	Definition
IFRT_FREQ	Application frequency (days). This variable allows the user to set the frequency at which fertilizer applications take place during the application period. For example, fertilizer can be applied every day (IFRT_FREQ = 1), every other day (IFRT_FREQ = 2), etc. Required.
CFRT_KG	Amount of fertilizer/manure applied to ground in each application (kg/ha). Required.

The format of the continuous fertilization line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
FERT_DAYS	space 20-23	4-digit integer	i4
CFRT_ID	space 25-27	3-digit integer	i3
IFRT_FREQ	space 29-30	2-digit integer	i2
CFRT_KG	space 32-43	decimal (xxxxxx.xxxxx)	f12.5

20.2.15 CONTINUOUS PESTICIDE OPERATION

A constant pesticide application operation can be used to periodically apply pesticide. A fixed amount of pesticide is applied repeatedly at user defined intervals for the duration specified.

The variables entered for the continuous pesticide operation are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 14 for continuous pesticide operation. Required.
CPST_ID	Pesticide identification number from pesticide database (see Chapter 16). Required.
PEST_DAYS	Number of days continuous pesticide will be simulated Required.
IPEST_FREQ	Number of days between applications. Required.
CPST_KG	Amount of pesticide applied to HRU on a given day (kg/ha). Required.

The format of the continuous pesticide line is:

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
CPST_ID	space 20-23	4-digit integer	i4
PEST_DAYS	space 25-27	3-digit integer	i3
IPEST_FREQ	space 29-30	2-digit integer	i2
CPST_KG	space 32-43	decimal (xxxxxx.xxxxx)	f12.5

20.2.16 BURN OPERATION

The variables entered for the burn operation are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 16 for burn operation. Required.
BURN_FRLB	Fraction of biomass and residue that burn (fraction)

The format of the burn operation line is:

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
BURN_FRLB	space 32-43	decimal (xxxxxx.xxxxx)	f12.5

20.2.17 END OF YEAR OPERATION

SWAT requires a blank line to be inserted after all operations for a single year are listed. The blank line lets the model know that there will be no more operations in the year.

If a rotation is being simulated in which the land is left fallow for one of the years with no operations occurring, a blank line should be entered for the fallow year.

20.3 REFERENCES

Pitt, R. 1979. Demonstration of non-point pollution abatement through improved street cleaning practices. EPA-600/2-79-161 (NTIS PB80-108988), U.S. Environmental Protection Agency, Cincinnati, OH.

Soil Conservation Service Engineering Division. 1986. Urban hydrology for small watersheds. U.S. Department of Agriculture, Technical Release 55.

U.S. Environmental Protection Agency. 1983. Results of the nationwide urban runoff program; Volume 1 final report. NTIS PB84-185552, U.S. Environmental Protection Agency, Washington, D.C.

Wischmeier, W.H., and D.D. Smith. 1978. Predicting rainfall losses: A guide to conservation planning. USDA Agricultural Handbook No. 537. U.S. Gov. Print. Office, Washington, D. C.

CHAPTER 21

SWAT INPUT DATA: .WUS

Consumptive water use is a management tool that removes water from the basin. This file is used to simulate removal of water for irrigation outside the watershed or removal of water for urban/industrial use. Water removed for consumptive use is considered to be lost from the system. SWAT allows water to be removed from the shallow aquifer, the deep aquifer, the reach or the pond within any subbasin in the watershed. Water also may be removed from reservoirs for consumptive use (see .res file, Chapter 29).

Consumptive water use is allowed to vary from month to month. For each month in the year, an average daily volume of water removed from the source is specified.

Following is a brief description of the variables in the water use input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first three lines of the .wus file are reserved for user comments. The comments may take up to 80 spaces on each line. The title lines are not processed by the model and may be left blank. Optional.
WUPND(mon)	Average daily water removal from the pond for the month (10^4 m^3/day). Optional.
WURCH(mon)	Average daily water removal from the reach for the month (10^4 m^3/day). Optional.
WUSHAL(mon)	Average daily water removal from the shallow aquifer for the month (10^4 m^3/day). Optional.
WUDEEP(mon)	Average daily water removal from the deep aquifer for the month (10^4 m^3/day). Optional.

The format of the water use file is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1-3	space 1-80	character	a80
WUPND(1)	4	space 1-10	decimal (xxxxxxxx.x)	f10.1
WUPND(2)	4	space 11-20	decimal (xxxxxxxx.x)	f10.1
WUPND(3)	4	space 21-30	decimal (xxxxxxxx.x)	f10.1
WUPND(4:)	4	space 31-40	decimal (xxxxxxxx.x)	f10.1
WUPND(5)	4	space 41-50	decimal (xxxxxxxx.x)	f10.1
WUPND(6)	4	space 51-60	decimal (xxxxxxxx.x)	f10.1

Variable name	Line #	Position	Format	F90 Format
WUPND(7)	5	space 1-10	decimal (xxxxxxxx.x)	f10.1
WUPND(8)	5	space 11-20	decimal (xxxxxxxx.x)	f10.1
WUPND(9)	5	space 21-30	decimal (xxxxxxxx.x)	f10.1
WUPND(10)	5	space 31-40	decimal (xxxxxxxx.x)	f10.1
WUPND(11)	5	space 41-50	decimal (xxxxxxxx.x)	f10.1
WUPND(12)	5	space 51-60	decimal (xxxxxxxx.x)	f10.1
WURCH(1)	6	space 1-10	decimal (xxxxxxxx.x)	f10.1
WURCH(2)	6	space 11-20	decimal (xxxxxxxx.x)	f10.1
WURCH(3)	6	space 21-30	decimal (xxxxxxxx.x)	f10.1
WURCH(4)	6	space 31-40	decimal (xxxxxxxx.x)	f10.1
WURCH(5)	6	space 41-50	decimal (xxxxxxxx.x)	f10.1
WURCH(6)	6	space 51-60	decimal (xxxxxxxx.x)	f10.1
WURCH(7)	7	space 1-10	decimal (xxxxxxxx.x)	f10.1
WURCH(8)	7	space 11-20	decimal (xxxxxxxx.x)	f10.1
WURCH(9)	7	space 21-30	decimal (xxxxxxxx.x)	f10.1
WURCH(10)	7	space 31-40	decimal (xxxxxxxx.x)	f10.1
WURCH(11)	7	space 41-50	decimal (xxxxxxxx.x)	f10.1
WURCH(12)	7	space 51-60	decimal (xxxxxxxx.x)	f10.1
WUSHAL(1)	8	space 1-10	decimal (xxxxxxxx.x)	f10.1
WUSHAL(2)	8	space 11-20	decimal (xxxxxxxx.x)	f10.1
WUSHAL(3)	8	space 21-30	decimal (xxxxxxxx.x)	f10.1
WUSHAL(4)	8	space 31-40	decimal (xxxxxxxx.x)	f10.1
WUSHAL(5)	8	space 41-50	decimal (xxxxxxxx.x)	f10.1
WUSHAL(6)	8	space 51-60	decimal (xxxxxxxx.x)	f10.1
WUSHAL(7)	9	space 1-10	decimal (xxxxxxxx.x)	f10.1
WUSHAL(8)	9	space 11-20	decimal (xxxxxxxx.x)	f10.1
WUSHAL(9)	9	space 21-30	decimal (xxxxxxxx.x)	f10.1
WUSHAL(10)	9	space 31-40	decimal (xxxxxxxx.x)	f10.1
WUSHAL(11)	9	space 41-50	decimal (xxxxxxxx.x)	f10.1
WUSHAL(12)	9	space 51-60	decimal (xxxxxxxx.x)	f10.1
WUDEEP(1)	10	space 1-10	decimal (xxxxxxxx.x)	f10.1
WUDEEP(2)	10	space 11-20	decimal (xxxxxxxx.x)	f10.1
WUDEEP(3)	10	space 21-30	decimal (xxxxxxxx.x)	f10.1
WUDEEP(4)	10	space 31-40	decimal (xxxxxxxx.x)	f10.1

Variable name	Line #	Position	Format	F90 Format
WUDEEP(5)	10	space 41-50	decimal (xxxxxxxx.x)	f10.1
WUDEEP(6)	10	space 51-60	decimal (xxxxxxxx.x)	f10.1
WUDEEP(7)	11	space 1-10	decimal (xxxxxxxx.x)	f10.1
WUDEEP(8)	11	space 11-20	decimal (xxxxxxxx.x)	f10.1
WUDEEP(9)	11	space 21-30	decimal (xxxxxxxx.x)	f10.1
WUDEEP(10)	11	space 31-40	decimal (xxxxxxxx.x)	f10.1
WUDEEP(11)	11	space 41-50	decimal (xxxxxxxx.x)	f10.1
WUDEEP(12)	11	space 51-60	decimal (xxxxxxxx.x)	f10.1

CHAPTER 22

SWAT INPUT DATA: .SOL

The soils data used by SWAT can be divided into two groups, physical characteristics and chemical characteristics. The physical properties of the soil govern the movement of water and air through the profile and have a major impact on the cycling of water within the HRU. Inputs for chemical characteristics are used to set initial levels of the different chemicals in the soil. While the physical properties are required, information on chemical properties is optional. The soil input (.sol) file defines the physical properties for all layers in the soil.

Following is a brief description of the variables in the soil input file. They are listed in the order they appear within the file. The soil input file will hold data for up to 25 layers.

Variable name	Definition
TITLE/TEXT	The first line of the .sol file is reserved for user comments. The comments may take up to 80 spaces. The title line is not processed by the model and may be left blank. Optional.
SNAM	Soil name. The soil name is printed in HRU summary tables. Optional.
HYDGRP	Soil hydrologic group (A, B, C, or D). Required only for the SWAT ArcView interface. The U.S. Natural Resource Conservation Service (NRCS) classifies soils into four hydrologic groups based on infiltration characteristics of the soils. NRCS Soil Survey Staff (1996) defines a hydrologic group as a group of soils having similar runoff potential under similar storm and cover conditions. Soil properties that influence runoff potential are those that impact the minimum rate of infiltration for a bare soil after prolonged wetting and when not frozen. These properties are depth to seasonally high water table, saturated hydraulic conductivity, and depth to a very slowly permeable layer. The definitions for the different classes are: A Soils having high infiltration rates even when thoroughly wetted, consisting chiefly of sands or gravel that are deep and well to excessively drained. These soils have a high rate of water transmission (low runoff potential). B Soils having moderate infiltration rates when thoroughly wetted, chiefly moderately deep to deep, moderately well to well drained, with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

Variable name	Definition
HYDGRP, cont.	C Soils having slow infiltration rates when thoroughly wetted, chiefly with a layer that impedes the downward movement of water or of moderately fine to fine texture and a slow infiltration rate. These soils have a slow rate of water transmission (high runoff potential).
	D Soils having very slow infiltration rates when thoroughly wetted, chiefly clay soils with a high swelling potential; soils with a high permanent water table; soils with a clay pan or clay layer at or near the surface; and shallow soils over nearly impervious materials. These soils have a very slow rate of water transmission.
	Guidelines used by USDA Soil Survey to categorize soils into Hydrologic Groups are summarized in Table 22-1.

Table 22-1: Hydrologic Group Rating Criteria

Criteria*	Hydrologic Soil Groups A	B	C	D
Final constant infiltration rate (mm/hr)	7.6-11.4	3.8-7.6	1.3-3.8	0-1.3
Mean permeability: surface layer (mm/hr)	> 254.0	84.0-254.0	8.4-84.0	< 8.4
Mean permeability: most restrictive layer below the surface layer to a depth of 1.0 m (mm/hr)	> 254.0	84.0-254.0	8.4-84.0	< 8.4
Shrink-swell potential: most restrictive layer**	Low	Low	Moderate	High, Very High
Depth to bedrock or cemented pan (mm)	> 1016	> 508	> 508	< 508
DUAL HYDROLOGIC GROUPS	**A/D**	**B/D**	**C/D**	
Mean depth to water table (m)	< 0.61	< 0.61	< 0.61	

* These criteria are guidelines only. They are based on the theory that the minimum permeability occurs within the uppermost 50 cm. If the minimum permeability occurs between a depth of 50 to 100 cm, then the Hydrologic Soil Group is increased one group. For example, C to B. If the minimum permeability occurs below a depth of 100 cm, the Hydrologic Soil Group is based on the permeability above 100 cm, using the rules previously given.

** Shrink-swell potential is assigned to a profile using the following guidelines:
Low: All soils with sand, loamy sand, sandy loam, loam or silt loam horizons that are at least 50 cm thick from the surface without a clay horizon within 100 cm of the surface.
Medium: All soils with clay loam horizons within 50 cm of the surface or soils with clay horizons from 50 to 100 cm beneath the surface.
High: All soils with clay horizons within 50 cm of the surface. Lower the shrink-swell potential one class when kaolinite clay is dominant.

Variable name	Definition
SOL_ZMX	Maximum rooting depth of soil profile (mm). If no depth is specified, the model assumes the roots can develop throughout the entire depth of the soil profile. Required
ANION_EXCL	Fraction of porosity (void space) from which anions are excluded. Most soil minerals are negatively charged at normal pH and the net interaction with anions such as nitrate is a repulsion from particle surfaces. This repulsion is termed negative adsorption or anion exclusion. Anions are excluded from the area immediately adjacent to mineral surfaces due to preferential attraction of cations to these sites. This process has a direct impact on the transport of anions through the soil for it effectively excludes anions from the slowest moving portion of the soil water volume found closest to the charged particle surfaces (Jury et al, 1991). In effect, the net pathway of the anion through the soil is shorter than it would be if all the soil water had to be used (Thomas and McMahon, 1972). If no value for ANION_EXCL is entered, the model will set ANION_EXCL = 0.50. Optional.
SOL_CRK	Potential or maximum crack volume of the soil profile expressed as a fraction of the total soil volume. To accurately predict surface runoff and infiltration in areas dominated by Vertisols, the temporal change in soil volume must be quantified. Bronswijk (1989, 1990) outlines methods used to determine the maximum crack volume. Optional.
TEXTURE	Texture of soil layer. This data is not processed by the model and the line may be left blank. Optional.

Variable name	Definition
SOL_Z(layer #)	Depth from soil surface to bottom of layer (mm). Required.
SOL_BD(layer #)	Moist bulk density (Mg/m^3 or g/cm^3). The soil bulk density expresses the ratio of the mass of solid particles to the total volume of the soil, $\rho_b = M_S / V_T$. In moist bulk density determinations, the mass of the soil is the oven dry weight and the total volume of the soil is determined when the soil is at or near field capacity. Bulk density values should fall between 1.1 and 1.9 Mg/m^3. Required.
SOL_AWC(layer #)	Available water capacity of the soil layer (mm H_2O/mm soil). The plant available water, also referred to as the available water capacity, is calculated by subtracting the fraction of water present at permanent wilting point from that present at field capacity, $AWC = FC - WP$ where AWC is the plant available water content, FC is the water content at field capacity, and WP is the water content at permanent wilting point. Available water capacity is estimated by determining the amount of water released between in situ field capacity (the soil water content at soil matric potential of -0.033 MPa) and the permanent wilting point (the soil water content at soil matric potential of -1.5 MPa). Required.
SOL_K(layer #)	Saturated hydraulic conductivity (mm/hr). The saturated hydraulic conductivity, K_{sat}, relates soil water flow rate (flux density) to the hydraulic gradient and is a measure of the ease of water movement through the soil. K_{sat} is the reciprocal of the resistance of the soil matrix to water flow. Required.
SOL_CBN(layer #)	Organic carbon content (% soil weight). When defining by soil weight, the soil is the portion of the sample that passes through a 2 mm sieve. Required.

Variable name	Definition
SOL_CLAY(layer #)	Clay content (% soil weight). The percent of soil particles which are < 0.002 mm in equivalent diameter. Required.
SOL_SILT(layer #)	Silt content (% soil weight). The percentage of soil particles which have an equivalent diameter between 0.05 and 0.002 mm. Required.
SOL_SAND(layer #)	Sand content (% soil weight). The percentage of soil particles which have a diameter between 2.0 and 0.05 mm. Required.
SOL_ROCK(layer #)	Rock fragment content (% total weight). The percent of the sample which has a particle diameter > 2 mm, i.e. the percent of the sample which does not pass through a 2 mm sieve. Required.
SOL_ALB(top layer)	Moist soil albedo. The ratio of the amount of solar radiation reflected by a body to the amount incident upon it, expressed as a fraction. The value for albedo should be reported when the soil is at or near field capacity. Required.
USLE_K(top layer)	USLE equation soil erodibility (K) factor (units: 0.013 (metric ton m2 hr)/(m3-metric ton cm)). Some soils erode more easily than others even when all other factors are the same. This difference is termed soil erodibility and is caused by the properties of the soil itself. Wischmeier and Smith (1978) define the soil erodibility factor as the soil loss rate per erosion index unit for a specified soil as measured on a unit plot. A unit plot is 22.1-m (72.6-ft) long, with a uniform length-wise slope of

Variable name	Definition
USLE_K, cont.	9-percent, in continuous fallow, tilled up and down the slope. Continuous fallow is defined as land that has been tilled and kept free of vegetation for more than 2 years. The units for the USLE soil erodibility factor in MUSLE are numerically equivalent to the traditional English units of 0.01 (ton acre hr)/(acre ft-ton inch).

Wischmeier and Smith (1978) noted that a soil type usually becomes less erodible with decrease in silt fraction, regardless of whether the corresponding increase is in the sand fraction or clay fraction.

Direct measurement of the erodibility factor is time consuming and costly. Wischmeier et al. (1971) developed a general equation to calculate the soil erodibility factor when the silt and very fine sand content makes up less than 70% of the soil particle size distribution.

$$K_{USLE} = \frac{0.00021 \cdot M^{1.14} \cdot (12 - OM) + 3.25 \cdot (c_{soilstr} - 2) + 2.5 \cdot (c_{perm} - 3)}{100}$$

where KUSLE is the soil erodibility factor, M is the particle-size parameter, OM is the percent organic matter (%), csoilstr is the soil structure code used in soil classification, and cperm is the profile permeability class.

The particle-size parameter, M, is calculated

$$M = (m_{silt} + m_{vfs}) \cdot (100 - m_c)$$

where msilt is the percent silt content (0.002-0.05 mm diameter particles), mvfs is the percent very fine sand content (0.05-0.10 mm diameter particles), and mc is the percent clay content (< 0.002 mm diameter particles).
The percent organic matter content, OM, of a layer can be calculated:

$$OM = 1.72 \cdot orgC$$

where orgC is the percent organic carbon content of the layer (%).

Variable name	Definition
USLE_K, cont.	Soil structure refers to the aggregation of primary soil particles into compound particles which are separated from adjoining aggregates by surfaces of weakness. An individual natural soil aggregate is called a ped. Field description of soil structure notes the shape and arrangement of peds, the size of peds, and the distinctness and durability of visible peds. USDA Soil Survey terminology for structure consists of separate sets of terms defining each of these three qualities. Shape and arrangement of peds are designated as type of soil structure; size of peds as class; and degree of distinctness as grade. Angular Blocky: bounded by planes intersecting at relatively sharp angles Subangular Blocky: having mixed rounded and plane faces with vertices mostly rounded The soil-structure codes for the equation are defined by the type and class of soil structure present in the layer. There are four primary types of structure, several of which are further broken down into subtypes: -Platy, with particles arranged around a plane, generally horizontal -Prismlike, with particles arranged around a verticle line and bounded by relatively flat vertical surfaces Prismatic: without rounded upper ends Columnar: with rounded caps -Blocklike or polyhedral, with particles arranged around a point and bounded by flat or rounded surfaces which are casts of the molds formed by the faces of surrounding peds -Spheroidal or polyhedral, with particles arranged around a point and bounded by curved or very irregular surfaces that are not accomodated to the adjoining aggregates Granular: relatively non-porous Crumb: very porous The size criteria for the class will vary by type of structure and are summarized in Table 22-2.

Variable name	Definition
USLE_K, cont.	

Table 22-2: Size classes of soil structure

	Shape of structure			
Size Classes	**Platy**	**Prismatic and Columnar**	**Blocky**	**Granular**
Very fine	< 1 mm	< 10 mm	< 5 mm	< 1 mm
Fine	1-2 mm	10-20 mm	5-10 mm	1-2 mm
Medium	2-5 mm	20-50 mm	10-20 mm	2-5 mm
Coarse	5-10 mm	50-100 mm	20-50 mm	5-10 mm
Very coarse	> 10 mm	> 100 mm	> 50 mm	> 10 mm

The codes assigned to $c_{soilstr}$ are:

1 very fine granular
2 fine granular
3 medium or coarse granular
4 blocky, platy, prismlike or massive

Permeability is defined as the capacity of the soil to transmit water and air through the most restricted horizon (layer) when moist. The profile permeability classes are based on the lowest saturated hydraulic conductivity in the profile. The codes assigned to c_{perm} are:

1 rapid (> 150 mm/hr)
2 moderate to rapid (50-150 mm/hr)
3 moderate (15-50 mm/hr)
4 slow to moderate (5-15 mm/hr)
5 slow (1-5 mm/hr)
6 very slow (< 1 mm/hr)

Williams (1995) proposed an alternative equation:

$$K_{USLE} = f_{csand} \cdot f_{cl-si} \cdot f_{orgc} \cdot f_{hisand}$$

where f_{csand} is a factor that gives low soil erodibility factors for soils with high coarse-sand contents and high values for soils with little sand, $f_{cl\text{-}si}$ is a factor that gives low soil erodibility factors for soils with high clay to silt ratios, f_{orgc} is a factor that reduces soil erodibility for soils with high organic carbon content, and f_{hisand} is a factor that reduces soil erodibility for soils with extremely high sand contents. The factors are calculated:

$$f_{csand} = \left(0.2 + 0.3 \cdot \exp\left[-0.256 \cdot m_s \cdot \left(1 - \frac{m_{silt}}{100} \right) \right] \right)$$

Variable name	Definition
USLE_K, cont.	$$f_{cl-si} = \left(\frac{m_{silt}}{m_c + m_{silt}} \right)^{0.3}$$ $$f_{orgc} = \left(1 - \frac{0.0256 \cdot orgC}{orgC + \exp\left[3.72 - 2.95 \cdot orgC\right]} \right)$$ $$f_{hisand} = \left(1 - \frac{0.7 \cdot \left(1 - \frac{m_s}{100} \right)}{\left(1 - \frac{m_s}{100} \right) + \exp\left[-5.51 + 22.9 \cdot \left(1 - \frac{m_s}{100} \right) \right]} \right)$$ where m_s is the percent sand content (0.05-2.00 mm diameter particles), m_{silt} is the percent silt content (0.002-0.05 mm diameter particles), m_c is the percent clay content (< 0.002 mm diameter particles), and $orgC$ is the percent organic carbon content of the layer (%). Required.
SOL_EC(layer #)	Electrical conductivity (dS/m). *Not currently active*

The format of the soil input file is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1	space 1-80	character	a80
SNAM	2	space 13-28	character	a16
HYDGRP	3	space 25	character	a1
SOL_ZMX	4	space 29-35	decimal(xxxxxxxxx.xx)	f12.2
ANION_EXCL	5	space 52-56	decimal(x.xxx)	f5.3
SOL_CRK	6	space 34-38	decimal(x.xxx)	f5.3
COMMENT LINE	7	space 1-147	character	a80
SOL_Z(1)	8	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_Z(2)	8	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_Z(3)	8	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_Z(4)	8	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_Z(5)	8	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_Z(6)	8	space 88-99	decimal(xxxxxxxxx.xx)	f12.2

Variable name	Line #	Position	Format	F90 Format
SOL_Z(7)	8	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_Z(8)	8	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_Z(9)	8	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_Z(10)	8	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
SOL_BD(1)	9	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_BD(2)	9	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_BD(3)	9	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_BD(4)	9	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_BD(5)	9	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_BD(6)	9	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SOL_BD(7)	9	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_BD(8)	9	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_BD(9)	9	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_BD(10)	9	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
SOL_AWC(1)	10	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_AWC(2)	10	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_AWC(3)	10	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_AWC(4)	10	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_AWC(5)	10	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_AWC(6)	10	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SOL_AWC(7)	10	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_AWC(8)	10	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_AWC(9)	10	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_AWC(10)	10	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
SOL_K(1)	11	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_K(2)	11	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_K(3)	11	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_K(4)	11	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_K(5)	11	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_K(6)	11	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SOL_K(7)	11	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_K(8)	11	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_K(9)	11	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_K(10)	11	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
SOL_CBN(1)	12	space 28-39	decimal(xxxxxxxxx.xx)	f12.2

Variable name	Line #	Position	Format	F90 Format
SOL_CBN(2)	12	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_CBN(3)	12	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_CBN(4)	12	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_CBN(5)	12	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_CBN(6)	12	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SOL_CBN(7)	12	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_CBN(8)	12	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_CBN(9)	12	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_CBN(10)	12	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
SOL_CLAY(1)	13	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_CLAY(2)	13	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_CLAY(3)	13	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_CLAY(4)	13	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_CLAY(5)	13	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_CLAY(6)	13	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SOL_CLAY(7)	13	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_CLAY(8)	13	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_CLAY(9)	13	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_CLAY(10)	13	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
SOL_SILT(1)	14	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_SILT(2)	14	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_SILT(3)	14	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_SILT(4)	14	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_SILT(5)	14	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_SILT(6)	14	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SOL_SILT(7)	14	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_SILT(8)	14	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_SILT(9)	14	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_SILT(10)	14	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
SOL_SAND(1)	15	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_SAND(2)	15	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_SAND(3)	15	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_SAND(4)	15	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_SAND(5)	15	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_SAND(6)	15	space 88-99	decimal(xxxxxxxxx.xx)	f12.2

Variable name	Line #	Position	Format	F90 Format
SOL_SAND(7)	15	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_SAND(8)	15	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_SAND(9)	15	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_SAND(10)	15	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
SOL_ROCK(1)	16	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_ROCK(2)	16	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_ROCK(3)	16	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_ROCK(4)	16	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_ROCK(5)	16	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_ROCK(6)	16	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SOL_ROCK(7)	16	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_ROCK(8)	16	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_ROCK(9)	16	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_ROCK(10)	16	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
SOL_ALB(1)	17	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
USLE_K(1)	18	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_EC(1)	19	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_EC(2)	19	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_EC(3)	19	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_EC(4)	19	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_EC(5)	19	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_EC(6)	19	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SOL_EC(7)	19	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_EC(8)	19	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_EC(9)	19	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_EC(10)	19	space 136-147	decimal(xxxxxxxxx.xx)	f12.2

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CHAPTER **23**

SWAT INPUT DATA: .CHM

The soils data used by SWAT can be divided into two groups, physical characteristics and chemical characteristics. Inputs for chemical characteristics are used to initialize amounts of chemicals in the soil.

Inclusion of an equilibration period (a year or so) at the beginning of a simulation period is recommended to get the hydrologic cycle fully operational. The equilibration period also allows nutrient levels in the soil to equilibrate, making initialization of chemical characteristics in the soil unnecessary in most cases. Initializing chemical properties is recommended if the levels of nutrients or pesticides in the soil is atypically high.

Following is a brief description of the variables in the soil chemical input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the .chm file is reserved for user comments. The comments may take up to 80 spaces. The title line is not processed by the model and may be left blank. Optional.
NUTRIENT TITLE	The second line of the .chm file is reserved for the nutrient data title. This line is not processed by the model and may be left blank. Optional.
SOIL LAYER	Number of soil layer. This line is not processed by the model and may be left blank. Optional.
SOL_NO3(layer #)	Initial NO_3 concentration in the soil layer (mg N/kg soil or ppm). Users may define the concentration of nitrate (dry weight basis) for all soil layers at the beginning of the simulation. If the user does not specify initial nitrate concentrations, SWAT will initialize levels of nitrate using the equations reviewed in Chapter 3:1 of the Theoretical Documentation. Optional.
SOL_ORGN(layer #)	Initial organic N concentration in the soil layer (mg N/kg soil or ppm). Users may define the concentration of organic nitrogen (dry weight basis) contained in humic substances for all soil layers at the beginning of the simulation. If the user does not specify initial nitrogen concentrations, SWAT will initialize levels of organic nitrogen using the equations reviewed in Chapter 3:1 of the Theoretical Documentation. Optional.

Variable name	Definition
SOL_SOLP(layer #)	Initial soluble P concentration in soil layer (mg P/kg soil or ppm). Users may define the concentration of solution P (dry weight basis) for all soil layers at the beginning of the simulation. If the user does not specify initial solution P concentrations, SWAT will initialize the concentration to 5 mg P/kg soil in all soil layers. Optional.
SOL_ORGP(layer #)	Initial organic P concentration in soil layer (mg P/kg soil or ppm). Users may define the concentration of organic phosphorus (dry weight basis) contained in humic substances for all soil layers at the beginning of the simulation. If the user does not specify initial organic P concentrations, SWAT will initialize levels of organic phosphorus using the equations reviewed in Chapter 3:2 of the Theoretical Documentation. Optional.
PPERCO_SUB	Phosphorus percolation coefficient in soil layer (10 m^3/Mg). The phosphorus percolation coefficient is the ratio of the solution phosphorus concentration in the surface 10 mm of soil to the concentration of phosphorus in percolate. The value of PPERCO_SUB can range from 10.0 to 17.5. If no value for PPERCO_SUB is entered the model will PPERCO_SUB = 10.0.
PESTICIDE TITLE	Lines 9-11 are reserved for the pesticide data titles. These lines are not processed by the model and may be left blank. Optional.
PESTNUM	Number of pesticide from pesticide database. Required if pesticide amounts are given.
PLTPST	Initial pesticide amount on foliage (kg ai/ha). Optional.

Variable name	Definition
SOLPST	Initial pesticide amount in soil (mg ai/kg soil or ppm). The pesticide is assumed to be found at this concentration (dry weight basis) in all soil layers. Optional.
PSTENR	Enrichment ratio for pesticide in the soil. As surface runoff flows over the soil surface, part of the water's energy is used to pick up and transport soil particles. The smaller particles weigh less and are more easily transported than coarser particles. When the particle size distribution of the transported sediment is compared to that of the soil surface layer, the sediment load to the main channel has a greater proportion of clay sized particles. In other words, the sediment load is enriched in clay particles. The sorbed phase of pesticide in the soil is attached primarily to colloidal (clay) particles, so the sediment load will also contain a greater proportion or concentration of pesticide than that found in the soil surface layer. The enrichment ratio is defined as the ratio of the concentration of sorbed pesticide transported with the sediment to the concentration in the soil surface layer. SWAT will calculate an enrichment ratio for each storm event, or allow the user to define a particular enrichment ratio for sorbed pesticide that is used for all storms during the simulation. To allow SWAT to calculate the enrichment ratio for each storm event, the value for PSTENR is set to zero. The default option is to allow the model to calculate the enrichment ratio. Optional.

The format of the soil chemical input file is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1	space 1-80	character	a80
NUTRIENT TITLE	2	space 1-80	character	a80
SOIL LAYERS	3	space 1-80	character	a80
SOL_NO3(1)	4	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_NO3(2)	4	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_NO3(3)	4	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_NO3(4)	4	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_NO3(5)	4	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_NO3(6)	4	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SOL_NO3(7)	4	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_NO3(8)	4	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_NO3(9)	4	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_NO3(10)	4	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGN(1)	5	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGN(2)	5	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGN(3)	5	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGN(4)	5	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGN(5)	5	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGN(6)	5	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGN(7)	5	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGN(8)	5	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGN(9)	5	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGN(10)	5	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
SOL_SOLP(1)	6	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_SOLP(2)	6	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_SOLP(3)	6	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_SOLP(4)	6	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_SOLP(5)	6	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_SOLP(6)	6	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SOL_SOLP(7)	6	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_SOLP(8)	6	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_SOLP(9)	6	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_SOLP(10)	6	space 136-147	decimal(xxxxxxxxx.xx)	f12.2

Variable name	Line #	Position	Format	F90 Format
SOL_ORGP(1)	7	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGP(2)	7	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGP(3)	7	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGP(4)	7	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGP(5)	7	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGP(6)	7	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGP(7)	7	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGP(8)	7	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGP(9)	7	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGP(10)	7	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
PPERCO_SUB(1)	8	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
PPERCO_SUB(2)	8	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
PPERCO_SUB(3)	8	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
PPERCO_SUB(4)	8	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
PPERCO_SUB(5)	8	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
PPERCO_SUB(6)	8	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
PPERCO_SUB(7)	8	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
PPERCO_SUB(8)	8	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
PPERCO_SUB(9)	8	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
PPERCO_SUB(10)	8	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
PESTICIDE TITLE	9-11	space 1-80	character	a80
PSTNUM	12-END		integer	free
PLTPST	12-END		real	free
SOLPST	12-END		real	free
PSTENR	12-END		real	free

CHAPTER 24

SWAT INPUT DATA: .GW

SWAT partitions groundwater into two aquifer systems: a shallow, unconfined aquifer which contributes return flow to streams within the watershed and a deep, confined aquifer which contributes no return flow to streams inside the watershed. The properties governing water movement into and out of the aquifers are initialized in the groundwater input file.

Following is a brief description of the variables in the groundwater input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the .gw file is reserved for user comments. The comments may take up to 80 spaces. The title line is not processed by the model and may be left blank. Optional.
SHALLST	Initial depth of water in the shallow aquifer (mm H_2O). We recommend using a 1 year equilibration period for the model where the watershed simulation is set to start 1 year prior to the period of interest. This allows the model to get the water cycling properly before any comparisons between measured and simulated data are made. When an equilibration period is incorporated, the value for SHALLST is not that important.
DEEPST	Initial depth of water in the deep aquifer (mm H_2O). We recommend using a 1 year equilibration period for the model where the watershed simulation is set to start 1 year prior to the period of interest. This allows the model to get the water cycling properly before any comparisons between measured and simulated data are made. When an equilibration period is incorporated, the value for DEEPST is not that important. In watersheds where there is no irrigation with water from the deep aquifer, this variable has no impact at all. If no value for DEEPST is entered, the model sets DEEPST = 1000.0 mm.
GW_DELAY	Groundwater delay time (days). Water that moves past the lowest depth of the soil profile by percolation or bypass flow enters and flows through the vadose zone before becoming shallow aquifer recharge. The lag between the time that water exits the soil profile and enters the shallow aquifer will depend on the depth to the water table and the hydraulic properties of the geologic formations in the vadose and groundwater zones.

Variable name	Definition
GW_DELAY	The delay time, δ_{gw}, cannot be directly measured. It can be estimated by simulating aquifer recharge using different values for δ_{gw} and comparing the simulated variations in water table level with observed values. Johnson (1977) developed a simple program to iteratively test and statistically evaluate different delay times for a watershed. Sangrey et al. (1984) noted that monitoring wells in the same area had similar values for δ_{gw}, so once a delay time value for a geomorphic area is defined, similar delay times can be used in adjoining watersheds within the same geomorphic province. Required.
ALPHA_BF	Baseflow alpha factor (days). The baseflow recession constant, α_{gw}, is a direct index of groundwater flow response to changes in recharge (Smedema and Rycroft, 1983). Values vary from 0.1-0.3 for land with slow response to recharge to 0.9-1.0 for land with a rapid response. Although the baseflow recession constant may be calculated, the best estimates are obtained by analyzing measured streamflow during periods of no recharge in the watershed. It is common to find the baseflow days reported for a stream gage or watershed. This is the number of days for base flow recession to decline through one log cycle. When baseflow days are known, the alpha facter can be calculated: $\alpha_{gw} = \frac{1}{N} \cdot \ln\left[\frac{Q_{gw,N}}{Q_{gw,0}}\right] = \frac{1}{BFD} \cdot \ln[10] = \frac{2.3}{BFD}$ where α_{gw} is the baseflow recession constant, and *BFD* is the number of baseflow days for the watershed. Required.
GWQMN	Threshold depth of water in the shallow aquifer required for return flow to occur (mm H_2O). Groundwater flow to the reach is allowed only if the depth of water in the shallow aquifer is equal to or greater than GWQMN. Required.

Variable name	Definition
GW_REVAP	Groundwater "revap" coefficient.
	Water may move from the shallow aquifer into the overlying unsaturated zone. In periods when the material overlying the aquifer is dry, water in the capillary fringe that separates the saturated and unsaturated zones will evaporate and diffuse upward. As water is removed from the capillary fringe by evaporation, it is replaced by water from the underlying aquifer. Water may also be removed from the aquifer by deep-rooted plants which are able to uptake water directly from the aquifer.
	This process is significant in watersheds where the saturated zone is not very far below the surface or where deep-rooted plants are growing. Because the type of plant cover will affect the importance of revap in the water balance, the parameters governing revap can be varied by land use.
	As GW_REVAP approaches 0, movement of water from the shallow aquifer to the root zone is restricted. As GW_REVAP approaches 1, the rate of transfer from the shallow aquifer to the root zone approaches the rate of potential evapotranspiration. The value for GW_REVAP should be between 0.02 and 0.20.
	This variable, along with REVAPMN, is the reason a different groundwater file is created for each HRU rather than each subbasin.
	Required.
REVAPMN	Threshold depth of water in the shallow aquifer for “revap” or percolation to the deep aquifer to occur (mm H_2O).
	Movement of water from the shallow aquifer to the unsaturated zone is allowed only if the volume of water in the shallow aquifer is equal to or greater than REVAPMN.
	This variable, along with GW_REVAP, is the reason a different groundwater file is created for each HRU rather than each subbasin.
	Required.

Variable name	Definition
RCHRG_DP	Deep aquifer percolation fraction. The fraction of percolation from the root zone which recharges the deep aquifer. The value for RCHRG_DP should be between 0.0 and 1.0. Required.
GWHT	Initial groundwater height (m). Steady-state groundwater flow and the height of the water table are linearly proportional. The equations used to calculate the change in groundwater height with change in flow are included in SWAT. However, the groundwater height is not currently printed out in any of the output files. *This variable is not active.*
GW_SPYLD	Specific yield of the shallow aquifer (m^3/m^3). Specific yield is defined as the ratio of the volume of water that drains by gravity to the total volume of rock. Specific yield is required to calculate groundwater height fluctuations. *This variable is not active*
SHALLST_N	Initial concentration of nitrate in shallow aquifer. (mg N/L or ppm). Nitrate levels in the shallow aquifer are modeled, allowing for variation in nitrate concentration and groundwater loadings of nitrate contributed to streamflow in the subbasin. Optional.
GWSOLP	Concentration of soluble phosphorus in groundwater contribution to streamflow from subbasin (mg P/L or ppm). This is a fixed concentration used throughout the entire period of simulation. Optional.

Variable name	Definition
HLIFE_NGW	Half-life of nitrate in the shallow aquifer (days). Nitrate in the shallow aquifer may be removed by uptake by bacteria present in the aquifer or by chemical conversion to other compounds in regions of the aquifer that are depleted in oxygen (reduced environment). The half-life, as for half-life values reported for pesticides, is the time period required for the concentration of nitrate to drop to one-half its original value. The reduction is a net reduction by all processes occurring in the shallow aquifer. Optional.
LAT_ORGN	Organic N in the base flow (mg/L) (range 0.0 – 200.0) default = 0.0 Optional.
LAT_ORGP	Organic P in the base flow (mg/L) (range 0.0 – 200.0) default = 0.0 Optional.

The groundwater file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line.

Variable name	Line #	Format	F90 Format
TITLE	1	character	a80
SHALLST	2	real	free
DEEPST	3	real	free
GW_DELAY	4	real	free
ALPHA_BF	5	real	free
GWQMN	6	real	free
GW_REVAP	7	real	free
REVAPMN	8	real	free
RCHRG_DP	9	real	free
GWHT	10	real	free
GW_SPYLD	11	real	free
SHALLST_N	12	real	free
GWSOLP	13	real	free
HLIFE_NGW	14	real	free
LAT_ORGN	15	real	free
LAT_ORGP	16	real	free

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Johnson, K.H. 1977. A predictive method for ground water levels. Master's Thesis, Cornell University, Ithica, N.Y.

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CHAPTER 25

SWAT INPUT DATA: .RTE

In order to simulate the physical processes affecting the flow of water and transport of sediment in the channel network of the watershed, SWAT requires information on the physical characteristics of the main channel within each subbasin. The main channel input file (.rte) summarizes the physical characteristics of the channel which affect water flow and transport of sediment, nutrients and pesticides.

Following is a brief description of the variables in the main channel input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the .rte file is reserved for user comments. The comments may take up to 80 spaces. The title line is not processed by the model and may be left blank. Optional.
CH_W(2)	Average width of main channel at top of bank (m). Required.
CH_D	Depth of main channel from top of bank to bottom (m). Required.
CH_S(2)	Average slope of main channel along the channel length (m/m). Required.
CH_L(2)	Length of main channel (km). Required.
CH_N(2)	Manning's "n" value for the main channel. Required.

Table 25-1: Values of Manning's roughness coefficient, *n*, for channel flow (Chow, 1959).[1]

Characteristics of Channel	Median	Range
Excavated or dredged		
Earth, straight and uniform	0.025	0.016-0.033
Earth, winding and sluggish	0.035	0.023-0.050
Not maintained, weeds and brush	0.075	0.040-0.140
Natural streams		
Few trees, stones or brush	0.050	0.025-0.065
Heavy timber and brush	0.100	0.050-0.150

[1] Chow (1959) has a very extensive list of Manning's roughness coefficients. These values represent only a small portion of those he lists in his book.

Variable name	Definition
CH_K(2)	Effective hydraulic conductivity in main channel alluvium (mm/hr).
	Required.
	Streams may be categorized by their relationship to the groundwater system. A stream located in a discharge area that receives groundwater flow is a gaining or effluent stream (Figure 25-1a). This type of stream is characterized by an increase in discharge downstream. A stream located in a recharge area is a losing or influent stream. This type of stream is characterized by a decrease in discharge downstream. A losing stream may be connected to (Figure 25-1b) or perched above (Figure 25-1c) the groundwater flow area. A stream that simultaneously receives and loses groundwater is a flow-through stream (Figure 25-1d).

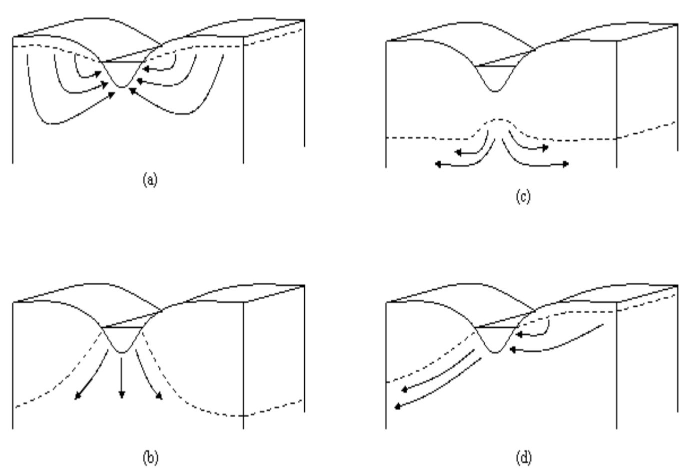

Figure 25-1: Stream-groundwater relationships: a) gaining stream receiving water from groundwater flow; b) losing stream connected to groundwater system; c) losing stream perched above groundwater system; and d) flow-through stream (After Dingman, 1994).

Typical values for K_{ch} for various alluvium materials are given in Table 25-2. For perennial streams with continuous groundwater contribution, the effective conductivity will be zero.

Variable name	**Definition**

CH_K(2), cont.

Table 25-2: Example hydraulic conductivity values for various bed materials (from Lane, 1983).

Bed material group	**Bed material characteristics**	**Hydraulic conductivity**
1 Very high loss rate	Very clean gravel and large sand	> 127 mm/hr
2 High loss rate	Clean sand and gravel, field conditions	51-127 mm/hr
3 Moderately high loss rate	Sand and gravel mixture with low silt-clay content	25-76 mm/hr
4 Moderate loss rate	Sand and gravel mixture with high silt-clay content	6-25 mm/hr
5 Insignificant to low loss rate	Consolidated bed material; high silt-clay content	0.025-2.5 mm/hr

CH_COV1

If CH_EQ is 0 the

CH_COV1 - Channel erodibility factor.

0 = non-erosive channel

1 = no resistance to erosion

The channel erodibility factor is conceptually similar to the soil erodibility factor used in the USLE equation. Channel erodibility is a function of properties of the bed or bank materials.

If CH_EQN $\neq$ 0:

Channel bank vegetation coefficient for critical shear stress (Julian and Torres, 2006)

Bank Vegetation	CH_COV1
None	1.00
Grassy	1.97
Sparse trees	5.40
Dense trees	19.20

Required.

Variable name	Definition
CH_COV2	If CH_EQ is 0 the Channel cover factor. 0 = channel is completely protected from erosion by cover 1 = no vegetative cover on channel The channel cover factor, C_{CH}, is defined as the ratio of degradation from a channel with a specified vegetative cover to the corresponding degradation from a channel with no vegetative cover. The vegetation affects degradation by reducing the stream velocity, and consequently its erosive power, near the bed surface. If CH_EQN ≠ 0: Channel bed vegetation coefficient for critical shear stress (Julian and Torres, 2006)

Bed Vegetation	CH_COV2
None	1.00
Grassy	1.97
Sparse trees	5.40
Dense trees	19.20

	Required.
CH_WDR	Channel width-depth ratio (m/m). While sediment transport calculations have traditionally been made with the same channel dimensions throughout a simulation, SWAT will model channel downcutting and widening. When channel downcutting and widening is simulated, channel dimensions are allowed to change during the simulation period. Required only if channel degradation is being modeled (IDEG = 1 in .bsn).

Variable name	Definition
ALPHA_BNK	Baseflow alpha factor for bank storage (days). Bank storage contributes flow to the main channel or reach within the subbasin. Bank flow is simulated with a recession curve similar to that used for groundwater.The baseflow alpha factor, or recession constant, characterizes the bank storage recession curve. This constant will be some number less than 1.0, and will be large (approach one) for flat recessions and small (approach zero) for steep recessions. If no value is entered for ALPHA_BNK, the variable will be set to the same value as ALPHA_BF from the groundwater (.gw) file. Required.
ICANAL	Code for irrigation canal. 0 = no irrigation canal 1 = irrigation canal (restricts outflow)
CH_ONCO	Organic nitrogen concentration in the channel (ppm) (0.0 – 100.0)
CH_OPCO	Organic phosphorus concentration in the channel (ppm) (0.0 – 100.0)
CH_SIDE	Change in horizontal distance per unit vertical distance(0.0 – 5.0) 0 = for vertical channel bank 1 = for channel bank with gentle side slope
CH_BNK_BD	Bulk density of channel bank sediment (g/cc) (1.1 – 1.9). If the bulk density is not given, the model assumes a default value of 1.4 g/cc for bank sediments assuming silt type material.
CH_BED_BD	Bulk density of channel bed sediment (g/cc) (1.1 – 1.9). If the bulk density is not given, the model assumes a default value of 1.5 g/cc for bed sediments assuming sand type material.

Variable name	Definition
CH_BNK_KD	Erodibility of channel bank sediment by jet test (cm^3/N-s)

Channel erodibility can be measured with a submerged vertical jet device. The basic premise of the test is that erosion of a vegetated or bare channel and local scour beneath an impinging jet are the result of hydraulic stresses, boundary geometry, and the properties of the material being eroded. Hanson (1990) developed a method for determining the erodibility coefficient of channels *in situ* with the submerged vertical jet. Allen et al. (1999) utilized this method to determine channel erodibility factors for thirty sites in Texas.

A submerged, vertical jet of water directed perpendicularly at the channel bed causes erosion of the bed material in the vicinity of the jet impact area (Figure 25-2). Important variables in the erosion process are: the volume of material removed during a jetting event, elevation of the jet above the ground surface, diameter of the jet nozzle, jet velocity, time, mass density of the fluid and coefficient of erodibility.

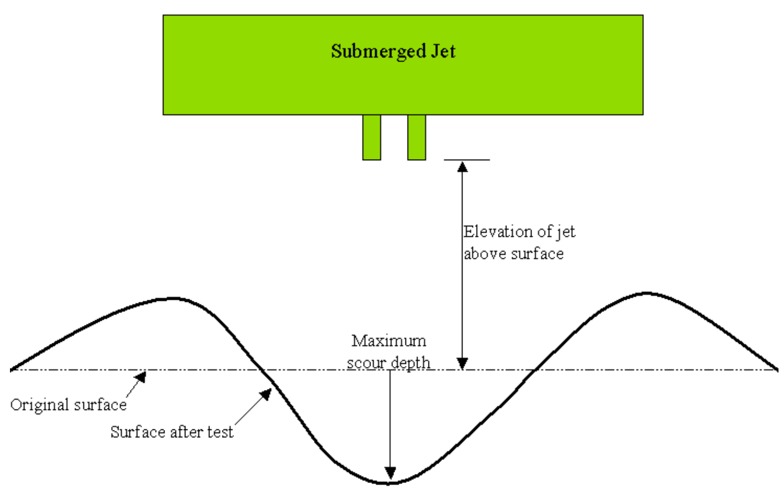

Figure 25-2: Simplified cross-section of submerged jet test (After Allen etal, 1999)

Variable name	Definition
CH_BNK_KD, Cont.	Hanson (1991) defined a jet index, J_i, to relate erodibility to scour created by the submerged jet. The jet index is a function of the depth of scour beneath the jet per unit time and the jet velocity. The jet index is determined by a least squares fit following the procedures outlined in ASTM standard D 5852-95. Once the jet index is determined, the channel erodibility coefficient is calculated: $K_{d,bank} = 0.003 \cdot \exp\left[385 \cdot J_i\right]$ where $K_{d,bank}$ is the channel erodibility coefficient (cm^3/N-s) and J_i is the jet index. In general, values for channel erodibility are an order of magnitude smaller than values for soil erodibility. CH_BNK_KD could range between 0.001 to 3.75 cm^3/N-s, from soils with low erodibility to high erodibility. If no value is entered, K_d is calculated from critical shear stress as: $k_d = 0.2 \cdot \tau_c^{-0.5}$
CH_BED_KD	Similar to CH_BNK_KD but calculated for channel bed (0.001 to 3.75 cm^3/N-s) Optional
CH_BNK_D50	D50 Median particle size diameter of channel bank sediment (µm). If no value is given, the model assumes 50 µm (silt size sediment) for bank. (1 to 10000 µm)
CH_BED_D50	D50 Median particle size diameter of channel bed sediment (µm). If no value is given, the model assumes 500 µm (sand size sediment) for bed. (1 to 10000 µm)
CH_BNK_TC	$T_{c,bank}$: Critical shear stress of channel bank (N/m^2) Critical Stress can also be calculated from Jet test. However if critical stress value is not available, then it is estimated based on silt and clay percentage of bank sediments using this regression relationship developed by Julian and Torres (2006): $\tau_{c,bnk} = \begin{pmatrix} 0.1 + 0.1779 \cdot SC + 0.0028 \cdot SC_{bnk}^{2} \\ - 2.34 \times 10^{-5} \cdot SC_{bnk}^{3} \end{pmatrix} \cdot CH\_COV1$ where SC_{bnk} is calculated based on the D50 particle size from Table 7:2-3 Critial Stress range between 0.0 to 400 N/m^2 for bed material with low resistance to high resistance for erosion.

Variable name	Definition
CH_BED_TC	$T_{c,bed}$: Critical shear stress of channel bed (N/m^2) Critical Stress can also be calculated from Jet test. However if critical stress value is not available, then it is estimated based on silt and clay percentage of bed sediments using this regression relationship developed by Julian and Torres (2006): $\tau_{c,bnk} = \begin{pmatrix} 0.1 + 0.1779 \cdot SC + 0.0028 \cdot SC_{bed}{}^2 \\ - 2.34 \times 10^{-5} \cdot SC_{bed}{}^3 \end{pmatrix} \cdot CH\_COV2$ where SC_{bed} is calculated based on the D50 particle size from Table 7:2-3 Critial Stress range between 0.0 to 400 N/m^2 for bed material with low resistance to high resistance for erosion.
CH_ERODMO	CH_ERODMO is set to a value between 0.0 and 1.0. A value of 0.0 indicates a non-erosive channel while a value of 1.0 indicates no resistance to erosion.
CH_EQN	Sediment routing methods: Model used for Channel Erosion 0 – Simplified Bagnold Equation (Default) All codes below routing by particle size 1 – Simplified Bagnold Equation 2 – Kodatie model 3 – Molinas and Wu model 4 – Yang sand and gravel model

The main channel file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the main channel input file is:

Variable name	Line #	Format	F90 Format
TITLE	1	character	a80
CH_W(2)	2	real	free
CH_D	3	real	free
CH_S(2)	4	real	free
CH_L(2)	5	real	free
CH_N(2)	6	real	free
CH_K(2)	7	real	free
CH_COV1	8	real	free
CH_COV2	9	real	free
CH_WDR	10	real	free
ALPHA_BNK	11	real	free
ICANAL	12	integer	free
CH_ONCO	13	real	free
CH_OPCO	14	real	free
CH_SIDE	15	real	free
CH_BNK_BD	16	real	free
CH_BED_BD	17	real	free
CH_BNK_KD	18	real	free
CH_BED_KD	19	real	free
CH_BNK_D50	20	real	free
CH_BED_D50	21	real	free
CH_BNK_TC	22	real	free
CH_BED_TC	23	real	free

Variable name	Line #	Format	F90 Format
CH_ERODMO(1)	24	real	f6.2
CH_ERODMO(2)	24	real	f6.2
CH_ERODMO(3)	24	real	f6.2
CH_ERODMO(4)	24	real	f6.2
CH_ERODMO(5)	24	real	f6.2
CH_ERODMO(6)	24	real	f6.2
CH_ERODMO(7)	24	real	f6.2
CH_ERODMO(8)	24	real	f6.2
CH_ERODMO(9)	24	real	f6.2
CH_ERODMO(10)	24	real	f6.2
CH_ERODMO(11)	24	real	f6.2
CH_ERODMO(12)	24	real	f6.2
CH_EQN	25	integer	free

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CHAPTER 26

SWAT INPUT DATA: .WWQ

While water quality is a broad subject, the primary areas of concern are nutrients, organic chemicals—both agricultural (pesticide) and industrial, heavy metals, bacteria and sediment levels in streams and large water bodies. SWAT is able to model processes affecting nutrient, pesticide and sediment levels in the main channels and reservoirs. The data used by SWAT for in-stream water quality processes is contained in two files: the stream water quality input file (.swq) for specific reaches and the general water quality input file (.wwq) for processes modeled uniformly over the entire watershed.

Following is a brief description of the variables in the general water quality input file. The variables are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line is reserved for user comments. This line is not processed by the model and may be left blank. Optional.
LAO	Qual2E light averaging option. Qual2E defines four light averaging options. 1 Depth-averaged algal growth attenuation factor for light (FL) is computed from one daylight average solar radiation value calculated in the steady state temperature heat balance. 2 FL is computed from one daylight average solar radiation value supplied by the user. 3 FL is obtained by averaging the hourly daylight values of FL computed from the hourly daylight values of solar radiation calculated in the steady state temperature heat balance. 4 FL is obtained by averaging the hourly daylight values of FL computed from the hourly daylight values of solar radiation calculated from a single value of total daily, photosynthetically active, solar radiation and an assumed cosine function. The only option currently active in SWAT is 2. Required if in-stream nutrient cycling is being modeled.
IGROPT	Qual2E algal specific growth rate option. Qual2E provides three different options for computing the algal growth rate. 1 Multiplicative: the effects of nitrogen, phosphorus and light are multiplied together to calculate the net effect on the local algal growth rate 2 Limiting nutrient: the local algal growth rate is limited by light and one of the nutrients (nitrogen or phosphorus) 3 Harmonic mean: the local algal growth rate is limited by light and the harmonic mean of the nutrient interactions

Variable name	Definition
IGROPT, cont.	The multiplicative option multiplies the growth factors for light, nitrogen and phosphorus together to determine their net effect on the local algal growth rate. This option has its biological basis in the mutiplicative effects of enzymatic processes involved in photosynthesis. The limiting nutrient option calculates the local algal growth rate as limited by light and either nitrogen or phosphorus. The nutrient/light effects are multiplicative, but the nutrient/nutrient effects are alternate. The algal growth rate is controlled by the nutrient with the smaller growth limitation factor. This approach mimics Liebig's law of the minimum. The harmonic mean is mathematically analogous to the total resistance of two resistors in parallel and can be considered a compromise between the multiplicative and limiting nutrient options. The algal growth rate is controlled by a multiplicative relation between light and nutrients, while the nutrient/nutrient interactions are represented by a harmonic mean. The default option is the limiting nutrient option (2). Required if in-stream nutrient cycling is being modeled.
AI0	Ratio of chlorophyll-a to algal biomass (µg-chla/mg algae). Values for AI0 should fall in the range 10-100. If no value for AI0 is entered, the model will set AI0 = 50.0. Required if in-stream nutrient cycling is being modeled.
AI1	Fraction of algal biomass that is nitrogen (mg N/mg alg). Values for AI1 should fall in the range 0.07-0.09. If no value for AI1 is entered, the model will set AI1 = 0.08. Required if in-stream nutrient cycling is being modeled.
AI2	Fraction of algal biomass that is phosphorus (mg P/mg alg). Values for AI2 should fall in the range 0.01-0.02. If no value for AI2 is entered, the model will set AI2 = 0.015. Required if in-stream nutrient cycling is being modeled.
AI3	The rate of oxygen production per unit of algal photosynthesis (mg O_2/mg alg). Values for AI3 should fall in the range 1.4-1.8. If no value for AI3 is entered, the model will set AI3 = 1.6. Required if in-stream nutrient cycling is being modeled.

Variable name	Definition
AI4	The rate of oxygen uptake per unit of algal respiration (mg O_2/mg alg). Values for AI4 should fall in the range 1.6-2.3. If no value for AI4 is entered, the model will set AI4 = 2.0. Required if in-stream nutrient cycling is being modeled.
AI5	The rate of oxygen uptake per unit of NH_3-N oxidation (mg O_2/mg NH_3-N). Values for AI5 should fall in the range 3.0-4.0. If no value for AI5 is entered, the model will set AI5 = 3.5. Required if in-stream nutrient cycling is being modeled.
AI6	The rate of oxygen uptake per unit of NO_2-N oxidation (mg O_2/mg NO_2-N). Values for AI6 should fall in the range 1.00-1.14. If no value for AI6 is entered, the model will set AI6 = 1.07. Required if in-stream nutrient cycling is being modeled.
MUMAX	Maximum specific algal growth rate at 20º C (day^{-1}). If routing is performed on an hourly time step (see IEVENT in .bsn file), MUMAX is converted to (hr^{-1}) by the model. Values for MUMAX should fall in the range 1.0-3.0. If no value for MUMAX is entered, the model will set MUMAX = 2.0. Required if in-stream nutrient cycling is being modeled.
RHOQ	Algal respiration rate at 20º C (day^{-1}). If routing is performed on an hourly time step (see IEVENT in .bsn file), RHOQ is converted to (hr^{-1}) by the model. Values for RHOQ should fall in the range 0.05-0.50. If no value for RHOQ is entered, the model will set RHOQ = 0.30. Required if in-stream nutrient cycling is being modeled.
TFACT	Fraction of solar radiation computed in the temperature heat balance that is photosynthetically active. Values for TFACT should fall in the range 0.01-1.0. If no value for TFACT is entered, the model will set TFACT = 0.3. Required if in-stream nutrient cycling is being modeled.

Variable name	Definition
K_L	Half-saturation coefficient for light (kJ/(m^2·min)). Values for K_L should fall in the range 0.2227-1.135. If no value for K_L is entered, the model will set K_L = 0.75. Required if in-stream nutrient cycling is being modeled.
K_N	Michaelis-Menton half-saturation constant for nitrogen (mg N/L). The Michaelis-Menton half-saturation constant for nitrogen and phosphorus define the concentration of N or P at which algal growth is limited to 50% of the maximum growth rate. Typical values for K_N range from 0.01 to 0.30 mg N/L. Values for K_N should fall in the range 0.01-0.30. If no value for K_N is entered, the model will set K_N = 0.02. Required if in-stream nutrient cycling is being modeled.
K_P	Michaelis-Menton half-saturation constant for phosphorus (mg P/L). The Michaelis-Menton half-saturation constant for nitrogen and phosphorus define the concentration of N or P at which algal growth is limited to 50% of the maximum growth rate. Typical values for K_P will range from 0.001 to 0.05 mg P/L. If no value for K_P is entered, the model will set K_P = 0.025. Required if in-stream nutrient cycling is being modeled.
LAMBDA0	Non-algal portion of the light extinction coefficient (m^{-1}). The light extinction coefficient, k_ℓ, is calculated as a function of the algal density using the nonlinear equation: $k_\ell = k_{\ell,0} + k_{\ell,1} \cdot \alpha_0 \cdot algae + k_{\ell,2} \cdot (\alpha_0 \cdot algae)^{2/3}$ where $k_{\ell,0}$ is the non-algal portion of the light extinction coefficient (m^{-1}), $k_{\ell,1}$ is the linear algal self shading coefficient (m^{-1} (µg-chla/L)$^{-1}$), $k_{\ell,2}$ is the nonlinear algal self shading coefficient (m^{-1} (µg-chla/L)$^{-2/3}$), α_0 is the ratio of chlorophyll *a* to algal biomass (µg chla/mg alg), and *algae* is the algal biomass concentration (mg alg/L).

Variable name	Definition
LAMBDA0, cont.	This equation allows a variety of algal, self-shading, light extinction relationships to be modeled. When $k_{\ell,1} = k_{\ell,2} = 0$, no algal self-shading is simulated. When $k_{\ell,1} \neq 0$ and $k_{\ell,2} = 0$, linear algal self-shading is modeled. When $k_{\ell,1}$ and $k_{\ell,2}$ are set to a value other than 0, non-linear algal self-shading is modeled. The Riley equation (Bowie et al., 1985) defines $k_{\ell,1} = 0.0088 \text{ m}^{-1} \left(\mu\text{g - chla/L}\right)^{-1}$ and $k_{\ell,2} = 0.054 \text{ m}^{-1} \left(\mu\text{g - chla/L}\right)^{-2/3}$. If no value for LAMBDA0 is entered, the model will set LAMBDA0 = 1.0. Required if in-stream nutrient cycling is being modeled.
LAMBDA1	Linear algal self-shading coefficient ($\text{m}^{-1}\cdot(\mu\text{g chla/L})^{-1}$). See explanation for LAMBDA0 for more information on this variable. Values for LAMBDA1 should fall in the range 0.0065-0.065. If no value for LAMBDA1 is entered, the model will set LAMBDA1 = 0.03. Required if in-stream nutrient cycling is being modeled.
LAMBDA2	Nonlinear algal self-shading coefficient ($\text{m}^{-1}\cdot(\mu\text{g chla/L})^{-2/3}$). See explanation for LAMBDA0 for more information on this variable. The recommended value for LAMBDA2 is 0.0541. If no value for LAMBDA2 is entered, the model will set LAMBDA2 = 0.054. Required if in-stream nutrient cycling is being modeled.
P_N	Algal preference factor for ammonia. Values for P_N should fall in the range 0.01-1.0. If no value for P_N is entered, the model will set P_N = 0.5. Required if in-stream nutrient cycling is being modeled.
CHLA-SUBCO	Regional adjustment on sub chla_a loading

The watershed water quality file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the general water quality input file is:

Variable name	Line #	Format	F90 Format
TITLE	1	character	a80
LAO	2	integer	free
IGROPT	3	integer	free
AI0	4	real	free
AI1	5	real	free
AI2	6	real	free
AI3	7	real	free
AI4	8	real	free
AI5	9	real	free
AI6	10	real	free
MUMAX	11	real	free
RHOQ	12	real	free
TFACT	13	real	free
K_L	14	real	free
K_N	15	real	free
K_P	16	real	free
LAMBDA0	17	real	free
LAMBDA1	18	real	free
LAMBDA2	19	real	free
P_N	20	real	free
CHLA_SUBCO	21	real	free

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CHAPTER 27

SWAT INPUT DATA: .SWQ

While water quality is a broad subject, the primary areas of concern are nutrients, organic chemicals—both agricultural (pesticide) and industrial, heavy metals, bacteria and sediment levels in streams and large water bodies. SWAT is able to model processes affecting nutrient, pesticide and sediment levels in the main channels and reservoirs. The data used by SWAT for in-stream water quality processes is contained in two files: the stream water quality input file (.swq) for specific reaches and the general water quality input file (.wwq) for processes modeled uniformly over the entire watershed.

Following is a brief description of the variables in the stream water quality input file. The variables are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line is reserved for user comments. This line is not processed by the model and may be left blank. Optional.
NUTRIENT TITLE	The second line is reserved for the nutrient section title. This line is not processed by the model and may be left blank. Optional.
RS1	Local algal settling rate in the reach at 20º C (m/day). If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of RS1 are converted to m/hr by the model. Values for RS1 should fall in the range 0.15 to 1.82 m/day. If no value for RS1 is entered, the model sets RS1 = 1.0 m/day. Required if in-stream nutrient cycling is being modeled.
RS2	Benthic (sediment) source rate for dissolved phosphorus in the reach at 20º C (mg dissolved P/(m^2·day)). If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of RS2 are converted to mg dissolved P/(m^2·hr) by the model. If no value for RS2 is entered, the model sets RS2 = 0.05 mg dissolved P/(m^2·day). Required if in-stream nutrient cycling is being modeled.
RS3	Benthic source rate for NH_4-N in the reach at 20º C (mg NH_4-N/(m^2·day)). If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of RS3 are converted to mg NH_4-N/(m^2·hr) by the model. If no value for RS3 is entered, the model sets RS3 = 0.5 mg NH_4-N/(m^2·day). Required if in-stream nutrient cycling is being modeled.

Variable name	Definition
RS4	Rate coefficient for organic N settling in the reach at 20º C (day^{-1}). If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of RS4 are converted to hr^{-1} by the model. Values for RS4 should fall in the range 0.001 to 0.10 day^{-1}. If no value for RS4 is entered, the model sets RS4 = 0.05 day^{-1}. Required if in-stream nutrient cycling is being modeled.
RS5	Organic phosphorus settling rate in the reach at 20º C (day^{-1}). If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of RS5 are converted to hr^{-1} by the model. Values for RS5 should fall in the range 0.001 to 0.1 day^{-1}. If no value for RS5 is entered, the model sets RS5 = 0.05 day^{-1}. Required if in-stream nutrient cycling is being modeled.
RS6	Rate coefficient for settling of arbitrary non-conservative constituent in the reach at 20º C (day^{-1}). If no value for RS6 is entered, the model sets RS6 = 2.5. *Not currently used by the model*.
RS7	Benthic source rate for arbitrary non-conservative constituent in the reach at 20º C (mg ANC/(m^2·day)). If no value for RS7 is entered, the model sets RS7 = 2.5. *Not currently used by the model*.
RK1	Carbonaceous biological oxygen demand deoxygenation rate coefficient in the reach at 20º C (day^{-1}). If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of RK1 are converted to hr^{-1} by the model. Values for RK1 should fall in the range 0.02 to 3.4 day^{-1}. If no value for RK1 is entered, the model sets RK1 = 1.71 day^{-1}. Required if in-stream nutrient cycling is being modeled.

Variable name	Definition
RK2	Oxygen reaeration rate in accordance with Fickian diffusion in the reach at 20º C (day^{-1}). Numerous methods have been developed to calculate the reaeration rate at 20°C, κ2,20. A few of the methods are listed below. Brown and Barnwell (1987) provide additional methods. Using field measurements, Churchill, Elmore and Buckingham (1962) derived the relationship: $$\kappa_{2,20} = 5.03 \cdot v_c^{0.969} \cdot depth^{-1.673}$$ where κ2,20 is the reaeration rate at 20°C (day^{-1}), v_c is the average stream velocity (m/s), and depth is the average stream depth (m). O'Connor and Dobbins (1958) incorporated stream turbulence characteristics into the equations they developed. For streams with low velocities and isotropic conditions, $$\kappa_{2,20} = 294 \cdot \frac{(D_m \cdot v_c)^{0.5}}{depth^{1.5}}$$ where $\kappa_{2,20}$ is the reaeration rate at 20°C (day^{-1}), D_m is the molecular diffusion coefficient (m^2/day), v_c is the average stream velocity (m/s), and *depth* is the average stream depth (m). For streams with high velocities and nonisotropic conditions, $$\kappa_{2,20} = 2703 \cdot \frac{D_m^{0.5} \cdot slp^{0.25}}{depth^{1.25}}$$ where $\kappa_{2,20}$ is the reaeration rate at 20°C (day^{-1}), D_m is the molecular diffusion coefficient (m^2/day), *slp* is the slope of the streambed (m/m), and *depth* is the average stream depth (m). The molecular diffusion coefficient is calculated $$D_m = 177 \cdot 1.037^{\bar{T}_{water} - 20}$$ where D_m is the molecular diffusion coefficient (m^2/day), and $\bar{T}_{water}$ is the average water temperature (°C).

Variable name	Definition
RK2, cont.	Owens et al. (1964) developed an equation to determine the reaeration rate for shallow, fast moving streams where the stream depth is 0.1 to 3.4 m and the velocity is 0.03 to 1.5 m/s. $$\kappa_{2,20} = 5.34 \cdot \frac{v_c^{0.67}}{depth^{1.85}}$$ where $\kappa_{2,20}$ is the reaeration rate at 20°C (day^{-1}), v_c is the average stream velocity (m/s), and *depth* is the average stream depth (m). If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of RK2 are converted to hr^{-1} by the model. Values for RK2 should fall in the range 0.01 to 100.0 day^{-1}. If no value for RK2 is entered, the model sets RK2 = 50.0 day^{-1}. Required if in-stream nutrient cycling is being modeled.
RK3	Rate of loss of carbonaceous biological oxygen demand due to settling in the reach at 20º C (day^{-1}). Values for RK3 should fall in the range -0.36 to 0.36 day^{-1}. The recommended default for RK3 is 0.36 day^{-1} (not set by model). Required if in-stream nutrient cycling is being modeled.
RK4	Benthic oxygen demand rate in the reach at 20º C (mg O_2/(m^2·day)). If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of RK4 are converted to (mg O_2/(m^2·hr)) by the model. If no value for RK4 is entered, the model sets RK4 = 2.0 mg O_2/(m^2·day). Required if in-stream nutrient cycling is being modeled.
RK5	Coliform die-off rate in the reach at 20º C (day^{-1}). Values for RK5 should fall in the range 0.05 to 4.0. If no value for RK5 is entered, the model sets RK5 = 2.0. *Not currently used by the model*.
RK6	Decay rate for arbitrary non-conservative constituent in the reach at 20º C (day^{-1}). If no value for RK6 is entered, the model sets RK6 = 1.71. *Not currently used by the model*.

Variable name	Definition
BC1	Rate constant for biological oxidation of NH_4 to NO_2 in the reach at 20º C in well-aerated conditions (day^{-1}). If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of BC1 are converted to hr^{-1} by the model. Values for BC1 should fall in the range 0.1 to 1.0 day^{-1}. If no value for BC1 is entered, the model sets BC1 = 0.55 day^{-1}. Required if in-stream nutrient cycling is being modeled.
BC2	Rate constant for biological oxidation of NO_2 to NO_3 in the reach at 20º C in well-aerated conditions (day^{-1}). If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of BC2 are converted to hr^{-1} by the model. Values for BC2 should fall in the range 0.2 to 2.0 day^{-1}. If no value for BC2 is entered, the model sets BC2 = 1.1 day^{-1}. Required if in-stream nutrient cycling is being modeled.
BC3	Rate constant for hydrolysis of organic N to NH_4 in the reach at 20º C (day^{-1}). If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of BC3 are converted to hr^{-1} by the model. Values for BC3 should fall in the range 0.2 to 0.4 day^{-1}. If no value for BC3 is entered, the model sets BC3 = 0.21 day^{-1}. Required if in-stream nutrient cycling is being modeled.
BC4	Rate constant for mineralization of organic P to dissolved P in the reach at 20º C (day^{-1}). If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of BC4 are converted to hr^{-1} by the model. Values for BC4 should fall in the range 0.01 to 0.70 day^{-1}. If no value for BC4 is entered, the model sets BC4 = 0.35 day^{-1}. Required if in-stream nutrient cycling is being modeled.

Variable name	Definition
PESTICIDE TITLE	This line is reserved for the pesticide section title. This line is not processed by the model and may be left blank.
CHPST_REA	Pesticide reaction coefficient in reach (day^{-1}). The rate constant is related to the aqueous half-life: $$k_{p,aq} = \frac{0.693}{t_{1/2,aq}}$$ where $k_{p,aq}$ is the rate constant for degradation or removal of pesticide in the water (1/day), and $t_{1/2,aq}$ is the aqueous half-life for the pesticide (days). If no value for CHPST_REA is entered, the model will set CHPST_REA = 0.007 day^{-1}. Required if in-stream pesticide cycling is being modeled.
CHPST_VOL	Pesticide volatilization coefficient in reach (m/day). The volatilization mass-transfer coefficient can be calculated based on Whitman's two-film or two-resistance theory (Whitman, 1923; Lewis and Whitman, 1924 as described in Chapra, 1997). While the main body of the gas and liquid phases are assumed to be well-mixed and homogenous, the two-film theory assumes that a substance moving between the two phases encounters maximum resistance in two laminar boundary layers where transfer is a function of molecular diffusion. In this type of system the transfer coefficient or velocity is: $$v_v = K_l \cdot \frac{H_e}{H_e + R \cdot T_K \cdot \left(K_l / K_g\right)}$$ where v_v is the volatilization mass-transfer coefficient (m/day), K_l is the mass-transfer velocity in the liquid laminar layer (m/day), K_g is the mass-transfer velocity in the gaseous laminar layer (m/day), H_e is Henry's constant (atm m^3 mole^{-1}), R is the universal gas constant (8.206 × 10^{-5} atm m^3 (K mole)$^{-1}$), and T_K is the temperature (K). For rivers where liquid flow is turbulent, the transfer coefficients are estimated using the surface renewal theory (Higbie, 1935; Danckwerts, 1951; as described by Chapra, 1997). The surface renewal model visualizes the system as

Variable name	Definition
CHPST_VOL, cont.	consisting of parcels of water that are brought to the surface for a period of time. The fluid elements are assumed to reach and leave the air/water interface randomly, i.e. the exposure of the fluid elements to air is described by a statistical distribution. The transfer velocities for the liquid and gaseous phases are calculated: $$K_l = \sqrt{r_l \cdot D_l} \qquad K_g = \sqrt{r_g \cdot D_g}$$ where K_l is the mass-transfer velocity in the liquid laminar layer (m/day), K_g is the mass-transfer velocity in the gaseous laminar layer (m/day), D_l is the liquid molecular diffusion coefficient (m^2/day), D_g is the gas molecular diffusion coefficient (m^2/day), r_l is the liquid surface renewal rate (1/day), and r_g is the gaseous surface renewal rate (1/day). O'Connor and Dobbins (1956) defined the surface renewal rate as the ratio of the average stream velocity to depth. $$r_l = \frac{86400 \cdot v_c}{depth}$$ where r_l is the liquid surface renewal rate (1/day), v_c is the average stream velocity (m/s) and *depth* is the depth of flow (m). If no value for CHPST_VOL is entered, the model will set CHPST_VOL = 0.01. Required if in-stream pesticide cycling is being modeled.
CHPST_KOC	Pesticide partition coefficient between water and sediment in reach (m^3/g). The pesticide partition coefficient can be estimated from the octanol-water partition coefficient (Chapra, 1997): $$K_d = 3.085 \times 10^{-8} \cdot K_{ow}$$ where K_d is the pesticide partition coefficient (m^3/g) and K_{ow} is the pesticide's octanol-water partition coefficient ($\text{mg m}^{-3}_{\text{octanol}} \left(\text{mg m}^{-3}_{\text{water}}\right)^{-1}$).

Variable name	Definition
CHPST_KOC	Values for the octanol-water partition coefficient have been published for many chemicals. If a published value cannot be found, it can be estimated from solubility (Chapra, 1997): $$\log(K_{ow}) = 5.00 - 0.670 \cdot \log(pst'_{sol})$$ where pst'_{sol} is the pesticide solubility (μmoles/L). The solubility in these units is calculated: $$pst'_{sol} = \frac{pst_{sol}}{MW} \cdot 10^3$$ where pst'_{sol} is the pesticide solubility (μmoles/L), pst_{sol} is the pesticide solubility (mg/L) and MW is the molecular weight (g/mole). If no value for CHPST_KOC is entered, the model will set CHPST_KOC = 0. Required if in-stream pesticide cycling is being modeled.
CHPST_STL	Settling velocity for pesticide sorbed to sediment (m/day). If no value for CHPST_STL is entered, the model will set CHPST_STL = 1.0. Required if in-stream pesticide cycling is being modeled.
CHPST_RSP	Resuspension velocity for pesticide sorbed to sediment (m/day). If no value for CHPST_RSP is entered, the model will set CHPST_RSP = 0.002. Required if in-stream pesticide cycling is being modeled.

Variable name	Definition
CHPST_MIX	Mixing velocity (diffusion/dispersion) for pesticide in reach (m/day). The diffusive mixing velocity, v_d, can be estimated from the empirically derived formula (Chapra, 1997): $v_d = \frac{69.35}{365} \cdot \phi \cdot MW^{-2/3}$ where v_d is the rate of diffusion or mixing velocity (m/day), ϕ is the sediment porosity, and MW is the molecular weight of the pesticide compound. If no value for CHPST_MIX is entered, the model will set CHPST_MIX = 0.001. Required if in-stream pesticide cycling is being modeled.
SEDPST_CONC	Initial pesticide concentration in reach bed sediment (mg/m^3 sediment). We recommend using a 1 year equilibration period for the model where the watershed simulation is set to start 1 year prior to the period of interest. This allows the model to get the water cycling properly before any comparisons between measured and simulated data are made. When an equilibration period is incorporated, the value for SEDPST_CONC is not going to be important if a pesticide with a short half-life is being modeled. For pesticides with a long half-life, this variable is important. Required if in-stream pesticide cycling is being modeled.
SEDPST_REA	Pesticide reaction coefficient in reach bed sediment (day^{-1}). The rate constant is related to the sediment half-life: $k_{p,sed} = \frac{0.693}{t_{1/2,sed}}$ where $k_{p,sed}$ is the rate constant for degradation or removal of pesticide in the sediment (1/day), and $t_{1/2,sed}$ is the sediment half-life for the pesticide (days). If no value for SEDPST_REA is entered, the model will set SEDPST_REA = 0.05. Required if in-stream pesticide cycling is being modeled.

Variable name	Definition
SEDPST_BRY	Pesticide burial velocity in reach bed sediment (m/day). If no value for SEDPST_BRY is entered, the model will set SEDPST_BRY = 0.002. Required if in-stream pesticide cycling is being modeled.
SEDPST_ACT	Depth of active sediment layer for pesticide (m). If no value for SEDPST_ACT is entered, the model will set SEDPST_ACT = 0.03. Required if in-stream pesticide cycling is being modeled.

The stream water quality file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the stream water quality input file is:

Variable name	Line #	Format	F90 Format
TITLE	1	character	a80
NUTRIENT TITLE	2	character	a80
RS1	3	real	free
RS2	4	real	free
RS3	5	real	free
RS4	6	real	free
RS5	7	real	free
RS6	8	real	free
RS7	9	real	free
RK1	10	real	free
RK2	11	real	free
RK3	12	real	free
RK4	13	real	free
RK5	14	real	free
RK6	15	real	free
BC1	16	real	free
BC2	17	real	free
BC3	18	real	free
BC4	19	real	free

Variable name	Line #	Format	F90 Format
PESTICIDE TITLE	20	character	a80
CHPST_REA	21	real	free
CHPST_VOL	22	real	free
CHPST_KOC	23	real	free
CHPST_STL	24	real	free
CHPST_RSP	25	real	free
CHPST_MIX	26	real	free
SEDPST_CONC	27	real	free
SEDPST_REA	28	real	free
SEDPST_BRY	29	real	free
SEDPST_ACT	30	real	free

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CHAPTER 28

SWAT INPUT DATA: .PND

Ponds and wetlands are impoundments located within the subbasin area. These impoundments receive loadings only from the land area in the subbasin. The .pnd file contains parameter information used to model the water, sediment and nutrient balance for ponds and wetlands. All processes are modeled the same for ponds and wetlands except for outflow.

Following is a brief description of the variables in the subbasin pond input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the file is reserved for user comments. The comments may take up to 80 spaces. The title line is not processed by the model and may be left blank.
POND SECTION TITLE	The second line of the file is reserved for a section title for the pond data. The title may take up to 80 spaces. The title line is not processed by the model and may be left blank.
PND_FR	Fraction of subbasin area that drains into ponds. The value for PND_FR should be between 0.0 and 1.0. Required.
PND_PSA	Surface area of ponds when filled to principal spillway (ha). Smaller impoundments usually do not have both a principal and emergency spillway. However, for SWAT to calculate the pond surface area each day the surface area at two different water volumes must to be defined. For simplicity, the same parameters required in reservoir input are used for ponds also. Variables referring to the principal spillway can be thought of as variables referring to the normal pond storage volume while variables referring to the emergency spillway can be thought of as variables referring to maximum pond storage volume. If users do not have information for the two water storage volumes, they may enter information for only one and allow SWAT to set values for the other based on the known surface area/volume. Required if PND_FR > 0.0.
PND_PVOL	Volume of water stored in ponds when filled to the principal spillway (10^4 m^3 H_2O). See explanation for PND_PSA for more information on this variable. Required if PND_FR > 0.0.

Variable name	Definition
PND_ESA	Surface area of ponds when filled to emergency spillway (ha). See explanation for PND_PSA for more information on this variable. Required if PND_FR > 0.0.
PND_EVOL	Volume of water stored in ponds when filled to the emergency spillway (10^4 m^3 H_2O). See explanation for PND_PSA for more information on this variable. Required if PND_FR > 0.0.
PND_VOL	Initial volume of water in ponds (10^4 m^3 H_2O). We recommend using a 1 year equilibration period for the model where the watershed simulation is set to start 1 year prior to the period of interest. This allows the model to get the water cycling properly before any comparisons between measured and simulated data are made. When an equilibration period is incorporated, the value for PND_VOL is not going to impact model results if the pond is small. However, if the pond is large a reasonably accurate value needs to be input for this value. Required if PND_FR > 0.0.
PND_SED	Initial sediment concentration in pond water (mg/L). We recommend using a 1 year equilibration period for the model where the watershed simulation is set to start 1 year prior to the period of interest. This allows the model to get the water cycling properly before any comparisons between measured and simulated data are made. When an equilibration period is incorporated, the value for PND_SED is not going to impact model results. Required if PND_FR > 0.0.
PND_NSED	Equilibrium sediment concentration in pond water (mg/L). The amount of suspended solid settling that occurs in the water body on a given day is calculated as a function of concentration. Settling occurs only when the sediment concentration in the water body exceeds the equilibrium sediment concentration specified by the user. Required if PND_FR > 0.0.

Variable name	Definition
PND_K	Hydraulic conductivity through bottom of ponds (mm/hr). If seepage occurs in the water body, the hydraulic conductivity must be set to a value other than 0. Required if PND_FR > 0.0.
IFLOD1	Beginning month of non-flood season. Pond outflow is calculated as a function of target storage. The target storage varies based on flood season and soil water content. The target pond volume is calculated: $V_{targ} = V_{em}$ when $mon_{fld,beg} < mon < mon_{fld,end}$, or $V_{targ} = V_{pr} + \frac{\left(1 - \min\left[\frac{SW}{FC}, \ 1\right]\right)}{2} \cdot (V_{em} - V_{pr})$ when $mon \leq mon_{fld,beg}$ or $mon \geq mon_{fld,end}$. where V_{targ} is the target pond volume for a given day (m^3 H_2O), V_{em} is the volume of water held in the pond when filled to the emergency spillway (m^3 H_2O), V_{pr} is the volume of water held in the pond when filled to the principal spillway (m^3 H_2O), SW is the average soil water content in the subbasin (mm H_2O), FC is the water content of the subbasin soil at field capacity (mm H_2O), mon is the month of the year, $mon_{fld,beg}$ is the beginning month of the flood season, and $mon_{fld,end}$ is the ending month of the flood season. Once the target storage is defined, the outflow is calculated: $V_{flowout} = \frac{V - V_{targ}}{ND_{targ}}$ where $V_{flowout}$ is the volume of water flowing out of the water body during the day (m^3 H_2O), V is the volume of water stored in the pond (m^3 H_2O), V_{targ} is the target pond volume for a given day (m^3 H_2O), and ND_{targ} is the number of days required for the pond to reach target storage. Required if PND_FR > 0.0.

Variable name	Definition
IFLOD2	Ending month of non-flood season. See explanation for IFLOD1 for more information on this variable. Required if PND_FR > 0.0.
NDTARG	Number of days needed to reach target storage from current pond storage. The default value for NDTARG is 15 days. See explanation for IFLOD1 for more information on this variable. Required if PND_FR > 0.0.
PSETLP1	Phosphorus settling rate in pond for months IPND1 through IPND2 (m/year). The apparent settling velocity is most commonly reported in units of m/year and this is how the values are input to the model. For natural lakes, measured phosphorus settling velocities most frequently fall in the range of 5 to 20 m/year although values less than 1 m/year to over 200 m/year have been reported (Chapra, 1997). Panuska and Robertson (1999) noted that the range in apparent settling velocity values for man-made reservoirs tends to be significantly greater than for natural lakes. Higgins and Kim (1981) reported phosphorus apparent settling velocity values from –90 to 269 m/year for 18 reservoirs in Tennessee with a median value of 42.2 m/year. For 27 Midwestern reservoirs, Walker and Kiihner (1978) reported phosphorus apparent settling velocities ranging from –1 to 125 m/year with an average value of 12.7 m/year. ***A negative settling rate indicates that the reservoir sediments are a source of N or P; a positive settling rate indicates that the reservoir sediments are a sink for N or P***. Table 28-1 summarizes typical ranges in phosphorus settling velocity for different systems. See explanation for IPND1 for more information about this variable. Required of PND_FR > 0.0 and nutrient cycling is being modeled.

Variable name	Definition
PSETLP1, cont.	

Table 28-1: Recommended apparent settling velocity values for phosphorus (Panuska and Robertson, 1999)

Nutrient Dynamics	Range in settling velocity values (m/year)
Shallow water bodies with high net internal phosphorus flux	$\nu \leq 0$
Water bodies with moderate net internal phosphorus flux	$1 < \nu < 5$
Water bodies with minimal net internal phosphorus flux	$5 < \nu < 16$
Water bodies with high net internal phosphorus removal	$\nu > 16$

PSETLP2

Phosphorus settling rate in pond for months other than IPND1-IPND2 (m/year).

See explanation for PSETLP1 and IPND1 for more information about this variable.

Required if PND_FR > 0.0 and nutrient cycling is being modeled.

NSETLP1

Nitrogen settling rate in pond for months IPND1 through IPND2 (m/year).

See explanation for PSETLP1 for more information about this variable.

Required if PND_FR > 0.0 and nutrient cycling is being modeled.

NSETLP2

Nitrogen settling rate in pond for months other than IPND1-IPND2 (m/year).

See explanation for PSETLP1 for more information about this variable.

Required if PND_FR > 0.0 and nutrient cycling is being modeled.

CHLAP

Chlorophyll a production coefficient for ponds.

The user-defined coefficient, Chlaco, is included to allow the user to adjust the predicted chlorophyll a concentration for limitations of nutrients other than phosphorus. When Chlaco is set to 1.00, no adjustments are made (the original equation is used). For most water bodies, the original equation will be adequate.

Variable name	Definition
CHLAP, cont.	The default value for CHLAP is 1.00, which uses the original equation. Required if PND_FR > 0.0 and nutrient cycling is being modeled.
SECCIP	Water clarity coefficient for ponds. The clarity of the pond is expressed by the secci-disk depth (m) which is calculated as a function of chlorophyll *a*. The user-defined coefficient, SD_{co}, is included to allow the user to adjust the predicted secchi-disk depth for impacts of suspended sediment and other particulate matter on water clarity that are ignored by the original equation. When SD_{co} is set to 1.00, no adjustments are made (the original equation is used). For most water bodies, the original equation will be adequate. The default value for SECCIP is 1.00, which uses the original equation. Required if PND_FR > 0.0 and nutrient cycling is being modeled.
PND_NO3	Initial concentration of NO_3-N in pond (mg N/L). We recommend using a 1 year equilibration period for the model where the watershed simulation is set to start 1 year prior to the period of interest. This allows the model to get the water cycling properly before any comparisons between measured and simulated data are made. When an equilibration period is incorporated, the value for PND_NO3 is not going to be important. Required if PND_FR > 0.0 and nutrient cycling is being modeled.
PND_SOLP	Initial concentration of soluble P in pond (mg P/L). See comment for PND_NO3. Required if PND_FR > 0.0 and nutrient cycling is being modeled.
PND_ORGN	Initial concentration of organic N in pond (mg N/L). See comment for PND_NO3. Required if PND_FR > 0.0 and nutrient cycling is being modeled.

Variable name	Definition
PND_ORGP	Initial concentration of organic P in pond (mg P/L). See comment for PND_NO3. Required if PND_FR > 0.0 and nutrient cycling is being modeled.
PND_D50	Median particle diameter of sediment (μm).

Sediment Class	Size (μm)	Approx. Size
Boulders	> 256,000	> Volley ball
Cobbles	> 64,000	> Tennis ball
Pebbles	> 2,000	> Match Head
Sand		
V. Course	1,500	
Medim	375	
V. Fine	94	
Silt		
V. Coarse	47	
Medium	11.7	No longer visible to the human eye
V. Fine	4.9	
Clay	1.95	

SWAT calculates the median sediment particle diameter for impoundments located within a subbasin using the equation:

$$d_{50} = \exp\left(0.41 \cdot \frac{m_c}{100} + 2.71 \cdot \frac{m_{silt}}{100} + 5.7 \cdot \frac{m_s}{100}\right)$$

where d_{50} is the median particle size of the sediment (μm), m_c is percent clay in the surface soil layer, m_{silt} is the percent silt in the surface soil layer, m_s is the percent sand in the surface soil layer.

Because ponds are located on the main channel network and receive sediment from the entire area upstream, defaulting the sand, silt, and clay fractions to those of a single subbasin or HRU in the upstream area is not appropriate. Instead the user is allowed to set the median particle size diameter to a representative value.

If no value is defined for the median particle diameter, the model will set PND_D50 = 10 μm.

Required.

Variable name	Definition
IPND1	Beginning month of mid-year nutrient settling –season”. The model allows the user to define two settling rates for each nutrient and the time of the year during which each settling rate is used. A variation in settling rates is allowed so that impact of temperature and other seasonal factors may be accounted for in the modeling of nutrient settling. To use only one settling rate for the entire year, both variables for the nutrient may be set to the same value. Setting all variables to zero will cause the model to ignore settling of nutrients in the water body. Required if PND_FR > 0.0.
IPND2	Ending month of mid-year nutrient settling –season”. See explanation for IPND1 for more information abour rhis variable. Required if PND_FR > 0.0.
WETLAND SECTION TITLE	The 28th line of the file is reserved for a section title for the wetland data. The title may take up to 80 spaces. The title line is not processed by the model and may be left blank.
WET_FR	Fraction of subbasin area that drains into wetlands. The value for WET_FR should be between 0.0 and 1.0. Required.
WET_NSA	Surface area of wetlands at normal water level (ha). For SWAT to calculate the wetland surface area each day the surface area at two different water volumes, normal and maximum, must to be defined. If users do not have information for the two water storage volumes, they may enter information for only one and allow SWAT to set values for the other based on the known surface area/volume. Required if WET_FR > 0.0.
WET_NVOL	Volume of water stored in wetlands when filled to normal water level (10^4 m^3 H_2O). See explanation for WET_NSA for more information on this variable. Required if WET_FR > 0.0.

Variable name	Definition
WET_MXSA	Surface area of wetlands at maximum water level (ha). See explanation for WET_NSA for more information on this variable. Required if WET_FR > 0.0.
WET_MXVOL	Volume of water stored in wetlands when filled to maximum water level (10^4 m^3 H_2O). See explanation for WET_NSA for more information on this variable. Required if WET_FR > 0.0.
WET_VOL	Initial volume of water in wetlands (10^4 m^3 H_2O). We recommend using a 1 year equilibration period for the model where the watershed simulation is set to start 1 year prior to the period of interest. This allows the model to get the water cycling properly before any comparisons between measured and simulated data are made. When an equilibration period is incorporated, the value for WET_VOL is not going to impact model results if the pond is small. However, if the wetland is large a reasonably accurate value needs to be input for this value. Required if WET_FR > 0.0.
WET_SED	Initial sediment concentration in wetland water (mg/L). We recommend using a 1 year equilibration period for the model where the watershed simulation is set to start 1 year prior to the period of interest. This allows the model to get the water cycling properly before any comparisons between measured and simulated data are made. When an equilibration period is incorporated, the value for WET_SED is not going to impact model results. Required if WET_FR > 0.0.
WET_NSED	Equilibrium sediment concentration in wetland water (mg/L). The amount of suspended solid settling that occurs in the water body on a given day is calculated as a function of concentration. Settling occurs only when the sediment concentration in the water body exceeds the equilibrium sediment concentration specified by the user. Required if WET_FR > 0.0.

Variable name	Definition
WET_K	Hydraulic conductivity through bottom of wetland (mm/hr). If seepage occurs in the water body, the hydraulic conductivity must be set to a value other than 0. Required if WET_FR > 0.0.
PSETLW1	Phosphorus settling rate in wetland for months IPND1 through IPND2 (m/year). See explanation for PSETLP1 and IPND1 for more information about this variable. Required if WET_FR > 0.0 and nutrient cycling is being modeled.
PSETLW2	Phosphorus settling rate in wetlands for months other than IPND1-IPND2 (m/year). See explanation for PSETLP1 and IPND1 for more information about this variable. Required if WET_FR > 0.0 and nutrient cycling is being modeled.
NSETLW1	Nitrogen settling rate in wetlands for months IPND1 through IPND2 (m/year). See explanation for PSETLP1 and IPND1 for more information about this variable. Required if WET_FR > 0.0 and nutrient cycling is being modeled.
NSETLW2	Nitrogen settling rate in wetlands for months other than IPND1-IPND2 (m/year). See explanation for PSETLP1 and IPND1 for more information about this variable. Required if WET_FR > 0.0 and nutrient cycling is being modeled.

Variable name	Definition
CHLAW	Chlorophyll *a* production coefficient for wetlands. The user-defined coefficient, $Chla_{co}$, is included to allow the user to adjust the predicted chlorophyll *a* concentration for limitations of nutrients other than phosphorus. When $Chla_{co}$ is set to 1.00, no adjustments are made (the original equation is used). For most water bodies, the original equation will be adequate. The default value for CHLAW is 1.00, which uses the original equation. Required if WET_FR > 0.0 and nutrient cycling is being modeled.
SECCIW	Water clarity coefficient for wetlands. The clarity of the wetland is expressed by the secci-disk depth (m) which is calculated as a function of chlorophyll *a*. The user-defined coefficient, SD_{co}, is included to allow the user to adjust the predicted secchi-disk depth for impacts of suspended sediment and other particulate matter on water clarity that are ignored by the original equation. When SD_{co} is set to 1.00, no adjustments are made (the original equation is used). For most water bodies, the original equation will be adequate. The default value for SECCIW is 1.00, which uses the original equation. Required if WET_FR > 0.0 and nutrient cycling is being modeled.
WET_NO3	Initial concentration of NO_3-N in wetland (mg N/L). We recommend using a 1 year equilibration period for the model where the watershed simulation is set to start 1 year prior to the period of interest. This allows the model to get the water cycling properly before any comparisons between measured and simulated data are made. When an equilibration period is incorporated, the value for WET_NO3 is not going to be important. Required if WET_FR > 0.0 and nutrient cycling is being modeled.

Variable name	Definition
WET_SOLP	Initial concentration of soluble P in wetland (mg P/L). See comment for WET_NO3. Required if WET_FR > 0.0 and nutrient cycling is being modeled.
WET_ORGN	Initial concentration of organic N in wetland (mg N/L). See comment for WET_NO3. Required if WET_FR > 0.0 and nutrient cycling is being modeled.
WET_ORGP	Initial concentration of organic P in wetland (mg P/L). See comment for WET_NO3. Required if WET_FR > 0.0 and nutrient cycling is being modeled.
PNDEVCOEFF	Actual pond evaporation is equal to the potential evaporation times the pond evaporation coefficient. Default = 0.6
WETEVCOEFF	Actual wetlands evaporation is equal to the potential evaporation times the pond evaporation coefficient. Default = 0.6

The pond input file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the pond input file is:

Variable name	Line #	Format	F90 Format
TITLE	1	character	a80
POND SECT. TITLE	2	character	a80
PND_FR	3	real	free
PND_PSA	4	real	free
PND_PVOL	5	real	free
PND_ESA	6	real	free
PND_EVOL	7	real	free
PND_VOL	8	real	free
PND_SED	9	real	free
PND_NSED	10	real	free
PND_K	11	real	free
IFLOD1	12	integer	free
IFLOD2	13	integer	free
NDTARG	14	integer	free
PSETLP1	15	real	free
PSETLP2	16	real	free
NSETLP1	17	real	free
NSETLP2	18	real	free
CHLAP	19	real	free
SECCIP	20	real	free
PND_NO3	21	real	free
PND_SOLP	22	real	free
PND_ORGN	23	real	free
PND_ORGP	24	real	free
POND/WETLAND SECT. TITLE	25	character	a80
IPND1	26	integer	free
IPND2	27	integer	free
WETLAND SECT. TITLE	28	character	a80
WET_FR	29	real	free
WET_NSA	30	real	free

Variable name	Line #	Format	F90 Format
WET_NVOL	31	real	free
WET_MXSA	32	real	free
WET_MXVOL	33	real	free
WET_VOL	34	real	free
WET_SED	35	real	free
WET_NSED	36	real	free
WET_K	37	real	free
PSETLW1	38	real	free
PSETLW2	39	real	free
NSETLW1	40	real	free
NSETLW2	41	real	free
CHLAW	42	real	free
SECCIW	43	real	free
WET_NO3	44	real	free
WET_SOLP	45	real	free
WET_ORGN	46	real	free
WET_ORGP	47	real	free
PNDEVCOEFF	48	real	free
WETEVCOEFF	49	real	free

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CHAPTER 29

SWAT INPUT DATA: .RES

Reservoirs are impoundments located on the main channel network of the watershed. Reservoirs receive loadings from all upstream subbasins. The reservoir input file (.res) contains input data to simulate water and sediment processes while the lake water quality file (.lwq) contains input data to simulate nutrient and pesticide cycling in the water body.

29.1 RESERVOIR FILE

Following is a brief description of the variables in the reservoir input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the file is reserved for user comments. The comments may take up to 80 spaces. The title line is not processed by the model and may be left blank.
RES_SUB	Number of the subbasin with which the reservoir is associated. Weather for the specified subbasin is used for the reservoir. If no subbasin number is assigned to RES_SUB, the model uses weather data from subbasin 1 to model climatic processes on the reservoir. Required.
MORES	Month the reservoir became operational (0-12). If 0 is input for MORES and IYRES, the model assumes the reservoir is in operation at the beginning of the simulation. Required.
IYRES	Year the reservoir became operational (eg 1980). If 0 is input for MORES and IYRES, the model assumes the reservoir is in operation at the beginning of the simulation. Required.
RES_ESA	Reservoir surface area when the reservoir is filled to the emergency spillway (ha). For SWAT to calculate the reservoir surface area each day the surface area at two different water volumes must to be defined. Variables referring to the principal spillway can be thought of as variables referring to the normal reservoir storage volume while variables referring to the emergency spillway can be thought of as variables referring to maximum reservoir storage volume. Required.

Variable name	Definition
RES_EVOL	Volume of water needed to fill the reservoir to the emergency spillway (10^4 m^3). See comment for RES_ESA. Required.
RES_PSA	Reservoir surface area when the reservoir is filled to the principal spillway (ha). See comment for RES_ESA. Required.
RES_PVOL	Volume of water needed to fill the reservoir to the principal spillway (10^4 m^3). See comment for RES_ESA. Required.
RES_VOL	Initial reservoir volume. If the reservoir is in existence at the beginning of the simulation period, the initial reservoir volume is the volume on the first day of simulation. If the reservoir begins operation in the midst of a SWAT simulation, the initial reservoir volume is the volume of the reservoir the day the reservoir becomes operational (10^4 m^3). Required.
RES_SED	Initial sediment concentration in the reservoir (mg/L). If the reservoir is in existence at the beginning of the simulation period, the initial sediment concentration is the concentration on the first day of simulation. If the reservoir begins operation in the midst of a SWAT simulation, the initial sediment concentration is the concentration the day the reservoir becomes operational (mg/L). Required.
RES_NSED	Equilibrium sediment concentration in the reservoir (mg/L). The amount of suspended solid settling that occurs in the water body on a given day is calculated as a function of concentration. Settling occurs only when the sediment concentration in the water body exceeds the equilibrium sediment concentration specified by the user. Required.

Variable name	Definition
RES_D50	Median particle diameter of sediment (μm).

Sediment Class	Size (μm)	Approx. Size
Boulders	> 256,000	> Volley ball
Cobbles	> 64,000	> Tennis ball
Pebbles	> 2,000	> Match Head
Sand		
V. Course	1,500	
Medim	375	
V. Fine	94	
Silt		
V. Coarse	47	
Medium	11.7	No longer visible to the human eye
V. Fine	4.9	
Clay	1.95	

SWAT calculates the median sediment particle diameter for impoundments located within a subbasin using the equation:

$$d_{50} = \exp\left(0.41 \cdot \frac{m_c}{100} + 2.71 \cdot \frac{m_{silt}}{100} + 5.7 \cdot \frac{m_s}{100}\right)$$

where d_{50} is the median particle size of the sediment (μm), m_c is percent clay in the surface soil layer, m_{silt} is the percent silt in the surface soil layer, m_s is the percent sand in the surface soil layer.

Because reservoirs are located on the main channel network and receive sediment from the entire area upstream, defaulting the sand, silt, and clay fractions to those of a single subbasin or HRU in the upstream area is not appropriate. Instead the user is allowed to set the median particle size diameter to a representative value.

If no value is defined for the median particle diameter, the model will set RES_D50 = 10 μm.

Required.

Variable name	Definition
RES_K	Hydraulic conductivity of the reservoir bottom (mm/hr). If seepage occurs in the water body, the hydraulic conductivity must be set to a value other than 0. Required.
IRESCO	Outflow simulation code: 0 compute outflow for uncontrolled reservoir with average annual release rate (if IRESCO=0, need RES_RR) 1 measured monthly outflow (if IRESCO=1, need RESOUT) 2 simulated controlled outflow—target release (if IRESCO=2, need STARG, IFLOD1R, IFLOD2D, and NDTARGR 3 measured daily outflow (if IRESCO=3, need RESDAYO) Required.
OFLOWMX(mon)	Maximum daily outflow for the month (m^3/s). This variable allows the user to set the upper limit on the reservoir discharge rate. Set all months to zero if you do not want to trigger this requirement. Optional.
OFLOWMN(mon)	Minimum daily outflow for the month (m^3/s). This variable allows the user to set the lower limit on the reservoir discharge rate. Set all months to zero if you do not want to trigger this requirement. Optional.
RES_RR	Average daily principal spillway release rate (m^3/s). The name for this variable is slightly misleading. SWAT uses this variable when the volume of water in the reservoir is between the principal and emergency spillway volumes. If the amount of water exceeding the principal spillway volume can be released at a rate ≤ RES_RR, than all of the water volume in excess of the principal spillway volume is released. Otherwise the release rate, RES_RR is used.

Variable name	Definition
RES_RR, cont.	When the water volume exceeds the emergency spillway volume, all water in excess of the emergency spillway volume is released plus the volume of water corresponding to the release rate from the principal spillway defined by RES_RR. Required if IRESCO = 0.
RESMONO	Name of monthly reservoir outflow file. Required if IRESCO = 1.
IFLOD1R	Beginning month of non-flood season. The target release approach tries to mimic general release rules that may be used by reservoir operators. Although the method is simplistic and cannot account for all decision criteria, it can realistically simulate major outflow and low flow periods. For the target release approach, the principal spillway volume corresponds to maximum flood control reservation while the emergency spillway volume corresponds to no flood control reservation. The model requires the beginning and ending month of the flood season. In the non-flood season, no flood control reservation is required, and the target storage is set at the emergency spillway volume. During the flood season, the flood control reservation is a function of soil water content. The flood control reservation for wet ground conditions is set at the maximum. For dry ground conditions, the flood control reservation is set at 50% of the maximum. The target storage may be specified by the user on a monthly basis or it can be calculated as a function of flood season and soil water content. If the target storage is specified: $V_{targ} = starg$ where V_{targ} is the target reservoir volume for a given day (m^3 H_2O), and *starg* is the target reservoir volume specified for a given month (m^3 H_2O). If the target storage is not specified, the target reservoir volume is calculated:

Variable name	Definition
IFLOD1R, cont.	$V_{targ} = V_{em}$ if $mon_{fld,beg} < mon < mon_{fld,end}$ $V_{targ} = V_{pr} + \frac{\left(1 - \min\left[\frac{SW}{FC}, \quad 1\right]\right)}{2} \cdot \left(V_{em} - V_{pr}\right)$ if $mon \le mon_{fld,beg}$ or $mon \ge mon_{fld,end}$ where V_{targ} is the target reservoir volume for a given day (m^3 H_2O), V_{em} is the volume of water held in the reservoir when filled to the emergency spillway (m^3 H_2O), V_{pr} is the volume of water held in the reservoir when filled to the principal spillway (m^3 H_2O), *SW* is the average soil water content in the subbasin (mm H_2O), *FC* is the water content of the subbasin soil at field capacity (mm H_2O), *mon* is the month of the year, $mon_{fld,beg}$ is the beginning month of the flood season, and $mon_{fld,end}$ is the ending month of the flood season. Required if IRESCO = 2.
IFLOD2R	Ending month of non-flood season. See explanation for IFLOD1R. Required if IRESCO = 2.
NDTARGR	Number of days to reach target storage from current reservoir storage. The reservoir outflow is calculated: $V_{flowout} = \frac{V - V_{targ}}{ND_{targ}}$ where $V_{flowout}$ is the volume of water flowing out of the water body during the day (m^3 H_2O), *V* is the volume of water stored in the reservoir (m^3 H_2O), V_{targ} is the target reservoir volume for a given day (m^3 H_2O), and ND_{targ} is the number of days required for the reservoir to reach target storage. See explanation for IFLOD1R for more information. Required if IRESCO = 2.

Variable name	Definition
STARG(mon)	Monthly target reservoir storage (10^4 m^3). This parameter allows the user to define the target storage for each month. See explanation for IFLOD1R for more information. Required if IRESCO = 2.
RESDAYO	Name of daily reservoir outflow file. Required if IRESCO = 3.
WURESN(mon)	Average amount of water withdrawn from reservoir each day in the month for consumptive use (10^4 m^3). This variable allows water to be removed from the reservoir for use outside the watershed. Optional.
WURTNF	Fraction of water removed from the reservoir via WURESN that is returned and becomes flow out of reservoir (m^3/m^3). Optional.
EVRSV	Lake evaporation coefficient. Default = 0.6
OFLOWMN_FPS	Minimum reservoir outflow as a fraction of the principal spillway volume (0-1).
STARG_FPS	Target volume as a fraction of the principal spillway volume. This input is needed if ISRECO = 2. Default = 1.0

The reservoir file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the reservoir input file is:

Variable name	Line #	Format	F90 Format
TITLE	1	character	a80
RES_SUB	2	integer	free
MORES	3	integer	free
IYRES	4	integer	free
RES_ESA	5	real	free
RES_EVOL	6	real	free
RES_PSA	7	real	free
RES_PVOL	8	real	free
RES_VOL	9	real	free
RES_SED	10	real	free
RES_NSED	11	real	free
RES_D50	12	real	free
RES_K	13	real	free
IRESCO	14	integer	free
COMMENT LINE	15	character	a80
OFLOWMX(1)	16	real	free
OFLOWMX(2)	16	real	free
OFLOWMX(3)	16	real	free
OFLOWMX(4)	16	real	free
OFLOWMX(5)	16	real	free
OFLOWMX(6)	16	real	free
COMMENT LINE	17	character	a80
OFLOWMX(7)	18	real	free
OFLOWMX(8)	18	real	free
OFLOWMX(9)	18	real	free
OFLOWMX(10)	18	real	free
OFLOWMX(11)	18	real	free
OFLOWMX(12)	18	real	free
COMMENT LINE	19	character	a80
OFLOWMN(1)	20	real	free
OFLOWMN(2)	20	real	free

Variable name	Line #	Format	F90 Format
OFLOWMN(3)	20	real	free
OFLOWMN(4)	20	real	free
OFLOWMN(5)	20	real	free
OFLOWMN(6)	20	real	free
COMMENT LINE	21	character	a80
OFLOWMN(7)	22	real	free
OFLOWMN(8)	22	real	free
OFLOWMN(9)	22	real	free
OFLOWMN(10)	22	real	free
OFLOWMN(11)	22	real	free
OFLOWMN(12)	22	real	free
RES_RR	23	real	free
RESMONO	24	character (len=13)	a13
IFLOD1R	25	integer	free
IFLOD2R	26	integer	free
NDTARGR	27	integer	free
COMMENT LINE	28	character	a80
STARG(1)	29	real	free
STARG(2)	29	real	free
STARG(3)	29	real	free
STARG(4)	29	real	free
STARG(5)	29	real	Free
STARG(6)	29	real	Free
COMMENT LINE	30	character	a80
STARG(7)	31	real	Free
STARG(8)	31	real	Free
STARG(9)	31	real	Free
STARG(10)	31	real	Free
STARG(11)	31	real	Free
STARG(12)	31	real	Free
RESDAYO	32	character (len=13)	a13
COMMENT LINE	33	character	a80
WURESN(1)	34	real	Free
WURESN(2)	34	real	Free
WURESN(3)	34	real	Free

Variable name	Line #	Format	F90 Format
WURESN(4)	34	real	Free
WURESN(5)	34	real	Free
WURESN(6)	34	real	Free
COMMENT LINE	35	character	a80
WURESN(7)	36	real	Free
WURESN(8)	36	real	Free
WURESN(9)	36	real	Free
WURESN(10)	36	real	Free
WURESN(11)	36	real	Free
WURESN(12)	36	real	Free
WURTNF	37	real	Free
EVRSV	38	real	Free
OFLOWMN_FPS	39	real	Free
STARG_FPS	40	real	Free

29.2 DAILY RESERVOIR OUTFLOW FILE

When measured daily outflow is used for a reservoir, the name of the file containing the data is assigned to the variable RESDAYO. The daily outflow file contains the flow rate for every day of operation of the reservoir, beginning with the first day of operation in the simulation. The daily outflow file contains one variable:

Variable name	Definition
TITLE	The first line of the file is reserved for a description. The description may take up to 80 spaces. The title line is not processed by the model and may be left blank.
RES_OUTFLOW	The water release rate for the day (m^3/sec).

The format of the daily reservoir outflow file is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1	space 1-80	character	a80
RES_OUTFLOW	2-END	space 1-8	decimal(xxxxx.xx)	f8.2

29.3 MONTHLY RESERVOIR OUTFLOW FILE

When outflow data summarized on a monthly basis is used for a reservoir, the name of the file containing the data is assigned to the variable RESMONO. The monthly outflow file contains the average daily flow rate for every month of operation of the reservoir, beginning with the first month of operation in the simulation. The monthly outflow file contains the following variables:

Variable name	Definition
TITLE	The first line of the file is reserved for a description. The description may take up to 80 spaces. The title line is not processed by the model and may be left blank.
RES_OUT(mon,yr)	Measured average daily outflow from the reservoir for the month (m^3/s). Needed when IRESCO = 1. There must be a line of input for every year of simulation.

Variable name	Line #	Format	F90 Format
TITLE	1	character	a80
If IRESCO = 1, the model will read the input data for RESOUT. There should be one line for data for RESOUT for each year of simulation beginning with the 1st year of simulation.			
RES_OUT(1,yr)	2-END	real	free
RES_OUT(2,yr)	2-END	real	free
RES_OUT(3,yr)	2-END	real	free
RES_OUT(4,yr)	2-END	real	free
RES_OUT(5,yr)	2-END	real	free
RES_OUT(6,yr)	2-END	real	free
RES_OUT(7,yr)	2-END	real	free
RES_OUT(8,yr)	2-END	real	free
RES_OUT(9,yr)	2-END	real	free
RES_OUT(10,yr)	2-END	real	free
RES_OUT(11,yr)	2-END	real	free
RES_OUT(12,yr)	2-END	real	free

CHAPTER 30

SWAT INPUT DATA: .LWQ

While water quality is a broad subject, the primary areas of concern are nutrients, organic chemicals—both agricultural (pesticide) and industrial, heavy metals, bacteria and sediment levels in streams and large water bodies. SWAT is able to model processes affecting nutrient, pesticide and sediment levels in the main channels and reservoirs. The data used by SWAT for water quality in impoundments located on the main channel network is contained in the lake water quality input file (.lwq).

Following is a brief description of the variables in the lake water quality input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line is reserved for user comments. This line is not processed by the model and may be left blank.
NUTRIENT TITLE	The second line is reserved for the nutrient section title. This line is not processed by the model and may be left blank.
IRES1	Beginning month of mid-year nutrient settling period. The model allows the user to define two settling rates for each nutrient and the time of the year during which each settling rate is used. A variation in settling rates is allowed so that impact of temperature and other seasonal factors may be accounted for in the modeling of nutrient settling. To use only one settling rate for the entire year, both variables for the nutrient may be set to the same value. Setting all variables to zero will cause the model to ignore settling of nutrients in the water body. Required.
IRES2	Ending month of mid-year nutrient settling period. See comment for IRES1. Required.
PSETLR1	Phosphorus settling rate in reservoir for months IRES1 through IRES2 (m/year). The apparent settling velocity is most commonly reported in units of m/year and this is how the values are input to the model. For natural lakes, measured phosphorus settling velocities most frequently fall in the range of 5 to 20 m/year although values less than 1 m/year to over 200 m/year have been reported (Chapra, 1997). Panuska and Robertson (1999) noted that the range in apparent settling velocity values for man-made reservoirs tends to be significantly greater than for natural lakes. Higgins and Kim (1981) reported phosphorus apparent settling velocity values from –90 to 269 m/year for 18 reservoirs in Tennessee with a median value of 42.2 m/year. For 27 Midwestern reservoirs, Walker and Kiihner (1978) reported phosphorus apparent settling velocities ranging

Variable name	Definition
PSETLR1, cont.	from –1 to 125 m/year with an average value of 12.7 m/year. A negative settling rate indicates that the reservoir sediments are a source of N or P; a positive settling rate indicates that the reservoir sediments are a sink for N or P. Table 30-1 summarizes typical ranges in phosphorus settling velocity for different systems. Required if nutrient cycling is being modeled.

Table 30-1: Recommended apparent settling velocity values for phosphorus (Panuska and Robertson, 1999)

Nutrient Dynamics	Range in settling velocity values (m/year)
Shallow water bodies with high net internal phosphorus flux	$\nu \leq 0$
Water bodies with moderate net internal phosphorus flux	$1 < \nu < 5$
Water bodies with minimal net internal phosphorus flux	$5 < \nu < 16$
Water bodies with high net internal phosphorus removal	$\nu > 16$

Variable name	Definition
PSETLR2	Phosphorus settling rate in reservoir for months other than IRES1-IRES2 (m/year). See explanation for PSETLR1 for more information about this parameter. Required if nutrient cycling is being modeled.
NSETLR1	Nitrogen settling rate in reservoir for months IRES1 through IRES2 (m/year). See explanation for PSETLR1 for more information about this parameter. Required if nutrient cycling is being modeled.
NSETLR2	Nitrogen settling rate in reservoir for months other than IRES1-IRES2 (m/year). See explanation for PSETLR1 for more information about this parameter. Required if nutrient cycling is being modeled.

Variable name	Definition
CHLAR	Chlorophyll *a* production coefficient for reservoir. Chlorophyll *a* concentration in the reservoir is calculated from the total phosphorus concentration. The equation assumes the system is phosphorus limited. The chlorophyll *a* coefficient was added to the equation to allow the user to adjust results to account for other factors not taken into account by the basic equation such as nitrogen limitations. The default value for CHLAR is 1.00, which uses the original equation. Required if nutrient cycling is being modeled.
SECCIR	Water clarity coefficient for the reservoir. The clarity of the reservoir is expressed by the secci-disk depth (m) which is calculated as a function of chlorophyll *a*. Because suspended sediment also can affect water clarity, the water clarity coefficient has been added to the equation to allow users to adjust for the impact of factors other than chlorophyll *a* on water clarity. The default value for SECCIR is 1.00, which uses the original equation. Required if nutrient cycling is being modeled.
RES_ORGP	Initial concentration of organic P in reservoir (mg P/L). We recommend using a 1 year equilibration period for the model where the watershed simulation is set to start 1 year prior to the period of interest. This allows the model to get the water cycling properly before any comparisons between measured and simulated data are made. When an equilibration period is incorporated, the value for RES_ORGP is not going to be important if the reservoir is in operation at the beginning of the simulation. However, if the reservoir starts operation in the middle of a simulation, this value needs to be reasonably accurate. Required if nutrient cycling is being modeled.
RES_SOLP	Initial concentration of soluble P in reservoir (mg P/L). See comment for RES_ORGP. Required if nutrient cycling is being modeled.

Variable name	Definition
RES_ORGN	Initial concentration of organic N in reservoir (mg N/L). See comment for RES_ORGP. Required if nutrient cycling is being modeled.
RES_NO3	Initial concentration of NO_3-N in reservoir (mg N/L). See comment for RES_ORGP. Required if nutrient cycling is being modeled.
RES_NH3	Initial concentration of NH_3-N in reservoir (mg N/L). See comment for RES_ORGP. Required if nutrient cycling is being modeled.
RES_NO2	Initial concentration of NO_2-N in reservoir (mg N/L). See comment for RES_ORGP. Required if nutrient cycling is being modeled.
PESTICIDE TITLE	This line is reserved for the pesticide section title. This line is not processed by the model and may be left blank.
LKPST_CONC	Initial pesticide concentration in the reservoir water for the pesticide defined by IRTPEST (mg/m^3). See comment for RES_ORGP. Required if pesticide cycling is being modeled.
LKPST_REA	Reaction coefficient of the pesticide in reservoir water (day^{-1}) The rate constant is related to the aqueous half-life: $k_{p,aq} = \frac{0.693}{t_{1/2,aq}}$ where $k_{p,aq}$ is the rate constant for degradation or removal of pesticide in the water (1/day), and $t_{1/2,aq}$ is the aqueous half-life for the pesticide (days). Required if pesticide cycling is being modeled.

Variable name	Definition
LKPST_VOL	Volatilization coefficient of the pesticide from the reservoir (m/day). The volatilization mass-transfer coefficient can be calculated based on Whitman's two-film or two-resistance theory (Whitman, 1923; Lewis and Whitman, 1924 as described in Chapra, 1997). While the main body of the gas and liquid phases are assumed to be well-mixed and homogenous, the two-film theory assumes that a substance moving between the two phases encounters maximum resistance in two laminar boundary layers where transfer is a function of molecular diffusion. In this type of system the transfer coefficient or velocity is: $$v_v = K_l \cdot \frac{H_e}{H_e + R \cdot T_K \cdot \left(K_l / K_g\right)}$$ where v_v is the volatilization mass-transfer coefficient (m/day), K_l is the mass-transfer velocity in the liquid laminar layer (m/day), K_g is the mass-transfer velocity in the gaseous laminar layer (m/day), H_e is Henry's constant (atm m^3 $mole^{-1}$), R is the universal gas constant (8.206×10^{-5} atm m^3 $(K\ mole)^{-1}$), and T_K is the temperature (K). For lakes, the transfer coefficients are estimated using a stagnant film approach: $$K_l = \frac{D_l}{z_l} \qquad K_g = \frac{D_g}{z_g}$$ where K_l is the mass-transfer velocity in the liquid laminar layer (m/day), K_g is the mass-transfer velocity in the gaseous laminar layer (m/day), D_l is the liquid molecular diffusion coefficient (m^2/day), D_g is the gas molecular diffusion coefficient (m^2/day), z_l is the thickness of the liquid film (m), and z_g is the thickness of the gas film (m). Alternatively, the transfer coefficients can be estimated with the equations: $$K_l = K_{l,O_2} \cdot \left(\frac{32}{MW}\right)^{0.25} \qquad K_g = 168 \cdot \mu_w \cdot \left(\frac{18}{MW}\right)^{0.25}$$

Variable name	Definition
LKPST_VOL, cont.	where K_l is the mass-transfer velocity in the liquid laminar layer (m/day), K_g is the mass-transfer velocity in the gaseous laminar layer (m/day), K_{l,O_2} is the oxygen transfer coefficient (m/day), MW is the molecular weight of the compound, and μ_w is the wind speed (m/s). Chapra (1997) lists several different equations that can be used to calculate K_{l,O_2}. Required if pesticide cycling is being modeled.
LKPST_KOC	Pesticide partition coefficient between water and sediment (m^3/g). The pesticide partition coefficient can be estimated from the octanol-water partition coefficient (Chapra, 1997): $K_d = 3.085 \times 10^{-8} \cdot K_{ow}$ where K_d is the pesticide partition coefficient (m^3/g) and K_{ow} is the pesticide's octanol-water partition coefficient ($\text{mg m}_{\text{octanol}}^{-3} \left(\text{mg m}_{\text{water}}^{-3}\right)^{-1}$). Values for the octanol-water partition coefficient have been published for many chemicals. If a published value cannot be found, it can be estimated from solubility (Chapra, 1997): $\log(K_{ow}) = 5.00 - 0.670 \cdot \log(pst'_{sol})$ where pst'_{sol} is the pesticide solubility (µmoles/L). The solubility in these units is calculated: $pst'_{sol} = \frac{pst_{sol}}{MW} \cdot 10^3$ where pst'_{sol} is the pesticide solubility (µmoles/L), pst_{sol} is the pesticide solubility (mg/L) and MW is the molecular weight (g/mole). LKPST_KOC ranges between 10^{-4} to 10 m^3/g. Required if pesticide cycling is being modeled.

Variable name	Definition
LKPST_STL	Settling velocity of pesticide sorbed to sediment (m/day). Pesticide in the particulate phase may be removed from the water layer by settling. Settling transfers pesticide from the water to the sediment layer. Required if pesticide cycling is being modeled.
LKPST_RSP	Resuspension velocity of pesticide sorbed to sediment (m/day). Pesticide in the sediment layer is available for resuspension which transfers it back into the water. Required if pesticide cycling is being modeled.
LKPST_MIX	Pesticide diffusion or mixing velocity (m/day) The diffusive mixing velocity, v_d, can be estimated from the empirically derived formula (Chapra, 1997): $v_d = \frac{69.35}{365} \cdot \phi \cdot MW^{-2/3}$ where v_d is the rate of diffusion or mixing velocity (m/day), ϕ is the sediment porosity, and MW is the molecular weight of the pesticide compound. Required if pesticide cycling is being modeled.
LKSPST_CONC	Initial pesticide concentration in the reservoir bottom sediments. (mg/m^3). We recommend using a 1 year equilibration period for the model where the watershed simulation is set to start 1 year prior to the period of interest. This allows the model to get the water cycling properly before any comparisons between measured and simulated data are made. When an equilibration period is incorporated, the value for LKSPST_CONC is not going to be important if a pesticide with a short half-life is being modeled. For pesticides with a long half-life, this variable is important. Required if pesticide cycling is being modeled.

Variable name	Definition
LKSPST_REA	Reaction coefficient of pesticide in reservoir bottom sediment (day^{-1}) The rate constant is related to the sediment half-life: $k_{p,sed} = \frac{0.693}{t_{1/2,sed}}$ where $k_{p,sed}$ is the rate constant for degradation or removal of pesticide in the sediment (1/day), and $t_{1/2,sed}$ is the sediment half-life for the pesticide (days). Required if pesticide cycling is being modeled.
LKSPST_BRY	Burial velocity of pesticide in reservoir bottom sediment (m/day). Pesticide in the sediment layer may be lost by burial. Required if pesticide cycling is being modeled.
LKSPST_ACT	Depth of active sediment layer in reservoir (m). Required if pesticide cycling is being modeled.

The lake water quality file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the lake water quality input file is:

Variable name	**Line #**	**Format**	**F90 Format**
TITLE	1	character	a80
NUTRIENT TITLE	2	character	a80
IRES1	3	integer	free
IRES2	4	integer	free
PSETLR1	5	real	free
PSETLR2	6	real	free
NSETLR1	7	real	free
NSETLR2	8	real	free
CHLAR	9	real	free
SECCIR	10	real	free
RES_ORGP	11	real	free
RES_SOLP	12	real	free
RES_ORGN	13	real	free
RES_NO3	14	real	free
RES_NH3	15	real	free
RES_NO2	16	real	free
PESTICIDE TITLE	17	character	a80
LKPST_CONC	18	real	free
LKPST_REA	19	real	free
LKPST_VOL	20	real	free
LKPST_KOC	21	real	free
LKPST_STL	22	real	free
LKPST_RSP	23	real	free
LKPST_MIX	24	real	free
LKSPST_CONC	25	real	free
LKSPST_REA	26	real	free
LKSPST_BRY	27	real	free
LKSPST_ACT	28	real	free

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CHAPTER 31

SWAT INPUT DATA: MEASURED

SWAT directly simulates the loading of water, sediment and other constituents off of land areas in the watershed. To simulate the loading of water and pollutants from sources not associated with a land area (e.g. sewage treatment plants, regional groundwater recharge, etc.), SWAT allows point source information to be read in at any point along the channel network. The point source loadings may be summarized on an hourly, daily, monthly, yearly, or average annual basis.

Files containing the point source loads are created by the user. The loads are read into the model and routed through the channel network using rechour, recday, recmon, recyear, or reccnst commands in the watershed configuration file. SWAT will read in water, sediment, nutrients, CBOD, dissolved oxygen, chlorophyll-a, pesticide, metal, and bacteria data from the point source files. Chapter 2 reviews the format of the command lines in the watershed configuration file while Chapter 31 reviews the format of the point source files.

31.1 HOURLY RECORDS (RECHOUR .DAT FILE)

The rechour command in the watershed configuration (.fig) file requires a file containing SWAT input data summarized on a hourly time step.

An unlimited* number of files with hourly flow data are allowed in the simulation. The file numbers assigned to the rechour files in the watershed configuration file (.fig) must be ≥ 1 and numbered sequentially.

Following is a brief description of the variables in the rechour input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first six lines of the file are reserved for user comments. The comments may take up to 80 spaces per line.
DAY	Julian date for record. If the julian date and year are provided for the records, SWAT will search for the beginning day of simulation in the record. If the julian date and year are left blank, SWAT assumes that the first line of record corresponds to the first day of simulation. SWAT uses the date and year to locate the record corresponding to the first day of simulation. Required.
YEAR	Four-digit year for record. See description of DAY for more information. Required.
HOUR	Hour in day for record. Required.
FLOHR	Contribution to streamflow for the hour (m^3). Required.
SEDHR	Sediment loading to reach for the hour (metric tons). Required.
ORGNHR	Organic N loading to reach for the hour (kg N). Required if nutrient cycling is being modeled.

* Please keep in mind that FORTRAN limits the total number of files that can be open at one time to something in the neighborhood of 250. The input files containing daily/hourly data (.pcp, .tmp, rechour and recday) remain open throughout the simulation.

Variable name	Definition
ORGPHR	Organic P loading to reach for the hour (kg P). Required if nutrient cycling is being modeled.
NO3HR	NO_3 loading to reach for the hour (kg N). Required if nutrient cycling is being modeled.
NH3HR	NH_3 loading to reach for the hour (kg N). Required if nutrient cycling is being modeled.
NO2HR	NO_2 loading to reach for the hour (kg N). Required if nutrient cycling is being modeled.
MINPHR	Mineral P loading to reach for the hour (kg P). Required if nutrient cycling is being modeled.
CBODHR	Loading of CBOD to reach for the hour (kg CBOD). Required if nutrient cycling is being modeled.
DISOXHR	Loading of dissolved oxygen to reach for the hour (kg O2). Required if nutrient cycling is being modeled.
CHLAHR	Loading of chlorophyll a to reach for the hour (kg chla). Required if nutrient cycling is being modeled.
SOLPSTHR	Loading of soluble pesticide to reach for the hour (mg ai) The type of pesticide is defined by IRTPEST (in .bsn). Required if pesticide cycling is being modeled.
SRBPSTHR	Loading of sorbed pesticide to reach for the hour (mg ai) The type of pesticide is defined by IRTPEST (in .bsn). Required if pesticide cycling is being modeled.
BACTPHR	Loading of persistent bacteria to reach for the hour (# cfu/100 mL). Required if bacteria transport is being modeled.
BACTLPHR	Loading of less persistent bacteria to reach for the hour (# cfu/100 mL). Required if bacteria transport is being modeled.
CMTL1HR	Loading of conservative metal #1 to reach for the hour (kg). Required if heavy metal transport is being modeled.

Variable name	Definition
CMTL2HR	Loading of conservative metal #2 to reach for the hour (kg). Required if heavy metal transport is being modeled.
CMTL3HR	Loading of conservative metal #3 to reach for the hour (kg). Required if heavy metal transport is being modeled.

Twenty-four lines of data are required for every day of the simulation period. The rechour data file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the rechour data file is:

Variable name	Line #	Format	F90 Format
TITLE	1 - 6	character	a80
DAY	7-END	integer	free
YEAR	7-END	integer	free
HOUR	7-END	integer	free
FLOHR	7-END	real or exponential	free
SEDHR	7-END	real or exponential	free
ORGNHR	7-END	real or exponential	free
ORGPHR	7-END	real or exponential	free
NO3HR	7-END	real or exponential	free
NH3HR	7-END	real or exponential	free
NO2HR	7-END	real or exponential	free
MINPHR	7-END	real or exponential	free
CBODHR	7-END	real or exponential	Free
DISOXHR	7-END	real or exponential	Free
CHLAHR	7-END	real or exponential	Free
SOLPSTHR	7-END	real or exponential	Free
SRBPSTHR	7-END	real or exponential	Free
BACTPHR	7-END	real or exponential	Free
BACTLPHR	7-END	real or exponential	Free
CMTL1HR	7-END	real or exponential	Free
CMTL2HR	7-END	real or exponential	Free
CMTL3HR	7-END	real or exponential	Free

31.2 DAILY RECORDS (RECDAY .DAT FILE)

The recday command in the watershed configuration (.fig) file requires a file containing SWAT input data summarized on a daily time step. An unlimited* number of files with daily flow data are allowed in the simulation. The file numbers assigned to the recday files in the watershed configuration file (.fig) must be ≥ 1 and numbered sequentially.

Following is a brief description of the variables in the recday input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first six lines of the file are reserved for user comments. The comments may take up to 80 spaces per line.
DAY	Julian date for record If the julian date and year are provided for the records, SWAT will search for the beginning day of simulation in the record. If the julian date and year are left blank, SWAT assumes that the first line of record corresponds to the first day of simulation. SWAT uses the date and year to locate the record corresponding to the first day of simulation. Required.
YEAR	Four-digit year for record. See description of DAY for more information. Required.
FLODAY	Contribution to streamflow for the day (m^3). Required.
SEDDAY	Sediment loading to reach for the day (metric tons). Required.
ORGNDAY	Organic N loading to reach for the day (kg N). Required if nutrient cycling being modeled.
ORGPDAY	Organic P loading to reach for the day (kg P). Required if nutrient cycling being modeled.

* Please keep in mind that FORTRAN limits the total number of files that can be open at one time to something in the neighborhood of 250. The input files containing daily data (.pcp, .tmp, and recday) remain open throughout the simulation.

Variable name	Definition
NO3DAY	NO_3 loading to reach for the day (kg N). Required if nutrient cycling being modeled.
NH3DAY	NH_3 loading to reach for the day (kg N). Required if nutrient cycling being modeled.
NO2DAY	NO_2 loading to reach for the day (kg N). Required if nutrient cycling being modeled.
MINPDAY	Mineral P loading to reach for the day (kg P). Required if nutrient cycling being modeled.
CBODDAY	Loading of CBOD to reach for the day (kg CBOD). Required if nutrient cycling being modeled.
DISOXDAY	Loading of dissolved oxygen to reach for the day (kg O2). Required if nutrient cycling being modeled.
CHLADAY	Loading of chlorophyll a to reach for the day (kg chla). Required if nutrient cycling being modeled.
SOLPSTDAY	Loading of soluble pesticide for the day (mg ai) The type of pesticide is defined by IRTPEST (in .bsn). Required if pesticide cycling being modeled.
SRBPSTDAY	Loading of sorbed pesticide for the day (mg ai) The type of pesticide is defined by IRTPEST (in .bsn). Required if pesticide cycling being modeled.
BACTPDAY	Loading of persistent bacteria to reach for the day (# cfu/100 mL). Required if bacteria transport being modeled.
BACTLPDAY	Loading of less persistent bacteria to reach for the day (# cfu/100 mL). Required if bacteria transport being modeled.
CMTL1DAY	Loading of conservative metal #1 to reach for the day (kg). Required if heavy metal transport being modeled.
CMTL2DAY	Loading of conservative metal #2 to reach for the day (kg). Required if heavy metal transport being modeled.

Variable name	Definition
CMTL3DAY	Loading of conservative metal #3 to reach for the day (kg). Required if heavy metal transport being modeled.

One line of data is required for every day of the simulation period. The recday data file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the recday data file is:

Variable name	Line #	Format	F90 Format
TITLE	1 - 6	character	a80
DAY	7-END	integer	free
YEAR	7-END	integer	free
FLODAY	7-END	real or exponential	free
SEDDAY	7-END	real or exponential	free
ORGNDAY	7-END	real or exponential	free
ORGPDAY	7-END	real or exponential	free
NO3DAY	7-END	real or exponential	free
NH3DAY	7-END	real or exponential	free
NO2DAY	7-END	real or exponential	free
MINPDAY	7-END	real or exponential	free
CBODDAY	7-END	real or exponential	free
DISOXDAY	7-END	real or exponential	free
CHLADAY	7-END	real or exponential	free
SOLPSTDAY	7-END	real or exponential	free
SRBPSTDAY	7-END	real or exponential	free
BACTPDAY	7-END	real or exponential	free
BACTLPDAY	7-END	real or exponential	free
CMTL1DAY	7-END	real or exponential	free
CMTL2DAY	7-END	real or exponential	free
CMTL3DAY	7-END	real or exponential	free

31.3 MONTHLY RECORDS (RECMON .DAT FILE)

The recmon command in the watershed configuration (.fig) file requires a file containing input data summarized on a monthly time step. SWAT will accept an unlimited number of data files with monthly flow data. The file numbers assigned to the files in the watershed configuration file (.fig) must be numbered sequentially and begin at 1.

Following is a brief description of the variables in the recmon data file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first 6 lines of the data file is reserved for user comments. The comments may take up to 80 spaces.
MONTH	Month of measured data. This variable is provided for the user—it is ignored by SWAT. The model assumes the first line of measured data in the file contains data for January of the first year of simulation. The monthly data file must contain a line of data for every month of simulation in consecutive order. Required.
YEAR	4-digit year of measured data. This variable is provided for the user—it is ignored by SWAT. The model assumes the first line of measured data in the file contains data for January of the first year of simulation. The monthly data file must contain a line of data for every month of simulation in consecutive order. Required.
FLOMON	Average daily water loading for month (m^3/day). Required.
SEDMON	Average daily sediment loading for month (metric tons/day). Required.
ORGNMON	Average daily organic nitrogen loading for month (kg N/day). Required if nutrient cycling being modeled.

Variable name	Definition
ORGPMON	Average daily organic phosphorus loading for month (kg P/day). Required if nutrient cycling being modeled.
NO3MON	Average daily nitrate loading for month (kg N/day). Required if nutrient cycling being modeled.
NH3MON	Average daily ammonia loading for month (kg N/day). Required if nutrient cycling being modeled.
NO2MON	Average daily nitrite loading for month (kg N/day). Required if nutrient cycling being modeled.
MINPMON	Average daily mineral (soluble) P loading for month (kg P/day). Required if nutrient cycling being modeled.
CBODMON	Average daily loading of CBOD for month (kg CBOD/day). Required if nutrient cycling being modeled.
DISOXMON	Average daily loading of dissolved oxygen for month (kg O_2/day). Required if nutrient cycling being modeled.
CHLAMON	Average daily loading of chlorophyll *a* for month (kg chla/day). Required if nutrient cycling being modeled.
SOLPSTMON	Average daily loading of soluble pesticide for month (mg ai/day) The type of pesticide is defined by IRTPEST (in .bsn). Required if pesticide cycling being modeled.
SRBPSTMON	Average daily loading of sorbed pesticide for month (mg ai/day). The type of pesticide is defined by IRTPEST (in .bsn). Required if pesticide cycling being modeled.
BACTPMON	Average daily loading of persistent bacteria for month (# cfu/100 mL). Required if bacteria transport being modeled.

Variable name	Definition
BACTLPMON	Average daily loading of less persistent bacteria for month (# cfu/100 mL). Required if bacteria transport being modeled.
CMTL1MON	Average daily loading of conservative metal #1 for month (kg/day). Required if heavy metal transport being modeled.
CMTL2MON	Average daily loading of conservative metal #2 for month (kg/day). Required if heavy metal transport being modeled.
CMTL3MON	Average daily loading of conservative metal #3 for month (kg /day). Required if heavy metal transport being modeled.

The file must contain one line of data for every month of simulation (Even if the simulation begins in a month other than January, the file must contain lines for every month of the first year.) The recmon data file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the recmon data file is:

Variable name	Line #	Format	F90 Format
TITLE	1-6	character	a80
MONTH	7 – END	integer	free
YEAR	7 – END	integer	free
FLOMON	7 – END	real or exponential	free
SEDMON	7 – END	real or exponential	free
ORGNMON	7 – END	real or exponential	free
ORGPMON	7 – END	real or exponential	free
NO3MON	7 – END	real or exponential	free
NH3MON	7 – END	real or exponential	free
NO2MON	7 – END	real or exponential	free
MINPMON	7 – END	real or exponential	free
CBODMON	7 – END	real or exponential	free

Variable name	Line #	Format	F90 Format
DISOXMON	7 – END	real or exponential	free
CHLAMON	7 – END	real or exponential	free
SOLPSTMON	7 – END	real or exponential	free
SRBPSTMON	7 – END	real or exponential	free
BACTPMON	7 – END	real or exponential	free
BACTLPMON	7 – END	real or exponential	free
CMTL1MON	7 – END	real or exponential	free
CMTL2MON	7 – END	real or exponential	free
CMTL3MON	7 – END	real or exponential	free

31.4 YEARLY RECORDS (RECYEAR .DAT FILE)

The recyear command in the watershed configuration (.fig) file requires a file containing SWAT input data summarized on an annual time step. SWAT will accept an unlimited number of data files with yearly flow data. The file numbers assigned to the recyear files in the watershed configuration file (.fig) must be numbered sequentially and begin at 1.

Following is a brief description of the variables in the recyear data file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first six lines of the data file are reserved for user comments. The comments may take up to 80 spaces per line.
YEAR	4-digit year of measured data. This variable is provided for the user—it is ignored by SWAT. The model assumes the first line of measured data in the file contains data for the first year of simulation. The yearly data file must contain a line of data for every year of simulation in consecutive order. Required.
FLOYR	Average daily water loading for year (m^3/day). Required.
SEDYR	Average daily sediment loading for year (metric tons/day). Required.
ORGNYR	Average daily organic nitrogen loading for year (kg N/day). Required if nutrient cycling being modeled.
ORGPYR	Average daily organic phosphorus loading for year (kg P/day). Required if nutrient cycling being modeled.
NO3YR	Average daily nitrate loading for year (kg N/day). Required if nutrient cycling being modeled.

Variable name	Definition
NH3YR	Average daily ammonia loading for year (kg N/day). Required if nutrient cycling being modeled.
NO2YR	Average daily nitrite loading for year (kg N/day). Required if nutrient cycling being modeled.
MINPYR	Average daily mineral (soluble) P loading for year (kg P/day). Required if nutrient cycling being modeled.
CBODYR	Average daily loading of CBOD for year (kg CBOD/day). Required if nutrient cycling being modeled.
DISOXYR	Average daily loading of dissolved oxygen for year (kg O2/day). Required if nutrient cycling being modeled.
CHLAYR	Average daily loading of chlorophyll *a* for year (kg/day). Required if nutrient cycling being modeled.
SOLPSTYR	Average daily loading of soluble pesticide for year (mg ai/day). The type of pesticide is defined by IRTPEST (in .bsn). Required if pesticide cycling being modeled.
SRBPSTYR	Average daily loading of sorbed pesticide for year (mg ai/day). The type of pesticide is defined by IRTPEST (in .bsn). Required if pesticide cycling being modeled.
BACTPYR	Average daily loading of persistent bacteria for year (# cfu/100 mL). Required if bacteria transport being modeled.
BACTLPYR	Average daily loading of less persistent bacteria for year (# cfu/100 mL). Required if bacteria transport being modeled.
CMTL1YR	Average daily loading of conservative metal #1 for year (kg/day). Required if heavy metal transport being modeled.

Variable name	Definition
CMTL2YR	Average daily loading of conservative metal #2 for year (kg/day). Required if heavy metal transport being modeled.
CMTL3YR	Average daily loading of conservative metal #3 for year (kg/day). Required if heavy metal transport being modeled.

The recyear data file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line.The format of the recyear data file is:

Variable name	Line #	Format	F90 Format
TITLE	1 - 6	character	a80
YEAR	7 - END	integer	free
FLOYR	7 - END	real or exponential	free
SEDYR	7 - END	real or exponential	free
ORGNYR	7 - END	real or exponential	free
ORGPYR	7 - END	real or exponential	free
NO3YR	7 - END	real or exponential	free
NH3YR	7 - END	real or exponential	free
NO2YR	7 - END	real or exponential	free
MINPYR	7 - END	real or exponential	free
CHLAYR	7 - END	real or exponential	free
DISOXYR	7 - END	real or exponential	free
CBODYR	7 - END	real or exponential	free
SOLPSTYR	7 - END	real or exponential	free
SRBPSTYR	7 - END	real or exponential	free
BACTPYR	7 - END	real or exponential	free
BACTLPYR	7 - END	real or exponential	free

Variable name	Line #	Format	F90 Format
CMTL1YR	7 - END	real or exponential	free
CMTL2YR	7 - END	real or exponential	free
CMTL3YR	7 - END	real or exponential	free

31.5 AVERAGE ANNUAL RECORDS (RECCNST .DAT FILE)

The reccnst command in the watershed configuration (.fig) file requires a file containing average annual SWAT input data. SWAT will accept an unlimited number of data files with average annual flow data. The file numbers assigned to the reccnst files in the watershed configuration file (.fig) must be numbered sequentially and begin at 1.

Following is a brief description of the variables in the reccnst data file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first six lines of the data file are reserved for user comments. The comments may take up to 80 spaces on each line.
FLOCNST	Average daily water loading (m^3/day). Required.
SEDCNST	Average daily sediment loading (metric tons/day). Required.
ORGNCNST	Average daily organic N loading (kg N/day). Required if nutrient cycling being modeled.
ORGPCNST	Average daily organic P loading (kg P/day). Required if nutrient cycling being modeled.
NO3CNST	Average daily NO_3 loading (kg N/day). Required if nutrient cycling being modeled.
NH3CNST	Average daily NH_3 loading (kg N/day). Required if nutrient cycling being modeled.
NO2CNST	Average daily NO_2 loading (kg N/day). Required if nutrient cycling being modeled.
MINPCNST	Average daily mineral P loading (kg P/day). Required if nutrient cycling being modeled.

Variable name	Definition
CBODCNST	Average daily loading of CBOD (kg CBOD/day). Required if nutrient cycling being modeled.
DISOXCNST	Average daily loading of dissolved oxygen (kg O_2/day). Required if nutrient cycling being modeled.
CHLACNST	Average daily loading of chlorophyll *a* (kg/day). Required if nutrient cycling being modeled.
SOLPSTCNST	Average daily loading of soluble pesticide (mg ai/day). The type of pesticide is defined by IRTPEST (in .bsn). Required if pesticide cycling being modeled.
SRBPSTCNST	Average daily loading of sorbed pesticide (mg ai/day). The type of pesticide is defined by IRTPEST (in .bsn). Required if pesticide cycling being modeled.
BACTPCNST	Average daily loading of persistent bacteria (# cfu/100 mL). Required if bacteria transport being modeled.
BACTLPCNST	Average daily loading of less persistent bacteria (# cfu/100 mL). Required if bacteria transport being modeled.
CMTL1CNST	Average daily loading of conservative metal #1 (kg/day). Required if heavy metal transport being modeled.
CMTL2CNST	Average daily loading of conservative metal #2 (kg/day). Required if heavy metal transport being modeled.
CMTL3CNST	Average daily loading of conservative metal #3 (kg/day). Required if heavy metal transport being modeled.

The format of the reccnst data file is:

Variable name	Line #	Format	F90 Format
TITLE	1-6	character	a80
FLOCNST	7	real or exponential	Free
SEDCNST	7	real or exponential	Free
ORGNCNST	7	real or exponential	Free
ORGPCNST	7	real or exponential	Free
NO3CNST	7	real or exponential	Free
NH3CNST	7	real or exponential	Free
NO2CNST	7	real or exponential	Free
MINPCNST	7	real or exponential	Free
CBODCNST	7	real or exponential	Free
DISOXCNST	7	real or exponential	Free
CHLACNST	7	real or exponential	Free
SOLPSTCNST	7	real or exponential	Free
SRBPSTCNST	7	real or exponential	Free
BACTPCNST	7	real or exponential	Free
BACTLPCNST	7	real or exponential	Free
CMTL1CNST	7	real or exponential	Free
CMTL2CNST	7	real or exponential	Free
CMTL3CNST	7	real or exponential	Free

CHAPTER 32

SWAT OUTPUT DATA: PRIMARY OUTPUT FILES

A number of output files are generated in every SWAT simulation. These files are: the summary input file (input.std), the summary output file (output.std), the HRU output file (output.hru), the subbasin output file (output.sub), and the main channel or reach output file (output.rch).

The detail of the data printed out in each file is controlled by the print codes in the master watershed file (Chapter 3). Average daily values are always printed in the HRU, subbasin and reach files, but the time period they are summarized over will vary. Depending on the print code selected, the output files may include all daily values, daily amounts averaged over the month, daily amounts averaged over the year, or daily amounts averaged over the entire simulation period.

32.1 INPUT SUMMARY FILE (INPUT.STD)

The input summary file prints summary tables of important input values. This file provides the user with a mechanism to spot-check input values. All model inputs are not printed, but the file does contain some of the most important.

32.2 OUTPUT SUMMARY FILE (OUTPUT.STD)

The standard output summary file provides watershed average annual, monthly or daily loadings from the HRU's to the streams. It si the first file a user should examine to obtain a basic understanding of the watershed's water, sediment, nutrient and pesticide balances. Average watershed or basin values are the weighted sum of HRU loadings before any channel or reservoir routing is simulated. It does not account for channel routing losses (ie. Water transmission losses, sediment deposition, and nutrient transformations) and does not account for reservoir losses. Following is a brief description of the output variables in the output summary file.

Variable name	Definition
UNIT TIME	Daily time step: the julian date Monthly time step: the month (1-12) Annual time step:
PREC	Average amount of precipitation in watershed for the day, month or year (mm)
SURQ	Surface runoff in watershed for the day, month or year (mm)
LATQ	Lateral flow contribution to streamflow in watershed for the day, month or year (mm)
GWQ	Groundwater contribution to stream in watershed on day, month or year (mm)
PERCO LATE	Water percolation past bottom of soil profile in watershed for the day, month or year (mm)
TILE Q	Drainage tile flow contribution to stream in watershed on the day, month or year (mm)
SW	Amount of water stored in soil profile in watershed for the day, month or year (mm)
ET	Actual evapotranspiration in watershed for the day, month or year (mm)

Variable name	Definition
PET	Potential evapotranspiration in watershed on the day, month or year (mm)
WATER YIELD	Water yield to streamflow from HRUs in watershed for the day, month or year (mm)
SED YIELD	Sediment yield from HRUs in watershed for the day, month or year (metric tons/ha)
NO3 SURQ	Nitrate loading to stream in surface runoff in watershed for the day, month or year (kg N/ha)
NO3 LATQ	Nitrate loading to stream in lateral flow for the day, month or year (kg N/ha)
NO3 PERC	Nitrate percolation past bottom of soil profile in watershed for the day, month or year (kg N/ha)
NO3CROP	Plant uptake of N in watershed for the day, month or year (kg N/ha)
N ORGANIC	Organic N loading to stream in watershed for the day, month or year (kg N/ha)
P SOLUBLE	Soluble P loading to stream in watershed for the day, month or year (kg P/ha)
P ORGANIC	Organic P loading to stream in watershed for the day, month or year (kg P/ha)

Tables are also included that present average annual HRU and subbasin values for a few parameters. The ―Average Crop Values" table provides the crop name for each HRU and the corresponding yield (kg/ha) and biomass (kg/ha) averages.

The ―AVE ANNUAL VALUES" table provides the average annual parameter values for each HRU. Following is a brief description of the output variables in the ―AVE ANNUAL VALUES" table.

Variable name	Definition
HRU	Hydrologic Response Unit number.
SUB	Subbasin in which HRU is located
CPMN	Crop name
SOIL	Soil series name
AREA	Are of HRU (km^2)
CN	SCS runoff curve number for moisture condition II
SWC	Amount of water held in the soil profile at field capacity (mm)
USLE_LS	USLE equation length slope (LS) factor
IRR	Amount of irrigation water applied to HRU during simulation (mm)
AUTON	Average annual amount of N (organic and mineral) auto-applied in HRU (kg N/ha)
AUTOP	Average annual amount of P (organic and mineral) auto-applied in HRU (kg P/ha)
MIXEF	Sum of mixing efficiencies in HRU
PREC	Precipitation in HRU during simulation (mm)
SURQ	Amount of surface runoff to main channel from HRU during simulation (ignores impact of transmission losses) (mm)
GWQ	Amount of lateral flow and ground water flow contribution to main channel from HRU during simulation (mm)
ET	Actual evapotranspiration in HRU during simulation (mm)
SED	Sediment Yield from HRU for simulation (metric tons/ha)
NO3	Nitrate in surface runoff and lateral flow in HRU during simulation (hg N/ha)
ORGN	Organic N in surface runoff in HRU during simulation (kg N/ha)
BIOM	Average annual biomass (dry weight) in HRU (metric tons/ha)

Variable name	Definition
YLD	Average annual yield (dry weight) in HRU (metric tons/ha)

The ―AVE MONTHLY BASIN VALUES" displays the average annual watershed monthly values. A brief description of the output variables are listed below.

Variable name	Definition
RAIN	Average annual precipitation in watershed falling during month (mm)
SNOW FALL	Average annual freezing rain in watershed falling during month (mm)
SURF Q	Average annual surface runoff in watershed during month (mm)
LAT Q	Average annual lateral flow in watershed during month (mm)
WATER YIELD	Average annual water yield in watershed during month (mm)
ET	Average annual actual evapotranspiration in watershed during month (mm)
SED YIELD	Average annual sediment yield in watershed during month (metric tons)
PET	Average annual potential evapotranspiration in watershed during month (mm)

Water balance and nutrient balance are displayed in the ―AVE ANNUAL BASIN VLUES" tables. The following is a brief description of the output variables for the water balance narrative.

Variable name	Definition
PRECIP	Average amount of precipitation in watershed for the simulation (mm)
SNOW FALL	Freezing rain/snow fall is watershed for the simulation (mm)
SNOW MELT	Snow melt in watershed for the simulation (mm)
SUBLIMATION	Water that changes directly to a gaseous state in the watershed for the simulation (mm)
SURFACE RUNOFF Q	Surface runoff in the watershed for the simulation (mm)
LATERAL SOIL Q	Lateral flow contribution to streamflow in watershed for simulation (mm)
TILE Q	Drainage tile flow contribution to stream in watershed for the simulation (mm)
GROUNDWATER (SHAL AQ) Q	Groundwater contribution to stream in watershed for the simulation (mm)
REVAP (SHAL AQ => SOIL/PLANTS)	Amount of water moving from shallow aquifer to plants/soil profile in watershed during simulation (mm)
DEEP AQ RECHARGE	Deep aquifer recharge in watershed during simulation (mm)
TOTAL AQ RECHARGE	Total amount of water entering both aquifers in watershed during simulation (mm)
TOTAL WATER YLD	Water yield to streamflow from HRUs in watershed for simulation (mm)
PERCOALTION OUT OF OSIL	Water percolation pat bottom of soil profile in watershed for simulation (mm)
ET	Actual evapotranspiration in watershed for simulation (mm)
PET	Potential evapotranspiration in watershed during simulation (mm)
TRANSMISSION LOSSES	Average amount of tributary channel transmission losses in watershed during simulation (mm)
TOTAL SEDIMENT LOADING	Sediment yield from HRUs in watershed for the simulation (metric tons/ha)

Variable name	Definition
POND BUDGET	
EVAPORATION	Evaporation from ponds in watershed during simulation (mm)
SEEPAGE	Seepage from ponds in watershed during simulation (mm)
RAINFALL ON POOL	Precipitation on ponds in watershed during simulation (mm)
INFLOW WATER	Volume of water entering ponds in watershed during simulation (mm)
INFLOW SEDIMENT	Sediment loading to ponds in watershed during simulation (metric tons/ha)
OUTFLOW WATER	Volume of water leaving ponds in watershed during simulation (mm)
OUTFLOW SEDIMENT	Sediment loading from ponds in watershed during simulation (metric tons/ha)
RESERVIOR BUDGET	
EVAPORATION	Average annual evaporation from reservoirs in watershed (mm)
SEEPAGE	Average annual seepage from reservoirs in watershed (mm)
RAINFALL ON RESERVOIR	Average annual precipitation on reservoirs in watershed (mm)
INFLOW WATER	Average annual amount of water transported into reservoirs in watershed (mm)
INFLOW SEDIMENT	Average annual amount of sediment transported into reservoirs in watershed (metric tons/ha)
OUTFLOW WATER	Average annual amount of water transported out of reservoirs in watershed (mm)
OUTFLOW SEDIMENT	Average annual amount of sediment transported out of reservoirs in watershed (metric tons/ha)

Variable name	Definition
YIELD LOSS FROM PONDS	
WATER	Net change in water volume of ponds in watershed during simulation (mm)
SEDIMENT	Net change in sediment level in ponds in watershed during simulation (metric tons/ha)
YIELD LOSS FROM RESERVOIRS	
WATER	Net change in water volume of reservoirs in watershed during simulation (mm)
SEDIMENT	Net change in sediment level in reservoirs in watershed during simulation (metric tons/ha)

The following is a brief description of the output variables for the nutrient balance narrative.

Variable name	Definition
ORGANIC N	Organic N loading to stream in water shed for the simulation (kg N/ha)
ORGANIC P	Organic P loading to stream in water shed for the simulation (kg P/ha)
NO3 YIELD (SQ)	Nitrate loading to stream in surface runoff in watershed for the simulation (kg N/ha)
NO3 YIELD (SSQ)	Nitrate loading to stream in lateral flow in watershed for the simulation (kg N/ha)
SOL P YIELD	Soluble P loading to stream in watershed for the simulation (kg P/ha)
NO3 LEACHED	Nitrate percolation past bottom of soil profile in watershed for the simulation (kg N/ha)_
P LEACHED	Average annual amount of P leached into second soil layer (kg P/ha)
N UPTAKE	Plant uptake of N in watershed for the simulation (kg N/ha)

Variable name	Definition
P UPTAKE	Average annual amount of plant uptake of P (kg P/ha)
NO3 YIELD (GWQ)	Nitrate loading to groundwater in watershed for the simulation (kg N/ha)
ACTIVE TO SOLUTION P FLOW	Average annual amount of P moving from labile mineral to active mineral pool in watershed (kg P/ha)
ACTIVE TO STABLE P FLOW	Average annual amount of P moving from active mineral to stable mineral pool in watershed (kg P/ha)
N FERTILIZER APPLIED	Average annual amount of N (mineral and organic) applied in watershed (kg N/ha)
P FERTILIZER APPLIED	Average annual amount of P (mineral and organic) applied in watershed (kg P/ha)
N FIXATION	Average annual amount of N added t the plant biomass via fixation (kg N/ha)
DETRIFICATION	Average annual amount of N lost from nitrate pool due to denitrification in watershed (kg N/ha)
HUMUS MIN ON ACTIVE ORG N	Average annual amount of N moving from active organic to nitrate pool in watershed (kg N/ha)
ACTIVE TO STABLE ORG N	Average annual amount of N moving from stable active N pool to stable organic N pool (kg N/ha)
HUMUS MIN ON ACTIVE ORG P	Average annual amount of P moving from active organic to nitrate pool in watershed (kg P/ha)
MIN FROM FRESH ORG N	Average annual amount of N moving from fresh organic (residue) to nitrate and active organic pools in watershed (kg N/ha)
MIN FROM FRESH ORG P	Average annual amount of P moving from fresh organic (residue) to labile and organic pools in watershed (kg P/ha)
NO3 IN RAINFALL	Average annual amount of NO_3 added to soil by rainfall in watershed (kg N/ha)
INITIAL NO3 IN SOIL	Initial average amount of N in the nitrate pool in watershed soil (kg N/ha)

Variable name	Definition
FINAL NO3 IN SOIL	Final average amount of N in the nitrate pool in watershed soil (kg N/ha)
INITIAL ORG N IN SOIL	Initial average amount of N in the organic N pool in watershed soil (kg N/ha)
FINAL ORG N IN SOIL	Final average amount of N in the organic N pool in watershed soil (kg N/ha)
INITIAL MIN P IN SOIL	Initial average amount of P in the mineral P pool in watershed soil (kg P/ha)
FINAL MIN P IN SOIL	Final average amount of P in the mineral P pool in watershed soil (kg P/ha)
INITIAL ORG P IN SOIL	Initial average amount of P in the organic P pool in watershed soil (kg P/ha)
FINAL ORG P IN SOIL	Final average amount of P in the organic P pool in watershed soil (kg P/ha)
NO3 IN FERT	Average annual amount of NO3-N applied in watershed (kg N/ha)
AMMONIA IN FERT	Average annual amount of NH3-N applied in watershed (kg N/ha)
ORG N IN FERT	Average annual amount of organic N applied in watershed (kg N/ha)
MINERAL P IN FERT	Average annual amount of mineral P applied in watershed (kg P/ha)
ORG P IN FERT	Average annual amount of mineral P applied in watershed (kg P/ha)
N REMOVED IN YIELD	Amount of N removed in watershed in yield (kg N/ha)
P REMOVED IN YIELD	Amount of P removed in watershed in yield (kg P/ha)
AMMONIA VOLATILIZATIO N	Average annual amount of N lost by ammonia volatilization in watershed (kg N/ha)
AMMONIA NITRIFICATION	Average annual amount of N moving fro mthe NH_3 to the NO_3 pool by nitrification in the watershed (kg N/ha)
NO3 EVAP-LAYER 2 TO 1	Amount of nitrate moving upwards in the soi profile in watershed (kgN/ha)

Directly below the nutrient summary narrative is the bacteria summary table. The following is a brief description of the variables included in this table. All variable units are number of colonies/ha.

Variable name	Definition
DIE-GRO P Q	Average annual change in the number of persistent bacteria colonies in soil solution in watershed
DIE-GRO LP Q	Average annual change in the number of less persistent bacteria colonies in soil solution in watershed
DIE-GRO P SED	Average annual change in the number of persistent bacteria colonies on soil particles in watershed
DIE-GRO LP SED	Average annual change in the number of less persistent bacteria colonies on soil particles in watershed
BACT P RUNOFF	Average annual number of persistent bacteria transported to main channel with surface runoff in solution
BACT LP RUNOFF	Average annual number of less persistent bacteria transported to main channel with surface runoff in solution
BACT P SEDIMENT	Average annual number of persistent bacteria transported with sediment in surface runoff
BACT LP SEDIMENT	Average annual number of less persistent bacteria transported with sediment in surface runoff
BACT P INCORP	Average annual number of persistent bacteria lost from soil surface layer by percolation
BACT LP INCORP	Average annual number of less persistent bacteria lost from soil surface layer by percolation

If pesticides were applied during the simulation, then a pesticide narrative will be displayed after the bacteria table. The pesticide narrative includes the amount of applied and decayed pesticide, the amount of dissolved and sorbed pesticide in surface runoff enter stream, the amount of pesticide leached out of soil profile, and the amount of pesticide in lateral flow entering stream. In addition, the final amounts of pesticide on the plants and in the ground will be displayed.

32.3 HRU OUTPUT FILE (OUTPUT.HRU)

The HRU output file contains summary information for each of the hydrologic response units in the watershed. The file is written in spreadsheet format.

Following is a brief description of the output variables in the HRU output file.

Variable name	Definition
LULC	Four letter character code for the cover/plant on the HRU. (code from crop.dat file)
HRU	Hydrologic response unit number
GIS	GIS code reprinted from watershed configuration file (.fig). See explanation of subbasin command (Chapter 2).
SUB	Topographically-defined subbasin to which the HRU belongs.
MGT	Management number. This is pulled from the management (.mgt) file. Used by the SWAT/GRASS interface to allow development of output maps by landuse/management type.

Variable name	Definition
MON	Daily time step: the julian date Monthly time step: the month (1-12) Annual time step: four-digit year Average annual summary lines: total number of years averaged together
AREA	Drainage area of the HRU (km^2).
PRECIP	Total amount of precipitation falling on the HRU during time step (mm H_2O).
SNOFALL	Amount of precipitation falling as snow, sleet or freezing rain during time step (water-equivalent mm H_2O).
SNOMELT	Amount of snow or ice melting during time step (water-equivalent mm H_2O).
IRR	Irrigation (mm H_2O). Amount of irrigation water applied to HRU during the time step.
PET	Potential evapotranspiration (mm H_2O). Potential evapotranspiration from the HRU during the time step.
ET	Actual evapotranspiration (soil evaporation and plant transpiration) from the HRU during the time step (mm H_2O).
SW_INIT	Soil water content (mm H_2O). For daily output, this column provides the amount of water in soil profile at beginning of day. For monthly and annual output, this is the average soil water content for the time period. The amount of water in the soil profile at the beginning of the day is used to calculate daily curve number values.
SW_END	Soil water content (mm H_2O). Amount of water in the soil profile at the end of the time period (day, month or year).
PERC	Water that percolates past the root zone during the time step (mm H_2O). There is usually a lag between the time the water leaves the bottom of the root zone and reaches the shallow aquifer. Over a long period of time, this variable should equal groundwater recharge (PERC = GW_RCHG as time $\rightarrow \infty$).
GW_RCHG	Recharge entering aquifers during time step (total amount of water entering shallow and deep aquifers during time step) (mm H_2O).
DA_RCHG	Deep aquifer recharge (mm H_2O). The amount of water from the root zone that recharges the deep aquifer during the time step. (shallow aquifer recharge = GW_RCHG - DA_RCHG)

Variable name	Definition
REVAP	Water in the shallow aquifer returning to the root zone in response to a moisture deficit during the time step (mm H_2O). The variable also includes water uptake directly from the shallow aquifer by deep tree and shrub roots.
SA_IRR	Irrigation from shallow aquifer (mm H_2O). Amount of water removed from the shallow aquifer for irrigation during the time step.
DA_IRR	Irrigation from deep aquifer (mm H_2O). Amount of water removed from the deep aquifer for irrigation during the time step.
SA_ST	Shallow aquifer storage (mm H_2O). Amount of water in the shallow aquifer at the end of the time period.
DA_ST	Deep aquifer storage (mm H_2O). Amount of water in the deep aquifer at the end of the time period.
SURQ_GEN	Surface runoff generated in HRU during time step (mm H_2O).
SURQ_CNT	Surface runoff contribution to streamflow in the main channel during time step (mm H_2O).
TLOSS	Transmission losses (mm H_2O). Water lost from tributary channels in the HRU via transmission through the bed. This water becomes recharge for the shallow aquifer during the time step. Net surface runoff contribution to the main channel streamflow is calculated by subtracting TLOSS from SURQ.
LATQ	Lateral flow contribution to streamflow (mm H_2O). Water flowing laterally within the soil profile that enters the main channel during time step.
GW_Q	Groundwater contribution to streamflow (mm H_2O). Water from the shallow aquifer that enters the main channel during the time step. Groundwater flow is also referred to as baseflow.
WYLD	Water yield (mm H_2O). Total amount of water leaving the HRU and entering main channel during the time step. (WYLD = SURQ + LATQ + GWQ – TLOSS – pond abstractions)
DAILYCN	Average curve number for time period. The curve number adjusted for soil moisture content.
TMP_AV	Average daily air temperature (°C). Average of mean daily air temperature for time period.

Variable name	Definition
TMP_MX	Average maximum air temperature (°C). Average of maximum daily air temperatures for time period.
TMP_MN	Average minimum air temperature (°C). Average of minimum daily air temperatures for time period.
SOL_TMP	Soil temperature (°C). Average soil temperature of first soil layer for time period.
SOLAR	Average daily solar radiation (MJ/m^2). Average of daily solar radiation values for time period.
SYLD	Sediment yield (metric tons/ha). Sediment from the HRU that is transported into the main channel during the time step.
USLE	Soil loss during the time step calculated with the USLE equation (metric tons/ha). This value is reported for comparison purposes only.
N_APP	Nitrogen fertilizer applied (kg N/ha). Total amount of nitrogen (mineral and organic) applied in regular fertilizer operations during the time step.
P_APP	Phosphorus fertilizer applied (kg P/ha). Total amount of phosphorus (mineral and organic) applied in regular fertilizer operations during the time step.
NAUTO	Nitrogen fertilizer auto-applied (kg N/ha). Total amount of nitrogen (mineral and organic) auto-applied during the time step.
PAUTO	Phosphorus fertilizer auto-applied (kg P/ha). Total amount of phosphorus (mineral and organic) auto-applied during the time step.
NGRZ	Nitrogen applied during grazing operation (kg N/ha). Total amount of nitrogen (mineral and organic) added to soil by grazing operation during the time step.
PGRZ	Phosphorus applied during grazing operation (kg P/ha). Total amount of phosphorus (mineral and organic) added to soil by grazing operation during the time step.
CFERTN	Nitrogen applied during continuous fertilizer operation (kg N/ha). Total amount of nitrogen (mineral and organic) added to soil by continuous fertilizer operation during time step.
CFERTP	Phosphorus applied during continuous fertilizer operation (kg P/ha). Total amount of phosphorus (mineral and organic) added to soil by continuous fertilizer operation during time step.

Variable name	Definition
NRAIN	Nitrate added to soil profile by rain (kg N/ha).
NFIX	Nitrogen fixation (kg N/ha). Amount of nitrogen fixed by legumes during the time step.
F-MN	Fresh organic to mineral N (kg N/ha). Mineralization of nitrogen from the fresh residue pool to the nitrate (80%) pool and active organic nitrogen (20%) pool during the time step. A positive value denotes a net gain in the nitrate and active organic pools from the fresh organic pool while a negative value denotes a net gain in the fresh organic pool from the nitrate and active organic pools.
A-MN	Active organic to mineral N (kg N/ha). Movement of nitrogen from the active organic pool to the nitrate pool during the time step.
A-SN	Active organic to stable organic N (kg N/ha). Movement of nitrogen from the active organic pool to the stable organic pool during the time step.
F-MP	Fresh organic to mineral P (kg P/ha). Mineralization of phosphorus from the fresh residue pool to the labile (80%) pool (P in solution) and the active organic (20%) pool. A positive value denotes a net gain in solution and active organic pools from the fresh organic pool while a negative value denotes a net gain in the fresh organic pool from the labile and active organic pools.
AO-LP	Organic to labile mineral P (kg P/ha). Movement of phosphorus between the organic pool and the labile mineral pool during the time step. A positive value denotes a net gain in the labile pool from the organic pool while a negative value denotes a net gain in the organic pool from the labile pool.
L-AP	Labile to active mineral P (kg P/ha). Movement or transformation of phosphorus between the "labile" mineral pool (P in solution) and the "active" mineral pool (P sorbed to the surface of soil particles) during the time step. A positive value denotes a net gain in the active pool from the labile pool while a negative value denotes a net gain in the labile pool from the active pool.

Variable name	Definition
A-SP	Active to stable P (kg P/ha). Movement or transformation of phosphorus between the "active" mineral pool (P sorbed to the surface of soil particles) and the "stable" mineral pool (P fixed in soil) during the time step. A positive value denotes a net gain in the stable pool from the active pool while a negative value denotes a net gain in the active pool from the stable pool.
DNIT	Denitrification (kg N/ha). Transformation of nitrate to gaseous compounds during the time step.
NUP	Plant uptake of nitrogen (kg N/ha). Nitrogen removed from soil by plants during the time step.
PUP	Plant uptake of phosphorus (kg P/ha). Phosphorus removed from soil by plants during the time step.
ORGN	Organic N yield (kg N/ha). Organic nitrogen transported out of the HRU and into the reach during the time step.
ORGP	Organic P yield (kg P/ha). Organic phosphorus transported with sediment into the reach during the time step.
SEDP	Sediment P yield (kg P/ha). Mineral phosphorus sorbed to sediment transported into the reach during the time step.
NSURQ	NO_3 in surface runoff (kg N/ha). Nitrate transported with surface runoff into the reach during the time step.
NLATQ	NO_3 in lateral flow (kg N/ha). Nitrate transported by lateral flow into the reach during the time step.
NO3L	NO_3 leached from the soil profile (kg N/ha). Nitrate that leaches past the bottom of the soil profile during the time step. *The nitrate is not tracked through the shallow aquifer.*
NO3GW	NO_3 transported into main channel in the groundwater loading from the HRU (kg N/ha).
SOLP	Soluble P yield (kg P/ha). Soluble mineral forms of phosphorus transported by surface runoff into the reach during the time step.
P_GW	Soluble phosphorus transported by groundwater flow into main channel during the time step (kg P/ha).
W_STRS	Water stress days during the time step (days).
TMP_STRS	Temperature stress days during the time step (days).
N_STRS	Nitrogen stress days during the time step (days).

Variable name	Definition
P_STRS	Phosphorus stress days during the time step (days).
BIOM	Biomass. Total biomass, i.e. aboveground and roots at the end of the time period reported as dry weight. Daily biomass is reported in kg ha^{-1}, monthly in tons ha^{-1} and yearly in tons ha^{-1}.
LAI	Leaf area index at the end of the time period.
YLD	Harvested yield (metric tons/ha). The model partitions yield from the total biomass on a daily basis (and reports it). However, the actual yield is not known until it is harvested. The harvested yield is reported as dry weight.
BACTP	Number of persistent bacteria in surface runoff entering reach (# cfu/100 mL).
BACTLP	Number of less persistent bacteria in surface runoff entering reach (#cfu/100 mL).
WTAB	Water table from above the soil profile (mm). (Written only in daily output file. This is not used in the tile flow equations).
WTABELO	Water table depth from the bottom of the soil surface (mm). (Written only in daily output file. This is not used in the tile flow equations).
SNO_HRU	Current snow content in the hru (mm). (Not summed)
CMUP_KGH	Current soil carbon for first soil layer (kg/ha)
CMTOT_KGH	Current soil carbon integrated – aggregating all soil layers (kg/ha)

The file format for the HRU output file (output.hru) is:

Variable name	Line #	Position	Format	F90 Format
LULC	All	space 1-4	character	a4
HRU	All	space 5-8	4-digit integer	i4
GIS	All	space 10-17	8-digit integer	i8
SUB	All	space 19-22	4-digit integer	i4
MGT	All	space 24-27	4-digit integer	i4
MON	All	space 29-32	4-digit integer	i4
AREA	All	space 33-42	decimal(xxxxxx.xxx)	f10.3
PRECIP	All	space 43-52	decimal(xxxxxx.xxx)	f10.3
SNOFALL	All	space 53-62	decimal(xxxxxx.xxx)	f10.3
SNOMELT	All	space 63-72	decimal(xxxxxx.xxx)	f10.3
IRR	All	space 73-82	decimal(xxxxxx.xxx)	f10.3
PET	All	space 83-92	decimal(xxxxxx.xxx)	f10.3
ET	All	space 93-102	decimal(xxxxxx.xxx)	f10.3
SW_INIT	All	space 103-112	decimal(xxxxxx.xxx)	f10.3
SW_END	All	space 113-122	decimal(xxxxxx.xxx)	f10.3
PERC	All	space 123-132	decimal(xxxxxx.xxx)	f10.3
GW_RCHG	All	space 133-142	decimal(xxxxxx.xxx)	f10.3
DA_RCHG	All	space 143-152	decimal(xxxxxx.xxx)	f10.3
REVAP	All	space 153-162	decimal(xxxxxx.xxx)	f10.3
SA_IRR	All	space 163-172	decimal(xxxxxx.xxx)	f10.3
DA_IRR	All	space 173-182	decimal(xxxxxx.xxx)	f10.3
SA_ST	All	space 183-192	decimal(xxxxxx.xxx)	f10.3
DA_ST	All	space 193-202	decimal(xxxxxx.xxx)	f10.3
SURQ_GEN	All	space 203-212	decimal(xxxxxx.xxx)	f10.3
SURQ_CNT	All	space 213-222	decimal(xxxxxx.xxx)	f10.3
TLOSS	All	space 223-232	decimal(xxxxxx.xxx)	f10.3
LATQ	All	space 233-242	decimal(xxxxxx.xxx)	f10.3
GW_Q	All	space 243-252	decimal(xxxxxx.xxx)	f10.3
WYLD	All	space 253-262	decimal(xxxxxx.xxx)	f10.3
DAILYCN	All	space 263-272	decimal(xxxxxx.xxx)	f10.3
TMP_AV	All	space 273-282	decimal(xxxxxx.xxx)	f10.3
TMP_MX	All	space 283-292	decimal(xxxxxx.xxx)	f10.3
TMP_MN	All	space 293-302	decimal(xxxxxx.xxx)	f10.3

Variable name	Line #	Position	Format	F90 Format
SOL_TMP	All	space 303-312	decimal(xxxxxx.xxx)	f10.3
SOLAR	All	space 313-322	decimal(xxxxxx.xxx)	f10.3
SYLD	All	space 323-332	decimal(xxxxxx.xxx)	f10.3
USLE	All	space 333-342	decimal(xxxxxx.xxx)	f10.3
N_APP	All	space 343-352	decimal(xxxxxx.xxx)	f10.3
P_APP	All	space 353-362	decimal(xxxxxx.xxx)	f10.3
NAUTO	All	space 363-372	decimal(xxxxxx.xxx)	f10.3
PAUTO	All	space 373-382	decimal(xxxxxx.xxx)	f10.3
NGRZ	All	space 383-392	decimal(xxxxxx.xxx)	f10.3
PGRZ	All	space 393-402	decimal(xxxxxx.xxx)	f10.3
CFERTN	All	space 403-412	decimal(xxxxxx.xxx)	f10.3
CFERTP	All	space 413-422	decimal(xxxxxx.xxx)	f10.3
NRAIN	All	space 423-432	decimal(xxxxxx.xxx)	f10.3
NFIX	All	space 433-442	decimal(xxxxxx.xxx)	f10.3
F-MN	All	space 443-452	decimal(xxxxxx.xxx)	f10.3
A-MN	All	space 453-462	decimal(xxxxxx.xxx)	f10.3
A-SN	All	space 463-472	decimal(xxxxxx.xxx)	f10.3
F-MP	All	space 473-482	decimal(xxxxxx.xxx)	f10.3
AO-LP	All	space 483-492	decimal(xxxxxx.xxx)	f10.3
L-AP	All	space 493-502	decimal(xxxxxx.xxx)	f10.3
A-SP	All	space 503-512	decimal(xxxxxx.xxx)	f10.3
DNIT	All	space 513-522	decimal(xxxxxx.xxx)	f10.3
NUP	All	space 523-532	decimal(xxxxxx.xxx)	f10.3
PUP	All	space 533-542	decimal(xxxxxx.xxx)	f10.3
ORGN	All	space 543-552	decimal(xxxxxx.xxx)	f10.3
ORGP	All	space 553-562	decimal(xxxxxx.xxx)	f10.3
SEDP	All	space 563-572	decimal(xxxxxx.xxx)	f10.3
NSURQ	All	space 573-582	decimal(xxxxxx.xxx)	f10.3
NLATQ	All	space 583-592	decimal(xxxxxx.xxx)	f10.3
NO3L	All	space 593-602	decimal(xxxxxx.xxx)	f10.3
NO3GW	All	space 603-612	decimal(xxxxxx.xxx)	f10.3
SOLP	All	space 613-622	decimal(xxxxxx.xxx)	f10.3
P_GW	All	space 623-632	decimal(xxxxxx.xxx)	f10.3
W_STRS	All	space 633-642	decimal(xxxxxx.xxx)	f10.3
TMP_STRS	All	space 643-652	decimal(xxxxxx.xxx)	f10.3

Variable name	Line #	Position	Format	F90 Format
N_STRS	All	space 653-662	decimal(xxxxxx.xxx)	f10.3
P_STRS	All	space 663-672	decimal(xxxxxx.xxx)	f10.3
BIOM	All	space 673-682	decimal(xxxxxx.xxx)	f10.3
LAI	All	space 683-692	decimal(xxxxxx.xxx)	f10.3
YLD	All	space 693-702	decimal(xxxxxx.xxx)	f10.3
BACTP	All	space 703-712	decimal(xxxxxx.xxx)	f10.3
BACTLP	All	space 713-722	decimal(xxxxxx.xxx)	f10.3
WTAB	All	space 723-732	decimal(xxxxxx.xxx)	f10.3
WTABELO	All	space 733-742	decimal(xxxxxx.xxx)	f10.3
SNO_HRU	All	space 743-752	decimal(xxxxxx.xxx)	f10.3
CMUP_KGH	All	space 753-762	decimal(xxxxxx.xxx)	f10.3
CMTOT_KGH	All	space 763-772	decimal(xxxxxx.xxx)	f10.3

32.4 SUBBASIN OUTPUT FILE (OUTPUT.SUB)

The subbasin output file contains summary information for each of the subbasins in the watershed. The reported values for the different variables are the total amount or weighted average of all HRUs within the subbasin. The subbasin output file is written in spreadsheet format.

Following is a brief description of the output variables in the subbasin output file.

Variable name	Definition
SUB	Subbasin number.
GIS	GIS code reprinted from watershed configuration file (.fig). See explanation of subbasin command.
MON	Daily time step: julian date Monthly time step: the month (1-12) Annual time step: four-digit year Average annual summary lines: total number of years averaged together
AREA	Area of the subbasin (km^2).
PRECIP	Total amount of precipitation falling on the subbasin during time step (mm H_2O).
SNOMELT	Amount of snow or ice melting during time step (water-equivalent mm H_2O).
PET	Potential evapotranspiration from the subbasin during the time step (mm H_2O).
ET	Actual evapotranspiration from the subbasin during the time step (mm).
SW	Soil water content (mm). Amount of water in the soil profile at the end of the time period.

Variable name	Definition
PERC	Water that percolates past the root zone during the time step (mm). There is potentially a lag between the time the water leaves the bottom of the root zone and reaches the shallow aquifer. Over a long period of time, this variable should equal groundwater percolation.
SURQ	Surface runoff contribution to streamflow during time step (mm H_2O).
GW_Q	Groundwater contribution to streamflow (mm). Water from the shallow aquifer that returns to the reach during the time step.
WYLD	Water yield (mm H_2O). The net amount of water that leaves the subbasin and contributes to streamflow in the reach during the time step. (WYLD = SURQ + LATQ + GWQ – TLOSS – pond abstractions)
SYLD	Sediment yield (metric tons/ha). Sediment from the subbasin that is transported into the reach during the time step.
ORGN	Organic N yield (kg N/ha). Organic nitrogen transported out of the subbasin and into the reach during the time step.
ORGP	Organic P yield (kg P/ha). Organic phosphorus transported with sediment into the reach during the time step.
NSURQ	NO_3 in surface runoff (kg N/ha). Nitrate transported by the surface runoff into the reach during the time step.
SOLP	Soluble P yield (kg P/ha). Phosphorus that is transported by surface runoff into the reach during the time step.
SEDP	Mineral P yield (kg P/ha). Mineral phosphorus attached to sediment that is transported by surface runoff into the reach during the time step.

The format of the subbasin output file (output.sub) is:

Variable name	Line #	Position	Format	F90 Format
SUB	All	space 7-10	4-digit integer	i4
GIS	All	space 12-19	8-digit integer	i8
MON	All	space 21-24	4-digit integer	i4
AREA	All	space 25-34	decimal(xxxxxx.xxx)	f10.3
PRECIP	All	space 35-44	decimal(xxxxxx.xxx)	f10.3
SNOMELT	All	space 45-54	decimal(xxxxxx.xxx)	f10.3
PET	All	space 55-64	decimal(xxxxxx.xxx)	f10.3
ET	All	space 65-74	decimal(xxxxxx.xxx)	f10.3
SW	All	space 75-84	decimal(xxxxxx.xxx)	f10.3
PERC	All	space 85-94	decimal(xxxxxx.xxx)	f10.3
SURQ	All	space 95-104	decimal(xxxxxx.xxx)	f10.3
GW_Q	All	space 105-114	decimal(xxxxxx.xxx)	f10.3
WYLD	All	space 115-124	decimal(xxxxxx.xxx)	f10.3
SYLD	All	space 125-134	decimal(xxxxxx.xxx)	f10.3
ORGN	All	space 135-144	decimal(xxxxxx.xxx)	f10.3
ORGP	All	space 145-154	decimal(xxxxxx.xxx)	f10.3
NSURQ	All	space 155-164	decimal(xxxxxx.xxx)	f10.3
SOLP	All	space 165-174	decimal(xxxxxx.xxx)	f10.3
SEDP	All	space 175-184	decimal(xxxxxx.xxx)	f10.3

32.5 MAIN CHANNEL OUTPUT FILE (OUTPUT.RCH)

The main channel output file contains summary information for each routing reach in the watershed. The file is written in spreadsheet format.

Following is a brief description of the output variables in the output.rch file.

Variable name	Definition
RCH	Reach number.
GIS	GIS number reprinted from watershed configuration (.fig) file.
MON	Daily time step: the julian date Monthly time step: the month (1-12) Annual time step: 4-digit year Average annual summary lines: number of years averaged together
AREA	Area drained by reach (km^2).
FLOW_IN	Average daily streamflow into reach during time step (m^3/s).
FLOW_OUT	Average daily streamflow out of reach during time step (m^3/s).
EVAP	Average daily rate of water loss from reach by evaporation during time step (m^3/s).
TLOSS	Average daily rate of water loss from reach by transmission through the streambed during time step (m^3/s).
SED_IN	Sediment transported with water into reach during time step (metric tons).
SED_OUT	Sediment transported with water out of reach during time step (metric tons).
SEDCONC	Concentration of sediment in reach during time step (mg/L).
ORGN_IN	Organic nitrogen transported with water into reach during time step (kg N).
ORGN_OUT	Organic nitrogen transported with water out of reach during time step (kg N).
ORGP_IN	Organic phosphorus transported with water into reach during time step (kg P).

Variable name	Definition
ORGP_OUT	Organic phosphorus transported with water out of reach during time step (kg P).
NO3_IN	Nitrate transported with water into reach during time step (kg N).
NO3_OUT	Nitrate transported with water out of reach during time step (kg N).
NH4_IN	Ammonium transported with water into reach during time step (kg N).
NH4_OUT	Ammonium transported with water out of reach during time step (kg N).
NO2_IN	Nitrite transported with water into reach during time step (kg N).
NO2_OUT	Nitrite transported with water out of reach during time step (kg N).
MINP_IN	Mineral phosphorus transported with water into reach during time step (kg P).
MINP_OUT	Mineral phosphorus transported with water out of reach during time step (kg P).
ALGAE_IN	Algal biomass transported with water into reach during time step (kg chl-a).
ALGAE_OUT	Algal biomass transported with water out of reach during time step (kg chl-a).
CBOD_IN	Carbonaceous biochemical oxygen demand of material transported into reach during time step (kg O_2).
CBOD_OUT	Carbonaceous biochemical oxygen demand of material transported out of reach during time step (kg O_2).
DISOX_IN	Amount of dissolved oxygen transported into reach during time step (kg O_2).
DISOX_OUT	Amount of dissolved oxygen transported out of reach during time step (kg O_2).

While more than one pesticide may be applied to the HRUs, due to the complexity of the pesticide equations only the pesticide listed in .bsn (Chapter 4) is routed through the stream network.

Variable name	Definition
SOLPST_IN	Soluble pesticide transported with water into reach during time step (mg active ingredient)

Variable name	Definition
SOLPST_OUT	Soluble pesticide transported with water out of reach during time step (mg active ingredient).
SORPST_IN	Pesticide sorbed to sediment transported with water into reach during time step (mg active ingredient).
SORPST_OUT	Pesticide sorbed to sediment transported with water out of reach during time step (mg active ingredient).
REACTPST	Loss of pesticide from water by reaction during time step (mg active ingredient).
VOLPST	Loss of pesticide from water by volatilization during time step (mg active ingredient).
SETTLPST	Transfer of pesticide from water to river bed sediment by settling during time step (mg active ingredient).
RESUSP_PST	Transfer of pesticide from river bed sediment to water by resuspension during time step (mg active ingredient).
DIFFUSEPST	Transfer of pesticide from water to river bed sediment by diffusion during time step (mg active ingredient).
REACBEDPST	Loss of pesticide from river bed sediment by reaction during time step (mg active ingredient).
BURYPST	Loss of pesticide from river bed sediment by burial during time step (mg active ingredient).
BED_PST	Pesticide in river bed sediment during time step (mg active ingredient).
BACTP_OUT	Number of persistent bacteria transported out of reach during time step (# cfu/100 mL).
BACTLP_OUT	Number of less persistent bacteria transported out of reach during time step (# cfu/100 mL).
CMETAL#1	Conservative metal #1 transported out of reach (kg).
CMETAL#2	Conservative metal #2 transported out of reach (kg).
CMETAL#3	Conservative metal #3 transported out of reach (kg).

The format of the main channel output file (output.rch) is:

Variable name	Line #	Position	Format	F90 Format
RCH	All	space 7-10	4-digit integer	i4
GIS	All	space 12-19	8-digit integer	i8
MON	All	space 21-25	5-digit integer	i5
AREA	All	space 26-37	exponential	e12.4
FLOW_IN	All	space 38-49	exponential	e12.4
FLOW_OUT	All	space 50-61	exponential	e12.4
EVAP	All	space 62-73	exponential	e12.4
TLOSS	All	space 74-85	exponential	e12.4
SED_IN	All	space 86-97	exponential	e12.4
SED_OUT	All	space 98-109	exponential	e12.4
SEDCONC	All	space 110-121	exponential	e12.4
ORGN_IN	All	space 122-133	exponential	e12.4
ORGN_OUT	All	space 134-145	exponential	e12.4
ORGP_IN	All	space 146-157	exponential	e12.4
ORGP_OUT	All	space 158-169	exponential	e12.4
NO3_IN	All	space 170-181	exponential	e12.4
NO3_OUT	All	space 182-193	exponential	e12.4
NH4_IN	All	space 194-205	exponential	e12.4
NH4_OUT	All	space 206-217	exponential	e12.4
NO2_IN	All	space 218-229	exponential	e12.4
NO2_OUT	All	space 230-241	exponential	e12.4
MINP_IN	All	space 242-253	exponential	e12.4
MINP_OUT	All	space 254-265	exponential	e12.4
CHLA_IN	All	space 266-277	exponential	e12.4
CHLA_OUT	All	space 278-289	exponential	e12.4
CBOD_IN	All	space 290-301	exponential	e12.4
CBOD_OUT	All	space 302-313	exponential	e12.4
DISOX_IN	All	space 314-325	exponential	e12.4
DISOX_OUT	All	space 326-337	exponential	e12.4
SOLPST_IN	All	space 338-349	exponential	e12.4
SOLPST_OUT	All	space 350-361	exponential	e12.4
SORPST_IN	All	space 362-373	exponential	e12.4
SORPST_OUT	All	space 374-385	exponential	e12.4
REACTPST	All	space 386-397	exponential	e12.4

Variable name	Line #	Position	Format	F90 Format
VOLPST	All	space 398-409	exponential	e12.4
SETTLPST	All	space 410-421	exponential	e12.4
RESUSP_PST	All	space 422-433	exponential	e12.4
DIFFUSEPST	All	space 434-445	exponential	e12.4
REACBEDPST	All	space 446-457	exponential	e12.4
BURYPST	All	space 458-469	exponential	e12.4
BED_PST	All	space 470-481	exponential	e12.4
BACTP_OUT	All	space 482-493	exponential	e12.4
BACTLP_OUT	All	space 494-505	exponential	e12.4
CMETAL#1	All	space 506-517	exponential	e12.4
CMETAL#2	All	space 518-529	exponential	e12.4
CMETAL#3	All	space 530-541	exponential	e12.4

32.6 HRU IMPOUNDMENT OUTPUT FILE (OUTPUT.WTR)

The HRU impoundment output file contains summary information for ponds, wetlands and depressional/impounded areas in the HRUs. The file is written in spreadsheet format.

Following is a brief description of the output variables in the HRU impoundment output file.

Variable name	Definition
LULC	Four letter character code for the cover/plant on the HRU. (code from crop.dat file)
HRU	Hydrologic response unit number
GIS	GIS code reprinted from watershed configuration file (.fig). See explanation of subbasin command (Chapter 2).
SUB	Topographically-defined subbasin to which the HRU belongs.
MGT	Management number. This is pulled from the management (.mgt) file. Used by the SWAT/GRASS interface to allow development of output maps by landuse/management type.
MON	Daily time step: the julian date Monthly time step: the month (1-12) Annual time step: year Average annual summary lines: total number of years averaged together
AREA	Drainage area of the HRU (km^2).
PNDPCP	Precipitation falling directly on the pond during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.
PND_IN	Pond inflow (mm H_2O). Surface runoff entering the pond during the time step. The depth of water is the volume divided by the area of the HRU.
PSED_I	Pond sediment inflow (metric tons/ha). Sediment transported into the pond during the time step. The loading is the mass divided by the area of the HRU.
PNDEVP	Evaporation from the pond surface during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.

Variable name	Definition
PNDSEP	Water that seeps through the bottom of the pond and recharges the shallow aquifer during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.
PND_OUT	Pond outflow (mm H_2O). Water leaving the pond and entering the reach during the time step. The depth of water is the volume divided by the area of the HRU.
PSED_O	Pond sediment outflow (metric tons/ha). Sediment transported out of the pond and entering the reach during the time step. . The loading is the mass divided by the area of the HRU.
PNDVOL	Volume of water in pond at end of time step (m^3 H_2O).
PNDORGN	Concentration of organic N in pond at end of time step (mg N/L or ppm).
PNDNO3	Concentration of nitrate in pond at end of time step (mg N/L or ppm).
PNDORGP	Concentration of organic P in pond at end of time step (mg P/L or ppm).
PNDMINP	Concentration of mineral P in pond at end of time step (mg P/L or ppm).
PNDCHLA	Concentration of chlorophyll-a in pond at end of time step (mg chl-a/L or ppm).
PNDSECI	Secchi-disk depth of pond at end of time step (m).
WETPCP	Precipitation falling directly on the wetland during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.
WET_IN	Wetland inflow (mm H_2O). Surface runoff entering the wetland during the time step. The depth of water is the volume divided by the area of the HRU.
WSED_I	Wetland sediment inflow (metric tons/ha). Sediment transported into the wetland during the time step. The loading is the mass divided by the area of the HRU.
WETEVP	Evaporation from the wetland during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.

Variable name	Definition
WETSEP	Water that seeps through the bottom of the wetland and recharges the shallow aquifer during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.
WET_OUT	Wetland outflow (mm H_2O). Water leaving the wetland and entering the reach during the time step. The depth of water is the volume divided by the area of the HRU.
WSED_O	Wetland sediment outflow (metric tons/ha). Sediment transported out of the wetland and entering the reach during the time step. . The loading is the mass divided by the area of the HRU.
WET_VOL	Volume of water in wetland at end of time step (m^3 H_2O).
WETORGN	Concentration of organic N in wetland at end of time step (mg N/L or ppm).
WETNO3	Concentration of nitrate in wetland at end of time step (mg N/L or ppm).
WETORGP	Concentration of organic P in wetland at end of time step (mg P/L or ppm).
WETMINP	Concentration of mineral P in wetland at end of time step (mg P/L or ppm).
WETCHLA	Concentration of chlorophyll-a in wetland at end of time step (mg chl-a/L or ppm).
WETSECI	Secchi-disk depth of wetland at end of time step (m).
POTPCP	Precipitation falling directly on the pothole during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.
POT_IN	Pothole inflow (mm H_2O). Surface runoff entering the pothole during the time step. The depth of water is the volume divided by the area of the HRU.
OSED_I	Pothole sediment inflow (metric tons/ha). Sediment transported into the pothole during the time step. The loading is the mass divided by the area of the HRU.
POTEVP	Evaporation from the pothole during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.

Variable name	Definition
POTSEP	Water that seeps through the bottom of the pothole and enters the underlying soil during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.
POT_OUT	Pothole outflow (mm H_2O). Water leaving the pothole and entering the reach during the time step. The depth of water is the volume divided by the area of the HRU.
OSED_O	Pothole sediment outflow (metric tons/ha). Sediment transported out of the pothole and entering the reach during the time step. . The loading is the mass divided by the area of the HRU.
POTVOL	Volume of water in pothole at end of time step (m^3 H_2O).
POT_SA	Surface area of pothole at end of time step (ha).
HRU_SURQ	Surface runoff contribution to streamflow in the main channel from entire HRU during the time step (mm H_2O).
PLANT_ET	Amount of water removed by transpiration from plants during the time step (mm H_2O).
SOIL_ET	Amount of water removed by evaporation from the soil during the time step (mm H_2O).

The format of the HRU impoundment output file (output.wtr) is:

Variable name	Line #	Position	Format	F90 Format
LULC	All	space 1-4	character	a4
HRU	All	space 5-8	4-digit integer	i4
GIS	All	space 10-17	8-digit integer	i8
SUB	All	space 19-22	4-digit integer	i4
MGT	All	space 24-27	4-digit integer	i4
MON	All	space 29-32	4-digit integer	i4
AREA	All	space 33-42	decimal(xxxxxx.xxx)	f10.3
PNDPCP	All	space 43-52	decimal(xxxxxx.xxx)	f10.3
PND_IN	All	space 53-62	decimal(xxxxxx.xxx)	f10.3
PSED_I	All	space 63-72	decimal(xxxxxx.xxx)	f10.3
PNDEVP	All	space 73-82	decimal(xxxxxx.xxx)	f10.3
PNDSEP	All	space 83-92	decimal(xxxxxx.xxx)	f10.3
PND_OUT	All	space 93-102	decimal(xxxxxx.xxx)	f10.3
PSED_O	All	space 103-112	decimal(xxxxxx.xxx)	f10.3

Variable name	Line #	Position	Format	F90 Format
PNDVOL	All	space 113-122	exponential	e10.4
PNDORGN	All	space 123-132	decimal(xxxxxx.xxx)	f10.3
PNDNO3	All	space 133-142	decimal(xxxxxx.xxx)	f10.3
PNDORGP	All	space 143-152	decimal(xxxxxx.xxx)	f10.3
PNDMINP	All	space 153-162	decimal(xxxxxx.xxx)	f10.3
PNDCHLA	All	space 163-172	decimal(xxxxxx.xxx)	f10.3
PNDSECI	All	space 173-182	decimal(xxxxxx.xxx)	f10.3
WETPCP	All	space 183-192	decimal(xxxxxx.xxx)	f10.3
WET_IN	All	space 193-202	decimal(xxxxxx.xxx)	f10.3
WSED_I	All	space 203-212	decimal(xxxxxx.xxx)	f10.3
WETEVP	All	space 213-222	decimal(xxxxxx.xxx)	f10.3
WETSEP	All	space 223-232	decimal(xxxxxx.xxx)	f10.3
WET_OUT	All	space 233-242	decimal(xxxxxx.xxx)	f10.3
WSED_O	All	space 243-252	decimal(xxxxxx.xxx)	f10.3
WET_VOL	All	space 253-262	exponential	e10.4
WETORGN	All	space 263-272	decimal(xxxxxx.xxx)	f10.3
WETNO3	All	space 273-282	decimal(xxxxxx.xxx)	f10.3
WETORGP	All	space 283-292	decimal(xxxxxx.xxx)	f10.3
WETMINP	All	space 293-302	decimal(xxxxxx.xxx)	f10.3
WETCHLA	All	space 303-312	decimal(xxxxxx.xxx)	f10.3
WETSECI	All	space 313-322	decimal(xxxxxx.xxx)	f10.3
POTPCP	All	space 323-332	decimal(xxxxxx.xxx)	f10.3
POT_IN	All	space 333-342	decimal(xxxxxx.xxx)	f10.3
OSED_I	All	space 343-352	decimal(xxxxxx.xxx)	f10.3
POTEVP	All	space 353-362	decimal(xxxxxx.xxx)	f10.3
POTSEP	All	space 363-372	decimal(xxxxxx.xxx)	f10.3
POT_OUT	All	space 373-382	decimal(xxxxxx.xxx)	f10.3
OSED_O	All	space 383-392	decimal(xxxxxx.xxx)	f10.3
POTVOL	All	space 393-402	exponential	e10.4
POT_SA	All	space 403-412	decimal(xxxxxx.xxx)	f10.3
HRU_SURQ	All	space 413-422	decimal(xxxxxx.xxx)	f10.3
PLANT_ET	All	space 423-432	decimal(xxxxxx.xxx)	f10.3
SOIL_ET	All	space 433-442	decimal(xxxxxx.xxx)	f10.3

32.7 RESERVOIR OUTPUT FILE (OUTPUT.RSV)

The reservoir output file contains summary information for reservoirs in the watershed. The file is written in spreadsheet format.

Following is a brief description of the output variables in the reservoir output file.

Variable name	Definition
RES	Reservoir number (assigned in .fig file, Chapter 2)
MON	Daily time step: the julian date Monthly time step: the month (1-12) Annual time step: four-digit year
VOLUME	Volume of water in reservoir at end of time step (m^3 H_2O).
FLOW_IN	Average flow into reservoir during time step (m^3/s H_2O).
FLOW_OUT	Average flow out of reservoir during time step (m^3/s H_2O).
PRECIP	Precipitation falling directly on the reservoir during the time step (m^3 H_2O).
EVAP	Evaporation from the reservoir during the time step (m^3 H_2O).
SEEPAGE	Water that seeps through the bottom of the reservoir and enters the shallow aquifer during the time step (m^3 H_2O).
SED_IN	Reservoir sediment inflow (metric tons). Sediment transported into the reservoir during the time step.
SED_OUT	Reservoir sediment outflow (metric tons). Sediment transported out of the reservoir during the time step.
RES_SED	Sediment concentration (mg/L). Sediment concentration in reservoir water during the time step.
ORGN_IN	Amount of organic nitrogen transported into reservoir during the time step (kg N).
ORGN_OUT	Amount of organic nitrogen transported out of reservoir during the time step (kg N).
RES_ORGN	Organic nitrogen concentration in reservoir water during time step (mg N/L).
ORGP_IN	Amount of organic phosphorus transported into reservoir during the time step (kg P).

Variable name	Definition
ORGP_OUT	Amount of organic phosphorus transported out of reservoir during the time step (kg P).
RES_ORGP	Concentration of organic phosphorus in reservoir water during the time step (mg P/L).
ORGP_OUT	Amount of organic phosphorus transported out of reservoir during the time step (kg P).
RES_ORGP	Concentration of organic phosphorus in reservoir water during the time step (mg P/L).
NO3_IN	Amount of nitrate transported into reservoir during the time step (kg N).
NO3_OUT	Amount of nitrate transported out of reservoir during the time step (kg N).
RES_NO3	Concentration of nitrate in reservoir water during time step (mg N/L).
NO2_IN	Amount of nitrite transported into reservoir during the time step (kg N).
NO2_OUT	Amount of nitrite transported out of reservoir during the time step (kg N).
RES_NO2	Concentration of nitrite in reservoir water during time step (mg N/L).
NH3_IN	Amount of ammonia transported into reservoir during the time step (kg N).
NH3_OUT	Amount of ammonia transported out of reservoir during the time step (kg N).
RES_NH3	Concentration of ammonia in reservoir water during the time step (mg N/L).
MINP_IN	Amount of mineral phosphorus transported into reservoir during the time step (kg P).
MINP_OUT	Amount of mineral phosphorus transported out of reservoir during the time step (kg P).
RES_MINP	Concentration of mineral phosphorus in reservoir water during time step (mg P/L).
CHLA_IN	Amount of chlorophyll *a* transported into reservoir during the time step (kg chla).
CHLA_OUT	Amount of chlorophyll *a* transported out of reservoir during the time step (kg chla).

Variable name	Definition
SECCHIDEPTH	Secchi-disk depth of reservoir at end of time step (m).
PEST_IN	Amount of pesticide transported into reservoir during the time step (mg active ingredient).
REACTPST	Loss of pesticide from water by reaction during time step (mg active ingredient).
VOLPST	Loss of pesticide from water by volatilization during time step (mg active ingredient).
SETTLPST	Transfer of pesticide from water to reservoir bed sediment by settling during time step (mg active ingredient).
RESUSP_PST	Transfer of pesticide from reservoir bed sediment to water by resuspension during time step (mg active ingredient).
DIFFUSEPST	Transfer of pesticide from water to reservoir bed sediment by diffusion during time step (mg active ingredient).
REACBEDPST	Loss of pesticide from reservoir bed sediment by reaction during time step (mg active ingredient).
BURYPST	Loss of pesticide from reservoir sediment by burial during time step (mg active ingredient).
PEST_OUT	Amount of pesticide transported out of reservoir during the time step (mg pesticide active ingredient).
PSTCNCW	Average concentration of pesticide in reservoir water during time step (mg active ingredient/m^3 H_2O or ppb).
PSTCNCB	Average concentration of pesticide in reservoir bed sediment during time step (mg active ingredient/m^3 H_2O or ppb).

The format of the reservoir output file (output.rsv) is:

Variable name	Line #	Position	Format	F90 Format
RES	All	space 7-14	integer	i8
MON	All	space 16-19	integer	i4
VOLUME	All	space 20-31	exponential	e12.4
FLOW_IN	All	space 32-43	exponential	e12.4
FLOW_OUT	All	space 44-55	exponential	e12.4
PRECIP	All	space 56-67	exponential	e12.4
EVAP	All	space 68-79	exponential	e12.4
SEEPAGE	All	space 80-91	exponential	e12.4
SED_IN	All	space 92-103	exponential	e12.4
SED_OUT	All	space 104-115	exponential	e12.4

Variable name	Line #	Position	Format	F90 Format
RES_SED	All	space 116-127	exponential	e12.4
ORGN_IN	All	space 128-139	exponential	e12.4
ORGN_OUT	All	space 140-151	exponential	e12.4
RES_ORGN	All	space 152-163	exponential	e12.4
ORGP_IN	All	space 164-175	exponential	e12.4
ORGP_OUT	All	space 176-187	exponential	e12.4
RES_ORGP	All	space 188-199	exponential	e12.4
NO3_IN	All	space 200-211	exponential	e12.4
NO3_OUT	All	space 212-223	exponential	e12.4
RES_NO3	All	space 224-235	exponential	e12.4
NO2_IN	All	space 236-247	exponential	e12.4
NO2_OUT	All	space 248-259	exponential	e12.4
RES_NO2	All	space 260-271	exponential	e12.4
NH3_IN	All	space 272-283	exponential	e12.4
NH3_OUT	All	space 284-295	exponential	e12.4
RES_NH3	All	space 296-307	exponential	e12.4
MINP_IN	All	space 308-319	exponential	e12.4
MINP_OUT	All	space 320-331	exponential	e12.4
RES_MINP	All	space 332-343	exponential	e12.4
CHLA_IN	All	space 344-355	exponential	e12.4
CHLA_OUT	All	space 356-367	exponential	e12.4
SECCHIDEPTH	All	space 368-379	exponential	e12.4
PEST_IN	All	space 380-391	exponential	e12.4
REACTPST	All	space 392-403	exponential	e12.4
VOLPST	All	space 404-415	exponential	e12.4
SETTLPST	All	space 416-427	exponential	e12.4
RESUSP_PST	All	space 428-439	exponential	e12.4
DIFFUSEPST	All	space 440-451	exponential	e12.4
REACBEDPST	All	space 452-463	exponential	e12.4
BURYPST	All	space 464-475	exponential	e12.4
PEST_OUT	All	space 476-487	exponential	e12.4
PSTCNCW	All	space 488-499	exponential	e12.4
PSTCNCB	All	space 500-511	exponential	e12.4

32.8 SEDIMENT LOADS OUTPUT FILE (OUTPUT.SED)

The sediment loads output file contains summary information for reservoirs in the watershed. The file is written in spreadsheet format.

Following is a brief description of the output variables in the sediment loads output file.

Variable name	Definition
RCH	Four letter character code for the reach number. The reach number is also the hydrograph number of the subbasin as defined in the .fig file.
GIS	GIS code reprinted from watershed configuration file (.fig).
MON	Daily time step: the julian date Monthly time step: the month (1-12) Annual time step: four-digit year Average annual summary lines: total number of years averaged together
AREA	Drainage area of the HRU (km$^{2)}$.
SED_IN	Total sediment transported into reach during time step (tons)
SED_OUT	Total sediment transported out of reach during time step (tons)
SAND_IN	Sand transported into reach during time step (tons)
SAND_OUT	Sand transported out of reach during time step (tons)
SILT_IN	Silt transported into reach during time step (tons)
SILT_OUT	Silt transported out of reach during time step (tons)
CLAY_IN	Clay transported into reach during time step (tons)
CLAY_OUT	Clay transported out of reach during time step (tons)
SMAG_IN	Small aggregates transported into reach during time step (tons)
SMAG_OUT	Small aggregates transported out of reach during time step (tons)
LAG_IN	Large aggregates transported into reach during time step (tons)

Variable name	Definition
LAG_OUT	Large aggregates transported out of reach during time step (tons)
GRA_IN	Gravel aggregates transported into reach during time step (tons)
GRA_OUT	Gravel aggregates transported out of reach during time step (tons)
CH_BNK	Bank erosion (tons)
CH_BED	Channel degradation (tons)
CH_DEP	Channel deposition (tons)
FP_DEP	Floodplain deposition (tons)
TSS	Total suspended sediments (mg/L)

The file format for the HRU output file (output.sed) is:

Variable name	Line #	Position	Format	F90 Format
RCH	All	Space 7-10	4-digit integer	i4
GIS	All	Space 12-19	8-digit integer	i8
MON	All	Space 21-25	5-digit integer	i5
AREA	All	Space 26-37	exponential	e12.4
SED_IN	All	Space 38-49	exponential	e12.4
SED_OUT	All	Space 50-61	exponential	e12.4
SAND_IN	All	Space 62-73	exponential	e12.4
SAND_OUT	All	Space 74-85	exponential	e12.4
SILT_IN	All	Space 86-97	exponential	e12.4
SILT_OUT	All	Space 98-109	exponential	e12.4
CLAY_IN	All	Space 110-121	exponential	e12.4
CLAY_OUT	All	Space 122-133	exponential	e12.4
SMAG_IN	All	Space 134-145	exponential	e12.4
SMAG_OUT	All	Space 146-157	exponential	e12.4
LAG_IN	All	Space 158-169	exponential	e12.4
LAG_OUT	All	Space 170-181	exponential	e12.4
GRA_IN	All	Space 170-181	exponential	e12.4
GRA_OUT	All	Space 182-193	exponential	e12.4
CH_BNK	All	Space 194-205	exponential	e12.4
CH_BED	All	Space 206-217	exponential	e12.4

Variable name	Line #	Position	Format	F90 Format
CH_DEP	All	Space 217-229	exponential	e12.4
FP_DEP	All	Space 230-241	exponential	e12.4
TSS	All	Space 242-253	exponential	e12.4

32.9 MANAGEMENT OUTPUT FILE (OUTPUT.MGT)

The management output file contains summary information for various management operations. Each time a scheduled operation occurs, the model prints to the OUTPUT.MGT file indicating the operation was simulated. These files can get very large. The user may indicate in file.cio if he/she would like to suppress the write statements (imgt = 0, do not write output.mgt file).

Following is a brief description of the output variables in the management output file.

Variable name	Definition
HRU	Hydrologic response unit number
YEAR	Current year of simulation (four digit)
DAY	Day being simulated (current Julian date)
MONTH	Monthly time step: (1-12)
OPERATION	Management operation being performed

Management operations addressed in the management output file.

Management name	Definition
PLANT	Plant/beginning of growing season, operation performed when no plant cover is growing.
IRRIGATE	Irrigation operation from shallow aquifer, deep aquifer and sources outside watershed
FERT APP	Fertilizer application
END GROW	Operation called at the end of the annual growing season as determined by length of day, dormant period for the plant and fraction of plant heat units.

Management name	Definition
HARV&KILL	Harvest and kill operation
HARVEST	Harvest operation, no kill
KILL	Kill operation
TILLAGE	Tillage operation, multiple tillage operation may be scheduled on same day
PEST APP	Pesticide application
RELEASE	Release/impound operation for rice fields

32.10 SOIL OUTPUT FILE (OUTPUT.SOL)

The soil output file contains summary information for nutrients in the soil profile. Following is a brief description of the output variables in the soil output file.

Variable name	Definition
DAY	Daily time step: the Julian date
HRU	Hydrologic response unit number
SURFACE SOL_RSD	Amount of organic matter in the soil classified as residue (kg/ha)
SOL_P	Soluble phosphorus in soil profile (kg P/ha)
NO3	Amount of nitrate in the soil profile (kg N/ha)
ORG_N	Amount of N stored in the stable organic N pool (kg N/ha)
ORG_P	Amount of P stored in the stable organic P pool (kg P/ha)
CN	Curve number for current day

32.11 SNOW AT ELEVATION BAND OUTPUT FILE (SNOWBAND.OUT)

The snowband output file contains summary information for the amount of moisture in snow at elevation bands.

Following is a brief description of the output variables in the snowband output file.

Variable name	Definition
DAY	Daily time step: the Julian date
HRU	Hydrologic response unit number
YR	Current year of simulation (four digit)
SNOW (1-7)	Snow water content in elevation band on current day (mm)

32.12 PESTICIDE OUTPUT FILE (OUTPUT.PST)

The pesticide output file contains summary information for the amount of pesticide that is sorbed to sediment and the amount that is soluble.

Following is a brief description of the output variables in the pesticide output file.

Variable name	Definition
PESTICIDE #	Pesticide number from the pesticide database
PESTICIDE NAME	Pesticide name from the database that was used in the simulation
HRU	Hydrologic response unit number
YEAR	Current year of simulation (four digit)
MON	Monthly time step: (1-12)
SOLUBLE	Amount of pesticide in solution in surface runoff (mg)
SORBED	Amount of pesticide sorbed to sediment in surface runoff (mg)

32.13 HOURLY OUTPUT FILE (HOURQ.OUT)

This output file contains summary information for the volume of water at a hydrograph storage location by year, day and hour.

Following is a brief description of the output variables in the hourly output file.

Variable name	Definition
YEAR	Current year of simulation (four digit)
DAY	Current day of simulation
HOUR	Current hour of simulation
HYD	The hydrograph storage location number for subbasin
TOTAL WATER YLD	Water yield (m^3) at the hydrograph storage location during hour

32.14 CHANNEL VELOCITY OUTPUT FILE (CHANVEL.OUT)

This output file contains summary information for the velocity of water at each reach by day and year. The user may input code (ITEMP) that is read from file.cio that controls the off/on (0=off/1=on) switch for writing output to this file.

Following is a brief description of the output variables in the channel velocity output file.

Variable name	Definition
YEAR	Current year of simulation (four digit)
DAY	Current day of simulation
CH_VEL	Velocity of water at each reach ($m\ s^{-1}$)

32.15 WATER DEPTH OUTPUT FILE (WATRDEP.OUT)

This output file contains summary information for the water depth at each reach by day and year. The user may input code (ITEMP) that is read from file.cio that controls the off/on (0=off/1=on) switch for writing output to this file.

Following is a brief description of the output variables in the channel velocity output file.

Variable name	Definition
YEAR	Current year of simulation (four digit)
DAY	Current day of simulation
AVE WATER DEPTH	Average water depth at each reach (m)

32.16 CARBON OUTPUT FILE (CSWAT_PROFILE.TXT)

This output file contains summary information for the mass of carbon in organic matter and manure for all soil layers as well as the mass of the residue in all soil layers for each HRU by day and year. The user may input code (CSWAT) that is read from .bsn that controls the off/on (0=off/1=on) switch for writing output to this file.

Following is a brief description of the output variables in carbon output file.

Variable name	Definition
IYR	Current year of simulation (four digit)
I	Current day of simulation
J	HRU number

Variable name	Definition
CMASS_PRO	Mass of soil carbon in the soil organic matter in the entire profile or the sum of all layers, not including residue or manure (kg/ha)
SOL_RSD_	Sum of the mass of residue for all soil layers (kg/ha)
SOL_MC_PRO	Sum of the carbon in manure in all soil layers (kg/ha)

CHAPTER 33

SWAT INPUT DATA: .OPS

The Scheduled Management Operations (.ops) file is an optional file which allows the simulation of non-reoccurring management related activities. The .ops file is particularly useful to initialize conservation measures mid-simulation. After their initialization, the practices remain in effect for the remainder of the simulation. The day and relevant operational parameters must be specified. Several conservation measures such as grassed waterways and filter strips are only available through the .ops file.

33.1 SCHEDULED MANAGEMENT OPERATIONS

SWAT will simulate 8 different types of management operations. The first four variables on all management lines are identical, these set the date and operation number. If the date is blank, the operation will be scheduled for the first day of the simulation. The remaining ten variables are operation specific. The type of operation simulated is identified by the code given for the variable MGT_OP.

The different codes for MGT_OP are:

1	**terracing operation:** this operation simulates a terrace to the HRU on the specified day
2	**tile drainage:** this operation simulates a tile to the HRU on the specified day
3	**contouring:** this operation simulates a contour to the HRU on the specified day
4	**filter strip**: this operation simulates a vegetative filter strip to the HRU on the specified day
5	**strip cropping:** this operation simulates strip cropping to the HRU on the specified day
6	**fire:** this operation simulates fire to the HRU on the specified day
7	**grassed waterways:** this operation simulates grassed waterways to the HRU on the specified day
8	**plant parameter update:** this operation updates crop parameters to the HRU on the specified day

For each year of management operations provided, the operations must be listed in chronological order starting in January.

33.1.1 TERRACING

A terrace is an embankment within in a field designed to intercept runoff and prevent erosion. A terrace is constructed across slope on a contour. A field generally contains several regularly spaced terraces. Terracing in SWAT is simulated by adjusting both erosion and runoff parameters. The USLE Practice (TERR_P) factor, the slope length (TERR_SL) and curve number (TERR_CN) are adjusted to simulate the effects of terracing. Appropriate curve number for terraced field can be found in Table 20-1. TERR_P values based on field slope are given in Table 33-1. TERR_SL should be set to a maximum of the distance between terraces.

Table 33-1 Universal Soil Loss Equation crop Practice (P) factors derived from Haan et al. (1994).

Condition	Slope range (%)	P factor
Strait Row	0-25	1.00
Contour	0-2	0.90
Contour	2-5	0.80
Contour	5-8	0.70
Contour	8-12	0.60
Contour	12-16	0.50
Contour	16-20	0.50
Contour	20-25	0.60
Terraced	0-2	0.12
Terraced	2-8	0.10
Terraced	8-12	0.12
Terraced	12-16	0.14
Terraced	16-20	0.16
Terraced	20-25	0.18

The variables which may be entered on the planting line are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. (Required)
DAY	Day operation takes place. (Required)
IYEAR	Year operation takes place. (Required)
MGT_OP	Management operation number. MGT_OP = 1 for terracing.
TERR_P	USLE practice factor adjusted for terraces
TERR_CN	Initial SCS curve number II value
TERR_SL	Average slope length (m). Should be set to the interval between terraces.

The format of the terracing operation line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
IYEAR	space 12-15	4-digit number	i4
MGT_OP	space 17-18	2-digit integer	i2
TERR_P	space 36-47	decimal (xxxxxx.xxxxx)	f12.5
TERR_CN	space 49-54	decimal (xxx.xx)	f6.2
TERR_SL	space 56-66	decimal (xxxxx.xxxxx)	f11.5

33.1.2 TILE DRAINAGE OPERATION

Tile drains remove excess water for an area to optimize plant growth. Drains may be added at the beginning of the simulation in the .mgt file. To account for the installation of tile drains mid-simulation, the option was included as a schedulable operation. The variables which may be entered on the irrigation line are listed and described below

Variable name	Definition
MONTH	Month operation takes place. (Required)
DAY	Day operation takes place. (Required)
IYEAR	Year operation takes place. (Required)
MGT_OP	Management operation number. MGT_OP = 2 for tile drainage.
DRAIN_D	Depth to the sub-surface drain (mm)
DRAIN_T	Time to drain soil to field capacity (hours)
DRAIN_G	Drain tile lag time. The amount of time between transfer of water from the soil to the drain tile and the release of the water from the drain tile to the reach (hours)
DRAIN_IDEP	Depth to impermeable layer (mm) Default = 6000.0

The format of the tile drainage line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
IYEAR	space 12-15	4-digit integer	i4
MGT_OP	space 17-18	2-digit integer	i2
DRAIN_D	space 36-47	decimal (xxxxxx.xxxxx)	f12.5
DRAIN_T	space 49-54	decimal (xxx.xx)	f6.2
DRAIN_G	space 56-66	decimal (xxxxx.xxxxx)	f11.5
DRAIN_IDEP	space 68-75	decimal (xxxxx.xx)	f8.2

33.1.3 CONTOUR PLANTING

Contour planting is the practice of tilling and planting crops following the contour of the field as apposed to strait rows. These contours are orientated at a right angle to the field slope at any point. Small ridges resulting from field operations increase surface storage and roughness, reducing runoff and sediment losses. Contour planting is simulated in SWAT by altering curve number (CONT_CN) to account for increased surface storage and infiltration (Table 20-1) and the USLE Practice factor (CONT_P) to account for decreased erosion (Table 33-1). The variables which may be entered on the fertilization line are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. (Required)
DAY	Day operation takes place. (Required)
IYEAR	Year operation takes place. (Required)
MGT_OP	Management operation number. MGT_OP = 3 for contouring.
CONT_CN	Initial SCS curve number II value
CONT_P	Contouring USLE P Factor

The format of the contour planting line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
IYEAR	space 12-15	4-digit integer	i4
MGT_OP	space 17-18	2-digit integer	i2
CONT_CN	space 36-47	decimal (xxxxxx.xxxxx)	f12.5
CONT_P	space 49-54	decimal (xxx.xx)	f6.2

33.1.4 FILTER STRIPS

A filter strip is a strip of dense vegetation located to intercept runoff from upslope pollutant sources and filter it. Filter strips remove contaminants by reducing overland flow velocity which results in the deposition of particulates. The filter strip area also acts as an area of increased infiltration, reducing both the runoff volume and non-particulate contaminants. The filter strip used algorithm used in SWAT was derived from White and Arnold (2009). Filter strips reduce sediment, nutrients, bacteria, and pesticides, but do not affect surface runoff in SWAT. The variables which may be entered on the pesticide application line are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. (Required)
DAY	Day operation takes place. (Required)
IYEAR	Year operation takes place. (Required)
MGT_OP	Management operation number. MGT_OP = 4 for filter strips.
FILTER_I	Flag for the simulation of filter strips (VFSI = 1/0 active/inactive).
FILTER_RATIO	Ratio of field area to filter strip area (ha^2/ ha^2). Ranges from 0 to 300 with values from 30-60 being most common. Default value is 40
FILTER_CON	Fraction of the HRU which drains to the most concentrated ten percent of the filters strip area (ha^2/ ha^2). Runoff generated upslope a filter strip is not uniformly distributed across the entire length of the strip. Ten percent of the filter strip can receive between 0.25 and 0.75 of the runoff from the entire filed. Default value is 0.5.
FILTER_CH	Fraction of the flow within the most concentrated ten percent of the filter strip which is fully channelized (dimensionless). Flow which is fully channelized is not subject to filtering or infiltration effects. Default value is 0.0

The format of the filter strips line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
IYEAR	space 12-15	4-digit integer	i4
MGT_OP	space 17-18	2-digit integer	i2
FILTER_I	space 20-23	4-digit integer	i4
FILTER_RATIO	space 29-34	decimal (xxx.xx)	f6.2
FILTER_CON	space 36-47	decimal (xxxxxx.xxxxx)	f12.5
FILTER_CH	space 49-54	decimal (xxx.xx)	f6.2

33.1.5 STRIP CROPPING

Strip cropping is the arrangement of bands of alternating crops within an agricultural field. The bands are generally positioned based on the contours of the field. Strip Cropping is simulated in SWAT by altering the Manning' N value for overland flow (STRIP_N) to represent increased surface roughness in the direction of runoff. Curve Number (STRIP_CN) may be adjusted to account for increased infiltration. USLE Cropping Factor (STRIP_C) may be adjusted to reflect the average value for multiple crops within the field. The USLE Practice factor may also be updated to represent strip cropping conditions. The variables which may be entered on the harvest and kill line are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. (Required)
DAY	Day operation takes place. (Required)
IYEAR	Year operation takes place. (Required)
MGT_OP	Management operation number. MGT_OP = 5 for strip cropping.
STRIP_N	Manning's N value for overland flow in strip cropped fields
STRIP_CN	SCS curve number II value for strip cropped fields
STRIP_C	USLE Cropping factor for strip cropped fields
STRIP_P	USLE Practice factor for strip cropped fields

The format of the strip cropping operation line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
IYEAR	space 12-15	4-digit integer	i4
MGT_OP	space 17-18	2-digit integer	i2
STRIP_N	space 36-47	decimal (xxxxxx.xxxxx)	f12.5
STRIP_CN	space 49-54	decimal (xxx.xx)	f6.2
STRIP_C	space 56-66	decimal (xxxxx.xxxxx)	f11.5
STRIP_P	space 68-75	decimal (xxxxx.xx)	f8.2

33.1.6 FIRE OPERATION

Fire may have a significant effect on hydrology which is represented via an adjustment to the curve number (FIRE_CN). Fire in SWAT does not account for biomass reduction due to fire. The variables for the tillage operation are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. (Required)
DAY	Day operation takes place. (Required)
IYEAR	Year operation takes place. (Required)
MGT_OP	Management operation number. MGT_OP = 6 for fire.
FIRE_CN	Post fire SCS curve number II value

The format of the fire operation line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
IYEAR	space 12-15	4-digit integer	i4
MGT_OP	space 17-18	2-digit integer	i2
FIRE_CN	space 36-47	decimal (xxxxxx.xxxxx)	f12.5

33.1.7 GRASS WATERWAYS OPERATION

Grassed waterways are vegetated channels which transport runoff from a field. Vegetation within the waterways reduces flow velocities, and protects the waterway from the scouring potential of concentrated flow. These are generally broad and shallow channels; the channel simulated in SWAT has a side slope of 8:1. Grasses waterways trap sediment and other contaminants by reducing flow velocities which increases deposition of particulate contaminates. The variables for the tillage operation are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. (Required)
DAY	Day operation takes place. (Required)
IYEAR	Year operation takes place. (Required)
MGT_OP	Management operation number. MGT_OP = 7 for grass waterways.
GWATI	Flag for the simulation of grass waterways (GWATI = 1/0 active/inactive).
GWATN	Manning's N value for overland flow. (Default 0.35)
GWATSPCON	Linear parameter for calculating sediment in Grassed waterways (default 0.005)

Variable name	Definition
GWATD	Depth of grassed waterway channel from top of bank to bottom (m). If no value of GWATD is entered, depth is set to 3/64 * GWATW
GWATW	Average width of grassed waterway (m) (Required)
GWATL	Length of grassed waterway (km). If no value for GWATL is entered, length defaults to a single side of a square HRU)
GWATS	Average slope of grassed waterway channel (m). If no value for GWATS is entered, the HRU slope * 0.75 is used.

The format of the grass waterways operation line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
IYEAR	space 12-15	4-digit integer	i4
MGT_OP	space 17-18	2-digit integer	i2
GWATI	space 20-23	4-digit integer	i4
GWATN	space 29-34	decimal (xxx.xx)	f6.2
GWATSPCON	space 36-47	decimal (xxxxxx.xxxxx)	f12.5
GWATD	space 49-54	decimal (xxx.xx)	f6.2
GWATW	space 56-66	decimal (xxxxx.xxxxx)	f11.5
GWATL	space 68-75	decimal (xxxxx.xx)	f8.2
GWATS	space 77-82	decimal (xx.xx)	f5.2

33.1.8 PLANT PARAMETER UPDATE

In modern agriculture, there is significant variability in individual cultivars. The rapid generation and adoption of improved varieties may be problematic in long simulations. The plant parameter update option allows new varieties with differing growth characteristics to be adopted mid-simulation. The variables for the tillage operation are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. (Required)
DAY	Day operation takes place. (Required)
IYEAR	Year operation takes place. (Required)
MGT_OP	Management operation number. MGT_OP = 8 for plant parameter update.
CROPNO_UPD	Updated crop number
HI_UPD	Updated harvest index
LAIMX_UPD	Updated maximum LAI

The format of the plant parameter update operation line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
IYEAR	space 12-15	4-digit integer	i4
MGT_OP	space 17-18	2-digit integer	i2
CROPNO_UPD	space 20-23	4-digit integer	i4
HI_UPD	space 36-47	decimal (xxxxxx.xxxxx)	f12.5
LAIMX_UPD	space 49-54	decimal (xxx.xx)	f6.2

33.2 REFERENCES

Haan, C.T., B.J. Barfield, and J.C. Hayes. 1994. Design hydrology and sedimentlogy for small catchments. New York: Academic Press.

CHAPTER 34

SWAT INPUT DATA: SEPTWQ.DAT

Information of water quality or effluent characteristics required to simulate different types of Onsite Wastewater Systems (OWSs) is stored in the septic water quality database. The database file distributed with SWAT includes water quality data for most of conventional, advanced, and failing septic systems. Information contained in the septic water quality database is septic tank effluent flow rate for per capita and effluent characteristics of various septic systems. The database is developed based on the field data summarized by Siegrist et al. (2005), McCray et al. (2005) and OWTS 201 (2005).

Following is a brief description of the variables in the septic water quality database file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first four lines of septwq.dat file are reserved for user comments. The title lines are not processed by the model and may be left blank. Required.

IST

Array storage number for a specific septic type

IST	Definition
1	Generic type conventional system
2	Generic type advanced system
3	Septic tank with conventional drainfield
4	Septic tank with SAS[a] type 1
5	Septic tank with SAS type 2
6	Septic tank with in-tank N removal and SAS
7	Septic tank with effluent N removal recycle
8	Septic tank with corrugated plastic trickling Filter
9	Septic tank with open-cell form trickling filter
10	Single pass sand filter 1
11	Single pass sand filter 2
12	Single pass sand filter 3
13	Single pass sand filter 4
14	At grade recirculating sand filter
15	Maryland style RSF[b]
16	RSF
17	Septic tank w/ constructed wetland and surface water discharge
18	Municipal wastewater w/ constructed wetland and surface water discharge 1
19	Municipal wastewater w/ constructed wetland and surface water discharge 2
20	Municipal wastewater w/ constructed wetland
21	Municipal wastewater w/ lagoon and constructed wetland
22	Waterloo biofilter (plastic media) 1
23	Waterloo biofilter (plastic media) 2
24	Peat biofilter
25	Recirculating textile filter
26	Foam or textile filter effluent
27	Septic, recirculating gravel filter, UV disinfection
28	Untreated Effluent - Texas A&M reference

a: Soil absorption system
b: Recirculating sand filter

Required.

Variable name	Definition
SPTNAME	Abridged name of a septic system

sptname	Definition
GCON	Generic type conventional system
GADV	Generic type advanced system
COND	Septic tank with conventional drainfield
SAS1	Septic tank with SAS[a] type 1
SAS2	Septic tank with SAS type 2
SAS3	Septic tank with in-tank N removal and SAS
SAS4	Septic tank with effluent N removal recycle
SAS5	Septic tank with corrugated plastic trickling Filter
SAS6	Septic tank with open-cell form trickling filter
SPF1	Single pass sand filter 1
SPF2	Single pass sand filter 2
SPF3	Single pass sand filter 3
SPF4	Single pass sand filter 4
RCF1	At grade recirculating sand filter
RCF2	Maryland style RSF[b]
RCF3	RSF
CWT1	Septic tank w/ constructed wetland and surface water discharge
CWT2	Municipal wastewater w/ constructed wetland and surface water discharge 1
CWT3	Municipal wastewater w/ constructed wetland and surface water discharge 2
CWT4	Municipal wastewater w/ constructed wetland
CWT5	Municipal wastewater w/ lagoon and constructed wetland
BFL1	Waterloo biofilter (plastic media) 1
BFL2	Waterloo biofilter (plastic media) 2
BFL3	Peat biofilter
TXF1	Recirculating textile filter
TXF2	Foam or textile filter effluent
GFL1	Septic, recirculating gravel filter, UV disinfection
USPT	Untreated Effluent - Texas A&M reference

a: Sand absorption system
b: Recirculating sand filter

Optional.

Variable name	Definition
SPTFULLNAME	Full name of a septic system This description is not used by the model and is present to assist the user in differentiating between septic systems. Optional.
IDSPTTYPE	Type of a septic system. There are three types of septic systems: conventional, advanced, and failing system. idspttype of 1 represents a conventional system, 2 is for an advanced system, and 3 indicates a system with no pretreatment. Generic systems for conventional and advanced types are available in case system specific information is not available. There are is three conventional and 22 advanced systems available in the septic water quality database. A system with no pretreatment is also defined as a type in the database. User can define a failing system in two ways: 1) set up a septic HRU as failing from the beginning of the simulation by defining *isep_opt* parameter as zero in *.sep files, or 2) a septic HRU turns failing during the simulation for any type of systems as a septic HRU gets clogged and hydraulic failure occurs. Septic systems constructed in areas of thin vadose zone may not operate successfully as groundwater table fluctuates. An advanced septic system has an advanced pretreatment system such as filters or recycling operations. Septic water quality database includes water quality information for 28 types of onsite septic systems. Required.

Variable name	Definition
SPTQ	Septic tank effluent (STE) flow rate (m^3/capita/day). McCray et al. (2005) proposed 0.227 m^3/capita/day as the median value for USA based on the data collected from various sources.

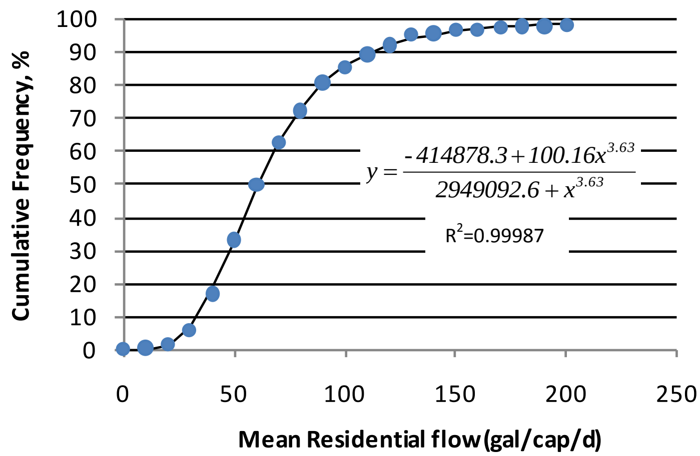

Figure 34.1 Cumulative frequency distribution for residential septic tank effluent flow rate (after McCray et al., 2005)

BOD	7 day Biochemical oxygen demand in STE (mg/L). BOD for a conventional system is typically 170 mg/L. The value varies greatly for different types of septic systems (See Table A-1 of Siegrist et al., 2005). Required.
TSS	Total suspended solids in STE (mg/L). TSS for a conventional system is typically 75 mg/L. The value varies greatly for different types of septic systems (See Table A-1 of Siegrist et al., 2005). Required.
TN	Total nitrogen in STE (mg-N/L). TN for a conventional system is typically 70 mg-N/L (ranging 12~453 mg-N/L). The value varies greatly for different types of septic systems (See Table A-1 of Siegrist et al., 2005). Required.

Variable name	Definition
NH_4	Ammonium nitrogen in STE (mg-N/L). NH_4 for a conventional system is typically 60 mg-N/L (ranging 17~78 mg-N/L). The value varies greatly for different types of septic systems (See Table A-1 of Siegrist et al., 2005).

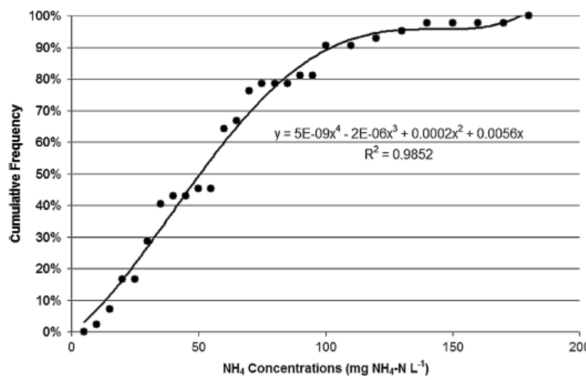

Figure 34.2 Cumulative frequency distribution for ammonium concentration in the septic tank effluent flow rate (after McCray et al., 2005)

Required.

Variable name	Definition
NO_3	Nitrate nitrogen in STE (mg-N/L). NO_3 for a conventional system ranges 0~1.94 mg-N/L. The value varies for different types of septic systems (See Table A-1 of Siegrist et al., 2005). Required.
NO_2	Nitrite nitrogen in STE (mg-N/L). NO_2 for a conventional system is typically very low. Required.
ORGN	Organic nitrogen in STE (mg-N/L). ORGN for a conventional system ranges 9.4~15 mg-N/L. Required.
TP	Total phosphorus in STE (mg-P/L). TP for a conventional system is typically 10 mg-P/L. The value varies for different types of septic systems (See Table A-1 of Siegrist et al., 2005). Required.

Variable name	Definition
PO_4	Phosphate phosphorus in STE (mg-P/L). PO_4 for a conventional system is typically 9 mg-P/L (ranging 1.2~21.8 mg-P/L).

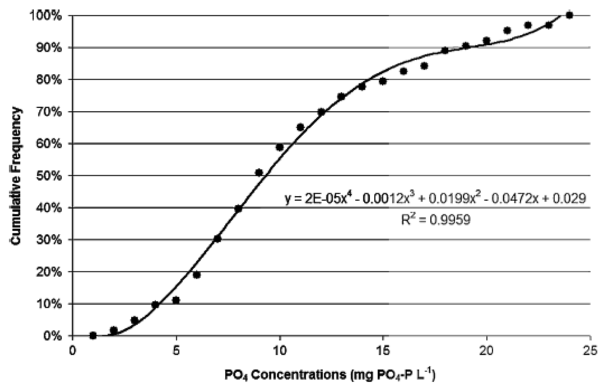

Figure 34.3 Cumulative frequency distribution for phosphate concentration in the septic tank effluent flow rate (after McCray et al., 2005)

Required.

Variable name	Definition
ORGP	Organic phosphorus in STE (mg-P/L). ORGP for a conventional system is typically 1 mg-p/L. Required.
FCOLI	Total number of fecal coliform in STE (cfu/100mL). FCOLI for a conventional system is typically 1E7 cfu/100mL. The value varies greatly for different types of septic systems (See Table A-1 of Siegrist et al., 2005). Required.

The format of the septic database input file is:

Variable name	Line #	Format	F90 Format
TITLE	1-4	Character	a80
IST	5	Integer	i3
SPTNAME	5	Character	a4
SPTFULLNAME	5	Character	a70
IDSPTTYPE	5	Integer	i4
SPTQ	6	Real	f8.3
BOD	6	Real	f8.3
TSS	6	Real	f8.3
TN	6	Real	f8.3
NH_4	6	Real	f8.3
NO_3	6	Real	f8.3
NO_2	6	Real	f8.3
ORGN	6	Real	f8.3
TP	6	Real	f8.3
PO_4	6	Real	f8.3
ORGP	7	Real	f8.3
FCOLI	7	Real	f11.1

Septic data for each septic system type is listed in three lines (e.g. lines 5-7 for GCON type) for 28 system types.

REFERENCES

McCray, J. E., S. L. Kirkland, R. L. Siegrist and G. D. Thyne (2005). "Model Parameters for Simulating Fate and Transport of On-Site Wastewater Nutrients." Ground Water **43**(4): 628-639.

Siegrist, R. L., J. McCray, L. Weintraub, C. Chen, J. Bagdol, P. Lemonds, S. Van Cuyk, K. Lowe, R. Goldstein and J. Rada (2005). Quantifying Site-Scale Processes and Watershed-Scale Cumulative Effects of Decentralized Wastewater Systems, Project No. WU-HT-00-27. Prepared for the National Decentralized Water Resources Capacity Development Project, Washington University, St. Louis, MO, by the Colorado School of Mines.

OWTS 201 (2005) Texas Corporative Extension, The Texas A&M University System

CHAPTER 35

SWAT INPUT DATA: .SEP

The Onsite Wastewater Systems (OWSs) input file contains information related to a diversity of features of OWSs within the subbasin. Data contained in the septic input file are: type of septic system, geometry of biozone, characteristics of biomass, and bio-physical reaction coefficients occurring in the biozone (Adapted from Siegrist et al., 2005).

Following is a brief description of the variables in the septic input file. They are listed in the order they appear within the file.

Variable name	**Definition**
TITLE	The first two lines of .sep file are reserved for user comments. The title line is not processed by the model and may be left blank.

ISEP_TYP The type of septic system

Type	Definition
1	Generic type conventional system
2	Generic type advanced system
3	Septic tank with conventional drainfield
4	Septic tank with SAS[a] type 1
5	Septic tank with SAS type 2
6	Septic tank with in-tank N removal and SAS
7	Septic tank with effluent N removal recycle
8	Septic tank with corrugated plastic trickling Filter
9	Septic tank with open-cell form trickling filter
10	Single pass sand filter 1
11	Single pass sand filter 2
12	Single pass sand filter 3
13	Single pass sand filter 4
14	At grade recirculating sand filter
15	Maryland style RSF[b]
16	RSF
17	Septic tank w/ constructed wetland and surface water discharge
18	Municipal wastewater w/ constructed wetland and surface water discharge 1
19	Municipal wastewater w/ constructed wetland and surface water discharge 2
20	Municipal wastewater w/ constructed wetland
21	Municipal wastewater w/ lagoon and constructed wetland
22	Waterloo biofilter (plastic media) 1
23	Waterloo biofilter (plastic media) 2
24	Peat biofilter
25	Recirculating textile filter
26	Foam or textile filter effluent
27	Septic, recirculating gravel filter, UV disinfection
28	Untreated Effluent - Texas A&M reference

a: Sand absorption system
b: Recirculating sand filter

Variable name	Definition
ISEP_IYR	Year the septic system became operational (eg 1980). If 0 is input for *isep_iyr*, the model assumes the septic system is in operation at the beginning of the simulation Required.
ISEP_OPT	Initial septic HRU operational condition. User can define the default condition of a septic HRU as either active (sep_opt=1), failing (sep_opt=2), or non-septic (sep_opt=0). An active system automatically becomes failing as biozone layer gets clogged over time. A failing system turns to an active system after user specified "number of days for rehabilitation" defined by *isep_tfail*. Required.
SEP_CAP	Number of permanent residents in the house. SEP_cap for a typical US residence is 2.5 and ranges 1~10000. Required.
BZ_AREA	Average area of drainfield of individual septic systems (m^2). Typically recommended drainfield area per person is about 40 to 70 (m^2). This varies from state to state in the United States. For a household with 2.5 people, generally a drainfield area of 100 (m^2) is recommended. User can modify the bz_area based on the number of people in a household. The bz_area and sep_cap may be modified appropriately to study the effects of larger population size using septic systems. Required
ISEP_TFAIL	Time until failing systems gets fixed (days). An active system becomes failing as the biozone gets clogged and hydraulic failure occurs. A failing system automatically turns active during the simulation and septic parameters are re-initialized to default values after the user specified number of days (days assigned for isep_tfail) for rehabilitation. The default value for *isep_tfail* is 70 days but it can range between 10~100000 days. For testing long term failure, isep_tfail can be increased as per the failing duration. isep_opt should be set at 2 for simulating failing conditions.. Required.

Variable name	Definition
BZ_Z	Depth to the top of biozone layer from the ground surface (mm). The thickness includes top soil layer and septic tank effluent (STE) distribution chamber including perforated pipe. The default is 500mm and the depth typically ranges between 10-10000mm. Required.
BZ_THK	Thickness of the biozone layer (mm). The biozone layer is thin soil layer underneath the STE distribution chamber where pollutants are degraded by naturally existing live biomass bacteria. The default thickness is 50mm and ranges 5~100mm. Required.
SEP_STRM_ DIST	Distance to the stream from the septic HRU (km) Currently not available.
SEP_DEN	Number of septic systems per square kilometer. Currently not available.
BIO_BD	Density of biomass (kg/m^3), typically in the range of 900~1100 kg/m^3. The default is 1000 kg/m^3. Required.
COEFF_BOD_ DC	BOD decay rate coefficient. Biozone BOD coefficient is normalized by the volume of biomass in the formula. The default value is 0.5 and the value ranges 0.1~ 5. Required.
COEFF_BOD_ CONV	A conversion factor representing the proportion of mass bacterial growth and mass BOD degraded in the STE. The default value is 0.32 and the value ranges 0.1~ 0.5. Required.
COEFF_FC1	Linear coefficient for calculation of field capacity in the biozone. The default value is 30 and the value ranges 0~ 50. Required.

Variable name	Definition
COEFF_FC2	Exponential coefficient for calculation of field capacity in the biozone. The default value is 0.8 and the value ranges 0.5~ 1. Required.
COEFF_FECAL	Fecal coliform bacteria decay rate coefficient. Biozone fecal coliform coefficient is normalized by the volume of biomass in the formula. The default value is 1.3 and the value ranges 0.5~ 2. Required.
COEFF_PLQ	Conversion factor for plaque from total dissolved solids. The default value is 0.1 and the value ranges 0.08~ 0.95. Required.
COEFF_MRT	Mortality rate coefficient. The default value is 0.5 and the value ranges 0.01~ 1. Required.
COEFF_RSP	Respiration rate coefficient. The default value is 0.16 and the value ranges 0.01~ 1. Required.
COEFF_SLG1	Linear coefficient for calculating the rate of biomass sloughing. The default value is 0.3 and the value ranges 0.01~ 0.5. Required.
COEFF_SLG2	Exponential coefficient for calculating the rate of biomass sloughing. The default value is 0.5 and the value ranges 0.1~ 2.5. Required.
COEFF_NITR	Nitrification rate coefficient. Biozone nitrification rate coefficient is normalized by the volume of biomass in the formula. The default value is 1.5 and the value ranges 0.1~ 300. Required.

Variable name	Definition
COEFF_DENITR	Denitrification rate coefficient. Biozone denitrification rate coefficient is normalized by the volume of biomass in the formula. The default value is 0.32 and the value ranges 0.1~50. Required.
COEFF_PDISTRB	Linear P sorption distribution coefficient (L/kg). The default value is 128 and the value ranges 1.4~478. Required.
COEFF_PSORPMAX	Maximum P sorption capacity (mg P/kg Soil). The default value is 850 and the value ranges 0~17600. Required.
COEFF_SOLPSLP	Slope of the linear effluent soluble P equation. The default value is 0.04 and the value ranges 0~0.3. Required.
COEFF_SOLPINTC	Intercept of the linear effluent soluble P equation. The default value is 3.1 and the value ranges 0~10. Required.

The septic input file is free format. However, it is advised that the free format variables be placed within 13th space and description for each variable follows on the same line with either comma separated or a tab space. Values for variables classified as integers should not include a decimal while values for variables classified as reals must contain a decimal point. A blank space denotes the end of an input value.

The format of the septic input file is:

Variable name	Line #	Format	F90 Format
TITLE	1	Character	a80
TITLE	2	Character	a80
ISEP_TYP	3	Integer	Free
ISEP_IYR	4	Integer	Free
ISEP_OPT	5	Integer	Free
SEP_CAP	6	Real	Free
BZ_AREA	7	Real	Free
ISEP_TFAIL	9	Integer	Free
BZ_Z	10	Real	Free
BZ_THK	11	Real	Free
SEP_STRM_DIST	12	Real	Free
SEP_DEN	13	Real	Free
BIO_BD	14	Real	Free
COEFF_BOD_DC	15	Real	Free
COEFF_BOD_CONV	16	Real	Free
COEFF_FC1	17	Real	Free
COEFF_FC2	18	Real	Free
COEFF_FECAL	19	Real	Free
COEFF_PLQ	20	Real	Free
COEFF_MRT	21	Real	Free
COEFF_RSP	22	Real	Free
COEFF_SLG1	23	Real	Free
COEFF_SLG2	24	Real	Free
COEFF_NITR	25	Real	Free
COEFF_DENITR	24	Real	Free
COEFF_PDISTRB	25	Real	Free
COEFF_PSORPMAX	25	Real	Free
COEFF_SOLPSLP	26	Real	Free
COEFF_SOLPINTC	27	Real	Free

REFERENCES

McCray, J. E., S. L. Kirkland, R. L. Siegrist and G. D. Thyne (2005). "Model Parameters for Simulating Fate and Transport of On-Site Wastewater Nutrients." Ground Water **43**(4): 628-639.

Siegrist, R. L., J. McCray, L. Weintraub, C. Chen, J. Bagdol, P. Lemonds, S. Van Cuyk, K. Lowe, R. Goldstein and J. Rada (2005). Quantifying Site-Scale Processes and Watershed-Scale Cumulative Effects of Decentralized Wastewater Systems, Project No. WU-HT-00-27. Prepared for the National Decentralized Water Resources Capacity Development Project, Washington University, St. Louis, MO, by the Colorado School of Mines.

CHAPTER 36

SWAT INPUT DATA: ATMO.ATM

The Atmospheric Deposition input file contains annual average atmospheric nitrogen deposition values including ammonium, nitrate, dry ammonium and dry nitrate. This file is optional.

ATMOSPHERIC DEPOSITION FILE (ATMO.ATM)

Following is a brief description of the variables in the atmospheric deposition input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first five lines of the atom.dat file are reserved for user comments. The title line is not processed by the model and may be left blank.
rammo_sub	Atmospheric deposition of ammonium (mg/l) values for entire watershed.
rcn_sub	Atmospheric deposition of nitrate (mg/l) for entire watershed.
drydep_nh4	Atmospheric dry deposition of ammonium (kg/ha/yr) for entire watershed.
drydep_no3	Atmospheric dry deposition of nitrates (kg/ha/yr) for entire watershed.

The septic input file is fixed format. The format for the atmospheric deposition input file is:

Variable name	Line #	Format	F90 Format
TITLE	1	character	a80
TITLE	2	character	a80
TITLE	3	character	a80
TITLE	4	character	a80
TITLE	5	character	a80
RAMMO_SUB	6	real	f10.3
RCN_SUB	7	real	f10.3
DRYDEP_NH4	8	real	f10.3
DRYDEP_NO3	9	real	f10.3

Included below is a CEAP National Project Technical Report entitled "Atmospheric Deposition of Nutrients" by Mauro DiLuzio.

1. Introduction

Atmospheric deposition occurs when airborne chemical compounds settle onto the land or water surface. Some of the most important chemical pollutants are those containing nitrogen or phosphorus. Nitrogen compounds are involved in acid rain, and both nitrogen and phosphorus compounds contribute to nutrient loadings. Nitrogen compounds can be deposited onto water and land surfaces through both wet and dry deposition mechanisms. Wet deposition occurs through the absorption of compounds by rain and snow as they fall carrying mainly nitrate (NO_3^-) and ammonium (NH_4^+); dry deposition is the direct adsorption of compounds to water or land surfaces and involves complex interactions between airborne nitrogen compounds and plant, water, soil, rock, or building surfaces.

The relative contribution of atmospheric deposition to total nutrient loadings is difficult to measure or indirectly assess, and many deposition mechanisms are not fully understood. Most studies and relatively extended data sets are available on wet deposition of nitrogen; dry deposition rates are not well defined. Phosphorus loadings due to atmospheric deposition have not been extensively studied and nation-wide extended data set were unavailable at the time of data preparation for the CEAP project. While research continues in these areas, data records generated by modeling approaches appear to be still under scrutiny.

A number of regional and local monitoring networks are operating in the U.S. mainly to address information targeting up to regional environmental issues. For instance the

Integrated Atmospheric Deposition Network (IADN) (Galarneau et al., 2006) that estimates deposition of toxic organic substances to the Great Lakes. Over the CONUS (conterminous United States), the National Atmospheric Deposition Program (NADP) National Trends Network (NTN) (NADP/NTN, 1995; NADP/NTN, 2000; Lamb and Van Bowersox, 2000) measures and ammonium in one-week rain and snow samples at nearly 240 regionally representative sites in the CONUS (Figure 1) and is considered the nation's primary source for wet deposition data.

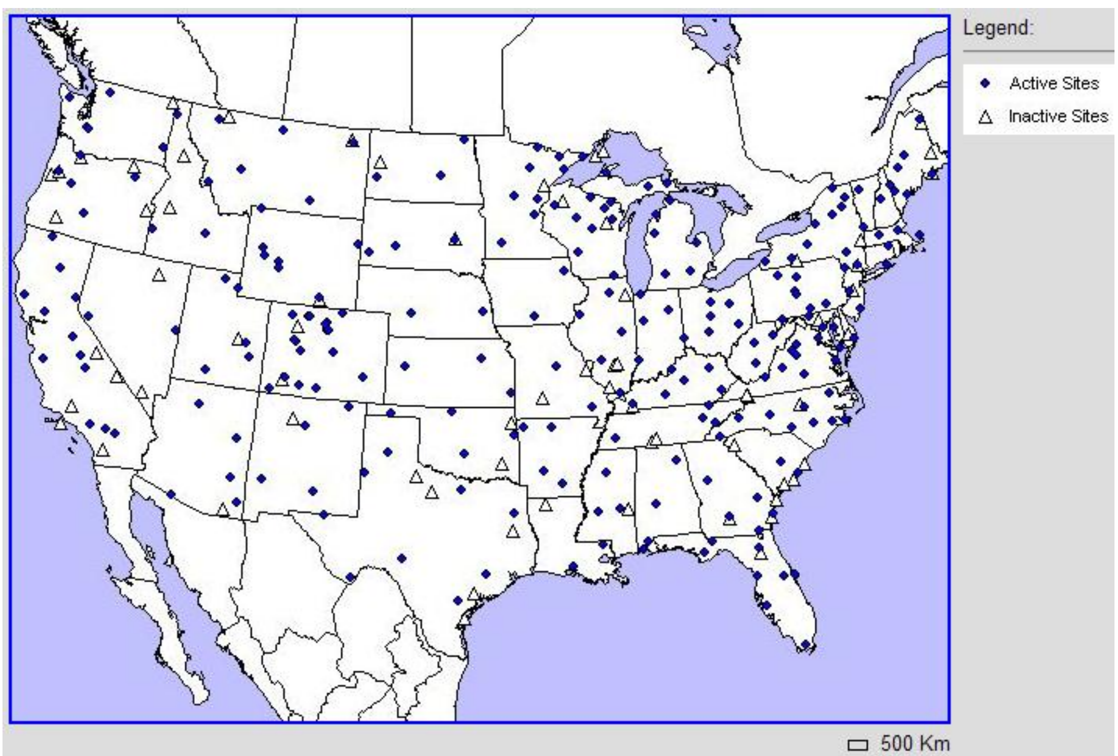

Figure 1. Location of NADP/NTN wet deposition sites

The U.S. Environmental Protection Agency Clean Air Status and Trends Network (CASTNET), developed form the National Dry Deposition Network (NDDN), operates a total of 86 operational sites (as for December 2007) located in or near rural areas and sensitive ecosystems (see Figure 2) collecting data on ambient levels of pollutants where urban influences are minimal (CASTNET, 2007). As part of an interagency agreement, the National Park Service (NPS) sponsors 27 sites which are located in national parks and other Class-I areas designated as deserving special protection from air pollution.

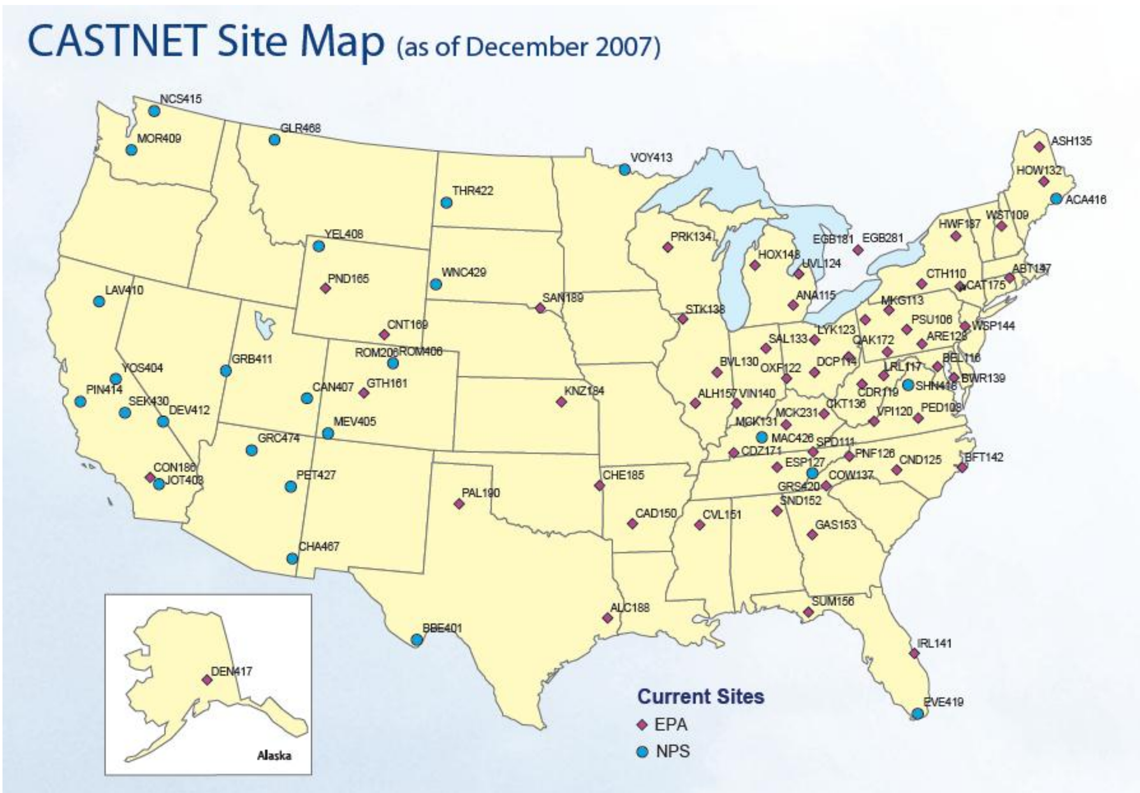

Figure 2. Location of the CASTNET dry deposition monitoring sites

NADP/NTN and CASTNET records are directly and/or indirectly the main sources of data for the CEAP national assessment project.

2. Nitrogen Wet Deposition concentration records for CEAP

The NADP publishes digital maps of nitrate and ammonium average yearly concentration (http://nadp.sws.uiuc.edu). Site records were previously validated for quality assurance (QA) and quality control (QC) before interpolation (Lehmann and Van Bowersox, 2003). For CEAP modeling, published digital maps in raster format, were elaborated in a Geographic Information System (GIS) environment to provide areal average on each 8-digit Hydrologic Units of the CONUS (USGS, 1994). Time series of yearly average concentrations of ammonium (NH_4^+) and nitrate (NO_3^-) were derived for each of the Hydrologic Units and for the period of data availability (1994-2006). Figure 3 plots the annual average estimated concentration of the ammonium ion for the period 1994-2006. Appendix 1 reports the averaged data and some spatial distribution statistics for each 8-digit area within the Upper Mississippi Basin.

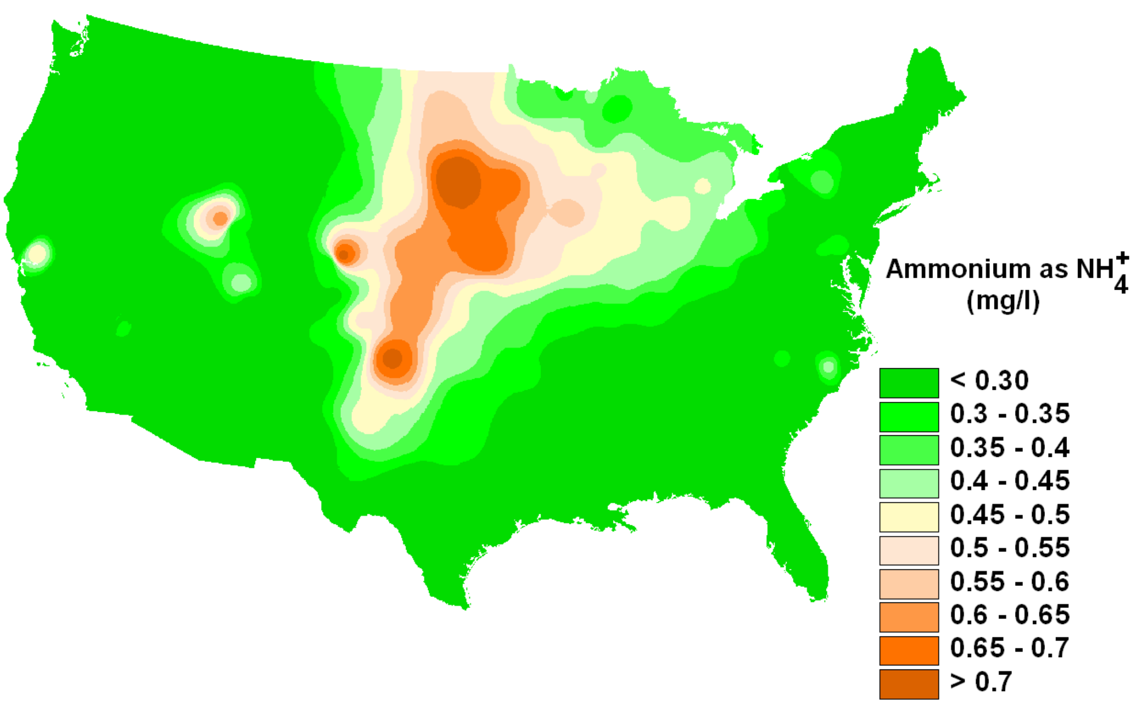

Figure 3 – Average annual ammonium (NH_4^+) concentration (mg/l) in the period 1994-2006. Derived from National Atmospheric Deposition Program/National Trends Network http://nadp.sws.uiuc.edu

Figure 4 plots the annual average estimated concentration of the nitrate ion for the period 1994-2006. Appendix 1 reports the same information and some spatial distribution statistics for each 8-digit area within the Upper Mississippi Basin.

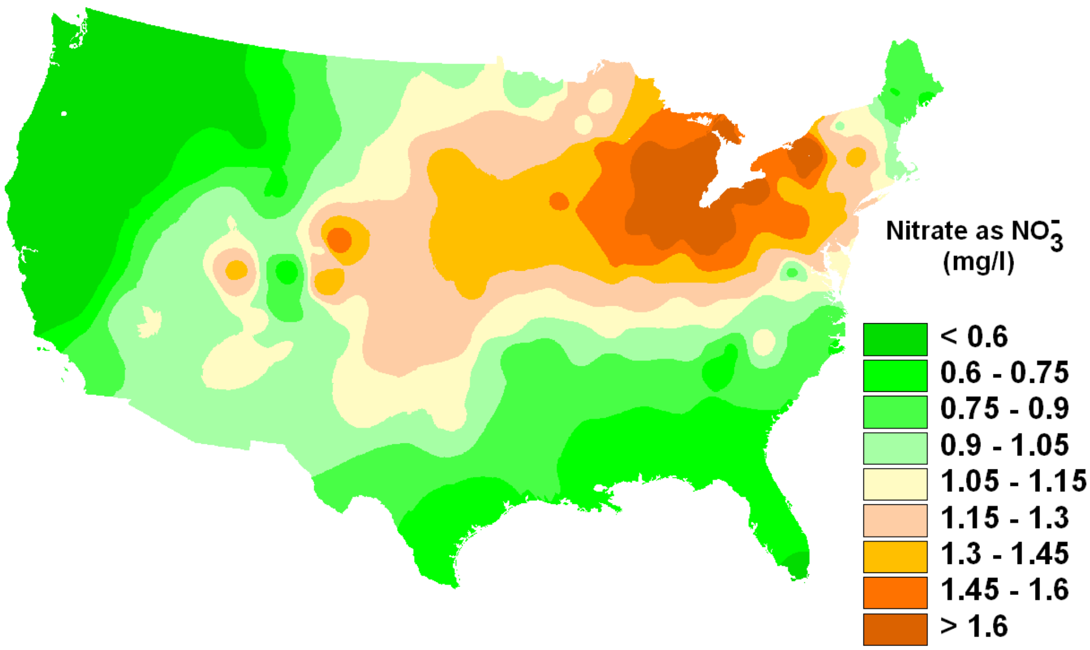

Figure 4 – Average annual nitrate (NO_3^-) concentration (mg/l) in the period 1994-2006.

Derived from National Atmospheric Deposition Program/National Trends Network
http://nadp.sws.uiuc.edu

3. Nitrogen Dry Deposition flux records for CEAP

Oak Ridge National Laboratory (ORNL) publishes maps of N deposition fluxes from site-network observations for the U.S, and Western Europe (Holland et al., 2005a). Observations from monitoring networks in the U.S. and Europe, were compiled in order to construct 0.5 x 0.5 degree resolution maps of N deposition by species. In the United States, measurements of ambient air concentrations, used to calculate dry deposition fluxes, were provided by the Clean Air Status and Trends Network (CASTNET) (CASTNET, 2007). The source data period extends from 1989 to 1994. The maps are necessarily restricted to the network measured quantities and consist of statistically (kriging) interpolated fields of particulate, ammonium (NH_4^+)' nitrate (NO_3^-), and gaseous nitric acid (HNO_3). A number of gaps remain in the data set including organic N and NH_3 deposition. The dry N deposition fluxes were estimated by multiplying interpolated surface air concentrations for each chemical species by model-calculated, spatially explicit deposition velocities (Holland et al., 2005b).

Figure 5, 6 and 7 shows the annual average dry Nitrogen, NH_4, NO_3, and HNO_3 flux, as published by ORNL.

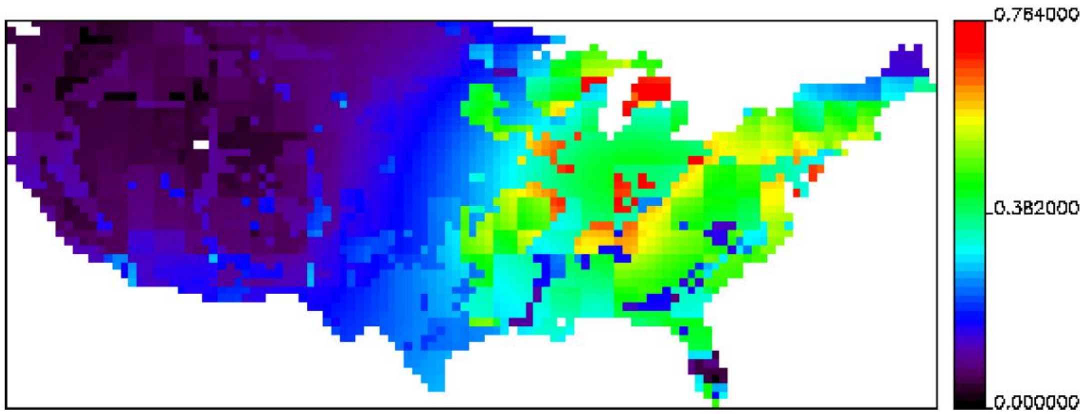

Figure 5 – Annual average dry NH_4 flux over the CONUS (kg N/ha/yr)

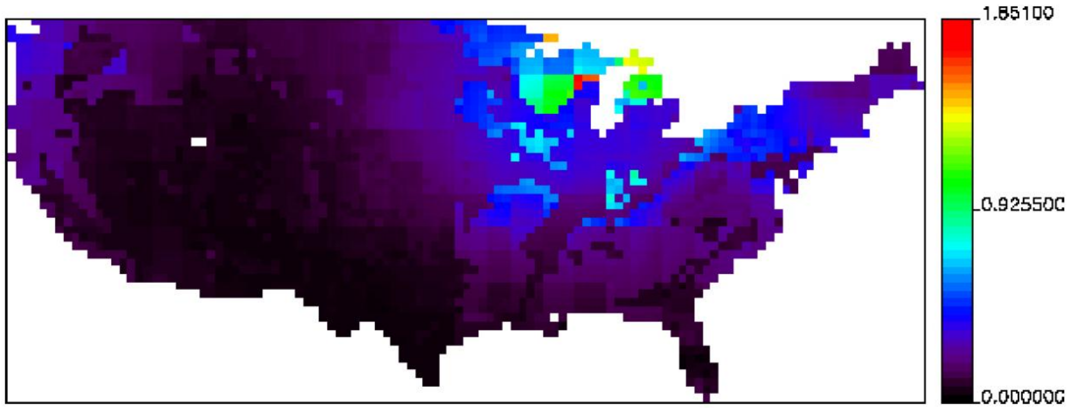

Figure 6 – Annual average dry NO_3 flux over the CONUS (kg N/ha/yr)

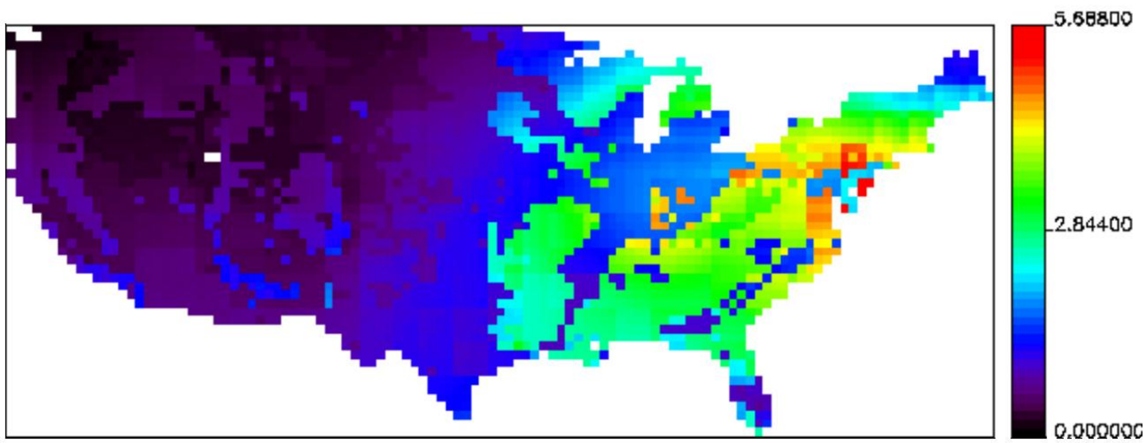

Figure 7 – Annual average dry HNO_3 flux over the CONUS (kg N /ha/yr)

In a Geographic Information System (GIS) environment, the spatially continuous annual average fields (NH_4, NO_3, and HNO_3) were spatially averaged on each Hydrologic Units of the CONUS (USGS, 1994). Appendix 2 reports the averaged data for each 8-digit area and some spatial distribution statistics for each 8-digit area within the Upper Mississippi Basin.

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Galarneau, E.; Bidleman, T. F.; Blanchard, P. Seasonality and interspecies differences in particle/gas partitioning of PAHs observed by the Integrated Atmospheric Deposition Network (IADN). Atmos. Environ. 2006, 40, 182-197.

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National Atmospheric Deposition Program (NRSP-3). 2009. NADP Program Office, Illinois State Water Survey, 2204 Griffith Dr., Champaign, IL 61820.

USGS, 1994: 1:250,000-scale Hydrologic Units of the United States. USGS Open-File Rep. 94-0236 [Available on line at **http://water.usgs.gov/GIS/metadata/usgswrd/XML/huc250k.xml**]

CHAPTER 37

SWAT INPUT DATA: LUP.DAT

The landuse update (hardwired filename = lup.dat) file is an optional file which allows HRU fraction updating during a simulation run. The lup.dat file is particularly useful to initialize conservation measures mid-simulation. After their initialization, the practices remain in effect for the remainder of the simulation. The day and relevant operational parameters must be specified.

37.1 LAND USE UPDATE FILE (LUP.DAT)

The lup.dat file is an optional file.

Variable name	Definition
NO_UP	Sequential number of update
MO	Month of update
IDAY	Day of update
IYEAR	Year of update
FNAM	The filename of the file that contains the fraction update parameters (see description of file in section 37.2.2)

The format of the landuse update file is:

Variable name	Position	Format	F90 Format
NO_UP	space 1-5	5-digit integer	i5
MO	space 6-10	5-digit integer	i5
IDAY	space 11-15	5-digit number	i5
IYEAR	space 16-20	5-digit integer	i5
FNAM	space 22-34	character	a13

37.2 DESCRIPTION OF FNAM FILE

This file contains the updated fraction values for any HRU. When adjusting the HRU fractions, keep in mind that all of the fractions in the HRU's should add up equal to 1.

Variable name	Definition
TITLDUM	The first line is reserved for user comments. This line is not processed by the model and may be left blank.
HRU	HRU number that has fraction update
HRU_FR	Updated HRU fraction value

The format of the fnam input file is free format. At least one space should be inserted between input variables on the same line.

Variable name	Line #	Format	F90 Format
TITLDUM	1	character	a13
HRU	2	integer	free
HRU_FR	2	real	free

CHAPTER 38

SWAT: CALIBRATION

One of the most common uses of SWAT is to evaluate the impact of alternative land management practices on stream water quality. To perform such a study, the user must first calibrate and validate the model for existing conditions. The calibration/validation process consists of three steps:

1) select some portion of observed data
2) run the model at different values for unknown parameters until fit to observations is good
3) apply model with calibrated parameters to remaining observations

For users setting up a SWAT watershed dataset without using a GIS interface to extract input data from maps, all input data is collected by the user. As a consequence, he/she usually has a very good feel for the level of accuracy connected to the input data. This is important knowledge to possess, because input variables whose values are estimated contain a higher uncertainty and should be the variables used to calibrate a model run.

The majority of users take advantage of the GIS interfaces (ArcView or GRASS) to quickly build SWAT watershed datasets. While these interfaces are invaluable for saving users a significant amount of time setting up a dataset, most users do not have a very good idea of how the interface sets values for input variables. Consequently the users do not have a good feel for which variables are best to use in calibration.

38.1 GIS INTERFACES AND CALIBRATION

The GIS interface for SWAT was originally developed in GRASS and then modified to run in ArcView. The algorithms used to process maps in both interfaces are the same.

The impetus for creation of a GIS interface was the HUMUS project. In this project, the entire contiguous United States was divided into 10 basins, with the 8-digit HUA boundaries defining subbasins. For such a large-scale project, assembling the SWAT datasets manually was impractical and the GIS interface was developed to process maps and assign values to required input variables. The implications of this history are:

- The GIS interfaces were designed for large-scale modeling. While the interface can most definitely be used to model small watersheds, the default parameter values assigned by the interface are highly generic. The interface does not vary input values based on watershed size or location in the world. For example, HRUs with corn growing on soil classified as hydrologic group D are assigned a curve number value of 80 whether they are in the United States or Europe, in an arid or tropical climate, on a 10% or 1% slope.
- The purpose of the GIS interfaces is to quickly build datasets so that the user is not spending a large amount of time manually creating input files for the model. To do this, many assumptions were incorporated into the

map processing. These assumptions may or may not be valid for a given watershed.

- The interface is not smarter than the user and it definitely does not know more about the watershed being studied than the user. The user should review all input values to ensure that they are correct. If the user knows the value to which a given input parameter should be set, the default value should be overwritten. To expect the interface to automatically set all input parameters to the ideal values for a watershed is unrealistic.

38.2 GENERAL CALIBRATION PROCEDURE

Calibration of a model run can be divided into several steps:

- calibration of water balance and stream flow
- calibration of sediment
- calibration of nutrients
- calibration of pesticides, etc.

Model results are calibrated for each of these components in succession.

38.3 CALIBRATION OF WATER BALANCE AND STREAM FLOW

To calibrate the water balance and stream flow you need to have some understanding of the actual conditions occurring in the watershed. Ideally, you have data from a stream gage located within or at the outlet of your watershed.

Calibration of stream flow is performed in two steps: calibration of average annual water balance and calibration of hydrograph shapes for daily stream flow graphs.

38.3.1 WATER BALANCE CALIBRATION

Normally the period of record used to calibrate and validate model results ranges from 2 to 10 years. This time period is usually restricted to the duration of data collection for a pollutant of concern in the watershed (i.e. nutrients, pesticides, bacteria, etc.). When the period of record is split into calibration and validation components, the actual time period of data used to calibrate the model

> The U.S. Geological Survey maintains a website (http://water.usgs.gov/) with daily records for all stream gages in the U.S. available for downloading.

Calibration for water balance and stream flow is first done for average annual conditions. Once the run is calibrated for average annual conditions, the user can shift to monthly or daily records to fine-tune the calibration.

The average annual observed and simulated results should be summarized in a manner similar to the following table:

	Total Water Yield	Baseflow	Surface Flow
Actual	200 mm	80 mm	120 mm
SWAT	300 mm	20 mm	280 mm

(When calibrating, we usually summarize data as depth of water in millimeters over the drainage area. Feel free to use whatever units you prefer.)

If you are calibrating at the watershed outlet, the SWAT values for the table are provided in the .std file. These values are listed in the table titled "Ave Annual Basin Values" located near the end of the .std file.

If you are calibrating a gage located within the watershed, the total water yield can be calculated from the FLOW_OUT variable in the reach (.rch) file. The values for Baseflow and Surface Flow have to be estimated from the HRU output (.sbs) file or the subbasin output file (.bsb). To estimate the contributions by baseflow and streamflow, the average annual values for GWQ, SURQ and WYLD need to be averaged so that an areally weighted value for the drainage area of interest is obtained. The surface flow and baseflow then need to be converted to fractions by dividing by the total water yield (WYLD). These fractions are then multiplied by the total water yield obtained from the reach output file. The values for GWQ and SURQ cannot be used directly because in-stream precipitation, evaporation, transmission losses, etc. will alter the net water yield from that predicted by the WYLD variable in the HRU or Subbasin Output files.

There are a number of methods available for partitioning observed stream flow into fractions contributed by baseflow and surface runoff. If daily steam flow is available, a baseflow filter program can be run which performs this analysis.

38.3.1.1 BASIC WATER BALANCE & TOTAL FLOW CALIBRATION

To calibrate for basic water balance and total flow follow the steps listed below:

Step 1: Adjust the curve number (CN2 in .mgt) until surface runoff is acceptable. Tables 38-1 through 38-4[1] contains curve number values for a wide variety of land covers. Table 38-5 summarizes the ranges for the general categories of land cover and lists the land cover category for all plants in the SWAT Land Cover/Plant database.

If surface runoff values are still not reasonable after adjusting curve numbers, adjust:-soil available water capacity (±0.04) (SOL_AWC in .sol) and/or soil evaporation compensation factor (ESCO in .bsn or .hru).

Step 2: Once surface runoff is calibrated, compare measured and simulated values of baseflow. If simulated baseflow is too high:

- increase the groundwater "revap" coefficient (GW_REVAP in .gw)—the maximum value that GW_REVAP should be set at is 0.20.
- decrease the threshold depth of water in the shallow aquifer for "revap" to occur (REVAPMN in .gw)—the minimum value that REVAPMN should be set at is 0.0.
- increase the threshold depth of water in the shallow aquifer required for base flow to occur (GWQMN in

[1] Tables 38-1 through 38-4 are reproduced from Urban Hydrology for Small Watersheds, USDA Soil Conservation Service Engineering Division, Technical Release 55, June 1986.

.gw)—the maximum value that GWQMN should be set at is left to user discretion.

If simulated baseflow is too low, check the movement of water into the aquifer. If groundwater recharge (GWQ in .sbs or .bsb) is greater than or equal to the desired baseflow:

- decrease the groundwater "revap" coefficient (GW_REVAP in .gw)—the minimum value that GW_REVAP should be set at is 0.02.
- increase the threshold depth of water in the shallow aquifer for "revap" to occur (REVAPMN in .gw).
- decrease the threshold depth of water in the shallow aquifer required for base flow to occur (GWQMN in .gw)—the minimum value that GWQMN should be set at is 0.0.

Step 3: Repeat steps 1 and 2 until values are acceptable. It may take several reiterations to get the surface runoff and baseflow correct.

Table 38.1: Runoff curve numbers for cultivated agricultural lands

Cover			Hydrologic Soil Group			
Land Use	**Treatment or practice**	**Hydrologic condition**	**A**	**B**	**C**	**D**
Fallow	Bare soil	- - - -	77	86	91	94
	Crop residue cover*	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row	Poor	72	81	88	91
		Good	67	78	85	89
	Straight row w/ residue	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured w/ residue	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced	Poor	66	74	80	82
		Good	62	71	78	81
	Contoured & terraced w/ residue	Poor	65	73	79	81
		Good	61	70	77	80
Small grains	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Straight row w/ residue	Poor	64	75	83	86
		Good	60	72	80	84
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured w/ residue	Poor	62	73	81	84
		Good	60	72	80	83
	Contoured & terraced	Poor	61	72	79	82
		Good	59	70	78	81
	Contoured & terraced w/ residue	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation	Straight row	Poor	66	77	85	89
		Good	58	72	81	85
	Contoured	Poor	64	75	83	85
		Good	55	69	78	83
	Contoured & terraced	Poor	63	73	80	83
		Good	51	67	76	80

* Crop residue cover applies only if residue is on at least 5% of the surface throughout the year.

Table 38.2: Runoff curve numbers for other agricultural lands

Cover		Hydrologic Soil Group			
Cover Type	**Hydrologic condition**	**A**	**B**	**C**	**D**
Pasture, grassland, or range—continuous forage for grazing[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	- - - -	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30	48	65	73
Woods—grass combination (orchard or tree farm)	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods[4]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	- - - -	59	74	82	86

[2] *Poor:* < 50% ground cover or heavily grazed with no mulch
Fair: 50 to 75% ground cover and not heavily grazed
Good: > 75% ground cover and lightly or only occasionally grazed

[3] *Poor:* < 50% ground cover
Fair: 50 to 75% ground cover
Good: > 75% ground cover

[4] *Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Table 38.3: Runoff curve numbers for urban areas

Cover Type	Hydrologic condition	Average % impervious area	Hydrologic Soil Group A	B	C	D
Fully developed urban areas						
Open spaces (lawns, parks, golf courses, cemeteries, etc.)[5]	Poor		68	79	86	89
	Fair		49	69	79	84
	Good		39	61	74	80
Impervious areas:						
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)	- - - -		98	98	98	98
Paved streets and roads; curbs and storm sewers (excluding right-of-way)	- - - -		98	98	98	98
Paved streets and roads; open ditches (including right-of-way)	- - - -		83	89	92	93
Gravel streets and roads (including right-of-way)	- - - -		76	85	89	91
Dirt streets and roads (including right-of way)	- - - -		72	82	87	89
Urban districts:						
Commercial and business		85%	89	92	94	95
Industrial		72%	81	88	91	93
Residential Districts by average lot size:						
1/8 acre (0.05 ha) or less (town houses)		65%	77	85	90	92
1/4 acre (0.10 ha)		38%	61	75	83	87
1/3 acre (0.13 ha)		30%	57	72	81	86
1/2 acre (0.20 ha)		25%	54	70	80	85
1 acre (0.40 ha)		20%	51	68	79	84
2 acres (0.81 ha)		12%	46	65	77	82
Developing urban areas:						
Newly graded areas (pervious areas only, no vegetation)			77	86	91	94

[5] *Poor:* grass cover < 50%
Fair: grass cover 50 to 75%
Good: grass cover > 75%

Table 38.4: Runoff curve numbers for arid and semiarid rangelands

Cover		Hydrologic Soil Group			
Cover Type	**Hydrologic condition**[6]	**A**	**B**	**C**	**D**
Herbaceous—mixture of grass, weeds, and low-growing brush, with brush the minor element.	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush.	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper—pinyon, juniper, or both: grass understory.	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory.	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub—major plants include saltbrush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite, and cactus.	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

[6] *Poor:* < 30% ground cover (litter, grass, and brush overstory)
Fair: 30 to 70% ground cover
Good: > 70% ground cover

Table 38.5: Guideline runoff curve number ranges

	Hydrologic Soil Group			
Land Cover Category	**A**	**B**	**C**	**D**
Row crop	61-72	70-81	77-88	80-91
Small grain/close grown crop	58-65	69-76	77-84	80-88
Perennial grasses	30-68	58-79	71-86	78-89
Annual grasses (close-seeded legumes)	51-66	67-77	76-85	80-89
Range	39-68	61-79	74-86	80-89
Semiarid/arid range	39-74	62-80	74-87	85-93
Brush	30-48	48-67	65-77	73-83
Woods	25-45	55-66	70-77	77-83
Orchard/tree farm	32-57	58-73	72-82	79-86
Urban	46-89	65-92	77-94	82-95

38.3.1.2 TEMPORAL FLOW CALIBRATION

Once average annual and annual surface runoff and baseflow are realistic, the temporal flow should look reasonable as well. A few problems that may still be present, which are discussed below.

Peaks are reasonable, but the recessions "bottom out" (Figure 38.1) Check the transmission losses/values for channel hydraulic conductivity (CH_K in .rte). The value for channel hydraulic conductivity is an *effective* hydraulic conductivity for movement of water **out** of the stream bed.

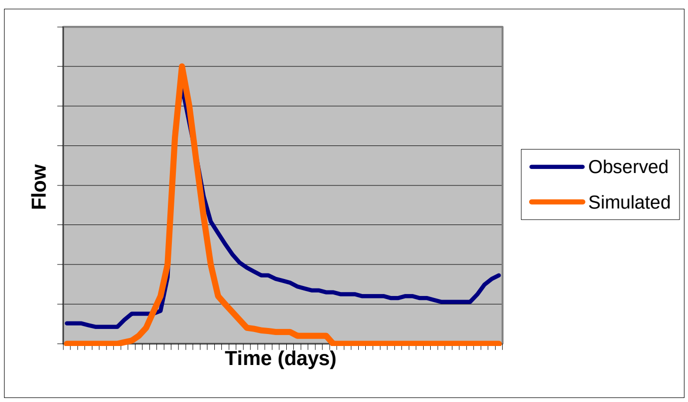

Figure 38.1 Peak flow calibration results.

For perennial streams receiving groundwater contribution to flow, the groundwater enters the stream through the sides and bottom of the stream bed, making the effective hydraulic conductivity of the channel beds to water losses equal to zero. The only time the channel hydraulic conductivity would be greater than zero is for ephemeral and transient streams that do not receive continuous groundwater contributions to streamflow.

A second variable that will affect the shape of the hydrograph is the baseflow alpha factor (ALPHA_BF in .gw).

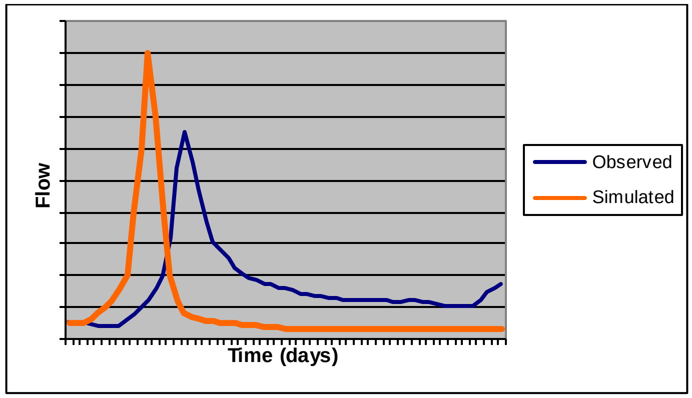

Figure 38.2 Simulated hydrograph with over predicted peak flow and under predicted base flow.

In snow melt months, the peaks are too high and recessions are too low (Figure 38.2): Check the values for maximum and minimum melt rates for snow (SMFMX and SMFMN in .bsn). These values may need to be lowered. Another variable that will impact snow melt is the temperature lapse rate (TLAPS in .sub). These values may need to be increased. Finally, the baseflow alpha factor may need to be modified (ALPHA_BF in .gw).

38.3.1.3 SPATIAL FLOW CALIBRATION

If you are calibrating a watershed with multiple stream gages, calibrate streamflow for the gage furthest upstream. Once that gage is calibrated, move downstream to the next gage and calibrate for that area. It is important that as you calibrate downstream gages you do not change parameters within the files associated with the drainage area of the upstream gages already calibrated.

38.4 SEDIMENT

There are two sources of sediment in the SWAT simulation: loadings from HRUs/subbasins and channel degradation/deposition. Once the ratio of surface runoff to baseflow contribution to streamflow is being simulated correctly, the sediment contribution (loadings from HRUs/subbasins) should be close to measured values. In most situations, the user will probably have little information about channel degradation/deposition. For those unable to directly assess the channel, we suggest that you adjust the loadings from the subbasins until they look reasonable and then assume that the remaining difference between actual and observed is due to channel degradation/deposition.

The average annual observed and simulated results should be summarized in a manner similar to Table 38.6. A more detailed table which contains the loadings by land use on a given soil type may also be used.

Table 38.6. Sediment Yields from Multiple Land uses

	Sediment (metric tons/yr)	Sediment (metric tons/ha/yr)
Loadings from mixed forest	187	0.14
Loadings from bermuda pasture	354	0.23
Loadings from range	1459	0.35
Loading from HRUs/subbasins	2,000	0.28
Amount of sediment leaving reach	2,873	
Actual	2,321	

Sediment loadings from the HRUs/subbasins can be calculated by summing values for SYLD in either the .sbs or .bsb file. The amount of sediment leaving the reach can be obtained from values reported for SED_OUT in the .rch file.

38.4.1 CHECK RESERVOIR/POND SIMULATION:

Reservoirs and ponds have a significant impact on sediment loadings. If the amount of sediment being simulated in the watershed is off, first verify that you are accounting for all the ponds and reservoirs in the watershed and that they are being simulated properly.

38.4.2 CALIBRATE SUBBASIN LOADINGS:

While surface runoff is the primary factor controlling sediment loadings to the stream, there are a few other variables that affect sediment movement into the stream as listed below.

1) Tillage has a great impact on sediment transport. With tillage, plant residue is removed from the surface causing erosion to increase. Verify that the tillage practices are being accurately simulated.
2) USLE equation support practices (P) factor (USLE_P in the .mgt file): Verify that you have accurately accounted for contouring and terracing in agricultural areas. In general, agricultural land with a slope greater that 5% will be terraced.
3) USLE equation slope length factor (SLSUBBSN in .hru file): There is usually a large amount of uncertainty in slope length measurements. The slope length will also be affected by support practices used in the HRU.
4) Slope in the HRUs (SLOPE in .hru file): Verify that the slopes given for the subbasin are correct.
5) USLE equation cropping practices (C) factor (USLE_C in crop.dat): In some cases, the minimum C value reported for the plant cover may not be accurate for your area.

38.4.3 CALIBRATE CHANNEL DEGRADATION/DEPOSITION:

Channel degradation will be significant during extreme storm events and in unstable subbasins. Unstable subbasins are those undergoing a significant change in land use patterns such as urbanization. Variables that affect channel degradation/deposition include:

1) The linear and exponential parameters used in the equation to calculate sediment reentrained in channel sediment routing (SPCON and SPEXP in .bsn file). These variables affect sediment routing in the entire watershed.
2) The channel erodibility factor (CH_EROD in .rte)
3) The channel cover factor (CH_COV in .rte)

38.5 NUTRIENTS

The nutrients of concern in SWAT are nitrate, soluble phosphorus, organic nitrogen and organic phosphorus. When calibrating for a nutrient, keep in mind that changes made will have an effect all the nutrient levels. Nutrient calibration can be divided into two steps: calibration of nutrient loadings and calibration of in-stream water quality processes.

38.5.1 CALIBRATE NUTRIENT LOADINGS (ALL NUTRIENTS)

1) Check that the initial concentrations of the nutrients in the soil are correct. These variables are set in the soil chemical input file (.chm):
    - nitrate (SOL_NO3 in .chm)
    - soluble P (SOL_MINP in .chm)
    - organic N (SOL_ORGN in .chm)
    - organic P (SOL_ORGP in .chm)

1) Verify that fertilizer applications are correct. Check amounts and the soil layer that the fertilizer is applied to. The fertilizer may be applied to the top 10mm of soil or incorporated in the first soil layer. The variable FRT_LY1 identifies the fraction of fertilizer applied to the top 10mm of soil. (If this variable is left at zero, the model will set FRT_LY1 = 0.20).
2) Verify that tillage operations are correct. Tillage redistributes nutrients in the soil and will alter the amount available for interaction or transport by surface runoff.
3) Alter the biological mixing efficiency (BIOMIX in .mgt file). Biological mixing acts the same as a tillage operation in that it incorporates residue and nutrients into the soil.
4) This variable controls mixing due to biological activity in the entire watershed.

38.5.2 CALIBRATE NUTRIENT LOADINGS (SPECIFIC NUTRIENTS)

In addition to the variables for all nutrients mentioned above, modifications for nitrate, soluble P and organic N and P may be made.

- Modify the nitrogen percolation coefficient (NPERCO in .bsn file)
- Modify the phosphorus percolation coefficient (PPERCO in .bsn file)
- Modify the phosphorus soil partitioning coefficient (PHOSKD in .bsn file).
- Organics are transported to the stream attached to sediment, so the movement of sediment will greatly impact the movement of organics.

38.5.3 CALIBRATE IN-STREAM NUTRIENT PROCESSES

SWAT includes in-stream nutrient cycling processes as described in the QUAL2E documentation. Variables in the watershed water quality (.wwq) and stream water quality (.swq) files control these processes.

CHAPTER 39

SWAT INPUT DATA: .SNO

Users can input snow variables by elevation band for each subbasin. If these values are not input, all variable default back to the snow related variables in the .bsn file (see Chapter 4)

The .sno file is an optional file.

Variable name	Definition
SUB_SFTMP	Snowfall temperature (ºC). Mean air temperature at which precipitation is equally likely to be rain as snow/freezing rain. The snowfall temperature should be between –5 ºC and 5 ºC. A default recommended for this variable is SFTMP = 1.0. Required in watersheds where snowfall is significant.
SUB_SMTMP	Snow melt base temperature (ºC). The snow pack will not melt until the snow pack temperature exceeds a threshold value, T_{mlt}. The snow melt base temperature should be between –5 ºC and 5 ºC. A default recommended for this variable is SMTMP = 0.50. Required in watersheds where snowfall is significant.
SUB_SMFMX	Melt factor for snow on June 21 (mm H_2O/ºC-day). If the watershed is in the Northern Hemisphere, SMFMX will be the maximum melt factor. If the watershed is in the Southern Hemisphere, SMFMX will be the minimum melt factor. SMFMX and SMFMN allow the rate of snow melt to vary through the year. The variables account for the impact of snow pack density on snow melt. In rural areas, the melt factor will vary from 1.4 to 6.9 mm H_2O/day-°C (Huber and Dickinson, 1988). In urban areas, values will fall in the higher end of the range due to compression of the snow pack by vehicles, pedestrians, etc. Urban snow melt studies in Sweden (Bengston, 1981; Westerstrom, 1981) reported melt factors ranging from 3.0 to 8.0 mm H_2O/day-°C. Studies of snow melt on asphalt (Westerstrom, 1984) gave melt factors of 1.7 to 6.5 mm H_2O/day-°C. If no value for SMFMX is entered, the model will set SMFMX = 4.5. Required in watersheds where snowfall is significant.

Variable name	Definition
SUB_SMFMN	Melt factor for snow on December 21 (mm H_2O/ºC-day). If the watershed is in the Northern Hemisphere, SMFMN will be the minimum melt factor. If the watershed is in the Southern Hemisphere, SMFMN will be the maximum melt factor. SMFMX and SMFMN allow the rate of snow melt to vary through the year. The variables account for the impact of snow pack density on snow melt. In rural areas, the melt factor will vary from 1.4 to 6.9 mm H_2O/day-°C (Huber and Dickinson, 1988). In urban areas, values will fall in the higher end of the range due to compression of the snow pack by vehicles, pedestrians, etc. Urban snow melt studies in Sweden (Bengston, 1981; Westerstrom, 1981) reported melt factors ranging from 3.0 to 8.0 mm H_2O/day-°C. Studies of snow melt on asphalt (Westerstrom, 1984) gave melt factors of 1.7 to 6.5 mm H_2O/day-°C. If no value for SMFMN is entered, the model will set SMFMN = 4.5. Required in watersheds where snowfall is significant.
SUB_TIMP	Snow pack temperature lag factor. The influence of the previous day's snow pack temperature on the current day's snow pack temperature is controlled by a lagging factor, ℓ_{sno}. The lagging factor inherently accounts for snow pack density, snow pack depth, exposure and other factors affecting snow pack temperature. TIMP can vary between 0.01 and 1.0. As ℓ_{sno} approaches 1.0, the mean air temperature on the current day exerts an increasingly greater influence on the snow pack temperature and the snow pack temperature from the previous day exerts less and less influence. As TIMP goes to zero, the snow pack's temperature will be less influenced by the current day's air temperature. If no value for TIMP is entered, the model will set TIMP = 1.0. Required in watersheds where snowfall is significant.

The format of the snow update file is:

Variable name	Line #	Position	Format	F90 Format
SUB_SFTMP(1)	1	space 1-8	Decimal (xxxx.xxx)	f8.3
SUB_SFTMP(2)	1	space 9-16	Decimal (xxxx.xxx)	f8.3
SUB_SFTMP(3)	1	space 17-24	Decimal (xxxx.xxx)	f8.3
SUB_SFTMP(4)	1	space 25-32	Decimal (xxxx.xxx)	f8.3
SUB_SFTMP(5)	1	space 33-40	Decimal (xxxx.xxx)	f8.3
SUB_SFTMP(6)	1	space 41-48	Decimal (xxxx.xxx)	f8.3
SUB_SFTMP(7)	1	space 49-56	Decimal (xxxx.xxx)	f8.3
SUB_SFTMP(8)	1	space 57-64	Decimal (xxxx.xxx)	f8.3
SUB_SFTMP(9)	1	space 65-72	Decimal (xxxx.xxx)	f8.3
SUB_SFTMP(10)	1	space 73-80	Decimal (xxxx.xxx)	f8.3
SUB_SMTMP(1)	2	space 1-8	Decimal (xxxx.xxx)	f8.3
SUB_SMTMP(2)	2	space 9-16	Decimal (xxxx.xxx)	f8.3
SUB_SMTMP(3)	2	space 17-24	Decimal (xxxx.xxx)	f8.3
SUB_SMTMP(4)	2	space 25-32	Decimal (xxxx.xxx)	f8.3
SUB_SMTMP(5)	2	space 33-40	Decimal (xxxx.xxx)	f8.3
SUB_SMTMP(6)	2	space 41-48	Decimal (xxxx.xxx)	f8.3
SUB_SMTMP(7)	2	space 49-56	Decimal (xxxx.xxx)	f8.3
SUB_SMTMP(8)	2	space 57-64	Decimal (xxxx.xxx)	f8.3
SUB_SMTMP(9)	2	space 65-72	Decimal (xxxx.xxx)	f8.3
SUB_SMTMP(10)	2	space 73-80	Decimal (xxxx.xxx)	f8.3
SUB_SMFMX(1)	3	space 1-8	Decimal (xxxx.xxx)	f8.3
SUB_SMFMX(2)	3	space 9-16	Decimal (xxxx.xxx)	f8.3
SUB_SMFMX(3)	3	space 17-24	Decimal (xxxx.xxx)	f8.3
SUB_SMFMX(4)	3	space 25-32	Decimal (xxxx.xxx)	f8.3
SUB_SMFMX(5)	3	space 33-40	Decimal (xxxx.xxx)	f8.3
SUB_SMFMX(6)	3	space 41-48	Decimal (xxxx.xxx)	f8.3
SUB_SMFMX(7)	3	space 49-56	Decimal (xxxx.xxx)	f8.3
SUB_SMFMX(8)	3	space 57-64	Decimal (xxxx.xxx)	f8.3
SUB_SMFMX(9)	3	space 65-72	Decimal (xxxx.xxx)	f8.3
SUB_SMFMX(10)	3	space 73-80	Decimal (xxxx.xxx)	f8.3

Variable name	Line #	Position	Format	F90 Format
SUB_SMFMN(1)	4	space 1-8	Decimal (xxxx.xxx)	f8.3
SUB_SMFMN(2)	4	space 9-16	Decimal (xxxx.xxx)	f8.3
SUB_SMFMN(3)	4	space 17-24	Decimal (xxxx.xxx)	f8.3
SUB_SMFMN(4)	4	space 25-32	Decimal (xxxx.xxx)	f8.3
SUB_SMFMN(5)	4	space 33-40	Decimal (xxxx.xxx)	f8.3
SUB_SMFMN(6)	4	space 41-48	Decimal (xxxx.xxx)	f8.3
SUB_SMFMN(7)	4	space 49-56	Decimal (xxxx.xxx)	f8.3
SUB_SMFMN(8)	4	space 57-64	Decimal (xxxx.xxx)	f8.3
SUB_SMFMN(9)	4	space 65-72	Decimal (xxxx.xxx)	f8.3
SUB_SMFMN(10)	4	space 73-80	Decimal (xxxx.xxx)	f8.3
SUB_TIMP(1)	3	space 1-8	Decimal (xxxx.xxx)	f8.3
SUB_TIMP(2)	3	space 9-16	Decimal (xxxx.xxx)	f8.3
SUB_TIMP(3)	3	space 17-24	Decimal (xxxx.xxx)	f8.3
SUB_TIMP(4)	3	space 25-32	Decimal (xxxx.xxx)	f8.3
SUB_TIMP(5)	3	space 33-40	Decimal (xxxx.xxx)	f8.3
SUB_TIMP(6)	3	space 41-48	Decimal (xxxx.xxx)	f8.3
SUB_TIMP(7)	3	space 49-56	Decimal (xxxx.xxx)	f8.3
SUB_TIMP(8)	3	space 57-64	Decimal (xxxx.xxx)	f8.3
SUB_TIMP(9)	3	space 65-72	Decimal (xxxx.xxx)	f8.3
SUB_TIMP(10)	3	space 73-80	Decimal (xxxx.xxx)	f8.3

APPENDIX A

MODEL DATABASES

The following sections describe the source of input for databases included with the model and any assumptions used in compilation of the database. Also, a methodology for appending additional information to the various databases is summarized.

A.1 LAND COVER/PLANT GROWTH DATABASE

The land cover/plant growth database contains information needed by SWAT to simulate the growth of a particular land cover. The growth parameters in the plant growth database define plant growth under ideal conditions and quantify the impact of some stresses on plant growth.

Table A-1 lists all the default plant species and Table A-2 lists all the generic land covers included in the database. When adding a new plant/land cover to the database, a review of existing literature should provide most of the parameter values needed to simulate plant growth. For users that plan to collect the data directly, the following sections briefly describe the methods used to obtain the plant growth parameters needed by SWAT.

Table A-1: Plants included in plant growth database.

Common Name	Plant Code	Taxonomic Name	Plant type
Corn	CORN	*Zea mays* L.	warm season annual
Corn silage	CSIL	*Zea mays* L.	warm season annual
Sweet corn	SCRN	*Zea mays* L. *saccharata*	warm season annual
Eastern gamagrass	EGAM	*Tripsacum dactyloides* (L.) L.	perennial
Grain sorghum	GRSG	*Sorghum bicolor* L. (Moench)	warm season annual
Sorghum hay	SGHY	*Sorghum bicolor* L. (Moench)	warm season annual
Johnsongrass	JHGR	*Sorghum halepense* (L.) Pers.	perennial
Sugarcane	SUGC	*Saccharum officinarum* L.	perennial
Spring wheat	SWHT	*Triticum aestivum* L.	cool season annual
Winter wheat	WWHT	*Triticum aestivum* L.	cool season annual
Durum wheat	DWHT	*Triticum durum* Desf.	cool season annual
Rye	RYE	*Secale cereale* L.	cool season annual
Spring barley	BARL	*Hordeum vulgare* L.	cool season annual
Oats	OATS	*Avena sativa* L.	cool season annual
Rice	RICE	*Oryza sativa* L.	warm season annual
Pearl millet	PMIL	*Pennisetum glaucum* L.	warm season annual
Timothy	TIMO	*Phleum pratense* L.	perennial
Smooth bromegrass	BROS	*Bromus inermis* Leysser	perennial
Meadow bromegrass	BROM	*Bromus biebersteinii* Roemer & Schultes	perennial
Tall fescue	FESC	*Festuca arundinacea*	perennial
Kentucky bluegrass	BLUG	*Poa pratensis*	perennial
Bermudagrass	BERM	*Cynodon dactylon*	perennial
Crested wheatgrass	CWGR	*Agropyron cristatum* (L.) Gaertner	perennial
Western wheatgrass	WWGR	*Agropyron smithii* (Rydb.) Gould	perennial

Common Name	Plant Code	Taxonomic Name	Plant type
Slender wheatgrass	SWGR	*Agropyron trachycaulum* Malte	perennial
Italian (annual) ryegrass	RYEG	*Lolium multiflorum* Lam.	cool season annual
Russian wildrye	RYER	*Psathyrostachys juncea* (Fisch.) Nevski	perennial
Altai wildrye	RYEA	*Leymus angustus* (Trin.) Pilger	perennial
Sideoats grama	SIDE	*Bouteloua curtipendula* (Michaux) Torrey	perennial
Big bluestem	BBLS	*Andropogon gerardii* Vitman	perennial
Little bluestem	LBLS	*Schizachyrium scoparium* (Michaux) Nash	perennial
Alamo switchgrass	SWCH	*Panicum virgatum* L.	perennial
Indiangrass	INDN	*Sorghastrum nutans* (L.) Nash	perennial
Alfalfa	ALFA	*Medicago sativa* L.	perennial legume
Sweetclover	CLVS	*Melilotus alba* Med.	perennial legume
Red clover	CLVR	*Trifolium pratense* L.	cool season annual legume
Alsike clover	CLVA	*Trifolium hybridum* L.	perennial legume
Soybean	SOYB	*Glycine max* L., Merr.	warm season annual legume
Cowpeas	CWPS	*Vigna sinensis*	warm season annual legume
Mung bean	MUNG	*Phaseolus aureus* Roxb.	warm season annual legume
Lima beans	LIMA	*Phaseolus lunatus* L.	warm season annual legume
Lentils	LENT	*Lens esculenta* Moench J.	warm season annual legume
Peanut	PNUT	*Arachis hypogaea* L.	warm season annual legume
Field peas	FPEA	*Pisum arvense* L.	cool season annual legume
Garden or canning peas	PEAS	*Pisum sativum* L. ssp. *sativum*	cool season annual legume
Sesbania	SESB	*Sesbania macrocarpa* Muhl [*exaltata*]	warm season annual legume
Flax	FLAX	*Linum usitatissum* L.	cool season annual
Upland cotton (harvested with stripper)	COTS	*Gossypium hirsutum* L.	warm season annual
Upland cotton (harvested with picker)	COTP	*Gossypium hirsutum* L.	warm season annual
Tobacco	TOBC	*Nicotiana tabacum* L.	warm season annual
Sugarbeet	SGBT	*Beta vulgaris (saccharifera)* L.	warm season annual
Potato	POTA	*Solanum tuberosum* L.	cool season annual
Sweetpotato	SPOT	*Ipomoea batatas* Lam.	warm season annual
Carrot	CRRT	*Daucus carota* L. subsp. *sativus* (Hoffm.) Arcang.	cool season annual
Onion	ONIO	*Allium cepa* L. var *cepa*	cool season annual
Sunflower	SUNF	*Helianthus annuus* L.	warm season annual
Spring canola-Polish	CANP	*Brassica campestris*	cool season annual
Spring canola-Argentine	CANA	*Brassica napus*	cool season annual
Asparagus	ASPR	*Asparagus officinalis* L.	perennial
Broccoli	BROC	*Brassica oleracea* L. var *italica* Plenck.	cool season annual
Cabbage	CABG	*Brassica oleracea* L. var *capitata* L.	perennial
Cauliflower	CAUF	*Brassica oleracea* L. var *botrytis* L.	cool season annual
Celery	CELR	*Apium graveolens* L. var *dulce* (Mill.) Pers.	perennial
Head lettuce	LETT	*Lactuca sativa* L. var *capitata* L.	cool season annual
Spinach	SPIN	*Spinacia oleracea* L.	cool season annual

Common Name	Plant Code	Taxonomic Name	Plant Type
Green beans	GRBN	*Phaseolus vulgaris*	warm season annual legume
Cucumber	CUCM	*Cucumis sativus* L.	warm season annual
Eggplant	EGGP	*Solanum melongena* L.	warm season annual
Cantaloupe	CANT	*Cucumis melo* L. Cantaloupensis group	warm season annual
Honeydew melon	HMEL	*Cucumis melo* L. Inodorus group	warm season annual
Watermelon	WMEL	*Citrullus lanatus* (Thunb.) Matsum and Nakai	warm season annual
Bell pepper	PEPR	*Capsicum annuum* L. Grossum group	warm season annual
Strawberry	STRW	*Fragaria* X *Ananassa* Duchesne.	perennial
Tomato	TOMA	*Lycopersicon esculentum* Mill.	warm season annual
Apple	APPL	*Malus domestica* Borkh.	trees
Pine	PINE	*Pinus*	trees
Oak	OAK	*Quercus*	trees
Poplar	POPL	*Populus*	trees
Honey mesquite	MESQ	*Prosopis glandulosa* Torr. var. *glandulosa*	trees

Table A-2: Generic Land Covers included in database.

Name	Plant Code	Origin of Plant Growth Values	Plant Type
Agricultural Land-Generic	AGRL	use values for Grain Sorghum	warm season annual
Agricultural Land-Row Crops	AGRR	use values for Corn	warm season annual
Agricultual Land-Close-grown	AGRC	use values for Winter Wheat	cool season annual
Orchard	ORCD	use values for Apples	trees
Hay[‡]	HAY	use values for Bermudagrass	perennial
Forest-mixed	FRST	use values for Oak	trees
Forest-deciduous	FRSD	use values for Oak	trees
Forest-evergreen	FRSE	use values for Pine	trees
Wetlands	WETL	use values for Alamo Switchgrass	perennial
Wetlands-forested	WETF	use values for Oak	trees
Wetlands-nonforested	WETN	use values for Alamo Switchgrass	perennial
Pasture[‡]	PAST	use values for Bermudagrass	perennial
Summer pasture	SPAS	use values for Bermudagrass	perennial
Winter pasture	WPAS	use values for Fescue	perennial
Range-grasses	RNGE	use values for Little Bluestem (LAI_{max}=2.5)	perennial
Range-brush	RNGB	use values for Little Bluestem (LAI_{max}=2.0)	perennial
Range-southwestern US	SWRN	use values for Little Bluestem (LAI_{max}=1.5)	perennial
Water[*]	WATR		not applicable

[‡] The Bermudagrass parameters input for Hay and Pasture are valid only in latitudes less than 35 to 37°. At higher latitudes, Fescue parameters should be used to model generic Hay and Pasture.

[*] Water was included in the plant growth database in order to process USGS map layers in the HUMUS project. This land cover should ***not*** be used as a land cover in an HRU. To model water bodies, create ponds, wetlands or reservoirs.

A.1.1 LAND COVER/PLANT TYPES IN DATABASE

When compiling the list of plants in the default database, we attempted to include the most economically important plants as well as those that are widely distributed in the landscape. This list is by no means exhaustive and users may need to add plants to the list. A number of generic land cover types were also compiled to facilitate linkage of land use/land cover maps to SWAT plant categories. Because of the broad nature of the some of the categories, a number of assumptions had to be made when compiling the plant growth parameter values. The user is strongly recommended to use parameters for a specific plant rather than those of the generic land covers any time information about plant types is available for the region being modeled.

Plant code (CPNM): The 4-letter codes in the plant growth and urban databases are used by the GIS interfaces to link land use/land cover maps to SWAT plant types. When adding a new plant species or land cover category, the four letter code for the new plant must be unique.

Land cover/plant classification (IDC): SWAT groups plants into seven categories: warm season annual legume, cold season annual legume, perennial legume, warm season annual, cold season annual, perennial and trees. (Biannual plants are classified as perennials.) The differences between the categories as modeled by SWAT are summarized in Chapter 5:1 in the theoretical documentation. Plant classifications can be easily found in horticulture books that summarize characteristics for different species. The classifications assigned to the plants in Table A-1 were obtained from Martin et al. (1976) and Bailey (1935).

A.1.2 TEMPERATURE RESPONSES

SWAT uses the base temperature (T_BASE) to calculate the number of heat units accrued every day. The minimum or base temperature for plant growth varies with growth stage of the plant. However, this variation is ignored by the model—SWAT uses the same base temperature throughout the growing season.

The optimal temperature (T_OPT) is used to calculate temperature stress for the plant during the growing season (temperature stress is the only calculation in which optimal temperature is used). Chapter 5:3 in the theoretical documentation reviews the influence of optimal temperature on plant growth.

Base temperature is measured by growing plants in growth chambers at several different temperatures. The rate of leaf tip appearance as a function of temperature is plotted. Extrapolating the line to the leaf tip appearance rate of 0.0 leaves/day gives the base or minimum temperature for plant growth. Figure A-1 plots data for corn. (Note that the line intersects the x-axis at 8°C.)

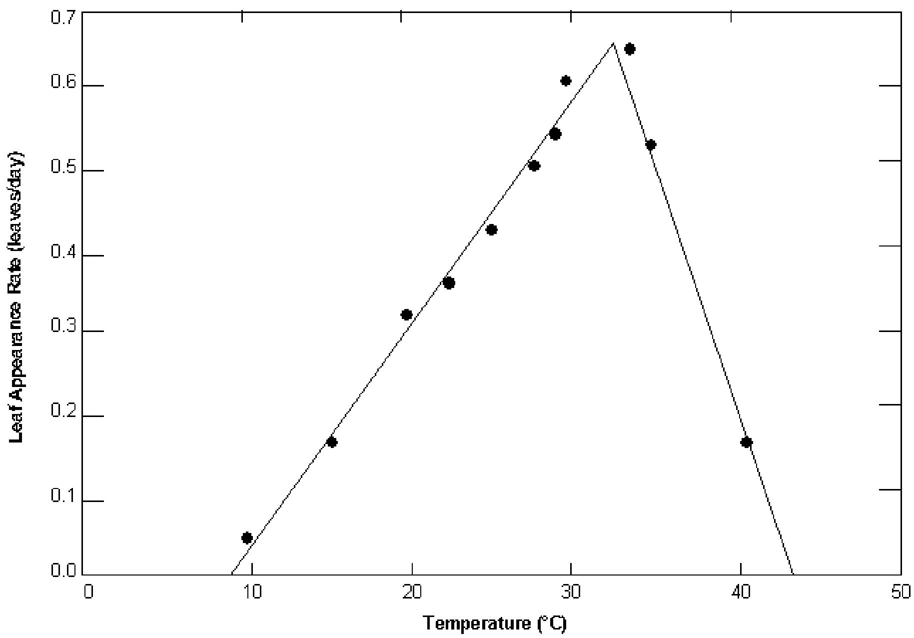

Figure A-1: Rate of leaf tip appearance as a function of temperature for corn.

Optimal temperature for plant growth is difficult to measure directly. Looking at Figure A-1, one might be tempted to select the temperature corresponding to the peak of the plot as the optimal temperature. This would not be correct. The peak of the plot defines the optimal temperature for leaf development—not for plant growth. If an optimal temperature cannot be obtained through a review of literature, use the optimal temperature listed for a plant already in the database with similar growth habits.

Review of temperatures for many different plants have provided generic values for base and optimal temperatures as a function of growing season. In situations, where temperature information is unavailable, these values may be used. For warm season plants, the generic base temperature is ~8ºC and the generic optimal temperature is ~25ºC. For cool season plants, the generic base temperature is ~0ºC and the generic optimal temperature is ~13ºC.

Base and optimal temperatures for the plants included in the database are listed in Table A-3.

Table A-3: Temperature parameters for plants included in plant growth database.

Common Name	Plant Code	T_{base}	T_{opt}	Reference
Corn	CORN	8	25	(Kiniry et al, 1995)
Corn silage	CSIL	8	25	(Kiniry et al, 1995)
Sweet corn	SCRN	12	24	(Hackett and Carolane, 1982)
Eastern gamagrass	EGAM	12	25	(Kiniry, personal comm., 2001)
Grain sorghum	GRSG	11	30	(Kiniry et al, 1992a)
Sorghum hay	SGHY	11	30	(Kiniry et al, 1992a)
Johnsongrass	JHGR	11	30	(Kiniry et al, 1992a)
Sugarcane	SUGC	11	25	(Kiniry and Williams, 1994)
Spring wheat	SWHT	0	18	(Kiniry et al, 1995)
Winter wheat	WWHT	0	18	(Kiniry et al, 1995)
Durum wheat	DWHT	0	15	estimated
Rye	RYE	0	12.5	estimated
Spring barley	BARL	0	25	(Kiniry et al, 1995)
Oats	OATS	0	15	(Kiniry, personal comm., 2001)
Rice	RICE	10	25	(Martin et al, 1976)
Pearl millet	PMIL	10	30	(Kiniry et al, 1991)
Timothy	TIMO	8	25	estimated
Smooth bromegrass	BROS	8	25	estimated
Meadow bromegrass	BROM	6	25	(Kiniry et al, 1995)
Tall fescue	FESC	0	15	estimated
Kentucky bluegrass	BLUG	12	25	(Kiniry, personal comm., 2001)
Bermudagrass	BERM	12	25	(Kiniry, personal comm., 2001)
Crested wheatgrass	CWGR	6	25	(Kiniry et al, 1995)
Western wheatgrass	WWGR	6	25	(Kiniry et al, 1995)
Slender wheatgrass	SWGR	8	25	estimated
Italian (annual) ryegrass	RYEG	0	18	estimated
Russian wildrye	RYER	0	15	(Kiniry et al, 1995)
Altai wildrye	RYEA	0	15	(Kiniry et al, 1995)
Sideoats grama	SIDE	12	25	(Kiniry, personal comm., 2001)
Big bluestem	BBLS	12	25	(Kiniry, personal comm., 2001)

Common Name	Plant Code	T_{base}	T_{opt}	Reference
Little bluestem	LBLS	12	25	(Kiniry, personal comm., 2001)
Alamo switchgrass	SWCH	12	25	(Kiniry et al, 1996)
Indiangrass	INDN	12	25	(Kiniry, personal comm., 2001)
Alfalfa	ALFA	4	20	(Kiniry, personal comm., 2001)
Sweetclover	CLVS	1	15	estimated
Red clover	CLVR	1	15	estimated
Alsike clover	CLVA	1	15	estimated
Soybean	SOYB	10	25	(Kiniry et al, 1992a)
Cowpeas	CWPS	14	28	(Kiniry et al, 1991; Hackett and Carolane, 1982)
Mung bean	MUNG	15	30	(Hackett and Carolane, 1982)
Lima beans	LIMA	18	26	(Hackett and Carolane, 1982)
Lentils	LENT	3	20	(Hackett and Carolane, 1982)
Peanut	PNUT	14	27	(Hackett and Carolane, 1982)
Field peas	FPEA	1	15	estimated
Garden or canning peas	PEAS	5	14	(Hackett and Carolane, 1982)
Sesbania	SESB	10	25	estimated
Flax	FLAX	5	22.5	estimated
Upland cotton (harvested with stripper)	COTS	15	30	(Martin et al, 1976)
Upland cotton (harvested with picker)	COTP	15	30	(Martin et al, 1976)
Tobacco	TOBC	10	25	(Martin et al, 1976)
Sugarbeet	SGBT	4	18	(Kiniry and Williams, 1994)
Potato	POTA	7	22	(Hackett and Carolane, 1982)
Sweetpotato	SPOT	14	24	(estimated; Hackett and Carolane, 1982)
Carrot	CRRT	7	24	(Kiniry and Williams, 1994)
Onion	ONIO	7	19	(Hackett and Carolane, 1982; Kiniry and Williams, 1994)
Sunflower	SUNF	6	25	(Kiniry et al, 1992b; Kiniry, personal communication, 2001)
Spring canola-Polish	CANP	5	21	(Kiniry et al, 1995)
Spring canola-Argentine	CANA	5	21	(Kiniry et al, 1995)
Asparagus	ASPR	10	24	(Hackett and Carolane, 1982)
Broccoli	BROC	4	18	(Hackett and Carolane, 1982)
Cabbage	CABG	1	18	(Hackett and Carolane, 1982)
Cauliflower	CAUF	5	18	(Hackett and Carolane, 1982)
Celery	CELR	4	22	(Hackett and Carolane, 1982)
Head lettuce	LETT	7	18	(Hackett and Carolane, 1982)
Spinach	SPIN	4	24	(Kiniry and Williams, 1994)
Green beans	GRBN	10	19	(Hackett and Carolane, 1982)
Cucumber	CUCM	16	32	(Kiniry and Williams, 1994)
Eggplant	EGGP	15	26	(Hackett and Carolane, 1982)
Cantaloupe	CANT	15	35	(Hackett and Carolane, 1982; Kiniry and Williams, 1994)

Common Name	Plant Code	T_{base}	T_{opt}	Reference
Honeydew melon	HMEL	16	36	(Kiniry and Williams, 1994)
Watermelon	WMEL	18	35	(Kiniry and Williams, 1994)
Bell pepper	PEPR	18	27	(Kiniry and Williams, 1994)
Strawberry	STRW	10	32	(Kiniry and Williams, 1994)
Tomato	TOMA	10	22	(Hackett and Carolane, 1982)
Apple	APPL	7	20	(Hackett and Carolane, 1982)
Pine	PINE	0	30	(Kiniry, personal comm., 2001)
Oak	OAK	10	30	(Kiniry, personal comm., 2001)
Poplar	POPL	10	30	(Kiniry, personal comm., 2001)
Honey mesquite	MESQ	10	30	(Kiniry, personal comm., 2001)

A.1.3 LEAF AREA DEVELOPMENT

Leaf area development is a function of the plant‟s growing season. Plant growth database variables used to quantify leaf area development are: BLAI, FRGRW1, LAIMX1, FRGRW2, LAIMX2, and DLAI. Figure A-2 illustrates the relationship of the database parameters to the leaf area development modeled by SWAT.

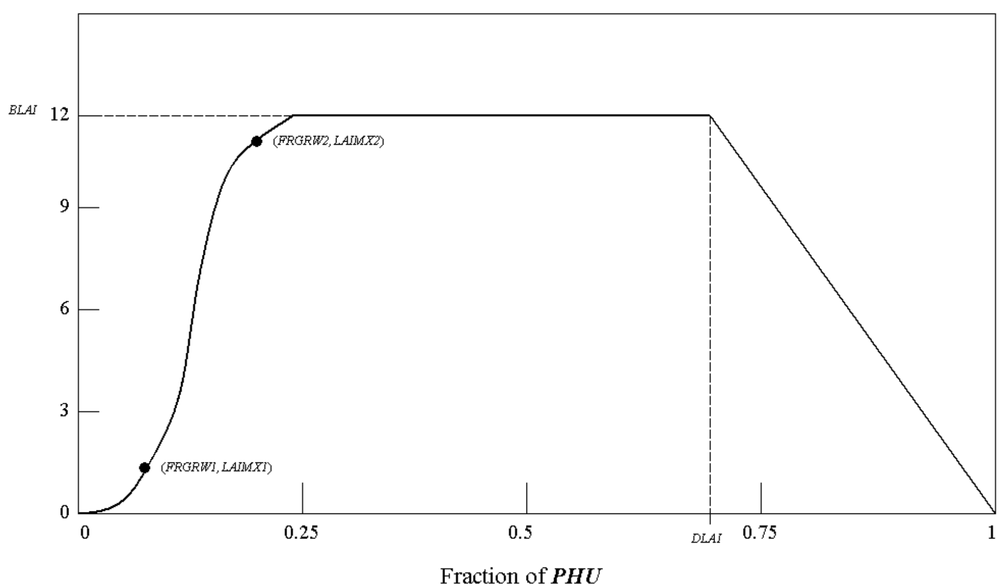

Figure A-2: Leaf area index as a function of fraction of growing season for Alamo switchgrass.

To identify the leaf area development parameters, record the leaf area index and number of accumulated heat units for the plant species throughout the growing season and then plot the results. For best results, several years worth of field data should be collected. At the very minimum, data for two years is recommended. It is important that the plants undergo no water or nutrient stress during the years in which data is collected.

The leaf area index incorporates information about the plant density, so field experiments should either be set up to reproduce actual plant densities or the maximum LAI value for the plant determined from field experiments should be adjusted to reflect plant densities desired in the simulation. Maximum LAI values in the default database correspond to plant densities associated with rainfed agriculture.

The leaf area index is calculated by dividing the green leaf area by the land area. Because the entire plant must be harvested to determine the leaf area, the field experiment needs to be designed to include enough plants to accommodate all leaf area measurements made during the year.

Although measuring leaf area can be laborious for large samples, there is no intrinsic difficulty in the process. The most common method is to obtain an electronic scanner and feed the harvested green leaves and stems into the scanner. Older methods for estimating leaf area include tracing of the leaves (or weighed subsamples) onto paper, the use of planimeters, the punch disk method of Watson (1958) and the linear dimension method of Duncan and Hesketh (1968).

Chapter 5:1 in the theoretical documentation reviews the methodology used to calculate accumulated heat units for a plant at different times of the year as well as determination of the fraction of total, or potential, heat units that is required for the plant database.

Leaf area development parameter values for the plants included in the database are listed in Table A-4 (LAI_{mx} = BLAI; $fr_{PHU,1}$ = FRGRW1; $fr_{LAI,1}$ = LAIMX1; $fr_{PHU,2}$ = FRGRW2; $fr_{LAI,2}$ = LAIMX2; $fr_{PHU,sen}$ = DLAI).

Table A-4: Leaf area development parameters for plants included in plant growth database.

Common Name	Plant Code	LAI_{mx}	$fr_{PHU,1}$	$fr_{LAI,1}$	$fr_{PHU,2}$	$fr_{LAI,2}$	$fr_{PHU,sen}$	Reference
Corn	CORN	3	0.15	0.05	0.50	0.95	0.90	(Kiniry et al, 1995; Kiniry, personal comm., 2001)
Corn silage	CSIL	4	0.15	0.05	0.50	0.95	0.90	(Kiniry et al, 1995; Kiniry, personal comm., 2001)
Sweet corn	SCRN	2.5	0.15	0.05	0.50	0.95	0.90	(Kiniry, personal comm., 2001; Kiniry and Williams, 1994)
Eastern gamagrass	EGAM	2.5	0.05	0.18	0.25	0.90	0.80	(Kiniry, personal comm., 2001)
Grain sorghum	GRSG	3	0.15	0.05	0.50	0.95	0.90	(Kiniry, personal comm., 2001; Kiniry and Bockholt, 1998)
Sorghum hay	SGHY	4	0.15	0.05	0.50	0.95	0.80	(Kiniry, personal comm., 2001; Kiniry and Bockholt, 1998)
Johnsongrass	JHGR	2.5	0.15	0.05	0.57	0.95	0.80	(Kiniry, personal comm., 2001; Kiniry et al, 1992a)
Sugarcane	SUGC	6	0.15	0.01	0.50	0.95	0.90	(Kiniry and Williams, 1994)
Spring wheat	SWHT	4	0.15	0.05	0.50	0.95	0.90	(Kiniry et al, 1995; Kiniry, personal comm., 2001)
Winter wheat	WWHT	4	0.05	0.05	0.45	0.95	0.90	(Kiniry et al, 1995; Kiniry, personal comm., 2001)
Durum wheat	DWHT	4	0.15	0.01	0.50	0.95	0.90	(Kiniry, personal communication, 2001; estimated)
Rye	RYE	4	0.15	0.01	0.50	0.95	0.80	(Kiniry, personal communication, 2001; estimated)
Spring barley	BARL	4	0.15	0.01	0.45	0.95	0.90	(Kiniry et al, 1995; Kiniry, personal comm., 2001)
Oats	OATS	4	0.15	0.02	0.50	0.95	0.90	(Kiniry, personal comm., 2001)
Rice	RICE	5	0.30	0.01	0.70	0.95	0.90	(Kiniry, personal comm., 2001; estimated)
Pearl millet	PMIL	2.5	0.15	0.01	0.50	0.95	0.90	(Kiniry, personal comm., 2001; estimated)
Timothy	TIMO	4	0.15	0.01	0.50	0.95	0.85	(Kiniry, personal comm., 2001; estimated)
Smooth bromegrass	BROS	5	0.15	0.01	0.50	0.95	0.85	(Kiniry, personal comm., 2001; estimated)
Meadow bromegrass	BROM	3	0.45	0.02	0.80	0.95	0.85	(Kiniry et al, 1995; Kiniry, personal comm., 2001)
Tall fescue	FESC	4	0.15	0.01	0.50	0.95	0.80	(Kiniry, personal comm, 2001; estimated)
Kentucky bluegrass	BLUG	2	0.05	0.05	0.30	0.70	0.80	(Kiniry, personal comm., 2001)
Bermudagrass	BERM	4	0.05	0.05	0.49	0.95	0.99	(Kiniry, personal comm, 2001)
Crested wheatgrass	CWGR	4	0.35	0.02	0.62	0.95	0.85	(Kiniry et al, 1995; Kiniry, personal comm., 2001)
Western wheatgrass	WWGR	4	0.50	0.02	0.89	0.95	0.85	(Kiniry et al, 1995; Kiniry, personal comm., 2001)
Slender wheatgrass	SWGR	4	0.15	0.01	0.50	0.95	0.85	(Kiniry, personal comm., 2001; estimated)
Italian (annual) ryegrass	RYEG	4	0.20	0.32	0.45	0.95	0.80	(Kiniry, personal comm., 2001; estimated)
Russian wildrye	RYER	3	0.35	0.02	0.62	0.95	0.80	(Kiniry et al, 1995)
Altai wildrye	RYEA	3	0.35	0.02	0.62	0.95	0.80	(Kiniry et al, 1995)
Sideoats grama	SIDE	1.7	0.05	0.05	0.30	0.70	0.80	(Kiniry, personal comm., 2001)

Common Name	Plant Code	LAI_{mx}	$fr_{PHU,1}$	$fr_{LAI,1}$	$fr_{PHU,2}$	$fr_{LAI,2}$	$fr_{PHU,sen}$	Reference
Big bluestem	BBLS	3	0.05	0.10	0.25	0.70	0.80	(Kiniry, personal comm., 2001)
Little bluestem	LBLS	2.5	0.05	0.10	0.25	0.70	0.80	(Kiniry, personal comm., 2001)
Alamo switchgrass	SWCH	6	0.10	0.20	0.20	0.95	0.80	(Kiniry, personal comm., 2001; Kiniry et al, 1996)
Indiangrass	INDN	3	0.05	0.10	0.25	0.70	0.80	(Kiniry, personal comm., 2001)
Alfalfa	ALFA	4	0.15	0.01	0.50	0.95	0.90	(Kiniry, personal comm., 2001)
Sweetclover	CLVS	4	0.15	0.01	0.50	0.95	0.80	(Kiniry, personal comm., 2001; estimated)
Red clover	CLVR	4	0.15	0.01	0.50	0.95	0.80	(Kiniry, personal comm., 2001; estimated)
Alsike clover	CLVA	4	0.15	0.01	0.50	0.95	0.80	(Kiniry, personal comm., 2001; estimated)
Soybean	SOYB	3	0.15	0.05	0.50	0.95	0.90	(Kiniry, personal comm., 2001; Kiniry et al, 1992a)
Cowpeas	CWPS	4	0.15	0.01	0.50	0.95	0.90	(Kiniry, personal comm., 2001; estimated)
Mung bean	MUNG	4	0.15	0.01	0.50	0.95	0.90	(Kiniry, personal comm., 2001; estimated)
Lima beans	LIMA	2.5	0.10	0.05	0.80	0.95	0.90	(Kiniry and Williams, 1994)
Lentils	LENT	4	0.15	0.02	0.50	0.95	0.90	(Kiniry, personal comm., 2001; estimated)
Peanut	PNUT	4	0.15	0.01	0.50	0.95	0.90	(Kiniry, personal comm., 2001; estimated)
Field peas	FPEA	4	0.15	0.01	0.50	0.95	0.90	(Kiniry, personal comm., 2001; estimated)
Garden or canning peas	PEAS	2.5	0.10	0.05	0.80	0.95	0.90	(Kiniry and Williams, 1994)
Sesbania	SESB	5	0.15	0.01	0.50	0.95	0.90	(Kiniry, personal comm., 2001; estimated)
Flax	FLAX	2.5	0.15	0.02	0.50	0.95	0.90	(Kiniry, personal comm., 2001; estimated)
Upland cotton (harvested with stripper)	COTS	4	0.15	0.01	0.50	0.95	0.95	(Kiniry, personal comm., 2001; estimated)
Upland cotton (harvested with picker)	COTP	4	0.15	0.01	0.50	0.95	0.95	(Kiniry, personal comm., 2001; estimated)
Tobacco	TOBC	4.5	0.15	0.05	0.50	0.95	0.90	(Kiniry and Williams, 1994)
Sugarbeet	SGBT	5	0.05	0.05	0.50	0.95	0.90	(Kiniry and Williams, 1994)
Potato	POTA	4	0.15	0.01	0.50	0.95	0.90	(Kiniry, personal comm., 2001; Kiniry and Williams, 1994)
Sweetpotato	SPOT	4	0.15	0.01	0.50	0.95	0.90	(Kiniry, personal comm., 2001; estimated)
Carrot	CRRT	3.5	0.15	0.01	0.50	0.95	0.90	(Kiniry and Williams, 1994)
Onion	ONIO	1.5	0.15	0.01	0.50	0.95	0.90	(Kiniry and Williams, 1994)
Sunflower	SUNF	3	0.15	0.01	0.50	0.95	0.90	(Kiniry, personal comm., 2001; Kiniry et al, 1992b)
Spring canola-Polish	CANP	3.5	0.15	0.02	0.45	0.95	0.90	(Kiniry et al, 1995)
Spring canola-Argentine	CANA	4.5	0.15	0.02	0.45	0.95	0.90	(Kiniry et al, 1995)
Asparagus	ASPR	4.2	0.25	0.23	0.40	0.86	1.00	(Kiniry and Williams, 1994)
Broccoli	BROC	4.2	0.25	0.23	0.40	0.86	1.00	(Kiniry and Williams, 1994)

Common Name	Plant Code	LAI_{mx}	$fr_{PHU,1}$	$fr_{LAI,1}$	$fr_{PHU,2}$	$fr_{LAI,2}$	$fr_{PHU,sen}$	Reference
Cabbage	CABG	3	0.25	0.23	0.40	0.86	1.00	(Kiniry and Williams, 1994)
Cauliflower	CAUF	2.5	0.25	0.23	0.40	0.86	1.00	(Kiniry and Williams, 1994)
Celery	CELR	2.5	0.25	0.23	0.40	0.86	1.00	(Kiniry and Williams, 1994)
Head lettuce	LETT	4.2	0.25	0.23	0.40	0.86	1.00	(Kiniry and Williams, 1994)
Spinach	SPIN	4.2	0.10	0.05	0.90	0.95	0.95	(Kiniry and Williams, 1994)
Green beans	GRBN	1.5	0.10	0.05	0.80	0.95	0.90	(Kiniry and Williams, 1994)
Cucumber	CUCM	1.5	0.15	0.05	0.50	0.95	0.90	(Kiniry and Williams, 1994)
Eggplant	EGGP	3	0.15	0.05	0.50	0.95	0.90	(Kiniry and Williams, 1994)
Cantaloupe	CANT	3	0.15	0.05	0.50	0.95	0.90	(Kiniry and Williams, 1994)
Honeydew melon	HMEL	4	0.15	0.05	0.50	0.95	0.90	(Kiniry and Williams, 1994)
Watermelon	WMEL	1.5	0.15	0.05	0.50	0.95	0.90	(Kiniry and Williams, 1994)
Bell pepper	PEPR	5	0.15	0.05	0.50	0.95	0.90	(Kiniry and Williams, 1994)
Strawberry	STRW	3	0.15	0.05	0.50	0.95	0.90	(Kiniry and Williams, 1994)
Tomato	TOMA	3	0.15	0.05	0.50	0.95	0.95	(Kiniry and Williams, 1994)
Apple	APPL	4	0.10	0.15	0.50	0.75	0.99	(Kiniry, personal comm., 2001; estimated)
Pine	PINE	5	0.15	0.70	0.25	0.99	0.99	(Kiniry, personal comm., 2001)
Oak	OAK	5	0.05	0.05	0.40	0.95	0.99	(Kiniry, personal comm., 2001)
Poplar	POPL	5	0.05	0.05	0.40	0.95	0.99	(Kiniry, personal comm., 2001)
Honey mesquite	MESQ	1.25	0.05	0.05	0.40	0.95	0.99	(Kiniry, 1998; Kiniry, personal communication, 2001)

A.1.4 ENERGY-BIOMASS CONVERSION

Radiation-use efficiency (RUE) quantifies the efficiency of a plant in converting light energy into biomass. Four variables in the plant growth database are used to define the RUE in ideal growing conditions (BIO_E), the impact of reduced vapor pressure on RUE (WAVP), and the impact of elevated CO_2 concentration on RUE (CO2HI, BIOEHI).

Determination of RUE is commonly performed and a literature review will provide those setting up experiments with numerous examples. The following overview of the methodology used to measure RUE was summarized from Kiniry et al (1998) and Kiniry et al (1999).

To calculate RUE, the amount of photosynthetically active radiation (PAR) intercepted and the mass of aboveground biomass is measured several times throughout a plant‟s growing season. The frequency of the measurements taken will vary but in general 4 to 7 measurements per growing season are considered to be adequate. As with leaf area determinations, the measurements should be performed on non-stressed plants.

Intercepted radiation is measured with a light meter. Whole spectrum and PAR sensors are available and calculations of RUE will be performed differently depending on the sensor used. A brief discussion of the difference between whole spectrum and PAR sensors and the difference in calculations is given in Kiniry (1999). The use of a PAR sensor in RUE studies is strongly encouraged.

When measuring radiation, three to five sets of measurements are taken rapidly for each plant plot. A set of measurements consists of 10 measurements above the leaf canopy, 10 below, and 10 more above. The light measurements should be taken between 10:00 am and 2:00 pm local time.

The measurements above and below the leaf canopy are averaged and the fraction of intercepted PAR is calculated for the day from the two values. Daily estimates of the fraction of intercepted PAR are determined by linearly interpolating the measured values.

The *fraction* of intercepted PAR is converted to an *amount* of intercepted PAR using daily values of incident total solar radiation measured with a standard weather station. To convert total incident radiation to total incident PAR, the daily solar radiation values are multiplied by the percent of total radiation that has a wavelength between 400 and 700 mm. This percent usually falls in the range 45 to 55% and is a function of cloud cover. 50% is considered to be a default value.

Once daily intercepted PAR values are determined, the total amount of PAR intercepted by the plant is calculated for each date on which biomass was harvested. This is calculated by summing daily intercepted PAR values from the date of seedling emergence to the date of biomass harvest.

To determine biomass production, aboveground biomass is harvested from a known area of land within the plot. The plant material should be dried at least 2 days at 65°C and then weighed.

RUE is determined by fitting a linear regression for aboveground biomass as a function of intercepted PAR. The slope of the line is the RUE. Figure A-4 shows the plots of aboveground biomass and summed intercepted photosynthetically active radiation for Eastern gamagrass. (Note that the units for RUE values in the graph, as well as values typically reported in literature, are different from those used by SWAT. To obtain the value used in SWAT, multiply by 10.)

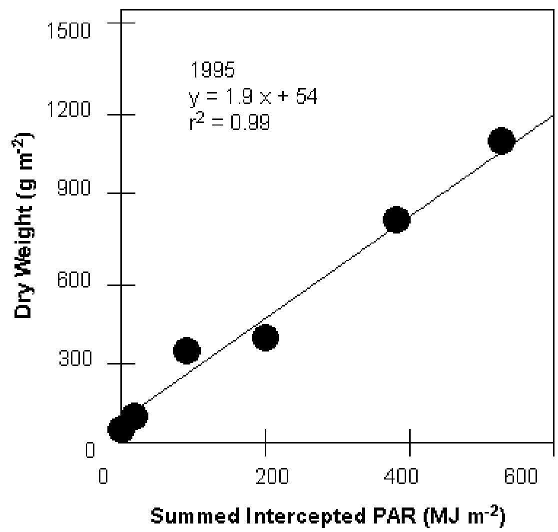

Figure A-4: Aboveground biomass and summed intercepted photosynthetically active radiation for Eastern gamagrass (from Kiniry et al.,1999).

Stockle and Kiniry (1990) first noticed a relationship between RUE and vapor pressure deficit and were able to explain a large portion of within-species variability in RUE values for sorghum and corn by plotting RUE values as a function of average daily vapor pressure deficit values. Since this first article, a number of other studies have been conducted that support the dependence of RUE on vapor pressure deficit. However, there is still some debate in the scientific community on the validity of this relationship. If the user does not wish to simulate a change in RUE with vapor pressure deficit, the variable WAVP can be set to 0.0 for the plant.

To define the impact of vapor pressure deficit on RUE, vapor pressure deficit values must be recorded during the growing seasons that RUE determinations are being made. It is important that the plants are exposed to no other stress than vapor pressure deficit, i.e. plant growth should not be limited by lack of soil water and nutrients.

Vapor pressure deficits can be calculated from relative humidity (see Chapter 1:2 in the theoretical documentation) or from daily maximum and minimum temperatures using the technique of Diaz and Campbell (1988) as described by Stockle and Kiniry (1990). The change in RUE with vapor pressure deficit is determined by fitting a linear regression for RUE as a function of vapor pressure deficit. Figure A-5 shows a plot of RUE as a function of vapor pressure deficit for grain sorghum.

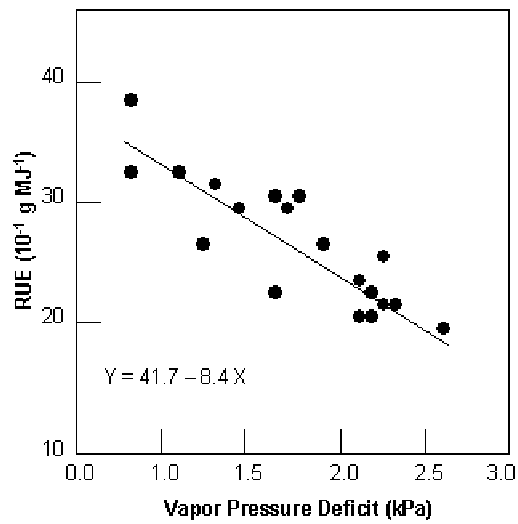

Figure A-5: Response of radiation-use efficiency to mean daily vapor pressure deficit for grain sorghum.

From Figure A-5, the rate of decline in radiation-use efficiency per unit increase in vapor pressure deficit, Δrue_{dcl}, for sorghum is 8.4×10^{-1} $g\cdot MJ^{-1}\cdot kPa^{-1}$. When RUE is adjusted for vapor pressure deficit, the model assumes the RUE value reported for BIO_E is the radiation-use efficiency at a vapor pressure deficit of 1 kPa.

In order to assess the impact of climate change on agricultural productivity, SWAT incorporates equations that adjust RUE for elevated atmospheric CO_2 concentrations. Values must be entered for CO2HI and BIOEHI in the plant database whether or not the user plans to simulate climate change.

For simulations in which elevated CO_2 levels are not modeled, CO2HI should be set to some number greater than 330 ppmv and BIOEHI should be set to some number greater than BIO_E.

To obtain radiation-use efficiency values at elevated CO_2 levels for plant species not currently in the database, plants should be established in growth chambers set up in the field or laboratory where CO_2 levels can be controlled. RUE values are determined using the same methodology described previously.

Radiation-use efficiency parameter values for the plants included in the database are listed in Table A-5 (RUE = BIO_E; Δrue_{dcl} = WAVP; RUE_{hi} = BIOEHI; CO_{2hi} = CO2HI).

Table A-5: Biomass production parameters for plants included in plant growth database.

Common Name	Plant Code	RUE	Δrue_{dcl}	RUE_{hi}	CO_{2hi}	Reference
Corn	CORN	39	7.2	45	660	(Kiniry et al, 1998; Kiniry et al, 1997; Kiniry, personal communication, 2001)
Corn silage	CSIL	39	7.2	45	660	(Kiniry et al, 1998; Kiniry et al, 1997; Kiniry, personal communication, 2001)
Sweet corn	SCRN	39	7.2	45	660	(Kiniry and Williams, 1994; Kiniry et al, 1997; Kiniry, personal communication, 2001)
Eastern gamagrass	EGAM	21	10	58	660	(Kiniry et al, 1999; Kiniry, personal communication, 2001)
Grain sorghum	GRSG	33.5	8.5	36	660	(Kiniry et al, 1998; Kiniry, personal communication, 2001)
Sorghum hay	SGHY	33.5	8.5	36	660	(Kiniry et al, 1998; Kiniry, personal communication, 2001)
Johnsongrass	JHGR	35	8.5	36	660	(Kiniry et al, 1992a; Kiniry, personal communication, 2001)
Sugarcane	SUGC	25	10	33	660	(Kiniry and Williams, 1994; Kiniry, personal communication, 2001)
Spring wheat	SWHT	35	8	46	660	(Kiniry et al, 1992a; Kiniry, personal communication, 2001; estimated)
Winter wheat	WWHT	30	6	39	660	(Kiniry et al, 1995; estimated)
Durum wheat	DWHT	30	7	45	660	(estimated)
Rye	RYE	35	7	45	660	(estimated)
Spring barley	BARL	35	7	45	660	(Kiniry et al, 1995; estimated)
Oats	OATS	35	10	45	660	(Kiniry, personal communication, 2001)

Common Name	Plant Code	*RUE*	Δrue_{dcl}	RUE_{hi}	CO_{2hi}	Reference
Rice	RICE	22	5	31	660	(Kiniry et al, 1989; estimated)
Pearl millet	PMIL	35	8	40	660	(estimated)
Timothy	TIMO	35	8	45	660	(estimated)
Smooth bromegrass	BROS	35	8	45	660	(estimated)
Meadow bromegrass	BROM	35	8	45	660	(Kiniry et al, 1995; estimated)
Tall fescue	FESC	30	8	39	660	(estimated)
Kentucky bluegrass	BLUG	18	10	31	660	(Kiniry, personal communication, 2001)
Bermudagrass	BERM	35	10	36	660	(Kiniry, personal communication, 2001)
Crested wheatgrass	CWGR	35	8	38	660	(Kiniry et al, 1995; Kiniry, personal communication, 2001)
Western wheatgrass	WWGR	35	8	45	660	(Kiniry et al, 1995; estimated)
Slender wheatgrass	SWGR	35	8	45	660	(estimated)
Italian (annual) ryegrass	RYEG	30	6	39	660	(estimated)
Russian wildrye	RYER	30	8	39	660	(Kiniry et al, 1995; estimated)
Altai wildrye	RYEA	30	8	46	660	(Kiniry et al, 1995; Kiniry, personal communication, 2001)
Sideoats grama	SIDE	11	10	21	660	(Kiniry et al, 1999; Kiniry, personal communication, 2001)
Big bluestem	BBLS	14	10	39	660	(Kiniry et al, 1999; Kiniry, personal communication, 2001)
Little bluestem	LBLS	34	10	39	660	(Kiniry, personal communication, 2001)
Alamo switchgrass	SWCH	47	8.5	54	660	(Kiniry et al, 1996; Kiniry, personal communication, 2001)
Indiangrass	INDN	34	10	39	660	(Kiniry, personal communication, 2001)
Alfalfa	ALFA	20	10	35	660	(Kiniry, personal communication, 2001)
Sweetclover	CLVS	25	10	30	660	(estimated)
Red clover	CLVR	25	10	30	660	(estimated)
Alsike clover	CLVA	25	10	30	660	(estimated)
Soybean	SOYB	25	8	34	660	(Kiniry et al, 1992a; Kiniry, personal communication, 2001)
Cowpeas	CWPS	35	8	39	660	(estimated)
Mung bean	MUNG	25	10	33	660	(estimated)
Lima beans	LIMA	25	5	34	660	(Kiniry and Williams, 1994; estimated)
Lentils	LENT	20	10	33	660	(estimated)
Peanut	PNUT	20	4	25	660	(estimated)
Field peas	FPEA	25	10	30	660	(estimated)
Garden or canning peas	PEAS	25	5	34	660	(Kiniry and Williams, 1994; estimated)
Sesbania	SESB	50	10	60	660	(estimated)
Flax	FLAX	25	10	33	660	(estimated)
Upland cotton (harvested with stripper)	COTS	15	3	19	660	(estimated)
Upland cotton (harvested with picker)	COTP	15	3	19	660	(estimated)
Tobacco	TOBC	39	8	44	660	(Kiniry and Williams, 1994; estimated)
Sugarbeet	SGBT	30	10	35	660	(Kiniry and Williams, 1994; estimated)

Common Name	Plant Code	*RUE*	Δrue_{dcl}	RUE_{hi}	CO_{2hi}	Reference
Potato	POTA	25	14.8	30	660	(Manrique et al, 1991; estimated)
Sweetpotato	SPOT	15	3	19	660	(estimated)
Carrot	CRRT	30	10	35	660	(Kiniry and Williams, 1994; estimated)
Onion	ONIO	30	10	35	660	(Kiniry and Williams, 1994; estimated)
Sunflower	SUNF	46	32.3	59	660	(Kiniry et al, 1992b; Kiniry, personal communication, 2001)
Spring canola-Polish	CANP	34	10	39	660	(Kiniry et al, 1995; estimated)
Spring canola-Argentine	CANA	34	10	40	660	(Kiniry et al, 1995; estimated)
Asparagus	ASPR	90	5	95	660	(Kiniry and Williams, 1994; estimated)
Broccoli	BROC	26	5	30	660	(Kiniry and Williams, 1994; estimated)
Cabbage	CABG	19	5	25	660	(Kiniry and Williams, 1994; estimated)
Cauliflower	CAUF	21	5	25	660	(Kiniry and Williams, 1994; estimated)
Celery	CELR	27	5	30	660	(Kiniry and Williams, 1994; estimated)
Head lettuce	LETT	23	8	25	660	(Kiniry and Williams, 1994; estimated)
Spinach	SPIN	30	5	35	660	(Kiniry and Williams, 1994; estimated)
Green beans	GRBN	25	5	34	660	(Kiniry and Williams, 1994; estimated)
Cucumber	CUCM	30	8	39	660	(Kiniry and Williams, 1994; estimated)
Eggplant	EGGP	30	8	39	660	(Kiniry and Williams, 1994; estimated)
Cantaloupe	CANT	30	3	39	660	(Kiniry and Williams, 1994; estimated)
Honeydew melon	HMEL	30	3	39	660	(Kiniry and Williams, 1994; estimated)
Watermelon	WMEL	30	3	39	660	(Kiniry and Williams, 1994; estimated)
Bell pepper	PEPR	30	8	39	660	(Kiniry and Williams, 1994; estimated)
Strawberry	STRW	30	8	39	660	(Kiniry and Williams, 1994; estimated)
Tomato	TOMA	30	8	39	660	(Kiniry and Williams, 1994; estimated)
Apple	APPL	15	3	20	660	(estimated)
Pine	PINE	15	8	16	660	(Kiniry, personal communication, 2001)
Oak	OAK	15	8	16	660	(Kiniry, personal communication, 2001)
Poplar	POPL	30	8	31	660	(Kiniry, personal communication, 2001)
Honey mesquite	MESQ	16.1	8	18	660	(Kiniry, 1998; Kiniry, personal comm., 2001)

A.1.5 LIGHT INTERCEPTION

Differences in canopy structure for a species are described by the number of leaves present (leaf area index) and the leaf orientation. Leaf orientation has a significant impact on light interception and consequently on radiation-use efficiency. More erect leaf types spread the incoming light over a greater leaf area, decreasing the average light intensity intercepted by individual leaves (Figure A-3). A reduction in light intensity interception by an individual leaf favors a more complete conversion of total canopy-intercepted light energy into biomass.

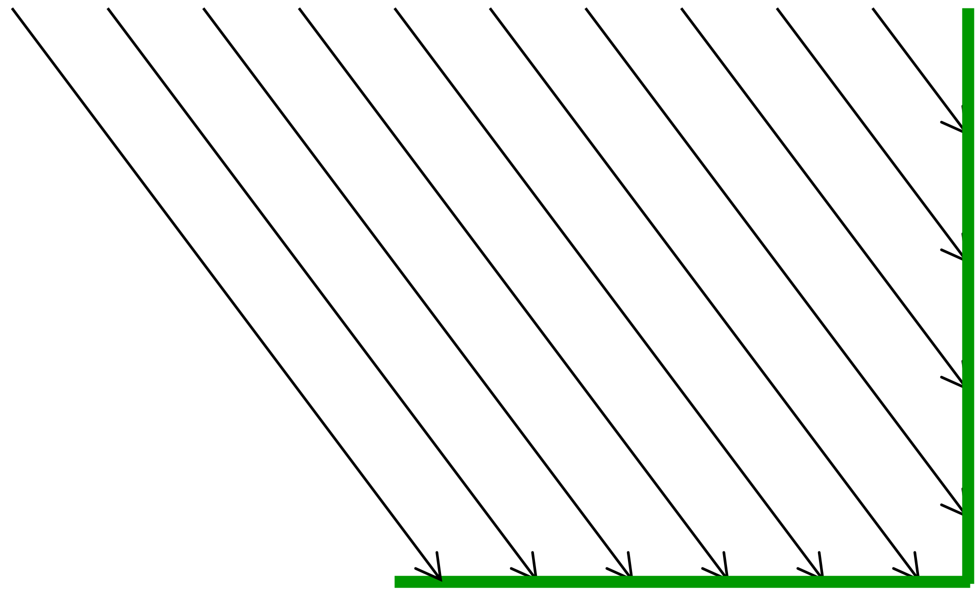

Figure A-3: Light intensity interception as a function of leaf orientation. The vertically oriented leaf intercepts 4 units of light while a horizontally oriented leaf of the same length intercepts 6 units of light.

Using the light extinction coefficient value (k_ℓ) in the Beer-Lambert formula (equation 5:2.1.1) to quantify efficiency of light interception per unit leaf area index, more erect leaf types have a smaller k_ℓ.

To calculate the light extinction coefficient, the amount of photosynthetically active radiation (PAR) intercepted and the mass of aboveground biomass (LAI) is measured several times throughout a plant‟s growing season using the methodology described in the previous sections. The light extinction coefficient is then calculated using the Beer-Lambert equation:

$$\frac{TPAR}{PAR} = \left(1 - \exp\left(-k_\ell \cdot LAI\right)\right) \text{ or } k_\ell = -\ln\left(\frac{TPAR}{PAR}\right) \cdot \frac{1}{LAI}$$

where *TPAR* is the transmitted photosynthetically active radiation, and *PAR* is the incoming photosynthetically active radiation.

A.1.6 STOMATAL CONDUCTANCE

Stomatal conductance of water vapor is used in the Penman-Monteith calculations of maximum plant evapotranspiration. The plant database contains three variables pertaining to stomatal conductance that are required only if the Penman-Monteith equations are chosen to model evapotranspiration: maximum stomatal conductance (GSI), and two variables that define the impact of vapor pressure deficit on stomatal conductance (FRGMAX, VPDFR).

Körner et al (1979) defines maximum leaf diffusive conductance as the largest value of conductance observed in fully developed leaves of well-watered plants under optimal climatic conditions, natural outdoor CO_2 concentrations and sufficient nutrient supply. Leaf diffusive conductance of water vapor cannot be measured directly but can be calculated from measurements of transpiration under known climatic conditions. A number of different methods are used to determine diffusive conductance: transpiration measurements in photosynthesis cuvettes, energy balance measurements or weighing experiments, ventilated diffusion porometers and non-ventilated porometers. Körner (1977) measured diffusive conductance using a ventilated diffusion porometer.

To obtain maximum leaf conductance values, leaf conductance is determined between sunrise and late morning until a clear decline or no further increase is observed. Depending on phenology, measurements are taken on at least three bright days in late spring and summer, preferably just after a rainy period. The means of maximum leaf conductance of 5 to 10 samples each day are averaged, yielding the maximum diffusive conductance for the species. Due to the variation of the location of stomata on plant leaves for different plant species, conductance values should be calculated for the total leaf surface area.

Körner et al (1979) compiled maximum leaf diffusive conductance data for 246 plant species. The data for each individual species was presented as well as summarized by 13 morphologically and/or ecologically comparable plant groups. All maximum stomatal conductance values in the plant growth database were based on the data included in Körner et al (1979) (see Table A-6).

As with radiation-use efficiency, stomatal conductance is sensitive to vapor pressure deficit. Stockle et al (1992) compiled a short list of stomatal conductance response to vapor pressure deficit for a few plant species. Due to the paucity of data, default values for the second point on the stomatal conductance vs. vapor pressure deficit curve are used for all plant species in the database. The fraction of maximum stomatal conductance (FRGMAX) is set to 0.75 and the vapor pressure deficit corresponding to the fraction given by FRGMAX (VPDFR) is set to 4.00 kPa. If the user has actual data, they should use those values, otherwise the default values are adequate.

A.1.7 CANOPY HEIGHT/ROOT DEPTH

Maximum canopy height (CHTMX) is a straightforward measurement. The canopy height of non-stressed plants should be recorded at intervals throughout the growing season. The maximum value recorded is used in the database.

To determine maximum rooting depth (RDMX), plant samples need to be grown on soils without an impermeable layer. Once the plants have reached maturity, soil cores are taken for the entire depth of the soil. Each 0.25 m increment is washed and the live plant material collected. Live roots can be differentiated from dead roots by the fact that live roots are whiter and more elastic and have an intact cortex. The deepest increment of the soil core in which live roots are found defines the maximum rooting depth. Table A-6 lists the maximum canopy height and maximum rooting depths for plants in the default database.

Table A-6: Maximum stomatal conductance ($g_{\ell,mx}$), maximum canopy height ($h_{c,mx}$), maximum root depth ($z_{root,mx}$), minimum USLE C factor for land cover ($C_{USLE,mn}$).

Common Name	Plant Code	$g_{\ell,mx}$	$h_{c,mx}$	$z_{root,mx}$	$C_{USLE,mn}$	Reference
Corn	CORN	.0071	2.5	2.0	.20	(Körner et al, 1979; Martin et al, 1976; Kiniry et al, 1995; Kiniry, personal comm., 2001)
Corn silage	CSIL	.0071	2.5	2.0	.20	(Körner et al, 1979; Martin et al, 1976; Kiniry et al, 1995; Kiniry, personal comm., 2001)
Sweet corn	SCRN	.0071	2.5	2.0	.20	(Körner et al, 1979, Kiniry and Williams, 1994; Kiniry, personal comm., 2001)
Eastern gamagrass	EGAM	.0055	1.7	2.0	.003	(Körner et al, 1979; Kiniry, personal comm., 2001)
Grain sorghum	GRSG	.0050	1.0	2.0	.20	(Körner et al, 1979; Kiniry, personal comm., 2001)
Sorghum hay	SGHY	.0050	1.5	2.0	.20	(Körner et al, 1979; Martin et al, 1976; Kiniry, personal comm., 2001)
Johnsongrass	JHGR	.0048	1.0	2.0	.20	(Körner et al, 1979; Kiniry et al, 1992a)
Sugarcane	SUGC	.0055	3.0	2.0	.001	(Körner et al, 1979; Kiniry and Williams, 1994)
Spring wheat	SWHT	.0056	0.9	2.0	.03	(Körner et al, 1979; Kiniry, personal comm., 2001)
Winter wheat	WWHT	.0056	0.9	1.3	.03	(Körner et al, 1979; Kiniry, personal comm., 2001; Kiniry et al, 1995)
Durum wheat	DWHT	.0056	1.0	2.0	.03	(Körner et al, 1979; estimated; Kiniry, personal comm., 2001)
Rye	RYE	.0100	1.0	1.8	.03	(Körner et al, 1979; estimated; Martin et al, 1976; Kiniry, personal comm., 2001)
Spring barley	BARL	.0083	1.2	1.3	.01	(Körner et al, 1979; Kiniry and Williams, 1994; Kiniry et al, 1995)
Oats	OATS	.0055	1.5	2.0	.03	(Körner et al, 1979; Martin et al, 1976; Kiniry, personal comm., 2001)
Rice	RICE	.0078	0.8	0.9	.03	(Körner et al, 1979; Martin et al, 1976; estimated)
Pearl millet	PMIL	.0143	3.0	2.0	.20	(Körner et al, 1979; Kiniry, personal comm., 2001; estimated)
Timothy	TIMO	.0055	0.8	2.0	.003	(Körner et al, 1979; estimated)
Smooth bromegrass	BROS	.0025	1.2	2.0	.003	(Körner et al, 1979; Martin et al, 1976; estimated)
Meadow bromegrass	BROM	.0055	0.8	1.3	.003	(Körner et al, 1979; estimated; Kiniry et al, 1995)
Tall fescue	FESC	.0055	1.5	2.0	.03	(Körner et al, 1979; Martin et al, 1976; estimated)
Kentucky bluegrass	BLUG	.0055	0.2	1.4	.003	(Körner et al, 1979; Kiniry, personal comm., 2001)
Bermudagrass	BERM	.0055	0.5	2.0	.003	(Körner et al, 1979; Kiniry, personal comm., 2001)
Crested wheatgrass	CWGR	.0055	0.9	1.3	.003	(Körner et al, 1979; Martin et al, 1976; Kiniry et al, 1995)
Western wheatgrass	WWGR	.0083	0.6	1.3	.003	(Körner et al, 1979; Martin et al, 1976; Kiniry et al, 1995; estimated)
Slender wheatgrass	SWGR	.0055	0.7	2.0	.003	(Körner et al, 1979; estimated)
Italian (annual) ryegrass	RYEG	.0055	0.8	1.3	.03	(Körner et al, 1979; estimated)
Russian wildrye	RYER	.0065	1.0	1.3	.03	(Körner et al, 1979; estimated; Kiniry et al, 1995)
Altai wildrye	RYEA	.0055	1.1	1.3	.03	(Körner et al, 1979; Kiniry, personal comm., 2001; Kiniry et al, 1995)

Common Name	Plant Code	$g_{\ell,mx}$	$h_{c,mx}$	$z_{root,mx}$	$C_{USLE,mn}$	Reference
Sideoats grama	SIDE	.0055	0.4	1.4	.003	(Körner et al, 1979; Kiniry, personal comm., 2001)
Big bluestem	BBLS	.0055	1.0	2.0	.003	(Körner et al, 1979; Kiniry, personal comm., 2001)
Little bluestem	LBLS	.0055	1.0	2.0	.003	(Körner et al, 1979; Kiniry, personal comm., 2001)
Alamo switchgrass	SWCH	.0055	2.5	2.2	.003	(Körner et al, 1979; Kiniry, personal comm., 2001; Kiniry et al, 1996)
Indiangrass	INDN	.0055	1.0	2.0	.003	(Körner et al, 1979; Kiniry, personal comm., 2001)
Alfalfa	ALFA	.0100	0.9	3.0	.01	(Jensen et al, 1990; Martin et al, 1976; Kiniry, personal comm., 2001)
Sweetclover	CLVS	.0055	1.5	2.4	.003	(Körner et al, 1979; Kiniry, personal comm., 2001; Martin et al, 1976; estimated)
Red clover	CLVR	.0065	0.75	1.5	.003	(Körner et al, 1979; Martin et al, 1976; estimated)
Alsike clover	CLVA	.0055	0.9	2.0	.003	(Körner et al, 1979; Martin et al, 1976; estimated)
Soybean	SOYB	.0071	0.8	1.7	.20	(Körner et al, 1979; Kiniry et al, 1992a)
Cowpeas	CWPS	.0055	1.2	2.0	.03	(Körner et al, 1979; estimated)
Mung bean	MUNG	.0055	1.5	2.0	.20	(Körner et al, 1979; estimated)
Lima beans	LIMA	.0055	0.6	2.0	.20	(Körner et al, 1979; Kiniry and Williams, 1994; Maynard and Hochmuth, 1997)
Lentils	LENT	.0055	0.55	1.2	.20	(Körner et al, 1979; Martin et al, 1976; Maynard and Hochmuth, 1997)
Peanut	PNUT	.0063	0.5	2.0	.20	(Körner et al, 1979; estimated)
Field peas	FPEA	.0055	1.2	1.2	.01	(Körner et al, 1979; Martin et al, 1976; Maynard and Hochmuth, 1997; estimated)
Garden or canning peas	PEAS	.0055	0.6	1.2	.20	(Körner et al, 1979; Kiniry and Williams, 1994; Maynard and Hochmuth, 1997)
Sesbania	SESB	.0055	2.0	2.0	.20	(Körner et al, 1979; Kiniry, personal comm., 2001; estimated)
Flax	FLAX	.0055	1.2	1.5	.20	(Körner et al, 1979; Martin et al, 1976; Jensen et al, 1990; estimated)
Upland cotton (harvested with stripper)	COTS	.0091	1.0	2.5	.20	(Monteith, 1965; Kiniry, personal comm., 2001; Martin et al, 1976)
Upland cotton (harvested with picker)	COTP	.0091	1.0	2.5	.20	(Monteith, 1965; Kiniry, personal comm., 2001; Martin et al, 1976)
Tobacco	TOBC	.0048	1.8	2.0	.20	(Körner et al, 1979; Martin et al, 1976; Kiniry and Williams, 1994)
Sugarbeet	SGBT	.0071	1.2	2.0	.20	(Körner et al, 1979; Kiniry and Williams, 1994)
Potato	POTA	.0050	0.6	0.6	.20	(Körner et al, 1979; Martin et al, 1976; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Sweetpotato	SPOT	.0065	0.8	2.0	.05	(Körner et al, 1979; estimated; Maynard and Hochmuth, 1997)
Carrot	CRRT	.0065	0.3	1.2	.20	(Körner et al, 1979; Kiniry and Williams, 1994; Maynard and Hochmuth, 1997)
Onion	ONIO	.0065	0.5	0.6	.20	(Körner et al, 1979; Kiniry and Williams, 1994; Maynard and Hochmuth, 1997)
Sunflower	SUNF	.0077	2.5	2.0	.20	(Körner et al, 1979; Kiniry, personal comm., 2001)

Common Name	**Plant Code**	$g_{\ell,mx}$	$h_{c,mx}$	$z_{root,mx}$	$C_{USLE,mn}$	**Reference**
Spring canola-Polish	CANP	.0065	0.9	0.9	.20	(Körner et al, 1979; estimated; Kiniry et al, 1995)
Spring canola-Argentine	CANA	.0065	1.3	1.4	.20	(Körner et al, 1979; estimated; Kiniry et al, 1995)
Asparagus	ASPR	.0065	0.5	2.0	.20	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Broccoli	BROC	.0065	0.5	0.6	.20	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Cabbage	CABG	.0065	0.5	0.6	.20	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Cauliflower	CAUF	.0065	0.5	0.6	.20	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Celery	CELR	.0065	0.5	0.6	.20	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Head lettuce	LETT	.0025	0.2	0.6	.01	(Körner et al, 1979; Kiniry and Williams, 1994; Maynard and Hochmuth, 1997)
Spinach	SPIN	.0065	0.5	0.6	.20	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Green beans	GRBN	.0077	0.6	1.2	.20	(Körner et al, 1979; Kiniry and Williams, 1994; Maynard and Hochmuth, 1997)
Cucumber	CUCM	.0033	0.5	1.2	.03	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997)
Eggplant	EGGP	.0065	0.5	1.2	.03	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Cantaloupe	CANT	.0065	0.5	1.2	.03	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Honeydew melon	HMEL	.0065	0.5	1.2	.03	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Watermelon	WMEL	.0065	0.5	2.0	.03	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Bell pepper	PEPR	.0053	0.5	1.2	.03	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Strawberry	STRW	.0065	0.5	0.6	.03	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Tomato	TOMA	.0077	0.5	2.0	.03	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Apple	APPL	.0071	3.5	2.0	.001	(Körner et al, 1979; estimated; Jensen et al, 1990)
Pine	PINE	.0019	10.0	3.5	.001	(Körner et al, 1979; Kiniry, personal comm., 2001)
Oak	OAK	.0020	6.0	3.5	.001	(Körner et al, 1979; Kiniry, personal comm., 2001)

Common Name	Plant Code	$g_{\ell,mx}$	$h_{c,mx}$	$z_{root,mx}$	$C_{USLE,mn}$	Reference
Poplar	POPL	.0036	7.5	3.5	.001	(Körner et al, 1979; Kiniry, personal comm., 2001)
Honey mesquite	MESQ	.0036	6.0	3.5	.001	(Körner et al, 1979; Kiniry, personal comm., 2001)

A.1.8 PLANT NUTRIENT CONTENT

In order to calculate the plant nutrient demand throughout a plant‟s growing cycle, SWAT needs to know the fraction of nutrient in the total plant biomass (on a dry weight basis) at different stages of crop growth. Six variables in the plant database provide this information: PLTNFR(1), PLTNFR(2), PLTNFR(3), PLTPFR(1), PLTPFR(2), and PLPPFR(3). Plant samples are analyzed for nitrogen and phosphorus content at three times during the growing season: shortly after emergence, near the middle of the season, and at maturity. The plant samples can be sent to testing laboratories to obtain the fraction of nitrogen and phosphorus in the biomass.

Ideally, the plant samples tested for nutrient content should include the roots as well as the aboveground biomass. Differences in partitioning of nutrients to roots and shoots can cause erroneous conclusions when comparing productivity among species if only the aboveground biomass is measured.

The fractions of nitrogen and phosphorus for the plants included in the default database are listed in Table A-7.

Table A-7: Nutrient parameters for plants included in plant growth database.

Common Name	Plant Code	$fr_{N,1}$	$fr_{N,2}$	$fr_{N,3}$	$fr_{P,1}$	$fr_{P,2}$	$fr_{P,3}$	Reference
Corn	CORN	.0470	.0177	.0138	.0048	.0018	.0014	(Kiniry et al., 1995)
Corn silage	CSIL	.0470	.0177	.0138	.0048	.0018	.0014	(Kiniry et al., 1995)
Sweet corn	SCRN	.0470	.0177	.0138	.0048	.0018	.0014	(Kiniry and Williams, 1994)
Eastern gamagrass	EGAM	.0200	.0100	.0070	.0014	.0010	.0007	(Kiniry, personal communication, 2001)
Grain sorghum	GRSG	.0440	.0164	.0128	.0060	.0022	.0018	(Kiniry, personal communication, 2001)
Sorghum hay	SGHY	.0440	.0164	.0128	.0060	.0022	.0018	(Kiniry, personal communication, 2001)
Johnsongrass	JHGR	.0440	.0164	.0128	.0060	.0022	.0018	(Kiniry et al., 1992a)
Sugarcane	SUGC	.0100	.0040	.0025	.0075	.0030	.0019	(Kiniry and Williams, 1994)
Spring wheat	SWHT	.0600	.0231	.0134	.0084	.0032	.0019	(Kiniry et al., 1992a)
Winter wheat	WWHT	.0663	.0255	.0148	.0053	.0020	.0012	(Kiniry et al., 1995)
Durum wheat	DWHT	.0600	.0231	.0130	.0084	.0032	.0019	estimated
Rye	RYE	.0600	.0231	.0130	.0084	.0032	.0019	estimated
Spring barley	BARL	.0590	.0226	.0131	.0057	.0022	.0013	(Kiniry et al., 1995)
Oats	OATS	.0600	.0231	.0134	.0084	.0032	.0019	(Kiniry, personal communication, 2001)
Rice	RICE	.0500	.0200	.0100	.0060	.0030	.0018	estimated
Pearl millet	PMIL	.0440	.0300	.0100	.0060	.0022	.0012	estimated
Timothy	TIMO	.0314	.0137	.0103	.0038	.0025	.0019	estimated
Smooth bromegrass	BROS	.0400	.0240	.0160	.0028	.0017	.0011	(Kiniry et al., 1995)
Meadow bromegrass	BROM	.0400	.0240	.0160	.0028	.0017	.0011	(Kiniry et al., 1995)
Tall fescue	FESC	.0560	.0210	.0120	.0099	.0022	.0019	estimated
Kentucky bluegrass	BLUG	.0200	.0100	.0060	.0014	.0010	.0007	(Kiniry, personal communication, 2001)
Bermudagrass	BERM	.0600	.0231	.0134	.0084	.0032	.0019	(Kiniry, personal communication, 2001)
Crested wheatgrass	CWGR	.0300	.0200	.0120	.0020	.0015	.0013	(Kiniry et al., 1995)
Western wheatgrass	WWGR	.0300	.0200	.0120	.0020	.0015	.0013	(Kiniry et al., 1995)

Common Name	Plant Code	$fr_{N,1}$	$fr_{N,2}$	$fr_{N,3}$	$fr_{P,1}$	$fr_{P,2}$	$fr_{P,3}$	Reference
Slender wheatgrass	SWGR	.0300	.0200	.0120	.0020	.0015	.0013	estimated
Italian (annual) ryegrass	RYEG	.0660	.0254	.0147	.0105	.0040	.0024	estimated
Russian wildrye	RYER	.0226	.0180	.0140	.0040	.0040	.0024	(Kiniry et al., 1995)
Altai wildrye	RYEA	.0226	.0180	.0140	.0040	.0040	.0024	(Kiniry et al., 1995)
Sideoats grama	SIDE	.0200	.0100	.0060	.0014	.0010	.0007	(Kiniry, personal communication, 2001)
Big bluestem	BBLS	.0200	.0120	.0050	.0014	.0010	.0007	(Kiniry, personal communication, 2001)
Little bluestem	LBLS	.0200	.0120	.0050	.0014	.0010	.0007	(Kiniry, personal communication, 2001)
Alamo switchgrass	SWCH	.0350	.0150	.0038	.0014	.0010	.0007	(Kiniry et al., 1996)
Indiangrass	INDN	.0200	.0120	.0050	.0014	.0010	.0007	(Kiniry, personal communication, 2001)
Alfalfa	ALFA	.0417	.0290	.0200	.0035	.0028	.0020	(Kiniry, personal communication, 2001)
Sweetclover	CLVS	.0650	.0280	.0243	.0060	.0024	.0024	estimated
Red clover	CLVR	.0650	.0280	.0243	.0060	.0024	.0024	estimated
Alsike clover	CLVA	.0600	.0280	.0240	.0060	.0025	.0025	estimated
Soybean	SOYB	.0524	.0265	.0258	.0074	.0037	.0035	(Kiniry et al., 1992a)
Cowpeas	CWPS	.0600	.0231	.0134	.0049	.0019	.0011	estimated
Mung bean	MUNG	.0524	.0265	.0258	.0074	.0037	.0035	estimated
Lima beans	LIMA	.0040	.0030	.0015	.0035	.0030	.0015	(Kiniry and Williams, 1994)
Lentils	LENT	.0440	.0164	.0128	.0074	.0037	.0023	estimated
Peanut	PNUT	.0524	.0265	.0258	.0074	.0037	.0035	estimated
Field peas	FPEA	.0515	.0335	.0296	.0033	.0019	.0014	estimated
Garden or canning peas	PEAS	.0040	.0030	.0015	.0030	.0020	.0015	(Kiniry and Williams, 1994)
Sesbania	SESB	.0500	.0200	.0150	.0074	.0037	.0035	estimated
Flax	FLAX	.0482	.0294	.0263	.0049	.0024	.0023	estimated
Upland cotton (harvested with stripper)	COTS	.0580	.0192	.0177	.0081	.0027	.0025	estimated
Upland cotton (harvested with picker)	COTP	.0580	.0192	.0177	.0081	.0027	.0025	estimated
Tobacco	TOBC	.0470	.0177	.0138	.0048	.0018	.0014	(Kiniry and Williams, 1994)
Sugarbeet	SGBT	.0550	.0200	.0120	.0060	.0025	.0019	(Kiniry and Williams, 1994)
Potato	POTA	.0550	.0200	.0120	.0060	.0025	.0019	(Kiniry and Williams, 1994)
Sweetpotato	SPOT	.0450	.0160	.0090	.0045	.0019	.0015	estimated
Carrot	CRRT	.0550	.0075	.0012	.0060	.0030	.0020	(Kiniry and Williams, 1994)
Onion	ONIO	.0400	.0300	.0020	.0021	.0020	.0019	(Kiniry and Williams, 1994)
Sunflower	SUNF	.0500	.0230	.0146	.0063	.0029	.0023	(Kiniry, personal communication, 2001)
Spring canola-Polish	CANP	.0440	.0164	.0128	.0074	.0037	.0023	(Kiniry et al., 1995)
Spring canola-Argentine	CANA	.0440	.0164	.0128	.0074	.0037	.0023	(Kiniry et al., 1995)
Asparagus	ASPR	.0620	.0500	.0400	.0050	.0040	.0020	(Kiniry and Williams, 1994)
Broccoli	BROC	.0620	.0090	.0070	.0050	.0040	.0030	(Kiniry and Williams, 1994)
Cabbage	CABG	.0620	.0070	.0040	.0050	.0035	.0020	(Kiniry and Williams, 1994)
Cauliflower	CAUF	.0620	.0070	.0040	.0050	.0035	.0020	(Kiniry and Williams, 1994)
Celery	CELR	.0620	.0150	.0100	.0060	.0050	.0030	(Kiniry and Williams, 1994)
Head lettuce	LETT	.0360	.0250	.0210	.0084	.0032	.0019	(Kiniry and Williams, 1994)
Spinach	SPIN	.0620	.0400	.0300	.0050	.0040	.0035	(Kiniry and Williams, 1994)

Common Name	Plant Code	$fr_{N,1}$	$fr_{N,2}$	$fr_{N,3}$	$fr_{P,1}$	$fr_{P,2}$	$fr_{P,3}$	Reference
Green beans	GRBN	.0040	.0030	.0015	.0040	.0035	.0015	(Kiniry and Williams, 1994)
Cucumber	CUCM	.0663	.0075	.0048	.0053	.0025	.0012	(Kiniry and Williams, 1994)
Eggplant	EGGP	.0663	.0255	.0075	.0053	.0020	.0015	(Kiniry and Williams, 1994)
Cantaloupe	CANT	.0663	.0255	.0148	.0053	.0020	.0012	(Kiniry and Williams, 1994)
Honeydew melon	HMEL	.0070	.0040	.0020	.0026	.0020	.0017	(Kiniry and Williams, 1994)
Watermelon	WMEL	.0663	.0075	.0048	.0053	.0025	.0012	(Kiniry and Williams, 1994)
Bell pepper	PEPR	.0600	.0350	.0250	.0053	.0020	.0012	(Kiniry and Williams, 1994)
Strawberry	STRW	.0663	.0255	.0148	.0053	.0020	.0012	(Kiniry and Williams, 1994)
Tomato	TOMA	.0663	.0300	.0250	.0053	.0035	.0025	(Kiniry and Williams, 1994)
Apple	APPL	.0060	.0020	.0015	.0007	.0004	.0003	estimated
Pine	PINE	.0060	.0020	.0015	.0007	.0004	.0003	(Kiniry, personal communication, 2001)
Oak	OAK	.0060	.0020	.0015	.0007	.0004	.0003	(Kiniry, personal communication, 2001)
Poplar	POPL	.0060	.0020	.0015	.0007	.0004	.0003	(Kiniry, personal communication, 2001)
Honey mesquite	MESQ	.0200	.0100	.0080	.0007	.0004	.0003	(Kiniry, personal communication, 2001)

A.1.9 HARVEST

Harvest operations are performed on agricultural crops where the yield is sold for a profit. Four variables in the database provide information used by the model to harvest a crop: HVSTI, WSYF, CNYLD, and CPYLD.

The harvest index defines the fraction of the aboveground biomass that is removed in a harvest operation. This value defines the fraction of plant biomass that is “lost” from the system and unavailable for conversion to residue and subsequent decomposition. For crops where the harvested portion of the plant is aboveground, the harvest index is always a fraction less than 1. For crops where the harvested portion is belowground, the harvest index may be greater than 1. Two harvest indices are provided in the database, the harvest index for optimal growing conditions (HVSTI) and the harvest index under highly stressed growing conditions (WSYF).

To determine the harvest index, the plant biomass removed during the harvest operation is dried at least 2 days at 65°C and weighed. The total aboveground plant biomass in the field should also be dried and weighed. The harvest index is then calculated by dividing the weight of the harvested portion of the plant biomass by the weight of the total aboveground plant biomass. Plants will need to be grown in two different plots where optimal climatic conditions and stressed conditions are produced to obtain values for both harvest indices.

In addition to the amount of plant biomass removed in the yield, SWAT needs to know the amount of nitrogen and phosphorus removed in the yield. The harvested portion of the plant biomass is sent to a testing laboratory to determine the fraction of nitrogen and phosphorus in the biomass.

Table A-8 lists values for the optimal harvest index (HI_{opt}), the minimum harvest index (HI_{min}), the fraction of nitrogen in the harvested portion of biomass ($fr_{N,yld}$), and the fraction of phosphorus in the harvested portion of biomass ($fr_{P,yld}$).

Table A-8: Harvest parameters for plants included in the plant growth database.

Common Name	**Plant Code**	HI_{opt}	HI_{min}	$fr_{N,yld}$	$fr_{P,yld}$	**Reference**
Corn	CORN	0.50	0.30	.0140	.0016	(Kiniry, personal communication, 2001; Kiniry et al, 1995)
Corn silage	CSIL	0.90	0.90	.0140	.0016	(Kiniry, personal communication, 2001; Kiniry et al, 1995)
Sweet corn	SCRN	0.50	0.30	.0214	.0037	(Kiniry, personal communication, 2001; Nutrition Monitoring Division, 1984a)
Eastern gamagrass	EGAM	0.90	0.90	.0160	.0022	(Kiniry, personal communication, 2001)
Grain sorghum	GRSG	0.45	0.25	.0199	.0032	(Kiniry and Bockholt, 1998; Nutrition Monitoring Division, 1984b)
Sorghum hay	SGHY	0.90	0.90	.0199	.0032	(Kiniry, personal communication, 2001; Nutrition Monitoring Division, 1984b)
Johnsongrass	JHGR	0.90	0.90	.0200	.0028	(Kiniry, personal communication, 2001; Kiniry et al, 1992a)
Sugarcane	SUGC	0.50	0.01	.0000	.0000	(Kiniry and Williams, 1994)
Spring wheat	SWHT	0.42	0.20	.0234	.0033	(Kinry et al, 1995; Kiniry et al, 1992a)
Winter wheat	WWHT	0.40	0.20	.0250	.0022	(Kiniry et al, 1995)
Durum wheat	DWHT	0.40	0.20	.0263	.0057	(Kiniry, personal communication, 2001; Nutrition Monitoring Division, 1984b)
Rye	RYE	0.40	0.20	.0284	.0042	(Kiniry, personal communication, 2001; Nutrition Monitoring Division, 1984b)
Spring barley	BARL	0.54	0.20	.0210	.0017	(Kiniry et al, 1995)
Oats	OATS	0.42	0.175	.0316	.0057	(Kiniry, personal communication, 2001; Nutrition Monitoring Division, 1984b)
Rice	RICE	0.50	0.25	.0136	.0013	(Kiniry, personal communication, 2001; Nutrition Monitoring Division, 1984b)
Pearl millet	PMIL	0.25	0.10	.0200	.0028	(Kiniry, personal communication, 2001; estimated)

Common Name	Plant Code	HI_{opt}	HI_{min}	$fr_{N,yld}$	$fr_{P,yld}$	Reference
Timothy	TIMO	0.90	0.90	.0234	.0033	(Kiniry, personal communication, 2001; estimated)
Smooth bromegrass	BROS	0.90	0.90	.0234	.0033	(Kiniry, personal communication, 2001; Kiniry et al, 1995)
Meadow bromegrass	BROM	0.90	0.90	.0234	.0033	(Kiniry, personal communication, 2001; Kiniry et al, 1995)
Tall fescue	FESC	0.90	0.90	.0234	.0033	(Kiniry, personal communication, 2001; estimated)
Kentucky bluegrass	BLUG	0.90	0.90	.0160	.0022	(Kiniry, personal communication, 2001)
Bermudagrass	BERM	0.90	0.90	.0234	.0033	(Kiniry, personal communication, 2001)
Crested wheatgrass	CWGR	0.90	0.90	.0500	.0040	(Kiniry, personal communication, 2001; Kiniry et al, 1995)
Western wheatgrass	WWGR	0.90	0.90	.0500	.0040	(Kiniry, personal communication, 2001; Kiniry et al, 1995)
Slender wheatgrass	SWGR	0.90	0.90	.0500	.0040	(Kiniry, personal communication, 2001; estimated)
Italian (annual) ryegrass	RYEG	0.90	0.90	.0220	.0028	(Kiniry, personal communication, 2001; estimated)
Russian wildrye	RYER	0.90	0.90	.0230	.0037	(Kiniry, personal communication, 2001; Kiniry et al, 1995)
Altai wildrye	RYEA	0.90	0.90	.0230	.0037	(Kiniry, personal communication, 2001; Kiniry et al, 1995)
Sideoats grama	SIDE	0.90	0.90	.0160	.0022	(Kiniry, personal communication, 2001)
Big bluestem	BBLS	0.90	0.90	.0160	.0022	(Kiniry, personal communication, 2001)
Little bluestem	LBLS	0.90	0.90	.0160	.0022	(Kiniry, personal communication, 2001)
Alamo switchgrass	SWCH	0.90	0.90	.0160	.0022	(Kiniry et al, 1996)
Indiangrass	INDN	0.90	0.90	.0160	.0022	(Kiniry, personal communication, 2001)
Alfalfa	ALFA	0.90	0.90	.0250	.0035	(Kiniry, personal communication, 2001)
Sweetclover	CLVS	0.90	0.90	.0650	.0040	(Kiniry, personal communication, 2001; estimated)
Red clover	CLVR	0.90	0.90	.0650	.0040	(Kiniry, personal communication, 2001; estimated)
Alsike clover	CLVA	0.90	0.90	.0600	.0040	(Kiniry, personal communication, 2001; estimated)
Soybean	SOYB	0.31	0.01	.0650	.0091	(Kiniry et al, 1992a)
Cowpeas	CWPS	0.42	0.05	.0427	.0048	(estimated; Nutrition Monitoring Division, 1984c)
Mung bean	MUNG	0.31	0.01	.0420	.0040	(estimated; Nutrition Monitoring Division, 1984c)
Lima beans	LIMA	0.30	0.22	.0368	.0046	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Lentils	LENT	0.61	0.01	.0506	.0051	(estimated; Nutrition Monitoring Division, 1984c)
Peanut	PNUT	0.40	0.30	.0505	.0040	(estimated; Nutrition Monitoring Division, 1984c)
Field peas	FPEA	0.45	0.10	.0370	.0021	estimated
Garden or canning peas	PEAS	0.30	0.22	.0410	.0051	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Sesbania	SESB	0.31	0.01	.0650	.0091	estimated

Common Name	Plant Code	HI_{opt}	HI_{min}	$fr_{N,yld}$	$fr_{P,yld}$	Reference
Flax	FLAX	0.54	0.40	.0400	.0033	estimated
Upland cotton (harvested with stripper)	COTS	0.50	0.40	.0140	.0020	(Kiniry, personal communication, 2001; estimated)
Upland cotton (harvested with picker)	COTP	0.40	0.30	.0190	.0029	(Kiniry, personal communication, 2001; estimated)
Tobacco	TOBC	0.55	0.55	.0140	.0016	(Kiniry and Williams, 1994)
Sugarbeet	SGBT	2.00	1.10	.0130	.0020	(Kiniry and Williams, 1994)
Potato	POTA	0.95	0.95	.0246	.0023	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Sweetpotato	SPOT	0.60	0.40	.0097	.0010	(estimated; Nutrition Monitoring Division, 1984a)
Carrot	CRRT	1.12	0.90	.0135	.0036	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Onion	ONIO	1.25	0.95	.0206	.0032	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Sunflower	SUNF	0.30	0.18	.0454	.0074	(Kiniry et al, 1992b; Nutrition Monitoring Division, 1984d)
Spring canola-Polish	CANP	0.23	0.01	.0380	.0079	(Kiniry et al, 1995)
Spring canola-Argentine	CANA	0.30	0.01	.0380	.0079	(Kiniry et al, 1995)
Asparagus	ASPR	0.80	0.95	.0630	.0067	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Broccoli	BROC	0.80	0.95	.0512	.0071	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Cabbage	CABG	0.80	0.95	.0259	.0031	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Cauliflower	CAUF	0.80	0.95	.0411	.0059	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Celery	CELR	0.80	0.95	.0199	.0049	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Head lettuce	LETT	0.80	0.01	.0393	.0049	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Spinach	SPIN	0.95	0.95	.0543	.0058	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Green beans	GRBN	0.10	0.10	.0299	.0039	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Cucumber	CUCM	0.27	0.25	.0219	.0043	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Eggplant	EGGP	0.59	0.25	.0218	.0041	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Cantaloupe	CANT	0.50	0.25	.0138	.0017	(Kiniry and Williams, 1994; Consumer Nutrition Center, 1982)
Honeydew melon	HMEL	0.55	0.25	.0071	.0010	(Kiniry and Williams, 1994; Consumer Nutrition Center, 1982)
Watermelon	WMEL	0.50	0.25	.0117	.0011	(Kiniry and Williams, 1994; Consumer Nutrition Center, 1982)
Bell pepper	PEPR	0.60	0.25	.0188	.0030	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Strawberry	STRW	0.45	0.25	.0116	.0023	(Kiniry and Williams, 1994; Consumer Nutrition Center, 1982)
Tomato	TOMA	0.33	0.15	.0235	.0048	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)

Common Name	Plant Code	HI_{opt}	HI_{min}	$fr_{N,yld}$	$fr_{P,yld}$	Reference
Apple	APPL	0.10	0.05	.0019	.0004	(estimated; Consumer Nutrition Center, 1982)
Pine	PINE	0.76	0.60	.0015	.0003	(Kiniry, personal communication, 2001)
Oak	OAK	0.76	0.01	.0015	.0003	(Kiniry, personal communication, 2001)
Poplar	POPL	0.76	0.01	.0015	.0003	(Kiniry, personal communication, 2001)
Honey mesquite	MESQ	0.05	0.01	.0015	.0003	(Kiniry, personal communication, 2001)

A.1.10 USLE C FACTOR

The USLE C factor is the ratio of soil loss from land cropped under specified conditions to the corresponding loss from clean-tilled, continuous fallow. This factor measures the combined effect of all the interrelated cover and management variables. SWAT calculates the actual C factor based on the amount of soil cover and the minimum C factor defined for the plant/land cover. The minimum C factor quantifies the maximum decrease in erosion possible for the plant/land cover. Because the USLE C factor is influenced by management, this variable may be adjusted by the user to reflect management conditions in the watershed of interest.

The minimum C factor can be estimated from a known average annual C factor using the following equation (Arnold and Williams, 1995):

$$C_{USLE,mn} = 1.463 \ln\left[C_{USLE,aa}\right] + 0.1034$$

where $C_{USLE,mn}$ is the minimum C factor for the land cover and $C_{USLE,aa}$ is the average annual C factor for the land cover. The minimum C factor for plants in the database are listed in Table A-6.

A.1.11 RESIDUE DECOMPOSITION

The plant residue decomposition coefficient is the fraction of residue that will decompose in a day assuming optimal moisture, temperature, C:N ratio, and C:P ratio. This variable was originally in the basin input file (.bsn), but was added to the crop database so that users could vary decomposition by land cover. A default value of 0.05 is used for all plant species in the database.

A.1.12 MINIMUM LAI/BIOMASS DURING DORMANCY

Minimum leaf area index for plants (perennials and trees) during dormancy was set by SWAT to 0.75 in versions prior to SWAT2009. Because this minimum leaf area index did not work well for trees, the variable was added to the plant growth database. Users may now adjust the value to any desired value. A default value of 0.75 is used for trees and perennials and 0.0 for all other plants.

The fraction of tree leaf biomass that drops during dormancy was originally set to 0.30 within SWAT. To allow users more control over the tree growth cycle, this variable was added to the plant database. A default value of 0.30 is assigned to all trees in the database.

A.2 TILLAGE DATABASE

The tillage database contains information needed by SWAT to simulate the redistribution of nutrients and pesticide that occurs in a tillage operation. Table A-9 lists all the default tillage implements. This list was summarized from a farm machinery database maintained by the USDA Economic Research Service. Depth of tillage for each implement was also obtained from the USDA Economic Research Service. The fraction of residue mixed into the soil was estimated for each implement from a „Residue Scorecard" provided by NACD"s (National Association of Conservation Districts) Conservation Technology Information Center.

Table A-9: Implements included in the tillage database.

Implement	Tillage Code	Mixing Depth	Mixing Efficiency
Duckfoot Cultivator	DUCKFTC	100 mm	0.55
Field Cultivator	FLDCULT	100 mm	0.30
Furrow-out Cultivator	FUROWOUT	25 mm	0.75
Marker (Cultivator)	MARKER	100 mm	0.45
Rolling Cultivator	ROLLCULT	25 mm	0.50
Row Cultivator	ROWCULT	25 mm	0.25
Discovator	DISCOVAT	25 mm	0.50
Leveler	LEVELER	25 mm	0.50
Harrow (Tines)	HARROW	25 mm	0.20
Culti-mulch Roller	CULMULCH	25 mm	0.25
Culti-packer Pulverizer	CULPKPUL	40 mm	0.35
Land Plane-Leveler	LANDLEVL	75 mm	0.50
Landall, Do-All	LANDALL	150 mm	0.30
Laser Planer	LASRPLAN	150 mm	0.30
Levee-Plow-Disc	LEVPLDIS	25 mm	0.75
Float	FLOAT	60 mm	0.10
Field Conditioner (Scratcher)	FLDCDSCR	60 mm	0.10
Lister (Middle-Buster)	LISTRMID	40 mm	0.15
Roller Groover	ROLLGROV	60 mm	0.25
Roller Packer Attachment	ROLPKRAT	40 mm	0.05
Roller Packer Flat Roller	ROLPKRFT	40 mm	0.35
Sand-Fighter	SANDFIGT	100 mm	0.70
Seedbed Roller	SEEDROLL	100 mm	0.70
Crust Buster	CRUSTBST	60 mm	0.10
Roller Harrow	ROLLHRRW	60 mm	0.40
Triple K	TRIPLE K	100 mm	0.40
Finishing Harrow	FINHARRW	100 mm	0.55
Flex-Tine Harrow CL	FLEXHARW	25 mm	0.20
Powered Spike Tooth Harrow	SPIKETTH	75 mm	0.40
Spike Tooth Harrow	SPIKTOTH	25 mm	0.25
Springtooth Harrow	SPRGTOTH	25 mm	0.35

Implement	Tillage Code	Mixing Depth	Mixing Efficiency
Soil Finisher	SOILFINS	75 mm	0.55
Rotary Hoe	ROTHOE	5 mm	0.10
Roterra	ROTERRA	5 mm	0.80
Roto-Tiller	ROTOTILL	5 mm	0.80
Rotovator-Bedder	ROTBEDDR	100 mm	0.80
Rowbuck	ROWBUCK	100 mm	0.70
Ripper	RIPPER	350 mm	0.25
Middle Buster	MIDBST1R	100 mm	0.70
Rod Weeder	RODWEEDR	25 mm	0.30
Rubber-Wheel Weed Puller	RUBWHWPL	5 mm	0.35
Multi-Weeder	MULTIWDR	25 mm	0.30
Moldboard Plow Reg	MLDBOARD	150 mm	0.95
Chisel Plow	CHISPLOW	150 mm	0.30
Coulter-Chisel	CCHPLOW	150 mm	0.50
Disk Plow	DISKPLOW	100 mm	0.85
Stubble-mulch Plow	STUBMLCH	75 mm	0.15
Subsoil Chisel Plow	SUBCHPLW	350 mm	0.45
Row Conditioner	ROWCOND	25 mm	0.50
Hipper	HIPPER	100 mm	0.50
Rice Roller	RICEROLL	50 mm	0.10
Paraplow	PARAPLOW	350 mm	0.15
Subsoiler-Bedder Hip-Rip	SBEDHIPR	350 mm	0.70
Deep Ripper-Subsoiler	RIPRSUBS	350 mm	0.25
V-Ripper	VRIPPER	350 mm	0.25
Bed Roller	BEDROLLR	50 mm	0.25
Bedder (Disk)	BEDDER D	150 mm	0.55
Bedder Disk-Hipper	BEDDHIPR	150 mm	0.65
Bedder Disk-Row	BEDDKROW	100 mm	0.85
Bedder Shaper	BEDDER S	150 mm	0.55
Disk Border Maker	DSKBRMKR	150 mm	0.55
Disk Chisel (Mulch Tiller)	DKCHMTIL	150 mm	0.55
Offset Disk-Heavy Duty	OFFSETHV	100 mm	0.70
Offset Disk-Light Duty	OFFSETLT	100 mm	0.55
One-Way (Disk Tiller)	ONE-WAYT	100 mm	0.60
Tandem Disk Plow	TANDEMPL	75 mm	0.55
Tandem Disk Reg	TANDEMRG	75 mm	0.60
Single Disk	SINGLDIS	100 mm	0.45
Power Mulcher	PWRMULCH	50 mm	0.70
Blade 10 ft	BLADE 10	75 mm	0.25
Furrow Diker	FURWDIKE	100 mm	0.70
Beet Cultivator	BEETCULT	25 mm	0.25
Cultiweeder	CLTIWEED	100 mm	0.30
Packer	PACKER	40 mm	0.35

In addition to information about specific implements, the tillage database includes default information for the different crop residue management categories. Table A-10 summarizes the information in the database on the different residue management categories.

Table A-10: Generic management scenarios included in the tillage database.

Implement	Tillage Code	Mixing Depth	Mixing Efficiency
Generic Fall Plowing Operation	FALLPLOW	150 mm	0.95
Generic Spring Plowing Operation	SPRGPLOW	125 mm	0.50
Generic Conservation Tillage	CONSTILL	100 mm	0.25
Generic No-Till Mixing	ZEROTILL	25 mm	0.05

ASAE (1998b) categorizes tillage implements into five different categories—primary tillage, secondary tillage, cultivating tillage, combination primary tillage, and combination secondary tillage. The definitions for the categories are (ASAE, 1998b):

Primary tillage: the implements displace and shatter soil to reduce soil strength and bury or mix plant materials, pesticides, and fertilizers in the tillage layer. This type of tillage is more aggressive, deeper, and leaves a rougher soil surface relative to secondary tillage. Examples include plows—moldboard, chisel, disk, bedder; moldboard listers; disk bedders; subsoilers; disk harrows—offset disk, heavy tandem disk; and powered rotary tillers.

Secondary tillage: the implements till the soil to a shallower depth than primary tillage implements, provide additional pulverization, mix pesticides and fertilizers into the soil, level and firm the soil, close air pockets, and eradicate weeds. Seedbed preparation is the final secondary tillage operation. Examples include harrows—disk, spring, spike, coil, tine-tooth, knife, packer, ridger, leveler, rotary ground driven; field or field conditioner cultivators; rod weeders; rollers; powered rotary tillers; bed shapers; and rotary hoes.

Cultivating tillage: the implements perform shallow post-plant tillage to aid the crop by loosening the soil and/or by mechanical eradication of undesired vegetation. Examples include row crop cultivators—rotary ground-driven, spring tooth, shank tooth; rotary hoes; and rotary tillers.

Combination primary tillage: the implements perform primary tillage functions and utilize two or more dissimilar tillage components as integral parts of the implement.

Combination secondary tillage: the implements perform secondary tillage functions and utilize two or more dissimilar tillage components as integral parts of the implement.

ASAE (1998b) provides detailed descriptions and illustrations for the major implements. These are very helpful for those who are not familiar with farm implements.

A.3 PESTICIDE DATABASE

The pesticide database file (pest.dat) summarizes pesticide attribute information for various pesticides. The pesticide data included in the database was originally compiled for the GLEAMS model in the early nineties (Knisel, 1993). The following table lists the pesticides included in the pesticide database.

Table A-11: SWAT Pesticide Database

Trade Name	Common Name	Koc	Wash-off Frac.	Half-Life Foliar	Half-Life Soil	Water Solubility
		(ml/g)		(days)	(days)	(mg/L)
2,4,5-TP	Silvex	2600	0.40	5.0	20.0	2.5
2 Plus 2	Mecoprop Amine	20	0.95	10.0	21.0	660000
Aatrex	Atrazine	100	0.45	5.0	60.0	33
Abate	Temephos	100000	0.65	5.0	30.0	0.001
Acaraben	Chlorobenzilate	2000	0.05	10.0	20.0	13
Accelerate	Endothall Salt	20	0.90	7.0	7.0	100000
Acclaim	Fenoxaprop-Ethyl	9490	0.20	5.0	9.0	0.8
Alanap	Naptalam Sodium Salt	20	0.95	7.0	14.0	231000
Alar	Daminozide	10	0.95	4.0	7.0	100000
Aldrin	Aldrin	300	0.05	2.0	28.0	0.1
Aliette	Fosetyl-Aluminum	20	0.95	0.1	0.1	120000
Ally	Metsulfuron-Methyl	35	0.80	30.0	120.0	9500
Amiben	Chloramben Salts	15	0.95	7.0	14.0	900000
Amid-Thin W	NAA Amide	100	0.60	5.0	10.0	100
Amitrol T	Amitrole	100	0.95	5.0	14.0	360000
Ammo	Cypermethrin	100000	0.40	5.0	30.0	0.004
Antor	Diethatyl-Ethyl	1400	0.40	10.0	21.0	105
A-Rest	Ancymidol	120	0.50	30.0	120.0	650
Arsenal	Imazapyr Acid	100	0.90	30.0	90.0	11000
Arsonate	MSMA	10000	0.95	30.0	100.0	1000000
Asana	Esfenvalerate	5300	0.40	8.0	35.0	0.002
Assert (m)	Imazamethabenz-m	66	0.65	18.0	35.0	1370
Assert (p)	Imazamethabenz-p	35	0.65	18.0	35.0	875
Assure	Quizalofop-Ethyl	510	0.20	15.0	60.0	0.31
Asulox	Asulam Sodium Salt	40	0.95	3.0	7.0	550000
Avenge	Difenzoquat	54500	0.95	30.0	100.0	817000
Azodrin	Monocrotophos	1	0.95	2.0	30.0	1000000
Balan	Benefin	9000	0.20	10.0	30.0	0.1
Banol	Propamocarb	1000000	0.95	15.0	30.0	1000000
Banvel	Dicamba	2	0.65	9.0	14.0	400000
Basagran	Bentazon	34	0.60	2.0	20.0	2300000

Trade Name	Common Name	Koc	Wash-off Frac.	Half-Life Foliar	Half-Life Soil	Water Solubility
		(ml/g)		(days)		(mg/L)
Basta	Glufosinate Ammonia	100	0.95	4.0	7.0	1370000
Bayleton	Triadimefon	300	0.30	8.0	26.0	71.5
Baytex	Fenthion	1500	0.65	2.0	34.0	4.2
Baythroid	Cyfluthrin	100000	0.40	5.0	30.0	0.002
Benlate	Benomyl	1900	0.25	6.0	240.0	2
Benzex	BHC	55000	0.05	3.0	600.0	0.1
Betamix	Phenmedipham	2400	0.70	5.0	30.0	4.7
Betanex	Desmedipham	1500	0.70	5.0	30.0	8
Bidrin	Dicrotophos	75	0.70	20.0	28.0	1000000
Bladex	Cyanazine	190	0.60	5.0	14.0	170
Bolero	Thiobencarb	900	0.70	7.0	21.0	28
Bolstar	Sulprofos	12000	0.55	0.5	140.0	0.31
Bordermaster	MCPA Ester	1000	0.50	8.0	25.0	5
Botran	DCNA (Dicloran)	1000	0.50	4.0	10.0	7
Bravo	Chlorothalonil	1380	0.50	5.0	30.0	0.6
Buctril	Bromoxynil Octan. Ester	10000	0.20	3.0	7.0	0.08
Butyrac Ester	2,4-DB Ester	500	0.45	7.0	7.0	8
Caparol	Prometryn	400	0.50	10.0	60.0	33
Carbamate	Ferbam	300	0.90	3.0	17.0	120
Carsoron	Dichlobenil	400	0.45	5.0	60.0	21.2
Carzol	Formetanate Hydrochlor	1000000	0.95	30.0	100.0	500000
Cerone	Ethephon	100000	0.95	5.0	10.0	1239000
Chem-Hoe	Propham (IPC)	200	0.50	2.0	10.0	250
Chlordane	Chlordane	100000	0.05	2.5	100.0	0.1
Chopper	Imazapyr Amine	100	0.80	30.0	90.0	500000
Classic	Chlorimuron-ethyl	110	0.90	15.0	40.0	1200
Cobra	Lactofen	100000	0.20	2.0	3.0	0.1
Comite	Propargite	4000	0.20	5.0	56.0	0.5
Command	Clomazone	300	0.80	3.0	24.0	1000
Cotoran	Fluometuron	100	0.50	30.0	85.0	110
Counter	Terbufos	500	0.60	2.5	5.0	5
Crossbow	Triclopyr Amine	20	0.95	15.0	46.0	2100000
Curacron	Profenofos	2000	0.90	3.0	8.0	28
Cygon	Dimethoate	20	0.95	3.0	7.0	39800
Cyprex	Dodine Acetate	100000	0.50	10.0	20.0	700
Cythion	Malathion	1800	0.90	1.0	1.0	130
Dacamine	2,4-D Acid	20	0.45	5.0	10.0	890
Dacthal	DCPA	5000	0.30	10.0	100.0	0.5
Dalapon	Dalapon Sodium Salt	1	0.95	37.0	30.0	900000
Dasanit	Fensulfothion	10000	0.90	4.0	24.0	0.01
DDT	DDT	240000	0.05	10.0	120.0	0.1

Trade Name	Common Name	Koc	Wash-off Frac.	Half-Life Foliar	Half-Life Soil	Water Solubility
		(ml/g)		(days)		(mg/L)
Dedweed	MCPA Amine	20	0.95	7.0	25.0	866000
DEF	Tribufos	5000	0.25	7.0	30.0	2.3
Dessicant L-10	Arsenic Acid	100000	0.95	10000.0	10000.0	17000
Devrinol	Napropamide	400	0.60	15.0	70.0	74
Di-Syston	Disulfoton	600	0.50	3.0	30.0	25
Dibrom	Naled	180	0.90	5.0	1.0	2000
Dieldrin	Dieldrin	50000	0.05	5.0	1400.0	0.1
Dimilin	Diflubenzuron	10000	0.05	27.0	10.0	0.08
Dinitro	Dinoseb Phenol	500	0.60	3.0	20.0	50
Diquat	Diquat Dibromide	1000000	0.95	30.0	1000.0	718000
Dithane	Mancozeb	2000	0.25	10.0	70.0	6
Dowpon	Dalapon	4	0.95	37.0	30.0	1000
Dropp	Thidiazuron	110	0.40	3.0	10.0	20
DSMA	Methanearsonic Acid Na	100000	0.95	30.0	1000.0	1400000
Du-ter	Triphenyltin Hydroxide	23000	0.40	18.0	75.0	1
Dual	Metolachlor	200	0.60	5.0	90.0	530
Dyfonate	Fonofos	870	0.60	2.5	40.0	16.9
Dylox	Trichlorfon	10	0.95	3.0	10.0	120000
Dymid	Diphenamid	210	0.80	5.0	30.0	260
Dyrene	Anilazine	3000	0.50	5.0	1.0	8
Elgetol	DNOC Sodium Salt	20	0.95	8.0	20.0	100000
EPN	EPN	13000	0.60	5.0	5.0	0.5
Eradicane	EPTC	200	0.75	3.0	6.0	344
Ethanox	Ethion	10000	0.65	7.0	150.0	1.1
Evik	Ametryn	300	0.65	5.0	60.0	185
Evital	Norflurazon	600	0.50	15.0	90.0	28
Far-Go	Triallate	2400	0.40	15.0	82.0	4
Fenatrol	Fenac	20	0.95	30.0	180.0	500000
Fenitox	Fenitrothion	2000	0.90	3.0	8.0	30
Fruitone CPA	3-CPA Sodium Salt	20	0.95	3.0	10.0	200000
Fundal	Chlordimeform Hydroclo.	100000	0.90	1.0	60.0	500000
Funginex	Triforine	540	0.80	5.0	21.0	30
Furadan	Carbofuran	22	0.55	2.0	50.0	351
Fusilade	Fluazifop-P-Butyl	5700	0.40	4.0	15.0	2
Glean	Chlorsulfuron	40	0.75	30.0	160.0	7000
Goal	Oxyfluorfen	100000	0.40	8.0	35.0	0.1
Guthion	Azinphos-Methyl	1000	0.65	2.0	10.0	29
Harmony	Thifensulfuron-Methyl	45	0.80	3.0	12.0	2400
Harvade	Dimethipin	10	0.80	3.0	10.0	3000
Hoelon	Diclofop-Methyl	16000	0.45	8.0	37.0	0.8
Hyvar	Bromacil	32	0.75	20.0	60.0	700

Trade Name	Common Name	Koc	Wash-off Frac.	Half-Life Foliar	Half-Life Soil	Water Solubility
		(ml/g)		(days)		(mg/L)
Imidan	Phosmet	820	0.90	3.0	19.0	20
Isotox	Lindane	1100	0.05	2.5	400.0	7.3
Karate	Lambda-Cyhalothrin	180000	0.40	5.0	30.0	0.005
Karathane	Dinocap	550	0.30	8.0	20.0	4
Karmex	Diuron	480	0.45	30.0	90.0	42
Kelthane	Dicofol	180000	0.05	4.0	60.0	1
Kerb	Pronamide	200	0.30	20.0	60.0	15
Krenite	Fosamine Ammon. Salt	150	0.95	4.0	8.0	1790000
Lannate	Methomyl	72	0.55	0.5	30.0	58000
Larvadex	Cyromazine	200	0.95	30.0	150.0	136000
Larvin	Thiodicarb	350	0.70	4.0	7.0	19.1
Lasso	Alachlor	170	0.40	3.0	15.0	240
Limit	Amidochlor	1000	0.70	8.0	20.0	10
Lontrel	Clopyralid	6	0.95	2.0	30.0	300000
Lorox	Linuron	400	0.60	15.0	60.0	75
Lorsban	Clorpyrifos	6070	0.65	3.3	30.0	0.4
Manzate	Maneb	1000	0.65	3.0	12.0	6
Marlate	Methoxychlor	80000	0.05	6.0	120.0	0.1
Matacil	Aminocarb	100	0.90	4.0	6.0	915
Mavrik	Fluvalinate	1000000	0.40	7.0	30.0	0.005
Metasystox	Oxydemeton-Methyl	10	0.95	3.0	10.0	1000000
Milogard	Propazine	154	0.45	5.0	135.0	8.6
Miral	Isazofos	100	0.65	5.0	34.0	69
Mitac	Amitraz	1000	0.45	1.0	2.0	1
Modown	Bifenox	10000	0.40	3.0	7.0	0.4
Monitor	Methamidophos	5	0.95	4.0	6.0	1000000
Morestan	Oxythioquinox	2300	0.50	10.0	30.0	1
Nemacur	Fenamiphos	240	0.70	5.0	5.0	400
Nemacur Sulfone	Fenamiphos Sulfone	45	0.70	18.0	18.0	400
Nemacur Sulfoxide	Fenamiphos Sulfoxide	40	0.70	42.0	42.0	400
Norton	Ethofumesate	340	0.65	10.0	30.0	50
Octave	Prochloraz	500	0.50	30.0	120.0	34
Oftanol	Isofenphos	600	0.65	30.0	150.0	24
Orthene	Acephate	2	0.70	2.5	3.0	818000
Orthocide	Captan	200	0.65	9.0	2.5	5.1
Oust	Sulfometuron-Methyl	78	0.65	10.0	20.0	70
Pay-Off	Flucythrinate	100000	0.40	5.0	21.0	0.06
Penncap-M	Methyl Parathion	5100	0.90	3.0	5.0	60
Phenatox	Toxaphene	100000	0.05	2.0	9.0	3
Phosdrin	Mevinphos	44	0.95	0.6	3.0	600000
Phoskil	Parathion (Ethyl)	5000	0.70	4.0	14.0	24

Trade Name	Common Name	Koc	Wash-off Frac.	Half-Life Foliar	Half-Life Soil	Water Solubility
		(ml/g)		(days)		(mg/L)
Pipron	Piperalin	5000	0.60	10.0	30.0	20
Pix	Mepiquat Chlor. Salt	1000000	0.95	30.0	1000.0	1000000
Plantvax	Oxycarboxin	95	0.70	10.0	20.0	1000
Poast	Sethoxydim	100	0.70	3.0	5.0	4390
Polyram	Metiram	500000	0.40	7.0	20.0	0.1
Pounce	Permethrin	100000	0.30	8.0	30.0	0.006
Pramitol	Prometon	150	0.75	30.0	500.0	720
Prefar	Bensulide	1000	0.40	30.0	120.0	5.6
Prelude	Paraquat	1000000	0.60	30.0	1000.0	620000
Prime	Flumetralin	10000	0.40	7.0	20.0	0.1
Princep	Simazine	130	0.40	5.0	60.0	6.2
Probe	Methazole	3000	0.40	5.0	14.0	1.5
Prowl	Pendimethalin	5000	0.40	30.0	90.0	0.275
Pursuit	AC 263,499	10	0.90	20.0	90.0	200000
Pydrin	Fenvalerate	5300	0.25	10.0	35.0	0.002
Pyramin	Pyrazon	120	0.85	5.0	21.0	400
Ramrod	Propaclor	80	0.40	3.0	6.0	613
Reflex	Fomesafen Salt	60	0.95	30.0	100.0	700000
Rescue	2,4-DB Sodium Amine	20	0.45	9.0	10.0	709000
Ridomil	Metalaxyl	50	0.70	30.0	70.0	8400
Ro-Neet	Cycloate	430	0.50	2.0	30.0	95
Ronstar	Oxadiazon	3200	0.50	20.0	60.0	0.7
Roundup	Glyphosate Amine	24000	0.60	2.5	47.0	900000
Rovral	Iprodione	700	0.40	5.0	14.0	13.9
Royal Slo-Gro	Maleic Hydrazide	20	0.95	10.0	30.0	400000
Rubigan	Fenarimol	600	0.40	30.0	360.0	14
Sancap	Dipropetryn	900	0.40	5.0	30.0	16
Savey	Hexythiazox	6200	0.40	5.0	30.0	0.5
Scepter	Imazaquin Ammonium	20	0.95	20.0	60.0	160000
Sencor	Metribuzin	60	0.80	5.0	40.0	1220
Sevin	Carbaryl	300	0.55	7.0	10.0	120
Sinbar	Terbacil	55	0.70	30.0	120.0	710
Slug-Geta	Methiocarb	300	0.70	10.0	30.0	24
Sonalan	Ethalfluralin	4000	0.40	4.0	60.0	0.3
Spectracide	Diazinon	1000	0.90	4.0	40.0	60
Spike	Tebuthiuron	80	0.90	30.0	360.0	2500
Sprout Nip	Chlorpropham	400	0.90	8.0	30.0	89
Stam	Propanil	149	0.70	1.0	1.0	200
Supracide	Methidathion	400	0.90	3.0	7.0	220
Surflan	Oryzalin	600	0.40	5.0	20.0	2.5
Sutan	Butylate	400	0.30	1.0	13.0	44

Trade Name	Common Name	Koc	Wash-off Frac.	Half-Life Foliar	Half-Life Soil	Water Solubility
		(ml/g)		(days)		(mg/L)
Swat	Phosphamidon	7	0.95	5.0	17.0	1000000
Tackle	Acifluorfen	113	0.95	5.0	14.0	250000
Talstar	Bifenthrin	240000	0.40	7.0	26.0	0.1
Tandem	Tridiphane	5600	0.40	8.0	28.0	1.8
Tanone	Phenthoate	250	0.65	2.0	40.0	200
Tattoo	Bendiocarb	570	0.85	3.0	5.0	40
TBZ	Thiabendazole	2500	0.60	30.0	403.0	50
Temik	Aldicarb	40	0.70	7.0	7.0	6000
Temik Sulfone	Aldicarb Sulfone	10	0.70	20.0	20.0	6000
Temik Sulfoxide	Aldicarb Sulfoxide	30	0.70	30.0	30.0	6000
Tenoran	Chloroxuron	3000	0.40	15.0	60.0	2.5
Terbutrex	Terbutryn	2000	0.50	5.0	42.0	22
Terrachlor	PCNB	5000	0.40	4.0	21.0	0.44
Terraneb	Chloroneb	1650	0.50	30.0	130.0	8
Terrazole	Etridiazole	1000	0.60	3.0	20.0	50
Thimet	Phorate	1000	0.60	2.0	60.0	22
Thiodan	Endosulfan	12400	0.05	3.0	50.0	0.32
Thiram	Thiram	670	0.50	8.0	15.0	30
Thistrol	MCPB Sodium Salt	20	0.95	7.0	14.0	200000
Tillam	Pebulate	430	0.70	4.0	14.0	100
Tilt	Propiconazole	1000	0.70	30.0	110.0	110
Tolban	Profluralin	2240	0.35	1.0	140.0	0.1
Topsin	Thiophanate-Methyl	1830	0.40	5.0	10.0	3.5
Tordon	Picloram	16	0.60	8.0	90.0	200000
Tralomethrin	Tralomethrin	100000	0.40	1.0	27.0	0.001
Treflan	Trifluralin	8000	0.40	3.0	60.0	0.3
Tre-Hold	NAA Ethyl Ester	300	0.40	5.0	10.0	105
Tupersan	Siduron	420	0.70	30.0	90.0	18
Turflon	Triclopyr Ester	780	0.70	15.0	46.0	23
Velpar	Hexazinone	54	0.90	30.0	90.0	3300
Vendex	Fenbutatin Oxide	2300	0.20	30.0	90.0	0.013
Vernam	Vernolate	260	0.80	2.0	12.0	108
Volck oils	Petroleum oil	1000	0.50	2.0	10.0	100
Vydate	Oxamyl	25	0.95	4.0	4.0	282000
Weedar	2,4-D amine	20	0.45	9.0	10.0	796000
Weed-B-Gon	2,4,5-T Amine	80	0.45	10.0	24.0	500000
Wedone	Dichlorprop Ester	1000	0.45	9.0	10.0	50
Zolone	Phosalone	1800	0.65	8.0	21.0	3

Knisel (1993) cites Wauchope et al. (1992) as the source for water solubility, soil half-life and K_{oc} values. Wash-off fraction and foliar half-life were obtained from Willis et al. (1980) and Willis and McDowell (1987).

A.3.1 WATER SOLUBILITY

The water solubility value defines the highest concentration of pesticide that can be reached in the runoff and soil pore water. While this is an important characteristic, researchers have found that the soil adsorption coefficient, K_{oc}, tends to limit the amount of pesticide entering solution so that the maximum possible concentration of pesticide in solution is seldom reached (Leonard and Knisel, 1988).

Reported solubility values are determined under laboratory conditions at a constant temperature, typically between 20°C and 30°C.

A.3.2 SOIL ADSORPTION COEFFICIENT

The pesticide adsorption coefficient reported in the pesticide database can usually be obtained from a search through existing literature on the pesticide.

A.3.3 SOIL HALF-LIFE

The half-life for a pesticide defines the number of days required for a given pesticide concentration to be reduced by one-half. The soil half-life entered for a pesticide is a lumped parameter that includes the net effect of volatilization, photolysis, hydrolysis, biological degradation and chemical reactions.

The pesticide half-life for a chemical will vary with a change in soil environment (e.g. change in soil temperature, water content, etc.). Soil half-life values provided in the database are "average" or representative values. Half-life values reported for a chemical commonly vary by a factor of 2 to 3 and sometimes by as much as a factor of 10. For example, the soil half-life for atrazine can range from 120 to 12 days when comparing values reported in cool, dry regions to those from warm, humid areas. Another significant factor is soil treatment history. Repeated soil treatment by the same or a chemically similar pesticide commonly results in a reduction in half-life for the pesticide. This reduction is attributed to the preferential build-up of microbial populations adapted to degrading the compound. Users are encouraged to replace the default soil half-life value with a site-specific or region-specific value whenever the information is available.

A.3.4 FOLIAR HALF-LIFE

As with the soil half-life, the foliar half-life entered for a pesticide is a lumped parameter describing the loss rate of pesticides on the plant canopy. For most pesticides, the foliar half-life is much less than the soil half-life due to enhanced volatilization and photodecomposition. While values for foliar half-life were available for some pesticides in the database, the majority of foliar half-life values were calculated using the following rules:

1) Foliar half-life was assumed to be less than the soil half-life by a factor of 0.5 to 0.25, depending on vapor pressure and sensitivity to photodegradation.
2) Foliar half-life was adjusted downward for pesticides with vapor pressures less than 10^{-5} mm Hg.
3) The maximum foliar half-life assigned was 30 days.

A.3.5 WASH-OFF FRACTION

The wash-off fraction quantifies the fraction of pesticide on the plant canopy that may be dislodged. The wash-off fraction is a function of the nature of the leaf surface, plant morphology, pesticide solubility, polarity of the pesticide molecule, formulation of the commercial product and timing and volume of the rainfall event. Some wash-off fraction values were obtained from Willis et al. (1980). For the remaining pesticides, solubility was used as a guide for estimating the wash-off fraction.

A.3.6 APPLICATION EFFICIENCY

The application efficiency for all pesticides listed in the database is defaulted to 0.75. This variable is a calibration parameter.

A.4 FERTILIZER DATABASE

The fertilizer database file (fert.dat) summarizes nutrient fractions for various fertilizers and types of manure. The following table lists the fertilizers and types of manure in the fertilizer database.

Table A-12: SWAT Fertilizer Database

Name	Name Code	Min-N	Min-P	Org-N	Org-P	NH_3-N/ Min N
Elemental Nitrogen	Elem-N	1.000	0.000	0.000	0.000	0.000
Elemental Phosphorous	Elem-P	0.000	1.000	0.000	0.000	0.000
Anhydrous Ammonia	ANH-NH3	0.820	0.000	0.000	0.000	1.000
Urea	UREA	0.460	0.000	0.000	0.000	1.000
46-00-00	46-00-00	0.460	0.000	0.000	0.000	0.000
33-00-00	33-00-00	0.330	0.000	0.000	0.000	0.000
31-13-00	31-13-00	0.310	0.057	0.000	0.000	0.000
30-80-00	30-80-00	0.300	0.352	0.000	0.000	0.000
30-15-00	30-15-00	0.300	0.066	0.000	0.000	0.000
28-10-10	28-10-10	0.280	0.044	0.000	0.000	0.000
28-03-00	28-03-00	0.280	0.013	0.000	0.000	0.000
26-13-00	26-13-00	0.260	0.057	0.000	0.000	0.000
25-05-00	25-05-00	0.250	0.022	0.000	0.000	0.000
25-03-00	25-03-00	0.250	0.013	0.000	0.000	0.000
24-06-00	24-06-00	0.240	0.026	0.000	0.000	0.000
22-14-00	22-14-00	0.220	0.062	0.000	0.000	0.000
20-20-00	20-20-00	0.200	0.088	0.000	0.000	0.000
18-46-00	18-46-00	0.180	0.202	0.000	0.000	0.000
18-04-00	18-04-00	0.180	0.018	0.000	0.000	0.000
16-20-20	16-20-20	0.160	0.088	0.000	0.000	0.000
15-15-15	15-15-15	0.150	0.066	0.000	0.000	0.000
15-15-00	15-15-00	0.150	0.066	0.000	0.000	0.000
13-13-13	13-13-13	0.130	0.057	0.000	0.000	0.000
12-20-00	12-20-00	0.120	0.088	0.000	0.000	0.000
11-52-00	11-52-00	0.110	0.229	0.000	0.000	0.000
11-15-00	11-15-00	0.110	0.066	0.000	0.000	0.000
10-34-00	10-34-00	0.100	0.150	0.000	0.000	0.000
10-28-00	10-28-00	0.100	0.123	0.000	0.000	0.000
10-20-20	10-20-20	0.100	0.088	0.000	0.000	0.000
10-10-10	10-10-10	0.100	0.044	0.000	0.000	0.000
08-15-00	08-15-00	0.080	0.066	0.000	0.000	0.000
08-08-00	08-08-00	0.080	0.035	0.000	0.000	0.000
07-07-00	07-07-00	0.070	0.031	0.000	0.000	0.000
07-00-00	07-00-00	0.070	0.000	0.000	0.000	0.000
06-24-24	06-24-24	0.060	0.106	0.000	0.000	0.000

Name	Name Code	Min-N	Min-P	Org-N	Org-P	NH_3-N/ Min N
05-10-15	05-10-15	0.050	0.044	0.000	0.000	0.000
05-10-10	05-10-10	0.050	0.044	0.000	0.000	0.000
05-10-05	05-10-05	0.050	0.044	0.000	0.000	0.000
04-08-00	04-08-00	0.040	0.035	0.000	0.000	0.000
03-06-00	03-06-00	0.030	0.026	0.000	0.000	0.000
02-09-00	02-09-00	0.020	0.040	0.000	0.000	0.000
00-15-00	00-15-00	0.000	0.066	0.000	0.000	0.000
00-06-00	00-06-00	0.000	0.026	0.000	0.000	0.000
Dairy-Fresh Manure	DAIRY-FR	0.007	0.005	0.031	0.003	0.990
Beef-Fresh Manure	BEEF-FR	0.010	0.004	0.030	0.007	0.990
Veal-Fresh Manure	VEAL-FR	0.023	***0.006***	0.029	***0.007***	0.990
Swine-Fresh Manure	SWINE-FR	0.026	0.011	0.021	0.005	0.990
Sheep-Fresh Manure	SHEEP-FR	***0.014***	0.003	***0.024***	0.005	0.990
Goat-Fresh Manure	GOAT-FR	***0.013***	***0.003***	***0.022***	***0.005***	0.990
Horse-Fresh Manure	HORSE-FR	***0.006***	0.001	***0.014***	0.003	0.990
Layer-Fresh Manure	LAYER-FR	0.013	0.006	0.040	0.013	0.990
Broiler-Fresh Manure	BROIL-FR	***0.010***	***0.004***	***0.040***	***0.010***	0.990
Turkey-Fresh Manure	TURK-FR	0.007	***0.003***	0.045	***0.016***	0.990
Duck-Fresh Manure	DUCK-FR	***0.023***	0.008	***0.025***	0.009	0.990

Values in bold italics are estimated (see section A.4.2)

A.4.1 COMMERCIAL FERTILIZERS

In compiling the list of commercial fertilizers in the database, we tried to identify and include commonly used fertilizers. This list is not comprehensive, so users may need to append the database with information for other fertilizers used in their watersheds.

When calculating the fractions of N and P for the database, it is important to remember that the percentages reported for a fertilizer are %N-%P_2O_5-%K_2O. The fraction of mineral N in the fertilizer is equal to %N divided by 100. To calculate the fraction of mineral P in the fertilizer, the fraction of P in P_2O_5 must be known. The atomic weight of phosphorus is 31 and the atomic weight of oxygen is 16, making the molecular weight of P_2O_5 equal to 142. The fraction of P in P_2O_5 is 62/142 = 0.44 and the fraction of mineral P in the fertilizer is equal to 0.44 (%P_2O_5 / 100).

A.4.2 MANURE

The values in the database for manure types were derived from manure production and characteristics compiled by the ASAE (1998a). Table A-13 summarizes the levels of nitrogen and phosphorus in manure reported by the ASAE. The data summarized by ASAE is combined from a wide range of published and unpublished information. The mean values for each parameter are determined by an arithmetic average consisting of one data point per reference source per year and represent fresh (as voided) feces and urine.

Table A-13: Fresh manure production and characteristics per 1000 kg live animal mass per day (from ASAE, 1998a)

			Animal Type‡										
Parameter			Dairy	Beef	Veal	Swine	Sheep	Goat	Horse	Layer	Broiler	Turkey	Duck
Total Manure	kg†	mean	86	58	62	84	40	41	51	64	85	47	110
		std dev	17	17	24	24	11	8.6	7.2	19	13	13	**
Total Solids	kg	mean	12	8.5	5.2	11	11	13	15	16	22	12	31
		std dev	2.7	2.6	2.1	6.3	3.5	1.0	4.4	4.3	1.4	3.4	15
Total Kjeldahl nitrogen‖	kg	mean	0.45	0.34	0.27	0.52	0.42	0.45	0.30	0.84	1.1	0.62	1.5
		std dev	0.096	0.073	0.045	0.21	0.11	0.12	0.063	0.22	0.24	0.13	0.54
Ammonia nitrogen	kg	mean	0.079	0.086	0.12	0.29	**	**	**	0.21	**	0.080	**
		std dev	0.083	0.052	0.016	0.10	**	**	**	0.18	**	0.018	**
Total phosphorus	kg	mean	0.094	0.092	0.066	0.18	0.087	0.11	0.071	0.30	0.30	0.23	0.54
		std dev	0.024	0.027	0.011	0.10	0.030	0.016	0.026	0.081	0.053	0.093	0.21
Ortho-phosphorus	kg	mean	0.061	0.030	**	0.12	0.032	**	0.019	0.092	**	**	0.25
		std dev	0.0058	**	**	**	0.014	**	0.0071	0.016	**	**	**

** Data not found.
† All values wet basis.
‡ Typical live animal masses for which manure values represent are: dairy, 640 kg; beef, 360 kg; veal, 91 kg; swine, 61 kg; sheep, 27 kg; goat, 64 kg; horse, 450 kg; layer, 1.8 kg; broiler, 0.9 kg; turkey, 6.8 kg; and duck, 1.4 kg.
‖ All nutrient values are given in elemental form.

The fractions of the nutrient pools were calculated on a Total Solids basis, i.e. the water content of the manure was ignored. Assumptions used in the calculations are: 1) the mineral nitrogen pool is assumed to be entirely composed of NH_3/NH_4^+, 2) the organic nitrogen pool is equal to total Kjeldahl nitrogen minus ammonia nitrogen, 3) the mineral phosphorus pool is equal to the value given for orthophosphorus, and 4) the organic phosphorus pool is equal to total phosphorus minus orthophosphorus.

Total amounts of nitrogen and phosphorus were available for all manure types. For manure types with either the ammonia nitrogen or orthophosphorus value missing, the ratio of organic to mineral forms of the provided element were used to partition the total amount of the other element. For example, in Table A-13 amounts of total Kjeldahl N, ammonia N, and total P are provided for veal but data for orthophosphorus is missing. To partition the total P into organic and mineral pools, the ratio of organic to mineral N for veal was used. If both ammonia nitrogen and orthophosphorus data are missing, the ratio of the organic to mineral pool for a similar animal was used to partition the total amounts of element into different fractions. This was required for goat and broiler manure calculations. The ratio of organic to mineral pools for sheep was used to partition the goat manure nutrient pools while layer manure nutrient ratios were used to partition the broiler manure nutrient pools.

As can be seen from the standard deviations in Table A-13, values for nutrients in manure can vary widely. If site specific data are available for the region or watershed of interest, those values should be used in lieu of the default fractions provided in the database.

A.5 URBAN DATABASE

The urban database file (urban.dat) summarizes urban landscape attributes needed to model urban areas. These attributes tend to vary greatly from region to region and the user is recommended to use values specific to the area being modeled. The following tables list the urban land types and attributes that are provided in the urban database.

Numerous urban land type classifications exist. For the default urban land types included in the database, an urban land use classification system created by Palmstrom and Walker (1990) was simplified slightly. Table A-14 lists the land type classifications used by Palmstrom and Walker and those provided in the database.

Table A-14: Urban land type classification systems

Palmstrom and Walker (1990)	SWAT Urban Database
Residential-High Density	Residential-High Density
Residential-Med/High Density	Residential-Medium Density
Residential-Med/Low Density	Residential-Med/Low Density
Residential-Low Density	Residential-Low Density
Residential-Rural Density	Commercial
Commercial	Industrial
Industrial-Heavy	Transportation
Industrial-Medium	Institutional
Transportation	
Institutional	

The urban database includes the following information for each urban land type: 1) fraction of urban land area that is impervious (total and directly connected); 2) curb length density; 3) wash-off coefficient; 4) maximum accumulated solids; 5) number of days for solid load to build from 0 kg/curb km to half of the maximum possible load; 6) concentration of total N in solid loading; 7) concentration of total P in solid loading; and 8) concentration of total NO_3-N in solid loading. The fraction of total and directly connected impervious areas is needed for urban surface runoff calculations. The remaining information is used only when the urban build up/wash off algorithm is chosen to model sediment and nutrient loading from the urban impervious area.

A.5.1 DRAINAGE SYSTEM CONNECTEDNESS

When modeling urban areas the connectedness of the drainage system must be quantified. The best methods for determining the fraction total and directly connected impervious areas is to conduct a field survey or analyze aerial photographs. However these methods are not always feasible. An alternative approach is to use data from other inventoried watersheds with similar land types. Table A-15 contains ranges and average values calculated from a number of different individual surveys (the average values from Table A-15 are the values included in the database). Table A-16 contains data collected from the cities of Madison and Milwaukee, Wisconsin and Marquett, Michigan.

Table A-15: Range and average impervious fractions for different urban land types.

Urban Land Type	Average total impervious	Range total impervious	Average connected impervious	Range connected impervious
Residential-High Density (> 8 unit/acre or unit/2.5 ha)	.60	.44 - .82	.44	.32 - .60
Residential-Medium Density (1-4 unit/acre or unit/2.5 ha)	.38	.23 - .46	.30	.18 - .36
Residential-Med/Low Density (> 0.5-1 unit/acre or unit/2.5 ha)	.20	.14 - .26	.17	.12 - .22
Residential-Low Density (< 0.5 unit/acre or unit/2.5 ha)	.12	.07 - .18	.10	.06 - .14
Commercial	.67	.48 - .99	.62	.44 - .92
Industrial	.84	.63 - .99	.79	.59 - .93
Transportation	.98	.88 - 1.00	.95	.85 – 1.00
Institutional	.51	.33 - .84	.47	.30 - .77

Table A-16: Impervious fractions for different urban land types in Madison and Milwaukee, WI and Marquett, MI.

Urban Land Type	Directly connected impervious	Indirectly connected impervious	Pervious
Residential-High Density	.51	.00	.49
Residential-Medium Density	.24	.13	.63
Residential-Low Density	.06	.10	.84
Regional Mall	.86	.00	.14
Strip Mall	.75	.00	.25
Industrial-Heavy	.80	.02	.18
Industrial-Light	.69	.00	.31
Airport	.09	.25	.66
Institutional	.41	.00	.59
Park	.08	.06	.86

A.5.2 CURB LENGTH DENSITY

Curb length may be measured directly by scaling the total length of streets off of maps and multiplying by two. To calculate the density the curb length is divided by the area represented by the map.

The curb length densities assigned to the different land uses in the database were calculated by averaging measured curb length densities reported in studies by Heaney et al. (1977) and Sullivan et al. (1978). Table A-17 lists the reported values and the averages used in the database.

Table A-17: Measured curb length density for various land types

Location: Land type	Tulsa, OK km/ha	10 Ontario Cities km/ha	Average of two values km/ha	SWAT database categories using average value:
Residential	0.30	0.17	0.24	All Residential
Commercial	0.32	0.23	0.28	Commercial
Industrial	0.17	0.099	0.14	Industrial
Park	0.17	--	0.17	
Open	0.063	0.059	0.06	
Institutional	--	0.12	0.12	Transportation, Institutional

A.5.3 WASH-OFF COEFFICENT

The database assigns the original default value, 0.18 mm^{-1}, to the wash-off coefficient for all land types in the database (Huber and Heaney, 1982). This value was calculated assuming that 13 mm of total runoff in one hour would wash off 90% of the initial surface load. Using sediment transport theory, Sonnen (1980) estimated values for the wash-off coefficient ranging from 0.002-0.26 mm^{-1}. Huber and Dickinson (1988) noted that values between 0.039 and 0.390 mm^{-1} for the wash-off coefficient give sediment concentrations in the range of most observed values. This variable is used to calibrate the model to observed data.

A.5.4 MAXIMUM SOLID ACCUMULATION AND RATE OF ACCUMULATION

The shape of the solid build-up equation is defined by two variables: the maximum solid accumulation for the land type and the amount of time it takes to build up from 0 kg/curb km to one-half the maximum value. The values assigned to the default land types in the database were extrapolated from a study performed by Sartor and Boyd (1972) in ten U.S. cities. They summarized the build-up of solids over time for residential, commercial, and industrial land types as well as providing results for all land types combined (Figure A-6).

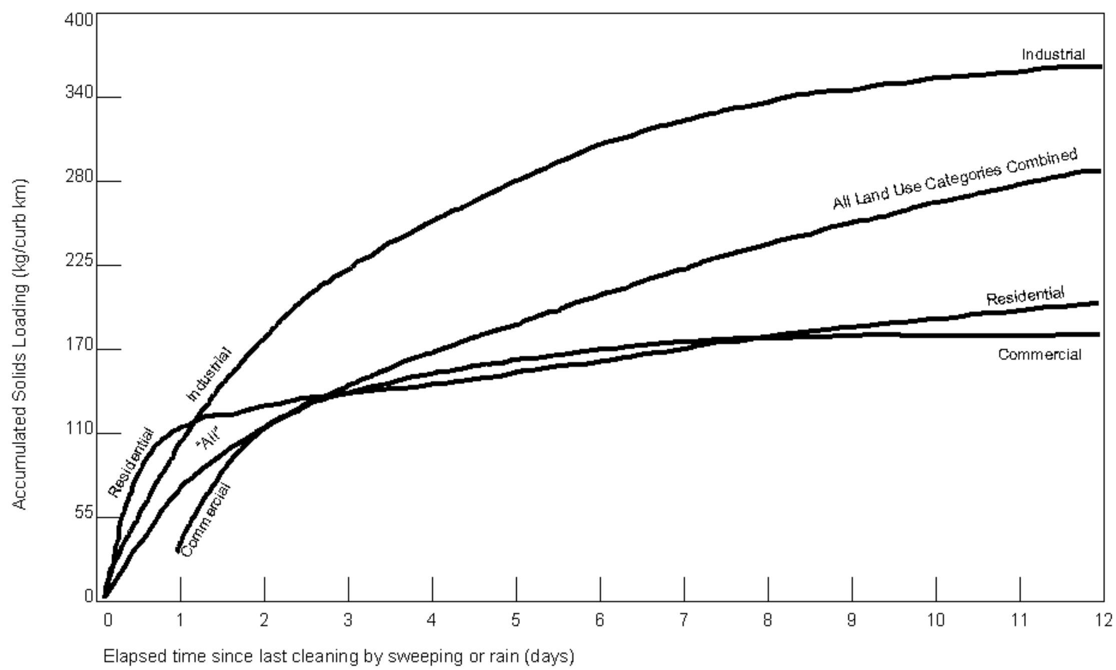

Figure A-6: Solid loading as a function of time (Sartor and Boyd, 1972)

The lines plotted in Figure A-6 were adapted for use in the database. Table A-18 lists maximum load values and time to accumulate half the maximum load that were derived from the graph. The assignment of values to the different land types is provided in the table also.

Table A-18: Maximum solid load and accumulation time (from Sartor and Boyd, 1972).

Land type	Maximum loading kg/curb km	time to accumulate ½ maximum load days	SWAT database categories using value:
Residential	225	0.75	All Residential
Commercial	200	1.60	Commercial
Industrial	400	2.35	Industrial
All land types	340	3.90	Transportation/Institutional

A.5.5 NUTRIENT CONCENTRATION IN SOLIDS

For the default land types in the database, nutrient concentrations in the solids were extrapolated from a nationwide study by Manning et al. (1977). The data published by Manning is summarized in Table A-19.

Three concentration values are required: total nitrogen (mg N/kg), nitrate nitrogen (mg NO_3-N/kg), and total phosphorus (mg P/kg). Manning provided total nitrogen values for all of his land use categories, nitrate values for one land use category and mineral phosphorus values for all the land use categories. To obtain nitrate concentrations for the other land use categories, the ratio of NO_3-N to total N for commercial areas was assumed to be representative for all the categories. The nitrate to total N ratio for commercial land was multiplied by the total N concentrations for the other categories to obtain a nitrate concentration. The total phosphorus concentration was estimated by using the ratio of organic phosphorus to orthophosphate provided by the Northern Virginia Planning District Commission (1979). Total phosphorus loads from impervious areas are assumed to be 75 percent organic and 25 percent mineral. Table A-20 summarizes the assignment of values to the default land types in the urban database.

Table A-19: Nationwide dust and dirt build-up rates and pollutant fractions (Manning et al., 1977)

Pollutant		**Land Use Category**				
		Single Family Residential	Mult. Family Residential	Commercial	Industrial	All Data
Dust & Dirt Accumulation	mean	17	32	47	90	45
(kg/curb km/day)	range	1-268	2-217	1-103	1-423	1-423
	# obs.	74	101	158	67	400
Total N-N	mean	460	550	420	430	480
(mg/kg)	range	325-525	356-961	323-480	410-431	323-480
	# obs.	59	93	80	38	270
NO_3	mean	--	--	24	--	24
(mg/kg)	range	--	--	10-35	--	10-35
	# obs.	--	--	21	--	21
PO_4-P	mean	49	58	60	26	53
(mg/kg)	range	20-109	20-73	0-142	14-30	0-142
	# obs.	59	93	101	38	291

Table A-20: Nutrient concentration assignments for default land types

	Manning et al (1977)	Modifications:	Final Value:	SWAT database categories using value:
Total Nitrogen-N				
Single Fam Res.	460 ppm	--	460 ppm	Residential: Med/Low & Low
Mult. Fam. Res.	550 ppm	--	550 ppm	Residential: Med. & High
Commercial	420 ppm	--	420 ppm	Commercial
Industrial	430 ppm	--	430 ppm	Industrial
All Data	480 ppm	--	480 ppm	Transportation/Institutional
Nitrate-N: multiply reported value by fraction of weight that is nitrogen to get NO_3-N				
Single Fam Res.		(5.5/420) x 460	6.0 ppm	Residential: Med/Low & Low
Mult. Fam. Res.		(5.5/420) x 550	7.2 ppm	Residential: Med. & High
Commercial	5.5 ppm	--	5.5 ppm	Commercial
Industrial		(5.5/420) x 430	5.6 ppm	Industrial
All Data		(5.5/420) x 480	6.3 ppm	Transportation/Institutional
Total Phosphorus-P: assume PO_4-P is 25% of total P				
Single Fam Res.	49 ppm PO_4-P	49/(.25)	196 ppm	Residential: Med/Low & Low
Mult. Fam. Res.	58 ppm PO_4-P	58/(.25)	232 ppm	Residential: Med. & High
Commercial	60 ppm PO_4-P	60/(.25)	240 ppm	Commercial
Industrial	26 ppm PO_4-P	26/(.25)	104 ppm	Industrial
All Data	53 ppm PO_4-P	53/(.25)	212 ppm	Transportation/Institutional

A.5.6 CURVE NUMBER

The database includes an entry for the SCS curve number value for moisture condition II to be used for impervious areas. This variable was added to the database to allow the user more control. The impervious area curve number is set to a default value of 98 for all urban land types.

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APPENDIX B

EXAMPLE WATERSHED CONFIGURATIONS

The watershed configuration file defines the spatial relationship of objects within the watershed. The three techniques used to subdivide a watershed are the subwatershed discretization, the hillslope discretization, and the grid cell discretization. The following sections describe how to set up the watershed configuration file for each of the different discretization techniques.

B.1 SUBWATERSHED DISCRETIZATION

The subwatershed discretization divides the watershed into subbasins based on topographic features of the watershed. This technique preserves the natural flow paths, boundaries, and channels required for realistic routing of water, sediment and chemicals. **All of the GIS interfaces developed for SWAT use the subwatershed discretization to divide a watershed.**

The number of subbasins chosen to model the watershed depends on the size of the watershed, the spatial detail of available input data and the amount of detail required to meet the goals of the project. When subdividing the watershed, keep in mind that topographic attributes (slope, slope length, channel length, channel width, etc.) are calculated or summarized at the subbasin level. The subbasin delineation should be detailed enough to capture significant topographic variability within the watershed.

Once the subbasin delineation has been completed, the user has the option of modeling a single soil/land use/management scheme for each subbasin or partitioning the subbasins into multiple hydrologic response units (HRUs). Hydrologic response units are unique soil/land use/management combinations within the subbasin which are modeled without regard to spatial positioning. When multiple HRUs are modeled within a subbasin, the land phase of the hydrologic cycle is modeled for each HRU and then the loadings from all HRUs within the subbasin are summed. The net loadings for the subbasin are then routed through the watershed channel network. HRUs are set up in the subbasin general attribute file (.sub).

The following sections demonstrate how to manually create a SWAT watershed configuration file using the subwatershed discretization.

B.1.1 SUBWATERSHED DISCRETIZATION: 3 SUBBASINS

Assume we have a watershed with 3 subbasins as illustrated in Figure B-1.

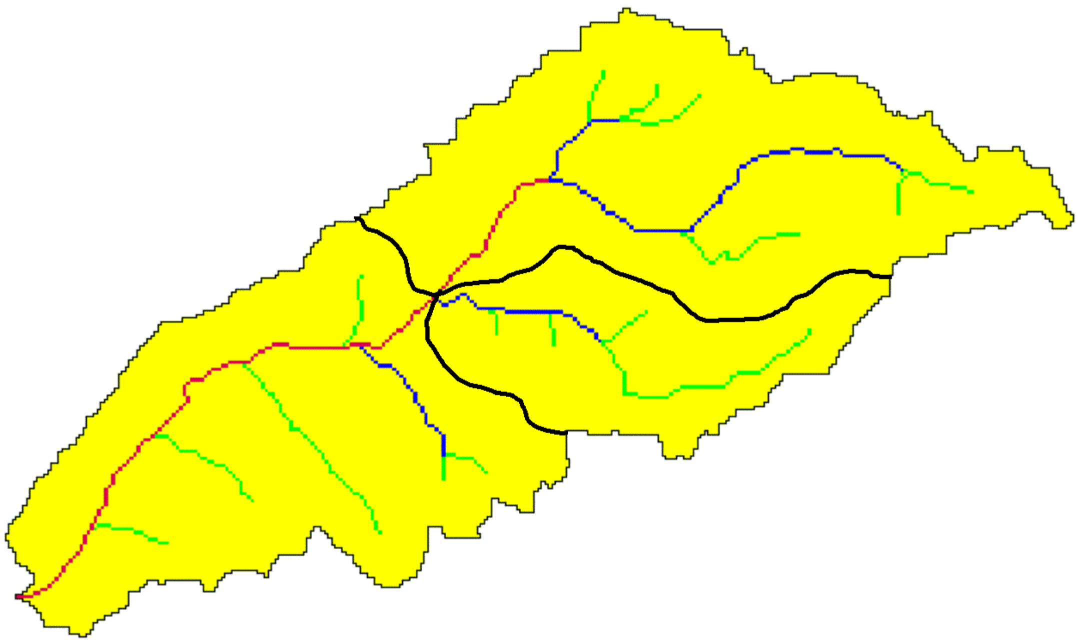

Figure B-1: Subwatershed delineation

Step 1: Write the subbasin command for each subbasin. (This command simulates the land phase of the hydrologic cycle.)

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
	ex01.sub						
subbasin	**1**	**2**	**2**				
	ex02.sub						
subbasin	**1**	**3**	**3**				
	ex03.sub						

Writing **subbasin** in space 1-10 is optional. The model identifies the configuration command by the code in column 1. The option of writing the command in space 1-10 is provided to assist the user in interpreting the configuration file.

Column 2 is the hydrograph storage location number (array location) where data for the loadings (water, sediment, chemicals) from the subbasin are stored.

Column 3 is the subbasin number. Unique numbers must be assigned to each subbasin.

The second line of the subbasin command lists the subbasin general input data file (.sub).

Step 2a: Route the stream loadings through the reach network. Begin by routing the headwater subbasin loadings through the main channel of the respective subbasin. (Headwater subbasins are those with no subbasins upstream.) Referring to Figure B-1, assume that subbasins 1 and 2 are upstream of subbasin 3. This would make subbasins 1 and 2 headwater subbasins.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
	ex01.sub						
subbasin	**1**	**2**	**2**				
	ex02.sub						
subbasin	**1**	**3**	**3**				
	ex03.sub						
route	**2**	**4**	**1**	**1**		**0.000**	
	ex01.rte		**ex01.swq**				
route	**2**	**5**	**2**	**2**		**0.000**	
	ex02.rte		**ex02.swq**				

As mentioned in the last step, column 1 is used to identify the command. Column 2 is the hydrograph storage location number identifying the location where results from the route simulation are placed.

Column 3 provides the number of the reach, or main channel, the inputs are routed through. The number of the reach in a particular subbasin is the same as the number of the subbasin.

Column 4 lists the number of the hydrograph storage location containing the data to be routed through the reach. The loadings from subbasin 1 are stored in hydrograph storage #1 and the loadings from subbasin 2 are stored in hydrograph storage #2.

Column 6 lists the fraction of overland flow. For the subwatershed discretization, this value will always be zero—flow is always considered to be channelized before entering the next subbasin.

The second line of the route command lists the names of the routing input data file (.rte) and the stream water quality data file (.swq).

Step 2b: Route the stream loadings through the reach network. Use the add and route commands to continue routing through the watershed. For this example, the water, sediment and chemicals flowing out of subbasins 1 and 2 and the loadings from subbasin 3 must be added together and routed through the main channel of subbasin 3. The loadings from the outlet of subbasin 1 are stored in hydrograph location #4; the loadings from the outlet of subbasin 2 are stored in hydrograph location #5; and the loadings from subbasin 3 are stored in hydrograph location #3.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	1	1	1				
	ex01.sub						
subbasin	1	2	2				
	ex02.sub						
subbasin	1	3	3				
	ex03.sub						
route	2	4	1	1		0.000	
	ex01.rte		ex01.swq				
route	2	5	2	2		0.000	
	ex02.rte		ex02.swq				
add	5	6	4	5			
add	5	7	6	3			
route	2	8	3	7		0.000	
	ex03.rte		ex03.swq				

The add command is specified in column 1 by the number 5. The hydrograph storage location numbers of the 2 data sets to be added are listed in columns 3 and 4. The summation results are stored in the hydrograph location number given in column 2.

Step 3: Once the stream loadings have been routed to the watershed outlet, append a finish command line to signify the end of the watershed routing file.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	1	1	1				
	ex01.sub						
subbasin	1	2	2				
	ex02.sub						
subbasin	1	3	3				
	ex03.sub						
route	2	4	1	1		0.000	
	ex01.rte		ex01.swq				
route	2	5	2	2		0.000	
	ex02.rte		ex02.swq				
add	5	6	4	5			
add	5	7	6	3			
route	2	8	3	7		0.000	
	ex03.rte		ex03.swq				
finish	0						

B.1.2 SUBWATERSHED DISCRETIZATION: SAVING SIMULATION RESULTS FOR DOWNSTREAM RUNS

If the watershed of interest is split up into subwatersheds that are modeled with separate SWAT runs, the outflow from the upstream subwatersheds must be saved in a file using the save command. This data will then be input into the SWAT simulation of the downstream portion of the watershed using a recday command.

In example B.1.1, the outflow from the watershed is stored in hydrograph location #8, so this is the data we need to store in a daily file for use in another SWAT simulation. The watershed configuration modified to store outflow data is:

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
	ex01.sub						
subbasin	**1**	**2**	**2**				
	ex02.sub						
subbasin	**1**	**3**	**3**				
	ex03.sub						
route	**2**	**4**	**1**	**1**		**0.000**	
	ex01.rte		**ex01.swq**				
route	**2**	**5**	**2**	**2**		**0.000**	
	ex02.rte		**ex02.swq**				
add	**5**	**6**	**4**	**5**			
add	**5**	**7**	**6**	**3**			
route	**2**	**8**	**3**	**7**		**0.000**	
	ex03.rte		**ex03.swq**				
save	**9**	**8**	**1**	**0**	**0**		
	wshd.eve						
finish	**0**						

The save command is specified in column 1 by the number 9. Column 2 lists the hydrograph storage location of the data to be saved in the event output file. Column 3 lists the number of the output file. Each save command must use a unique file number between 1 and 10. Column 4 lists the code that governs the print frequency of output in the file (daily or hourly). Column 5 lists the print format (SWAT ASCII or SWAT/AV interface). The name of the event output file is listed on the second line of the save command and usually possesses the .eve file extension. Up to 10 save commands are allowed in a simulation.

The event file output is the same as that described for the rechour or recday input files in Chapter 31.

B.1.3 SUBWATERSHED DISCRETIZATION: INCORPORATING POINT SOURCE/UPSTREAM SIMULATION DATA

Point source and upstream simulation data may be incorporated into a run using one of four record commands: recday, recmon, recyear, and reccnst. The recday command reads data from a file containing loadings of different constituents for each day of simulation. The recmon command reads data from a file containing average daily loadings for each month. The recyear command reads data from a file containing average daily loadings for each year. The reccnst command reads in average annual daily loadings. The record command chosen to read in the data is a function of the detail of data available. To read in upstream simulation data, the recday command is always used.

Assuming the subbasin delineation in Figure B-1 is used with one point source (sewage treatment plants) per subbasin, the watershed configuration file is:

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
	ex01.sub						
subbasin	**1**	**2**	**2**				
	ex02.sub						
subbasin	**1**	**3**	**3**				
	ex03.sub						
recday	**10**	**4**	**1**				
	sub1.pnt						
add	**5**	**5**	**4**	**1**			
route	**2**	**6**	**1**	**5**		**0.000**	
	ex01.rte		**ex01.swq**				
recday	**10**	**7**	**2**				
	sub2.pnt						
add	**5**	**8**	**7**	**2**			
route	**2**	**9**	**2**	**8**		**0.000**	
	ex02.rte		**ex02.swq**				
add	**5**	**10**	**6**	**9**			
recday	**10**	**11**	**3**				
	sub3.pnt						
add	**5**	**12**	**11**	**10**			
add	**5**	**13**	**12**	**3**			
route	**2**	**14**	**3**	**13**		**0.000**	
	ex03.rte		**ex03.swq**				
finish	**0**						

All of the record commands require 2 lines. On the first line, column 1 contains the command code for the specific record command, column 2 contains the hydrologic storage location where the data from the file is stored, and column 3 contains the file number. A different file number must be used for each point source of a specific type (e.g., all recday commands must have unique file numbers). The second line lists the name of the file containing the input data.

A description of the four types of record files is given in Chapter 31.

B.1.4 SUBWATERSHED DISCRETIZATION: INCORPORATING RESERVOIRS

Water bodies located along the main channel are modeled using reservoirs. To incorporate a reservoir into a simulation, a routres command is used. There is no limitation on the number of reservoirs modeled.

Assuming the subbasin delineation in Figure B-1 is used with one reservoir located at the outlet, the watershed configuration file is:

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
	ex01.sub						
subbasin	**1**	**2**	**2**				
	ex02.sub						
subbasin	**1**	**3**	**3**				
	ex03.sub						
route	**2**	**4**	**1**	**1**		**0.000**	
	ex01.rte		**ex01.swq**				
route	**2**	**5**	**2**	**2**		**0.000**	
	ex02.rte		**ex02.swq**				
add	**5**	**6**	**4**	**5**			
add	**5**	**7**	**6**	**3**			
route	**2**	**8**	**3**	**7**		**0.000**	
	ex03.rte		**ex03.swq**				
routres	**3**	**9**	**1**	**8**	**3**		
	lakefork.res		**lakefork.lwq**				
finish	**0**						

The routres command requires 2 lines. On the first line, the routres command is identified with the number 3 in column 1. Column 2 gives the hydrograph storage location where outflow data from the reservoir is stored. Column 3 lists the reservoir number. A different reservoir number must be assigned to each reservoir and the numbers should be sequential beginning with 1. Column 4 gives the hydrograph storage location of the data to be routed through the reservoir. Column 5 lists the subbasin with which the reservoir is associated. The second line lists two file names, the reservoir input file (.res) and the reservoir water quality file (.lwq).

B.1.5 SUBWATERSHED DISCRETIZATION: SAVING SIMULATION RESULTS FOR ONE LOCATION

Users often need to compare streamflow, sediment, nutrient and/or pesticide levels predicted by the model with levels measured in the stream. To save daily or hourly model output data for a particular location on the stream, the saveconc command is used.

Assume there is a stream gage at the outlet of the watershed shown in Figure B-1 and that we want to compare simulated and measured streamflow for this location. Hydrograph storage location #8 stores the flow data for this location in the watershed, so this is the data we need to process to create the saveconc output file. The watershed configuration modified to process data for this location is:

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
	ex01.sub						
subbasin	**1**	**2**	**2**				
	ex02.sub						
subbasin	**1**	**3**	**3**				
	ex03.sub						
route	**2**	**4**	**1**	**1**		**0.000**	
	ex01.rte		**ex01.swq**				
route	**2**	**5**	**2**	**2**		**0.000**	
	ex02.rte		**ex02.swq**				
add	**5**	**6**	**4**	**5**			
add	**5**	**7**	**6**	**3**			
route	**2**	**8**	**3**	**7**		**0.000**	
	ex03.rte		**ex03.swq**				
saveconc	**14**	**8**	**1**	**0**			
	strgage.out						
finish	**0**						

The saveconc command requires 2 lines. On the first line, the saveconc command is identified with the number 14 in column 1. Column 2 gives the hydrograph storage location of the data to be processed for the saveconc output file. Column 3 lists the file number. Column 4 gives the print frequency (daily or hourly). More than one saveconc command may be used in a simulation. A different file number must be assigned to each saveconc output file and the file numbers should be sequential beginning with 1. The second line lists the name of the saveconc output file.

The saveconc command differs from the save command in that it converts the mass amounts of water, sediment, and chemicals to units that are commonly used to report measured values. Output files produced by the saveconc command cannot be read into another SWAT run—the save command must be used to produce input for another simulation.

B.2 HILLSLOPE DISCRETIZATION

The hillslope discretization allows overland flow from one subbasin to flow onto the land area of another subbasin. As the name implies, this discretization allows SWAT to model hillslope processes.

The hillslope discretization incorporates more detail into the watershed configuration file than the subwatershed discretization. The number of subbasins chosen to model the watershed will depend on the size of the watershed, the spatial relationship of different land uses to one another, the spatial detail of available input data and the amount of detail required to meet the goals of the project. Because this discretization scheme places more emphasis on land use, the subbasins are delineated so that there is one land use and soil per subbasin.

The hillslope discretization can be combined with the subwatershed discretization to provide detailed modeling of particular land use areas while modeling the remaining land use areas with the more generalized approach.

Useful applications of this discretization include: watersheds with concentrated animal feeding operations, watersheds where detailed modeling of filter strips is desired, and microwatersheds where the scale of the simulation allows detail about relative land use positions to be incorporated.

B.2.1 HILLSLOPE DISCRETIZATION: MODELING A DAIRY OPERATION

Assume a microwatershed containing a concentrated animal feeding operation with several different areas of land use and management is being modeled. Milking cows are confined in stalls. All waste produced by the milking cows is collected and applied over manure application fields also located in the microwatershed. The dry cows are kept in pastures. The pastured cows keep the areas adjacent to the farm buildings denuded of grass. Runoff from the denuded areas flows onto the pasture. Runoff from the pasture flows into a filter strip or buffer zone. Runoff exiting the filter strip enters the stream. The manure application fields are isolated from the rest of the dairy operation. Runoff from the application fields flows into a filter strip, and then enters the steam. Figure B-2 illustrates the relationship of land areas in the dairy operation. Areas of the microwatershed outside of the daily operation are forested.

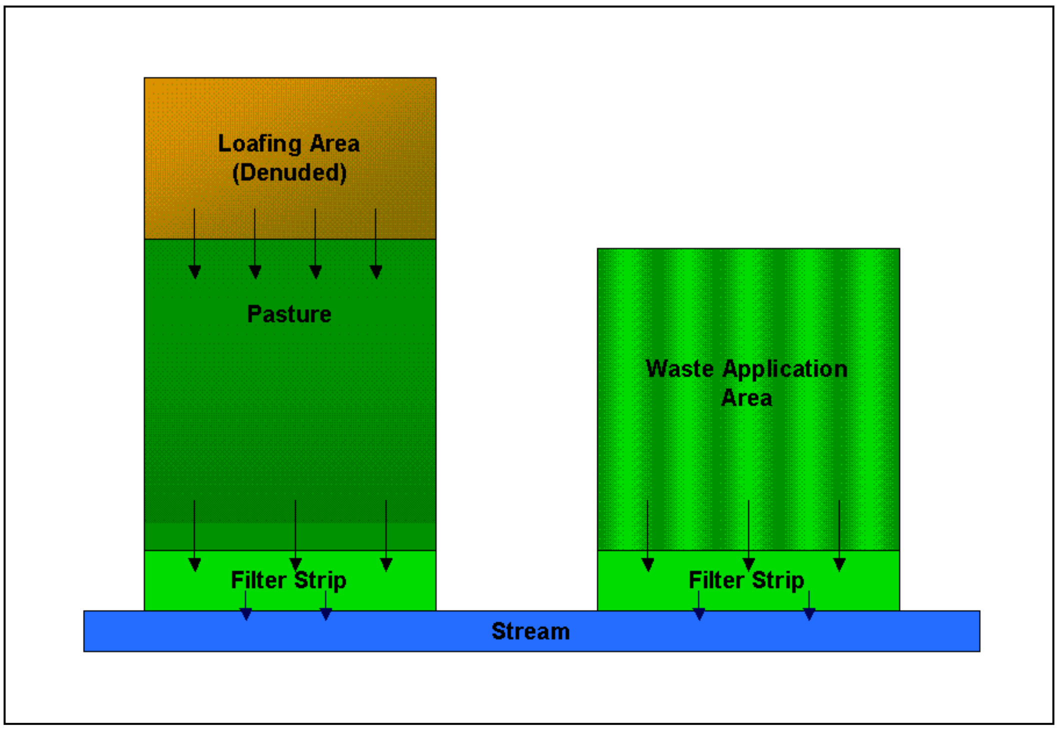

Figure B-2: Spatial positioning of land areas in dairy operation.

This microwatershed will be divided into 6 subbasins:

Subbasin 1: loafing area
Subbasin 2: pasture
Subbasin 3: filter strip associated with pasture
Subbasin 4: waste application area
Subbasin 5: filter strip associated with waste application area
Subbasin 6: completely channelized stream and forest in microwatershed

Step 1: Write the subbasin command for each subbasin. (This command simulates the land phase of the hydrologic cycle.)

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
	dairy01.sub						
subbasin	**1**	**2**	**2**				
	dairy02.sub						
subbasin	**1**	**3**	**3**				
	dairy03.sub						
subbasin	**1**	**4**	**4**				
	dairy04.sub						
subbasin	**1**	**5**	**5**				
	dairy05.sub						
subbasin	**1**	**6**	**6**				
	dairy06.sub						

Writing **subbasin** in space 1-10 is optional. The model identifies the configuration command by the code in column 1. The option of writing the command in space 1-10 is provided to assist the user in interpreting the configuration file.

Column 2 is the hydrograph storage location number (array location) where data for the loadings (water, sediment, chemicals) from the subbasin are stored.

Column 3 is the subbasin number. Unique numbers must be assigned to each subbasin.

The second line of the subbasin command lists the subbasin general input data file (.sub).

Step 2: Route the stream loadings.

The hillslope discretization differs from the subwatershed discretization primarily in the method used to route loadings through the watershed. Loadings from subbasins are not routed through the subbasin if the flow leaving the subbasin is not completely channelized. For our example, subbasin 6 is the only subbasin completely channelized.

Assume that runoff from the denuded areas (subbasin 1) is sheet flow, i.e. there are no rills, gullies or any other evidence of channelized flow in the denuded area. Runoff from the denuded area will be routed to the pasture (subbasin 2) using the route command:

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
route	**2**	**7**	**2**	**1**		**1.000**	
	dairy02.rte		**dairy02.swq**				

As mentioned in the last step, column 1 is used to identify the command. Column 2 is the hydrograph storage location number identifying the location where results from the channelized portion of the route simulation are placed. In this instance, because there is no channelized flow, this storage location will contain no data.

Column 3 provides the number of the reach or subbasin the inputs are routed through. (The number of the reach in a particular subbasin is the same as the number of the subbasin.) The fraction of the loadings classified as overland flow are applied to the subbasin land area while the fraction of the loadings classified as channelized flow are routed through the main channel of the subbasin and are exposed to in-stream processes. Channelized flow has no interaction with the land area in the subbasin.

Column 4 lists the number of the hydrograph storage location containing the data to be routed through the reach. The loadings from subbasin 1 are stored in hydrograph storage #1.

Column 6 lists the fraction of overland flow. For completely channelized flow this fraction is zero. For 100% overland flow, this fraction is 1.00.

The entire watershed configuration to this point looks like:

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
	dairy01.sub						
subbasin	**1**	**2**	**2**				
	dairy02.sub						
subbasin	**1**	**3**	**3**				
	dairy03.sub						
subbasin	**1**	**4**	**4**				
	dairy04.sub						
subbasin	**1**	**5**	**5**				
	dairy05.sub						
subbasin	**1**	**6**	**6**				
	dairy06.sub						
route	**2**	**7**	**2**	**1**		**1.000**	
	dairy02.rte		**dairy02.swq**				

Assume that runoff from the pasture is slightly channelized (10% channels).

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	1	1	1				
	dairy01.sub						
subbasin	1	2	2				
	dairy02.sub						
subbasin	1	3	3				
	dairy03.sub						
subbasin	1	4	4				
	dairy04.sub						
subbasin	1	5	5				
	dairy05.sub						
subbasin	1	6	6				
	dairy06.sub						
route	2	7	2	1		1.000	
	dairy02.rte		dairy02.swq				
route	2	8	3	2		0.900	
	dairy03.rte		dairy03.swq				

Flow from the pasture is routed to the filter strip (subbasin 3) using the next route command:

As mentioned previously, hydrograph storage location #7 contains no data because none of the runoff entering subbasin 2 is channelized. Consequently, when routing runoff leaving subbasin 2, this hydrograph storage location can be ignored. For subbasin 3, however, there will be data in hydrograph storage location #8 from the 10% of flow that is channelized in that subbasin. Loadings from subbasin 3 will enter the main stream in subbasin 6. The total loadings from the denuded area/pasture/filter strip section of the microwatershed are determined by adding the runoff generated from subbasin 3 and the channelized flow routing results.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	1	1	1				
	dairy01.sub						
subbasin	1	2	2				
	dairy02.sub						
subbasin	1	3	3				
	dairy03.sub						
subbasin	1	4	4				
	dairy04.sub						
subbasin	1	5	5				
	dairy05.sub						
subbasin	1	6	6				
	dairy06.sub						
route	2	7	2	1		1.000	
	dairy02.rte		dairy02.swq				
route	2	8	3	2		0.900	
	dairy03.rte		dairy03.swq				
add	5	9	3	8			

The loadings from simulation of the land phase of the hydrologic cycle in subbasin 3 are stored in hydrograph storage location #3 and the loadings from simulation of the channelized flow in subbasin 3 are stored in hydrograph location #8. The add command is specified in column 1 by the number 5. The hydrograph storage location numbers of the 2 data sets to be added are listed in columns 3 and 4. The summation results are stored in the hydrograph location number given in column 2. Net loadings from the denuded area/pasture/filter strip is stored in hydrograph location #9.

Assume that the manure application area (subbasin 4) is well managed and all runoff from this area is overland flow (no channelized flow). To route flow from the application area to the associated filter strip (subbasin 5) a route command will be appended to the end of the configuration:

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	1	1	1				
	dairy01.sub						
subbasin	1	2	2				
	dairy02.sub						
subbasin	1	3	3				
	dairy03.sub						
subbasin	1	4	4				
	dairy04.sub						
subbasin	1	5	5				
	dairy05.sub						
subbasin	1	6	6				
	dairy06.sub						
route	2	7	2	1		1.000	
	dairy02.rte		dairy02.swq				
route	2	8	3	2		0.900	
	dairy03.rte		dairy03.swq				
add	5	9	3	8			
route	2	10	5	4		1.000	
	dairy05.rte		dairy05.swq				

Hydrograph storage location #10 contains no data because none of the runoff entering subbasin 5 is channelized. Consequently, when routing runoff leaving subbasin 5, this hydrograph storage location can be ignored. Net loadings from the waste application area/filter strip section of the watershed is stored in hydrograph location #5.

Flow through subbasin 6, which contains the stream, is completely channelized. All of the loadings for the stream must be summed together and then routed through the stream. There are 3 sources of loading to the stream: the denuded area/pasture/filter strip (hydrograph location #9), the waste application area/filter strip (hydrograph location #10), and the forest land area (hydrograph location #6). Add commands are used to sum the loadings.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
	dairy01.sub						
subbasin	**1**	**2**	**2**				
	dairy02.sub						
subbasin	**1**	**3**	**3**				
	dairy03.sub						
subbasin	**1**	**4**	**4**				
	dairy04.sub						
subbasin	**1**	**5**	**5**				
	dairy05.sub						
subbasin	**1**	**6**	**6**				
	dairy06.sub						
route	**2**	**7**	**2**	**1**		**1.000**	
	dairy02.rte		**dairy02.swq**				
route	**2**	**8**	**3**	**2**		**0.900**	
	dairy03.rte		**dairy03.swq**				
add	**5**	**9**	**3**	**8**			
route	**2**	**10**	**5**	**4**		**1.000**	
	dairy05.rte		**dairy05.swq**				
add	**5**	**11**	**9**	**5**			
add	**5**	**12**	**6**	**11**			

Flow is routed through the stream using a route command:

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	1	1	1				
	dairy01.sub						
subbasin	1	2	2				
	dairy02.sub						
subbasin	1	3	3				
	dairy03.sub						
subbasin	1	4	4				
	dairy04.sub						
subbasin	1	5	5				
	dairy05.sub						
subbasin	1	6	6				
	dairy06.sub						
route	2	7	2	1		1.000	
	dairy02.rte		dairy02.swq				
route	2	8	3	2		0.900	
	dairy03.rte		dairy03.swq				
add	5	9	3	8			
route	2	10	5	4		1.000	
	dairy05.rte		dairy05.swq				
add	5	11	9	5			
add	5	12	6	11			
route	2	13	6	12		0.000	
	dairy06.rte		dairy06.swq				

Step 3: Once the stream loadings have been routed to the watershed outlet, append a finish command line to signify the end of the watershed routing file.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	1	1	1				
	dairy01.sub						
subbasin	1	2	2				
	dairy02.sub						
subbasin	1	3	3				
	dairy03.sub						
subbasin	1	4	4				
	dairy04.sub						
subbasin	1	5	5				
	dairy05.sub						
subbasin	1	6	6				
	dairy06.sub						
route	2	7	2	1		1.000	
	dairy02.rte		dairy02.swq				
route	2	8	3	2		0.900	
	dairy03.rte		dairy03.swq				
add	5	9	3	8			
route	2	10	5	4		1.000	
	dairy05.rte		dairy05.swq				
add	5	11	9	5			
add	5	12	6	11			
route	2	13	6	12		0.000	
	dairy06.rte		dairy06.swq				
finish	0						

B.2.2 HILLSLOPE DISCRETIZATION: COMBINING WITH SUBWATERSHED DISCRETIZATION

The hillslope discretization is a very detailed discretization scheme and is suited to small watersheds. However, it can be used in combination with the subwatershed discretization to provide detailed simulation of certain land uses in a large watershed whose spatial relationships are important to the study.

As an example, assume that the dairy operation described in Section B.2.1 is located in a headwater region of the watershed example used in Section B.1. Figure B-3 illustrates the location of the dairy in the larger watershed. (Assume the microwatershed modeled in Section B.2.1 is subbasin B in Figure B-3.)

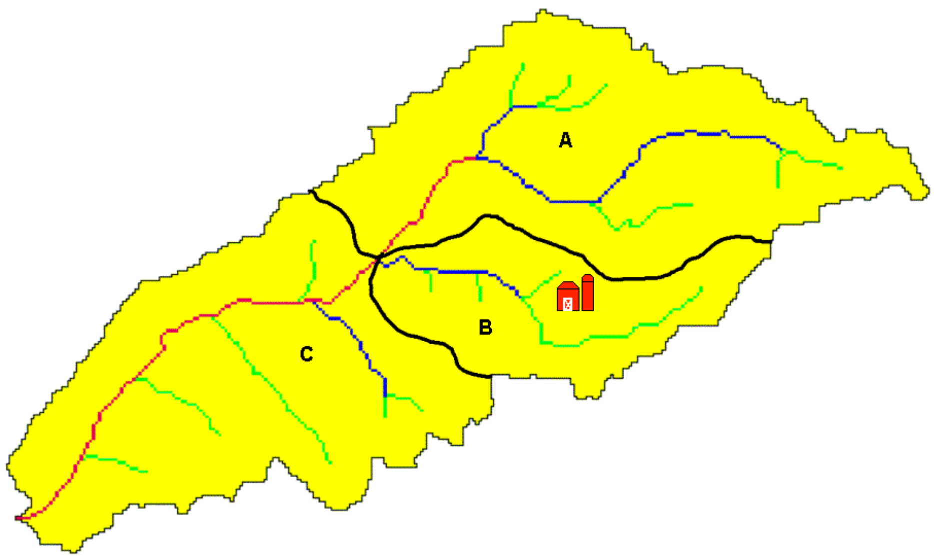

Figure B-3: Watershed with dairy operation

There are two options that may be used to combine the detailed modeling of the dairy with the less detailed modeling of the other land uses in the watershed. The first option is to model the dairy in a separate simulation and save the loadings from the microwatershed using the save command. These daily loadings will then be read into the simulation of the larger watershed using a recday command. The second option is to merge the watershed configuration given in Section B.2.1 with the watershed configuration given Section B.1.1

Option 1: Two separate runs.

The watershed configuration file for simulation of the microwatershed with the dairy will be modified to save the outflow data to an event file. The name of the event file is specified as "dairy.eve" in the save command.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
	dairy01.sub						
subbasin	**1**	**2**	**2**				
	dairy02.sub						
subbasin	**1**	**3**	**3**				
	dairy03.sub						
subbasin	**1**	**4**	**4**				
	dairy04.sub						
subbasin	**1**	**5**	**5**				
	dairy05.sub						
subbasin	**1**	**6**	**6**				
	dairy06.sub						
route	**2**	**7**	**2**	**1**		**1.000**	
	dairy02.rte		**dairy02.swq**				
route	**2**	**8**	**3**	**2**		**0.900**	
	dairy03.rte		**dairy03.swq**				
add	**5**	**9**	**3**	**8**			
route	**2**	**10**	**5**	**4**		**1.000**	
	dairy05.rte		**dairy05.swq**				
add	**5**	**11**	**9**	**5**			
add	**5**	**12**	**6**	**11**			
route	**2**	**13**	**6**	**12**		**0.000**	
	dairy06.rte		**dairy06.swq**				
save	**9**	**13**	**1**	**0**	**0**		
	dairy.eve						
finish	**0**						

Because the area in subbasin B is modeled in the microwatershed simulation, the area will not be directly modeled in the large watershed simulation. Instead, the data in the file dairy.eve will be read in and routed.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
	A.sub						
subbasin	**1**	**2**	**2**				
	C.sub						
route	**2**	**3**	**1**	**1**		**0.000**	
	A.rte		**A.swq**				
recday	**10**	**4**	**1**				
	dairy.eve						
add	**5**	**5**	**3**	**4**			
add	**5**	**6**	**5**	**2**			
route	**2**	**7**	**2**	**6**		**0.000**	
	C.rte		**C.swq**				
finish	**0**						

In the above configuration, subbasin A is subbasin 1, subbasin C is subbasin 2 and outflow from subbasin B is read in with the recday command.

Option 2: A combined simulation.

In this simulation, the routing for the entire watershed is contained in one configuration file. We will include comment lines in this watershed configuration to identify the different portions of the watershed being simulated. Subbasin B will be divided into 6 separate subbasins numbered 1-6 with the same land use assignments listed in section B.2.1. Subbasin A is subbasin 7 in this simulation while subbasin C is subbasin 8.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
* land phase for subbasin B							
subbasin	1	1	1				
	dairy01.sub						
subbasin	1	2	2				
	dairy02.sub						
subbasin	1	3	3				
	dairy03.sub						
subbasin	1	4	4				
	dairy04.sub						
subbasin	1	5	5				
	dairy05.sub						
subbasin	1	6	6				
	dairy06.sub						
* land phase for subbasin A							
subbasin	1	7	7				
	A.sub						
* land phase for subbasin C							
subbasin	1	8	8				
	C.sub						
* route flow through subbasin A							
route	2	9	7	7		0.000	
	A.rte		A.swq				
* route flow through subbasin B							
route	2	10	2	1		1.000	
	dairy02.rte		dairy02.swq				
route	2	11	3	2		0.900	
	dairy03.rte		dairy03.swq				
add	5	12	3	11			
route	2	13	5	4		1.000	
	dairy05.rte		dairy05.swq				
add	5	14	12	5			
add	5	15	6	14			
route	2	16	6	15		0.000	
	dairy06.rte		dairy06.swq				
* add outflow from subbasin A and B to loadings from subbasin C							
add	5	17	9	16			
add	5	18	8	17			
* route flow through subbasin C							
route	2	19	8	18		0.000	
	C.rte		C.swq				
finish	0						

Comment lines are denoted by an asterisk in the first space. When SWAT reads an asterisk in this location it knows the line is a comment line and does not process the line.

B.3 GRID CELL DISCRETIZATION

The grid cell discretization allows a user to capture a high level of spatial heterogeneity or variability in the simulation. The grid cells should be small enough to obtain homogenous land use, soil, and topographic characteristics for the area in each cell but large enough to keep the amount of data required for the run at a reasonable level.

The routing methodology for the grid cell discretization is the same as that for the subwatershed discretization. The difference between the two discretization schemes lies in the average size of the subbasin and the method used to define subbasin boundaries.

The GIS interfaces are currently not able to delineate a watershed using a grid cell discretization. However, there are plans to create a GIS tool capable of generating a grid cell discretization.

B.3.1 GRID CELL DISCRETIZATION: 9 CELLS

To illustrate the grid cell discretization, a simple nine-cell example will be used.

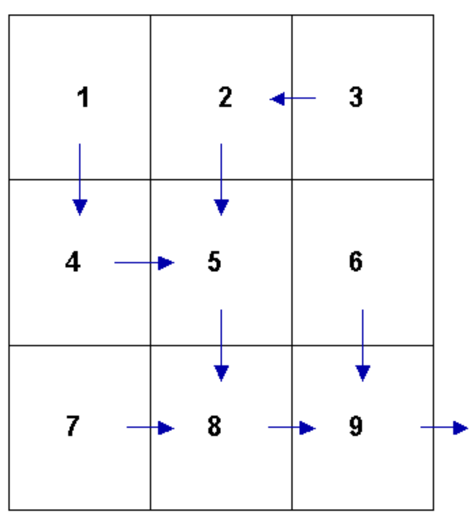

Figure B-4: Grid cell delineation with flow paths shown.

Step 1: Write the subbasin command for each cell. (This command simulates the land phase of the hydrologic cycle.)

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	1	1	1				
	cell1.sub						
subbasin	1	2	2				
	cell2.sub						
subbasin	1	3	3				
	cell3.sub						
subbasin	1	4	4				
	cell4.sub						
subbasin	1	5	5				
	cell5.sub						
subbasin	1	6	6				
	cell6.sub						
subbasin	1	7	7				
	cell7.sub						
subbasin	1	8	8				
	cell8.sub						
subbasin	1	9	9				
	cell9.sub						

Writing **subbasin** in space 1-10 is optional. The model identifies the configuration command by the code in column 1. The option of writing the command in space 1-10 is provided to assist the user in interpreting the configuration file.

Column 2 is the hydrograph storage location number (array location) where data for the loadings (water, sediment, chemicals) from the subbasin are stored.

Column 3 is the subbasin number. Each subbasin number must be unique.

Step 2a: Route the stream loadings through the flow path network. Begin by routing the headwater subbasin loadings through the main channel of the respective subbasin. (Headwater subbasins are those with no subbasins upstream.) Referring to Figure B-4, subbasins 1, 3, 6 and 7 are headwater subbasins.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
	cell1.sub						
subbasin	**1**	**2**	**2**				
	cell2.sub						
subbasin	**1**	**3**	**3**				
	cell3.sub						
subbasin	**1**	**4**	**4**				
	cell4.sub						
subbasin	**1**	**5**	**5**				
	cell5.sub						
subbasin	**1**	**6**	**6**				
	cell6.sub						
subbasin	**1**	**7**	**7**				
	cell7.sub						
subbasin	**1**	**8**	**8**				
	cell8.sub						
subbasin	**1**	**9**	**9**				
	cell9.sub						
route	**2**	**10**	**1**	**1**		**0.000**	
	cell1.rte		**cell1.swq**				
route	**2**	**11**	**3**	**3**		**0.000**	
	cell3.rte		**cell3.swq**				
route	**2**	**12**	**6**	**6**		**0.000**	
	cell6.rte		**cell6.swq**				
route	**2**	**13**	**7**	**7**		**0.000**	
	cell7.rte		**cell7.swq**				

As mentioned in the last step, column 1 is used to identify the command. Column 2 is the hydrograph storage location number identifying the location where results from the route simulation are placed.

Column 3 provides the number of the reach, or main channel, the inputs are routed through. The number of the reach in a particular subbasin is the same as the number of the subbasin.

Column 4 lists the number of the hydrograph storage location containing the data to be routed through the reach.

Column 6 lists the fraction of overland flow. For the grid cell discretization, this value will always be zero.

Step 2b: Route the stream loadings through the reach network. Use the add and route commands to continue routing through the watershed.

First, add the outflow from subbasin 1 to the loadings from subbasin 4 and route the total through the channel in subbasin 4.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	1	1	1				
	cell1.sub						
subbasin	1	2	2				
	cell2.sub						
subbasin	1	3	3				
	cell3.sub						
subbasin	1	4	4				
	cell4.sub						
subbasin	1	5	5				
	cell5.sub						
subbasin	1	6	6				
	cell6.sub						
subbasin	1	7	7				
	cell7.sub						
subbasin	1	8	8				
	cell8.sub						
subbasin	1	9	9				
	cell9.sub						
route	2	10	1	1		0.000	
	cell1.rte		cell1.swq				
route	2	11	3	3		0.000	
	cell3.rte		cell3.swq				
route	2	12	6	6		0.000	
	cell6.rte		cell6.swq				
route	2	13	7	7		0.000	
	cell7.rte		cell7.swq				
add	5	14	10	4			
route	2	15	4	14		0.000	
	cell4.rte		cell4.swq				

The loadings from the outlet of subbasin 1 are stored in hydrograph location #10; the loadings from subbasin 4 are stored in hydrograph location #4.

The add command is specified in column 1 by the number 5. The hydrograph storage location numbers of the 2 data sets to be added are listed in columns 3 and 4. The summation results are stored in the hydrograph location number given in column 2.

Next, add the outflow from subbasin 3 to the loadings from subbasin 2 and route the total through the channel in subbasin 2.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	1	1	1				
	cell1.sub						
subbasin	1	2	2				
	cell2.sub						
subbasin	1	3	3				
	cell3.sub						
subbasin	1	4	4				
	cell4.sub						
subbasin	1	5	5				
	cell5.sub						
subbasin	1	6	6				
	cell6.sub						
subbasin	1	7	7				
	cell7.sub						
subbasin	1	8	8				
	cell8.sub						
subbasin	1	9	9				
	cell9.sub						
route	2	10	1	1		0.000	
	cell1.rte		cell1.swq				
route	2	11	3	3		0.000	
	cell3.rte		cell3.swq				
route	2	12	6	6		0.000	
	cell6.rte		cell6.swq				
route	2	13	7	7		0.000	
	cell7.rte		cell7.swq				
add	5	14	10	4			
route	2	15	4	14		0.000	
	cell4.rte		cell4.swq				
add	5	16	11	2			
route	2	17	2	16		0.000	
	cell2.rte		cell2.swq				

Next, add the outflow from subbasin 2 and 4 to the loadings from subbasin 5 and route the total through the channel in subbasin 5.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	1	1	1				
	cell1.sub						
subbasin	1	2	2				
	cell2.sub						
subbasin	1	3	3				
	cell3.sub						
subbasin	1	4	4				
	cell4.sub						
subbasin	1	5	5				
	cell5.sub						
subbasin	1	6	6				
	cell6.sub						
subbasin	1	7	7				
	cell7.sub						
subbasin	1	8	8				
	cell8.sub						
subbasin	1	9	9				
	cell9.sub						
route	2	10	1	1		0.000	
	cell1.rte		cell1.swq				
route	2	11	3	3		0.000	
	cell3.rte		cell3.swq				
route	2	12	6	6		0.000	
	cell6.rte		cell6.swq				
route	2	13	7	7		0.000	
	cell7.rte		cell7.swq				
add	5	14	10	4			
route	2	15	4	14		0.000	
	cell4.rte		cell4.swq				
add	5	16	11	2			
route	2	17	2	16		0.000	
	cell2.rte		cell2.swq				
add	5	18	15	17			
add	5	19	18	5			
route	2	20	5	19		0.000	
	cell5.rte		cell5.swq				

Next, add the outflow from subbasin 5 and 7 to the loadings from subbasin 8 and route the total through the channel in subbasin 8.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	1	1	1				
	cell1.sub						
subbasin	1	2	2				
	cell2.sub						
subbasin	1	3	3				
	cell3.sub						
subbasin	1	4	4				
	cell4.sub						
subbasin	1	5	5				
	cell5.sub						
subbasin	1	6	6				
	cell6.sub						
subbasin	1	7	7				
	cell7.sub						
subbasin	1	8	8				
	cell8.sub						
subbasin	1	9	9				
	cell9.sub						
route	2	10	1	1		0.000	
	cell1.rte		cell1.swq				
route	2	11	3	3		0.000	
	cell3.rte		cell3.swq				
route	2	12	6	6		0.000	
	cell6.rte		cell6.swq				
route	2	13	7	7		0.000	
	cell7.rte		cell7.swq				
add	5	14	10	4			
route	2	15	4	14		0.000	
	cell4.rte		cell4.swq				
add	5	16	11	2			
route	2	17	2	16		0.000	
	cell2.rte		cell2.swq				
add	5	18	15	17			
add	5	19	18	5			
route	2	20	5	19		0.000	
	cell5.rte		cell5.swq				
add	5	21	20	13			
add	5	22	21	8			
route	2	23	8	22		0.000	
	cell8.rte		cell8.swq				

Next, add the outflow from subbasin 8 and 6 to the loadings from subbasin 9, route the total through the channel in subbasin 9, and append a finish command line to signify the end of the watershed routing file.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	1	1	1				
	cell1.sub						
subbasin	1	2	2				
	cell2.sub						
subbasin	1	3	3				
	cell3.sub						
subbasin	1	4	4				
	cell4.sub						
subbasin	1	5	5				
	cell5.sub						
subbasin	1	6	6				
	cell6.sub						
subbasin	1	7	7				
	cell7.sub						
subbasin	1	8	8				
	cell8.sub						
subbasin	1	9	9				
	cell9.sub						
route	2	10	1	1		0.000	
	cell1.rte		cell1.swq				
route	2	11	3	3		0.000	
	cell3.rte		cell3.swq				
route	2	12	6	6		0.000	
	cell6.rte		cell6.swq				
route	2	13	7	7		0.000	
	cell7.rte		cell7.swq				
add	5	14	10	4			
route	2	15	4	14		0.000	
	cell4.rte		cell4.swq				
add	5	16	11	2			
route	2	17	2	16		0.000	
	cell2.rte		cell2.swq				
add	5	18	15	17			
add	5	19	18	5			
route	2	20	5	19		0.000	
	cell5.rte		cell5.swq				
add	5	21	20	13			
add	5	22	21	8			
route	2	23	8	22		0.000	
	cell8.rte		cell8.swq				
add	5	24	23	12			
add	5	25	24	9			
route	2	26	9	25		0.000	
	cell9.rte		cell9.swq				
finish	0						

As illustrated in section B.2.2 for the hillslope discretization, it is possible to combine the grid cell discretization with the subwatershed discretization to provide detailed modeling of portions of a large watershed while treating less significant areas in the more generalized approach used in the subwatershed discretization.

APPENDIX C

EXAMPLE MANAGEMENT SCENARIOS

SWAT allows a great degree of detail to be incorporated into the management scenarios for the different land uses. The following sections describe how to set up the management operations for the different land use types.

C.1 DEFINING OPERATIONS FOR A LAND USE

Prior to setting up the management file, the user must obtain the set of operations being modeled. The method used to obtain the set of operations depends in large part on the funding and time available. For projects that require a typical or representative set of management operations, farm enterprise budgets published for the region of interest are a good source of management information.

In the US, each state's land-grant university (Department of Agricultural Economics) is responsible for publishing and maintaining farm enterprise budgets for the state. These budgets are created to quantify the cost and profit associated with different farming enterprises typical to the area. As part of the cost analysis, the budgets list the typical schedule (timing) of operations as well as the quantity for fertilizer and pesticides used in the region.

C.2 SCHEDULING OF OPERATIONS

SWAT allows operations to be scheduled using dates or heat units. Heat unit scheduling is valuable for simulation of very large watershed where the timing of operations in one section of the watershed varies from that in another by 2 weeks or more. Using heat unit scheduling allows

The number of subbasins chosen to model the watershed depends on the size of the watershed, the spatial detail of available input data and the amount of detail required to meet the goals of the project. When subdividing the watershed, keep in mind that topographic attributes (slope, slope length, channel length, channel width, etc.) are calculated or summarized at the subbasin level. The subbasin delineation should be detailed enough to capture significant topographic variability within the watershed.

Once the subbasin delineation has been completed, the user has the option of modeling a single soil/land use/management scheme for each subbasin or partitioning the subbasins into multiple hydrologic response units (HRUs).

Hydrologic response units are unique soil/land use/management combinations within the subbasin which are modeled without regard to spatial positioning. When multiple HRUs are modeled within a subbasin, the land phase of the hydrologic cycle is modeled for each HRU and then the loadings from all HRUs within the subbasin are summed. The net loadings for the subbasin are then routed through the watershed channel network. HRUs are set up in the subbasin general attribute file (.sub).

The following sections demonstrate how to create a SWAT watershed configuration file using the subwatershed discretization.

C.2.1 SUBWATERSHED DISCRETIZATION: 3 SUBBASINS

Assume we have a watershed with 3 subbasins as illustrated in Figure C-1.

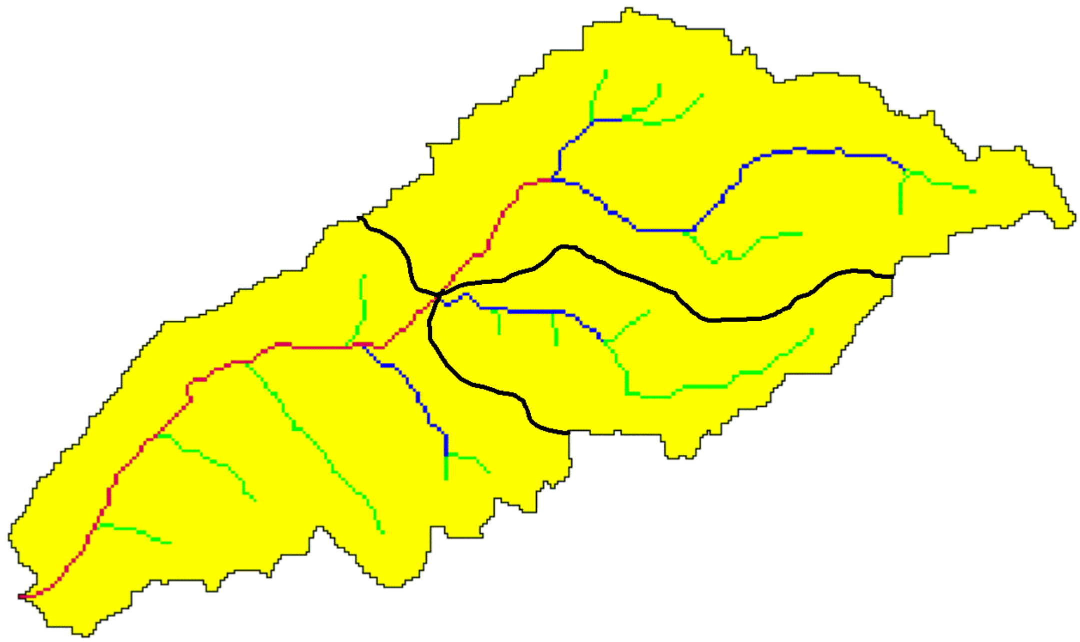

Figure C-1: Subwatershed delineation

Step 1: Write the subbasin command for each subbasin. (This command simulates the land phase of the hydrologic cycle.)

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				

Writing **subbasin** in space 1-10 is optional. The model identifies the configuration command by the code in column 1. The option of writing the command in space 1-10 is provided to assist the user in interpreting the configuration file.

Column 2 is the hydrograph storage location number (array location) where data for the loadings (water, sediment, chemicals) from the subbasin are stored.

Column 3 is the subbasin number. The subbasin number tells SWAT which input files listed in file.cio contain the data used to model the subbasin. Subbasin numbers are assigned sequentially in file.cio to each pair of lines after line 14. The files listed on lines 15 & 16 of file.cio are used to model subbasin 1, the files listed on lines 17 & 18 of file.cio are used to model subbasin 2, the files listed on lines 19 & 20 of file.cio are used to model subbasin 3, and so on.

APPENDIX D

SOILS DATABASE

D.1 HYDROLOGIC SOIL GROUPS

The U.S. Natural Resource Conservation Service (NRCS) classifies soils into four hydrologic groups based on infiltration characteristics of the soils. NRCS Soil Survey Staff (1996) defines a hydrologic group as a group of soils having similar runoff potential under similar storm and cover conditions. Soil properties that influence runoff potential are those that impact the minimum rate of infiltration for a bare soil after prolonged wetting and when not frozen. These properties are depth to seasonally high water table, saturated hydraulic conductivity, and depth to a very slowly permeable layer. Soil may be placed in one of four groups, A, B, C, and D, or three dual classes, A/D, B/D, and C/D. Definitions of the classes are:

A: (Low runoff potential). The soils have a high infiltration rate even when thoroughly wetted. They chiefly consist of deep, well drained to excessively drained sands or gravels. They have a high rate of water transmission.

B: The soils have a moderate infiltration rate when thoroughly wetted. They chiefly are moderately deep to deep, moderately well-drained to well-drained soils that have moderately fine to moderately coarse textures. They have a moderate rate of water transmission.

C: The soils have a slow infiltration rate when thoroughly wetted. They chiefly have a layer that impedes downward movement of water or have moderately fine to fine texture. They have a slow rate of water transmission.

D. (High runoff potential). The soils have a very slow infiltration rate when thoroughly wetted. They chiefly consist of clay soils that have a high swelling potential, soils that have a permanent water table, soils that have a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. They have a very slow rate of water transmission.

Dual hydrologic groups are given for certain wet soils that can be adequately drained. The first letter applies to the drained condition, the second to the undrained. Only soils that are rated D in their natural condition are assigned to dual classes. Guidelines used by USDA Soil Survey to categorize soils into Hydrologic Groups are summarized in Table D-1.

Table D-1: Hydrologic Group Rating Criteria

Criteria*	Hydrologic Soil Groups A	B	C	D
Final constant infiltration rate (mm/hr)	7.6-11.4	3.8-7.6	1.3-3.8	0-1.3
Mean permeability: surface layer (mm/hr)	> 254.0	84.0-254.0	8.4-84.0	< 8.4
Mean permeability: most restrictive layer below the surface layer to a depth of 1.0 m (mm/hr)	> 254.0	84.0-254.0	8.4-84.0	< 8.4
Shrink-swell potential: most restrictive layer**	Low	Low	Moderate	High, Very High
Depth to bedrock or cemented pan (mm)	> 1016	> 508	> 508	< 508
DUAL HYDROLOGIC GROUPS	**A/D**	**B/D**	**C/D**	
Mean depth to water table (m)	< 0.61	< 0.61	< 0.61	

* These criteria are guidelines only. They are based on the theory that the minimum permeability occurs within the uppermost 50 cm. If the minimum permeability occurs between a depth of 50 to 100 cm, then the Hydrologic Soil Group is increased one group. For example, C to B. If the minimum permeability occurs below a depth of 100 cm, the Hydrologic Soil Group is based on the permeability above 100 cm, using the rules previously given.

** Shrink-swell potential is assigned to a profile using the following guidelines:
Low: All soils with sand, loamy sand, sandy loam, loam or silt loam horizons that are at least 50 cm thick from the surface without a clay horizon within 100 cm of the surface.
Medium: All soils with clay loam horizons within 50 cm of the surface or soils with clay horizons from 50 to 100 cm beneath the surface.
High: All soils with clay horizons within 50 cm of the surface. Lower the shrink-swell potential one class when kaolinite clay is dominant.

D.2 SCHEDULING OF OPERATIONS

SWAT allows operations to be scheduled using dates or heat units. Heat unit scheduling is valuable for simulation of very large watershed where the timing of operations in one section of the watershed varies from that in another by 2 weeks or more. Using heat unit scheduling allows