A Guide to Using Special Actions in the Hydrological Simulation Program--FORTRAN (HSPF)

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inside front cover

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Aqua Terra Consultants**

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A Guide to Using Special Actions in the Hydrological Simulation Program—FORTRAN (HSPF)

***By* Thomas H. Jobes, John L. Kittle, Jr., and Brian R. Bicknell, AQUA TERRA Consultants**

ABSTRACT

The Hydrological Simulation Program - FORTRAN (HSPF) model (Bicknell, et al, (1997)) is a comprehensive watershed hydrology and water quality simulation package that has been used in hundreds of applications across the U.S. and abroad. Special Actions are used in HSPF to represent human intervention in the natural processes that occur in a watershed. They can also be used to simply represent natural processes not simulated in the model. These effects are accomplished by directly modifying variables at specified times during the run.

Special Actions can greatly increase the ability of HSPF to represent many types of events in a watershed. Typical uses for Special Actions include: 1) changing a parameter value in a manner not feasible with the standard HSPF input; 2) performing agricultural operations such as tillage, fertilizer applications, and harvesting; and 3) simulating river basin management and reservoir operation based on logical rules and environmental conditions. As a result of the power and flexibility offered by Special Actions, the inputs necessary to specify them are often complex. This document was written to assist modelers in using Special Actions.

This document is a user's guide to Special Actions, based on HSPF Version 11. It describes how Special Actions relate to the HSPF code and data structure, and provides both an overview and a detailed description of Special Actions components. It also documents the format of the Special Actions block and the output resulting from execution of Special Actions. Three detailed case studies are presented to illustrate different types of applications.

INTRODUCTION

The Hydrological Simulation Program - FORTRAN (HSPF) model (Bicknell, et al, (1997)) is a comprehensive watershed hydrology and water quality simulation package that has been used in hundreds of applications across the U.S. and abroad. HSPF Special Actions are a means to represent human intervention in the natural processes that occur in a watershed. They can also be used to represent processes not simulated in the model. These effects are accomplished by directly modifying variables at specified times during the run.

Beginning with HSPF Version 11, many improvements are included in the program that dramatically increase the power and flexibility of Special Actions, and can simplify the input required to implement existing applications. However, for some applications, the inputs necessary to specify Special Actions are complex. This document was written to assist modelers in using Special Actions. It assumes general familiarity with the HSPF model, and should therefore be used as companion documentation with release

11 of the HSPF User's Manual (Bicknell et al, 1997). Later releases of HSPF are expected to maintain upward compatibility with the features and syntax presented in this document. Typical uses for Special Actions include:

- **Simple changes to parameter values**

  If a parameter that is considered constant in HSPF, such as the infiltration capacity, is required to change over time in order to adequately represent actual conditions in the watershed of interest, Special Actions can be used to alter the parameter value.

- **Agricultural operations**

  Events such as plowing, cultivation, fertilizer and pesticide application, and harvesting can be simulated using Special Actions to reset or increment the state variables representing chemical and sediment storages in a pervious land segment.

- **Reservoir operation and basin management**

  The HYDR section of the RCHRES module has built-in flexibility to simulate the operation of a reservoir or diversion. However, Special Actions may be used to greatly increase that capability. For instance, input timeseries such as irrigation demands can be generated using Special Actions to determine reservoir releases and canal diversions.

Special Actions and the HSPF Program Structure

Some knowledge of the structure of HSPF is required to fully understand how Special Actions work. This user's guide assumes the reader is already familiar with the HSPF program and the User's Control Input (UCI) file. This section is a synopsis of the points needed to understand and write Special Actions.

Operation Status Vector

The user's input for each operation listed in the OPN SEQUENCE block is translated into an array called the Operation Status Vector, or OSV. It contains all of the information needed by the program to perform the simulation of a PERLND, IMPLND, or RCHRES, or to execute a utility operation such as COPY or DISPLY. This includes all of the input flags and parameters, state variables, current and accumulated values of fluxes, and the current values of input and output timeseries. All OSVs for a given operation type have identical structure, but each contains different values, representing the current states of the individual operations. The OSVs are initially populated by the Run Interpreter and then managed by the Operations Supervisor.

Each variable in the OSV has a numerical address that is unique to that operation type. For example, the variable LZSN, which is the lower soil zone nominal moisture storage in the PWATER section of the PERLND module, is found at address 308 in every PERLND operation. The variable MON, which is the current month in the simulation time span, is located at address 67 in a RCHRES OSV, and at address 19 in a COPY OSV. These numeric addresses may change with each new release of HSPF as new variables and capabilities are added to the model.

Run Interpreter

Before the HSPF simulation begins, a section of the program called the Run Interpreter reads the UCI file and translates the information into instructions that HSPF can execute and data it can understand. The Run Interpreter logically groups elements from the UCI file into categories:

- Overall structure of the run (GLOBAL and OPN SEQUENCE blocks)
- Parameters and initial state variables from operation-type blocks (PERLND, IMPLND, RCHRES, COPY, PLTGEN, DISPLY, DURANL, GENER, and MUTSIN)
- Timeseries linkages (EXT SOURCES, EXT TARGETS, NETWORK, SCHEMATIC, MASS-LINK, PATHNAMES, and FORMATS blocks)
- Special Actions (SPEC-ACTIONS)
- Other information (FILES, FTABLES, MONTH-DATA and CATEGORY blocks)

For each operation in the OPN SEQUENCE block, the Run Interpreter creates an OSV and places in it all of the input parameters, flags, and state variables contained in the UCI for that operation. It also creates instructions in internal format for the Operations Supervisor, the timeseries routines, and the Special Actions.

Operation Supervisor

The Operation Supervisor takes control of the simulation after the Run Interpreter has processed the input file. For each operation in the OPN SEQUENCE block, the Operation Supervisor:

- Gets input timeseries from external data files (specified in the EXT SOURCES block) or from previous operations (specified in the NETWORK and SCHEMATIC blocks), and places them in a data structure called the INPAD.
- Initiates the operation. The number of time steps or intervals it runs, called the INSPAN, may be anywhere from a single interval to the entire span of the run, depending on the complexity of the Special Actions block and timeseries connections. In each interval, the operation first performs any Special Actions. Then, the simulation phase begins. Input timeseries are read from the INPAD to the OSV as needed during this phase, and all fluxes and state variables are calculated. At the end of the interval, output timeseries are transferred from the OSV to the INPAD so that the Operations Supervisor can work with them.
- Transfers output timeseries (specified in the EXT TARGETS block) from the INPAD to external data files.

This sequence is repeated until the full time span of the run is complete.

Special Action Execution

A Special Action instructs HSPF to directly modify the value at a specific address in the OSV of an operation at a specified date and time during the run. The address is normally specified in the form of a variable name, and the value can be reset, incremented, or otherwise altered in a variety of ways. Since this modification occurs at the beginning of each computation interval, before any calculations and before any timeseries are read from the INPAD, a Special Action can effectively target some kinds of variables, but not others. Also, some variables are recalculated only intermittently, (i.e., not every interval), so changing their values will work as expected in some intervals, but not in others. The following list of variable classes gives a definition of each, and specifies whether it is a valid target for Special Action.

- **Principal state variables (Yes) -** State variables, as the name implies, describe the state of the system at the end of each computation interval. Most state variables, especially storages, are both an output of the previous interval and an input to the current interval. These values can be modified normally. For example, the addition of agricultural chemicals and the removal of plant nitrogen and phosphorus to simulate crop harvests can be represented by altering the respective storage variables.

- **Auxiliary state variables (No) -** These are state variables whose new value are not dependent on the value at the end of the previous computation interval. They are independently recalculated from other variables every interval prior to being used, with no dependence on their previous value. For example, the storage (mass) of many instream water quality constituents is computed every interval as the concentration times the volume of water in the stream reach (both principal state variables). Special Actions have no practical effect on these auxiliary state variables, since the new value assigned before the beginning of the interval will be superseded by the value resulting from the calculation before it has a chance to affect the model results. For these variables, it is only possible to modify the other principal state variables or parameters upon which this variable depends, so that the newly computed value is altered accordingly.

- **Intermittent state variables (Not recommended) -** There are other state variables that are calculated intermittently before being used (i.e., only after a number of intervals, with the recalculation interval either regular or dependent on conditions), and the new value is not dependent on the previous value. On the specific recalculation intervals, these variables are essentially auxiliary state variables as described above, so changing the value with a Special Action will have no effect for the reason outlined above, but during "off" intervals, the previous value is left unchanged, and they function temporarily as principal state variables, meaning that the value set by the Special Action will actually be used. However, since this new value will be superseded in just a few intervals, the effectiveness of attempting to modify these variables is usually slight. The approach of modifying other variables to influence the value of an intermittently calculated state variable is considered rarely useful, and is not recommended.

- **Parameters (Yes, with exceptions) -** These are values defined in the UCI file which control the various algorithms. They can be altered normally using Special Actions. For example, the parameter INFILT, which sets the infiltration rate of water into the soil column in the PWATER section of the PERLND module, can be increased or decreased to reflect phenomena such as plowing or frozen ground on a parameter that is normally assumed to maintain a constant value.

  The exceptions occur when a parameter is treated as a different class of variable due to the option flag settings originally chosen in the UCI file. Some parameters in the UCI file can be made to vary over the year by turning on the appropriate option flag. When this option is selected, the parameter is treated as an intermittent state variable whose value is recomputed on the first interval of each day. (See **Intermittent state variables**.) Also, some parameters can be treated as input timeseries by setting an option flag in the UCI. In this case, the parameter value in the UCI and any Special Actions that target it will be ignored in favor of the input timeseries. (See **Input timeseries**.)

- **Option flags (No) -** These are integer parameters that affect the behavior or meaning of other values. Modifying an option flag may change the meaning of another parameter, or require different input timeseries, or even require the definition of other parameters that were originally missing or ignored in the UCI file. Altering option flags with Special Actions, even when possible, is not recommended without careful attention to how they interact with other parameters, and can cause invalid results (possibly without warning) and/or program crashes if done improperly. It is therefore recommended that they not be changed in this way.

- **Input timeseries (No) -** The value of an input timeseries that is stored in the OSV at the time Special Actions are performed is left over from the previous interval, and will be overwritten when the new value is obtained from the INPAD during the simulation phase. Therefore, Special Actions designed to change the values of these input timeseries will have no effect.
- **Output fluxes (No) -** These quantities, like input timeseries, are overwritten by new calculations during the simulation phase. A very few output fluxes are actually intermittently calculated flux **rates** (i.e., essentially state variables) which are also used for the current value of the fluxes. As noted above, however, modifying intermittent state variables is not recommended. (See **Intermittent state variables**.)
- **Character variables (No) -** Variables containing text rather than numerical data cannot be modified by Special Actions.
- **Date and time (No) -** The date and time of the simulation run should not be changed with Special Actions.

The Special Action Variable Library (Appendix A) lists the names of all of the OSV variables that HSPF recognizes in the SPEC-ACTIONS block. It contains definitions, internal units, the type (real, integer, or double precision) and an indication of whether the variable is a valid target of Special Actions. All of the variables listed, even if not classed as valid Special Action targets, may be used as sources, or base variables, of user-defined variable quantities (UVQUANs). (For more information, refer to the description of UVQUANs in the next section, Overview of Special Actions Block Components.) The program has its own internal copy of the Special Action Variable Library, against which it checks the name given in the Special Action.

Numerical addresses in the OSV are likely to change with each new release of HSPF. Therefore, it is strongly recommended that the names from the Variable Library be used instead of numerical addresses, in order to make the UCI compatible with new versions of the program. The Variable Library was intended to include all variables useful to a user without specialized knowledge of the code. However, any other OSV variable not contained in the Library may still be addressed numerically. The complete variable address list for every operation for HSPF version 11 is available in the OSV documentation (AQUA TERRA, 1996).

In HSPF version 11, Special Actions can be performed on variables in the PERLND, IMPLND, RCHRES, PLTGEN, and GENER operations. However, PLTGEN has no names listed in the Variable Library; therefore, numerical addresses (obtained from the OSV documentation) must be used to perform Special Actions on operations of this type. The COPY operation has no variables that can be effectively modified with Special Actions, but it has several variables that can be used as sources or base variables; therefore these are listed in the Variable Library. Variables in the DISPLY, DURANL, and MUTSIN operations are not recognized in the SPEC-ACTIONS block.

Special Action Accumulators

A user may instruct the program to create (throughout the course of the run) periodic summaries of program output to be stored on disk. HSPF keeps track of the fluxes and storages of any constituent for which a mass balance is maintained, including flow, sediment, pesticides, nitrogen, and phosphorus; and whenever a periodic printout occurs, the overall mass balance is checked for continuity, so that the user can be sure that the model is not “creating” or “destroying” matter due to some error in either the code or the input. If a gain or loss of mass is detected, a “warning” message is included in one of the output files. In previous versions of HSPF, when a variable which represents the storage of such a constituent was modified by Special Actions, the mass balance check did not account for any increase or decrease, and the user was often confronted with large numbers of false warning messages. This problem was most noticeable when applying the Agricultural Chemical sections (PEST, NITR, PHOS, TRACER) of PERLND.

Beginning in version 11, when Special Actions are used in PERLND to increment the storage of nitrate, ammonia, or organic N in NITR, or phosphate or organic P in PHOS, a corresponding accumulator variable in the PERLND OSV is also incremented so that the printed fluxes in the output file contain the total input flux of each constituent due to Special Actions. These particular constituents were chosen because they are the most common Special Action targets that do not have an input timeseries available. See Appendix B for the current list of variables and their accumulators. Future versions of HSPF may add accumulators for other Special Action inputs.

Special Actions Block Components and Usage

The SPEC-ACTIONS block is the part of the HSPF User's Control Input (UCI) file that contains all of the Special Actions instructions. This section presents first an overview of each type of input line that may appear in this block, and how these basic lines, singly and in combinations, can be used to represent a variety of situations. (Complete formal syntactic description of each line type appears in the following chapter.) Then, an example set of Special Actions is used to show, step by step, the order in which variable values are evaluated and modified. The Global Workspace capability allows the use of “scratch” variables for complex intermediate calculations before altering the value of an actual HSPF program variable (i.e., OSV). Because this facility is both more complex than the others described and is expected to be used more rarely, the discussion is reserved for the end of the section. Five kinds of input lines may appear in the Special Actions block:

- Action
- Distribution (DISTRB)
- User-defined Variable Name (UVNAME)
- User-defined Variable Quantity (UVQUAN)
- Condition

Types of Actions

Special Actions can be used in a variety of combinations to implement a wide array of situations. Table 1 describes the various types of Special Actions that are possible using the various types of lines. Each input line type is then presented along with examples of each type of action.

Many of these types of actions can be combined. For instance, undated actions are often also conditional actions, so that a modeled human intervention can depend on the conditions in the watershed rather than a preset schedule. There are a few combinations that are not allowed, however. These prohibitions, which are enforced by the program, will be mentioned as the corresponding action types are introduced in this chapter.

Table 1. Summary of Special Actions and associated input lines

Type of Action	Definition	Input Line Type
Simple	Cause an Action to occur at a single point in time for a named variable in one operation.	Action
Numerical target address	Cause an action to occur for an OSV variable identified by a numerical address.	Action
Multiple operations	Cause an Action to occur for a range of operation numbers	Action
Repeated	Cause an Action to occur at regular intervals during the run	Action
Undated	Cause an Action to occur every interval of the run	Action
Distributed	Cause an action to be spread over ten (or fewer) regularly-spaced intervals	Action, DISTRB
User-defined target	Cause an action to affect one or more OSV variables which are linked to a user-defined name	Action, UVNAME
Special user-defined target	Perform one of three special operations to simulate mixing of agri-chemicals due to plowing	Action, UVNAME
User-defined action quantity	Modify a variable by an amount derived from an OSV variable rather than a pre-defined constant amount	Action, UVQUAN
Conditional	Cause an action to take place only when logical conditions are met	Action, Conditional
Deferred Conditional	Cause a conditional action to be deferred until the next interval during which the logical conditions are satisfied	Action, Conditional
Deferred Distributed	Cause a conditional distributed action to be deferred within a distribution period	Action, DISTRB, Conditional
Global Workspace	Enable an action to modify a user-defined "scratch variable" rather than an OSV variable.	Action, UVNAME, UVQUAN

Simple Action

```
***                                             <addrss>-------   ----<uvqn>
***            dc ds                  d t         or                  or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
  PERLND  1         1991/03/15 16:00   3  SAMAD           +=      10.0
```

In its simplest form, an action line modifies a single OSV variable, called the **target**, in a single operation at a single time in the run. The line contains a number of column-specific fields that define the target variable and the intended change. It is important to place each value of the line in its proper column. Several fields are optional, and can be left blank.

In the Simple Action example, the first two fields specify that the operation containing the variable to be modified is PERLND number 1. Next comes the date and time during the simulation that the change is scheduled to happen. The "3" near the middle of the line under the heading "t" (for "type") is a code meaning that the target variable is a single-precision real value, as opposed to integer (type 2) or double precision (type 4). This is the default, and so the "3" could have been omitted. Modification of character variables (type 1) is not currently supported.

The target variable is specified by a case-sensitive name (all are uppercase) and up to three array subscripts. In this example, the target variable is called SAMAD, which, according to the Special Action Variable Library in Appendix A, represents the storage of adsorbed ammonia in the surface soil layer. It is a scalar rather than an array, and so no subscripts are necessary.

The next occupied field is called the action code. It defines the mathematical operation to be performed. The code "+=" tells HSPF to add the following number to the current value of the target variable, and reset the target to equal the total. The available action codes are listed in the detailed formats in the next section.

The number following the code is the action value itself. In order to know what number to use, the user must know the units of the variable. Each applicable (real-valued) variable in the OSV has defined internal units, listed in the Variable Library. These units may or may not differ according to the setting of the flag UNITFG in the GLOBAL block of the UCI file. Also, these units may or may not be the same as the units defined externally in either the parameter tables in the model input or the Timeseries Catalog in the HSPF Manual, so it is very important to check the Library.

For SAMAD, the internal units can be either lb/ac or kg/ha. Assuming that this simulation is using English units, the overall effect of this input line is that the value of SAMAD is incremented by 10.0 lb/ac for PERLND number 1 on March 15, 1991 at 4:00pm.

Numerical Target Address Action

```
***                                       <addrss>-------   ----<uvqn>
***           dc ds                 d t     or                   or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
  PLTGEN  1         1988/05/01 00:00   2       173         =         1
```

In order to modify an OSV variable that is not found in the Special Action Variable Library, a numerical OSV address must be used. For example, to set the PLTGEN variable PLTFLG, which controls the output to the PLTGEN file, the corresponding numerical address must be used, since PLTGEN variables are not included in the Variable Library. It should be recalled however, that numerical addresses are subject to change in new versions of HSPF. The address shown above is based on version 11. Fortunately, all commonly used variables appear in the Variable Library.

There are two additional changes from the previous example. First, the "`2`" in the type field indicates that PLTFLG is an integer. This variable type must match the actual type of the variable. Also note that in some cases there are overlapping columns for alternative fields. Thus, the address for PLTFLG is rightjustified in the “`addrss`” field, ignoring the columns for the variable name and subscripts.

Multiple Operations Action

```
***                                       <addrss>-------   ----<uvqn>
***           dc ds                 d t     or                   or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
  PERLND  1   5     1991/03/15 16:00      SAMAD           +=      10.0
```

An action line may refer to more than one operation of a given type by giving a range of operation numbers. This example differs from the Simple Actions example in that it applies to any PERLNDs numbered 1 through 5 that are active. Thus if PERLNDs 2, 4, and 6 appear in the OPN SEQUENCE block, this action will apply to PERLNDs 2 and 4, but not 6.

Repeated Action

```
***                                       <addrss>-------   ----<uvqn>
***           dc ds                 d t     or                   or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
  PERLND  1         1991/04/01 12:00      SPS     1  1    +=      10.0 YR   1 10
```

An action may also occur at regular intervals during the run by specifying 1) a 2-letter time code “`tc`” (YR, MO, DY, HR or MI, case sensitive); 2) an integer time step “`ts`”; and 3) the number of times to repeat the action “`num`”. These inputs are near the end of the line. The time code and time step together determine how long to wait between occurrences of the action. The possible time codes range from minutes to years, and are given in the detailed format in the next chapter. The above action is performed annually (time step=1, time code=YR) for ten repetitions, beginning on April 1, 1991 at noon. Note that the number of repetitions is a maximum. If the run ends in 1995, then the action will occur every year of the run, and the extra repetitions are ignored. If, however, the simulation period extends beyond 2001, then in later years this action would not occur.

Undated Action

```
***                                         <addrss>-------   ----<uvqn>
***            dc ds                  d t     or                 or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
  GENER   1                               K       1      MIN      50.0
```

Normally, Special Actions occur only on the specified date(s) during the run. However if the date is left blank, then the action is considered undated, and occurs every interval of the run. Only the year field "`yr`"is checked to determine if date is blank. If the year is positive, then other blank date fields are treated as "beginning of next larger time interval". (Blank day means the first day of month, etc.)

The example line shown above tells HSPF to reset the value of the GENER parameter K(1) to the minimum of its current value and 50.0 for every time step, effectively setting a ceiling of 50.0. (K(1) is presumably being periodically reset earlier in the SPEC-ACTIONS block, since it is normally a constant.) Because these actions are repeated every interval, use of repeat codes (tc, ts, and num) would be redundant, and is not permitted.

Distributed Action

```
***      ds  ct tc ts
***kwrd>< > < > <> < > <dff>  <frc><frc><frc><frc><frc><frc><frc><frc><frc><frc>
  DISTRB  1   3 DY   4         0.25  0.5 0.25

***                                         <addrss>-------   ----<uvqn>
***            dc ds                  d t     or                 or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
  PERLND  1         1991/03/15 16:00 1    SAMAD           +=      40.0
  PERLND  2         1991/03/15 16:00 1    SAMAD           +=      40.0 YR   1  5
```

A Special Action, especially one that increments a storage, may be divided so that it occurs over several intervals. The distribution declaration is contained in a line marked by the keyword DISTRB, each with an index number "`ds`", which can be in the range 1-50. In this line, the items specified are: the number of intervals "`ct`" (up to ten), the time code "`tc`" and time step "`ts`" of the gap between intervals, and fractions or multipliers "`frc`", which are applied successively to the quantity in the associated action line. The multipliers need not be between zero and one, nor need they sum to one.

Once a distribution is defined, any subsequent action line may refer to it by placing the index number in the distribution field "`d`", (not "`ds`") near the center of the line. Any number of action lines may refer to any given distribution. In the action line for PERLND 1 in the example above, a single application of adsorbed ammonia to the surface soil layer (SAMAD) is distributed into three actions which are four days apart, with 10 lb/ac added on March 15th, 20 lb/ac on the 19th, and 10 lb/ac on the 23rd.

A distributed action may be repeated, but the user is responsible to ensure that the distribution period and repeat interval make sense together. The distribution period should completely end before the next repetition occurs. PERLND 2 in the example above uses the same distribution as PERLND 1, and performs the same function as the first one on March 15 of every year for five years starting in 1991. Undated actions may not be distributed, since they occur every interval.

User-defined Target Action

```
***                 <addrss>-------              <addrss>-------
***            cnt    or               act         or               act
***kwrd>  <unam>< > <vari><1><2><3> <frc> <  >    <vari><1><2><3> <frc> <  >
  UVNAME  MANURE  2 SAMAD             0.4 QUAN    SORGN             0.6 QUAN

***                                    <addrss>-------   ----<uvqn>
***           dc ds                d t    or                    or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
  PERLND  1         1992/06/10 10:00      MANURE          +=      20.0
```

This type of line allows the user to define a single name to represent one or more standard OSV variables to be used as the target of a Special Action. First, the target is defined using the UVNAME line. If a UVNAME is used to represent multiple standard variables, then a single action line referring to that UVNAME as a target will cause multiple Special Actions to occur. Following the UVNAME keyword, this line contains: 1) a case-sensitive user-defined name limited to six characters; 2) the number (count) of standard variables that are included in the set; 3) the variable names (or OSV addresses); 4) fractions or multipliers for the action quantity that will be applied to each variable; and 5) an optional operation code.

The above example creates a new variable name "MANURE" that is used in the following action line just as if it were an existing name in the Variable Library. This line causes two Special Actions to occur. The first adds 8 lb/ac (0.4*20.0) of adsorbed ammonia to the surface layer (SAMAD) and the second adds 12 lb/ac (0.6*20.0) of surface layer particulate labile organic nitrogen (SORGN). Both actions occur in the same interval. The action value of 20.0 is in units of lb/ac of total nitrogen, which is assumed to be composed of the constant fractions given.

In this example, the UVNAME operation code is "QUAN". This is the default for UVNAMEs, and means simply that the action code found on the action line is used. Most UVNAMEs will use this code.

Special User-defined Target Action

```
***                 <addrss>-------              <addrss>-------
***            cnt    or               act         or               act
***kwrd>  <unam>< > <vari><1><2><3> <frc> <  >    <vari><1><2><3> <frc> <  >
  UVNAME  MOVTOT  2 SAMAD             0.1 MOVT    UAMAD
  UVNAME  MOVONE  2 SAMAD             0.8 MOV1    UAMAD
  UVNAME  MOVTWO  4 SAMAD             0.2 MOV2    UAMAD
                    SNO3              0.2 MOV2    UNO3
***                                    <addrss>-------   ----<uvqn>
***           dc ds                d t    or                    or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
  PERLND  1         1994/05/15 12:00      MOVTOT          =
  PERLND  2         1994/05/15 12:00      MOVONE          =
  PERLND  3         1994/05/15 12:00      MOVTWO          =
```

Three additional options for the UVNAME operation code are available. These options were designed to simulate specific plowing operations that overturn the surface and upper soil layers and mix the existing storages of agricultural chemicals. They behave differently enough from the previous example that they warrant a separate discussion.

When these operation codes are selected, the OSV variables that are members of the UVNAME are treated in pairs, and the corresponding action line results in a transfer from one storage to the other. The amount to be transfered is controlled by the multiplier given for the first variable. This multiplier is considered a fraction, and should be between zero and one (although HSPF does not enforce this). The operation code and fraction for the second variable in the UVNAME line are ignored. Since the amount of the transfer is determined by the first operation code and fraction in the UVNAME lines, the action code and quantity in the action line are not used, although a valid action code must be present to satisfy the Run Interpreter. Action lines that refer to these UVNAMEs may not be undated nor distributed over several intervals because of the nature of the processes they are intended to represent. These special UVNAME operation codes are defined as follows:

- **MOVT -** The total storage in the two variables is summed and re-divided, with the first receiving the fraction indicated, and the second receiving the remainder. This can be used to simulate complete mixing of the surface and upper soil layers (e.g., from heavy disking) by specifying the fraction of the soil mass involved that resides in the surface layer.
- **MOV1 -** The first storage keeps the indicated fraction of its original amount, while the rest is moved to the second storage. This can be used to simulate a variety of tillage operations (e.g., chisel plowing) that result in partial incorporation. The appropriate fraction depends on the specific process being modeled.
- **MOV2 -** The first storage receives the indicated fraction of the amount in the second storage, and the second storage gets the remaining total. This can be used to model a plowing operation that turns a portion of the upper zone onto the surface, while incorporating the entire surface layer into the upper zone (e.g., moldboard plowing). If the fraction is the ratio of the amount of soil in the surface (depth times bulk density) to that of the upper layer, then the resulting concentration in the surface layer will equal the original concentration in the upper layer.

The examples shown above demonstrate each operation code. Assume that at the beginning of the interval, all three PERLNDs have the following storages: SAMAD=20, UAMAD=10, SNO3=2, and UNO3=1 (units = lb/ac).

The UVNAME to which the first Special Action refers uses the MOVT operation code. In this case, the total storage of adsorbed ammonia (30 lb/ac) is re-divided, with one tenth in the surface layer and the rest in the upper layer. The new value of SAMAD is 0.1*(20+10)=3, and UAMAD is 30-3=27.

The second action line targets the user-defined name MOVONE, which uses the operation code MOV1. Here, the surface layer retains 80 percent of its original adsorbed ammonia storage, with the rest being transferred to the upper layer. Therefore, SAMAD and UAMAD become 0.8*20=16 and (0.2*20)+10=14, respectively.

The last action refers to MOVTWO, which uses MOV2. The surface layer receives one fifth of the upper layer's storage of both adsorbed ammonia and nitrate, while the entire original surface storages are incorporated into the upper layer. SAMAD becomes 0.2*10=2, UAMAD becomes 30-2=28, SNO3 becomes 0.2*1=0.2, and UNO3 becomes (1+2)-0.2=2.8.

User-defined Action Quantity

```
***                         <addrss>-------
***                            or                         lc ls ac as agfn
***kwrd> <uqnm> <oper> <#> <vari><1><2><3><t><multfact> <>< > <>< > <  >
  UVQUAN myval  RCHRES   2 OVOL    1             0.0001

***                                        <addrss>-------   ----<uvqn>
***            dc ds                    d t    or                  or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
  PERLND  5         1995/08/20 12:00      SURS           +=     myval
```

In some cases, the action value needs to depend on the conditions in some part of the watershed, rather than be a predetermined constant. The UVQUAN line creates a user-defined variable quantity which can be used either as an action value for a Special Action or as a value to be compared in a condition line (see below).

A UVQUAN refers to a "base variable", which is an OSV variable in a single HSPF operation. Whenever the UVQUAN appears, it is replaced by the last-calculated value of the base variable. Optionally, the UVQUAN may return a lagged value (e.g., 5 intervals ago); an aggregated value (e.g., the average over the previous day); or a combination (e.g., the sum over three days ending 24 hours ago). The result can also be multiplied by a constant factor.

The declaration line for a UVQUAN contains: 1) the keyword “UVQUAN”; 2) a case-sensitive user-defined name limited to six characters; 3) the name (or OSV address) of the base variable; 3) the type code of the base variable, (defaulted to “real” in the example); 4) an optional multiplier; 5) optional time code and time step for lag; and 6) optional time code, time step, and aggregation function (SUM, AVER, MAX or MIN) for accumulated values.

The quantity “myval” in the example above will be equal to the current value of OVOL(1) (the outflow volume from the first reach exit) for RCHRES 2 in cubic feet (the internal units found in the Library), multiplied by a factor which accounts for both the difference in units and the acreage over which the water is to be spread. The corresponding action line applies (on the specified date) this amount of water to the surface storage of PERLND 5, thus simulating irrigation water diverted from the stream.

If lagged and/or aggregated values are used, HSPF tracks the appropriate number of intervals in a "pipe", so that it can "look back" and calculate the desired quantity. At the start of the run, the pipe is filled with the base variable's initial value. Therefore, the lagged and/or aggregated value may not be accurate for the first few intervals of the run.

It is important to note the difference between a UVQUAN and a UVNAME. A UVQUAN is a **value**, just like a constant. A UVNAME is a **target address** for a Special Action. Thus, any variable in the Library may be useful as the base variable of a UVQUAN, but only variables that make valid Special Action targets should be referenced by a UVNAME. The examples in this manual will always use uppercase for the UVNAME and lowercase for the UVQUAN to stress this conceptual difference.

Conditional Action

```
***                         <addrss>-------
***                            or                         lc ls ac as agfn
***kwrd> <uqnm> <oper> <#> <vari><1><2><3><t><multfact> <>< > <>< > <  >
  UVQUAN puncom RCHRES   2 CVOL    tx

IF (puncom > 10000) THEN
***                                        <addrss>-------   ----<uvqn>
***            dc ds                    d t    or                  or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
  RCHRES  2                             4  CVOL    pw        =       0.0
  RCHRES  2                             4  CVOL    tx       +=    puncom
END IF
```

Special Actions may depend on whether a user-specified logical condition is true or false, and can be either skipped or deferred to a later time if the condition is false. Special Actions can be grouped into "logical blocks" by placing IF, ELSE IF, ELSE, and END IF lines appropriately among the action lines. For example, the action lines placed between an IF line and the next logical delimiter are executed only if the condition specified on the IF line is true on the date and time of each action. Both of the action lines shown in the example will take place only if the current value of “puncom” exceeds ten thousand.

The logical condition (puncom > 10000) is evaluated once in each interval, the first time that it is needed. Thus, even though the first action alters the value of puncom’s base variable, the second action is performed without re-evaluating the inequality.

A simple logical condition is defined as a comparison between two numerical values. Either or both of these values may be UVQUANs, but not UVNAMEs nor OSV variable names. Complex conditions are built by connecting simple conditions together with the logical operators AND and OR. For example:

- Simple
  month <= 2
  6226.0 <= tstage
  tfish < faradj
- Complex
  [month = 10 OR (tstage >= 6226.0 AND {month >= 11 OR month <= 2})]

Parentheses are used to specify the order of evaluation, just as in a programming language. By default, the logical operators are evaluated from right to left, but it is good practice to use parentheses in all cases to ensure clarity. There are three types: round (), square [], and curly {}. They are all equivalent, but the program requires that matching left-right pairs must be of the same type, in order to help the user prevent unintended effects in complicated conditions.

The four types of condition lines differ from other Special Action input lines in that they are free-format, rather than column dependent. IF lines consist of three components: the keyword IF, a logical condition, and the keyword THEN. The IF keyword may appear anywhere on the line, as long as it is the first non-blank. The condition may be simple or complex, and may span multiple lines. When an IF line is found, the program keeps reading lines until the THEN keyword is found. ELSE IF lines are processed in the same manner. ELSE and END IF are expected to appear alone on a line, and anything after the keyword is ignored. The "ELSE IF" and "END IF" keywords must contain **exactly** one space between the two words.

Conditional lines may also be nested up to ten IFs deep to allow specification of complex logical blocks. Because all of these lines are column-independent, they can be indented in order to make the nesting of logical blocks clear.

Deferred Conditional Action

```
IF (rain < 0.01) THEN
***                                       <addrss>-------   ----<uvqn>
***            dc ds                d t      or                    or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
  PERLND  1    DY  71991/03/15 16:00      SAMAD           +=      10.0
END IF
```

If the logical condition that applies to an action line is false, then normally, the action is skipped entirely, but it may instead be deferred and retried later. The user specifies a deferral interval by the usual time code “`dc`” and time step “`ds`”scheme, this time in the action line just before the date. In this example, if rainfall occurred on March 15, 1991 at 4pm, then the action is put back into the queue with a new date of

March 22 (i.e., 7 days later). If the condition is still false (still at 4pm), the action is deferred for another seven days, and will be regularly retried until it either succeeds or the run ends. Note that undated action lines may not be deferred, since they are executed every interval.

Deferred Distributed Action

```
***      ds  ct tc ts
***kwrd>< > < > <> < > <dff>  <frc><frc><frc><frc><frc><frc><frc><frc><frc><frc>
  DISTRB  1   5 DY   2 ACCUM   0.25  0.5 0.25  0.0  0.0

IF (rain < 0.01) THEN
***                                     <addrss>-------   ----<uvqn>
***           dc ds                d t     or                   or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
  PERLND  1         1991/03/15 16:00 1    SAMAD           +=      40.0
END IF
```

If a distributed action line depends on a logical condition, and that condition is false, then deferral is handled differently than for undistributed actions. A deferral code flag “`dff`” tells the program to: 1) SKIP the amount for that interval (i.e., no deferral), which is the default; 2) ACCUMulate it with the following interval's fraction; or 3) SHIFT the amount equally over the remaining intervals in the distribution. In all cases, any remaining amount caused by the failure of the condition on the last interval of the distribution is skipped.

In the above example, if logical conditions fail on March 15th, then no SAMAD (surface ammonia) will be applied on that date, and 30 lb/ac will be applied two days later on the 17th if the condition has become true. The two zero-fraction days at the end of the distribution are intended to allow more time at the end of the distribution period (in this case March 25) for the action to occur without being skipped, since farmers in the field aren’t likely to simply give up on a fertilizer application.

Evaluation Order

```
*** Condition A
IF month >= 9 THEN
  *** Action 1
  RCHRES130                            4  CVOL   pw      +=     tavlq
  *** Action 2
  RCHRES130                            4  CVOL   tx      -=     tavlq

 *** Condition B
 IF (tstage > 6226.0) THEN
  *** Action 3
  RCHRES100                            4  CVOL   tx      +=     puncom

 *** Condition C
 ELSE IF (tstage > 6225.0) THEN
  *** Action 4
  RCHRES100                            4  CVOL   pw      +=     puncom

 ELSE
  *** Action5
  RCHRES130                            4  CVOL   na      -=     puncom
  *** Action6
  RCHRES130                            4  CVOL   ac      +=     puncom
 END IF

  *** Action7
  RCHRES130                            4  CVOL   sp      +=     tavlq

*** Condition D
ELSE IF month >= 4 THEN
  *** Action8
  RCHRES130                            4  CVOL   tc      +=     tavlq

*** Condition E
ELSE IF (tfish <= 0.0) THEN
```

```
  *** Action9
  RCHRES130         1991/04/29 12:00   4  CVOL   pw      +=     puncom
  *** Action10
  RCHRES130         1991/05/01 12:00   4  CVOL   tx      -=     puncom

ELSE
  *** Action11
  RCHRES130                            4  CVOL   na      -=     tavlq

END IF

  *** Action12
  RCHRES130                            4  CVOL   ac      +=     tavlq
```

This example illustrates how HSPF decides whether to perform a Special Action in a more complex situation. Note the effect of nesting IF-END IF blocks. In this case:

Actions 1, 2, and 7 are performed only if Condition A is true.
Action 3 is performed only if Conditions A and B are both true.
Action 4 is performed only if Conditions A and C are true and Condition B is false.
Actions 5 and 6 are performed only if Condition A is true and Conditions B and C are false.
Action 8 is performed only if Condition A is false and Condition D is true.
Actions 9 and 10 are performed only if Conditions A and D are false and Condition E is true.
Action 11 is performed only if Conditions A, D, and E are false.
Action 12 is always performed.

Each IF or ELSE IF line is evaluated a maximum of once per interval, at the time of execution of the first Special Action that depends on it in that interval. The UVQUAN values used for the numerical comparisons are computed from the base variables at the point of evaluation, taking into account Special Actions appearing before the condition line.

Assume that in the example above for 15 October 1991, the UVQUANs **month** = 10, **tstage** = 6224.5, and **tfish** = 0. HSPF will perform the following steps:

1) Fetch the value of **month**.
2) Evaluate Condition A as true.
3) Perform action 1, since A is true.
4) Perform action 2, since A is true.
5) Fetch the value of **tstage**.
6) Evaluate Condition B as false.
7) Skip action 3, since B is false.
8) Re-fetch the value of tstage.
9) Evaluate Condition C as false.
10) Skip action 4, since C is false.
11) Perform actions 5 and 6, since A is true, while B and C are both false.
12) Perform action 7, since A is true.
13) Skip action 8, since A is true. Note that Condition D does not need to be evaluated because the action is skipped regardless of D's value.
14) Ignore actions 9 and 10, since they do not occur on this date.
15) Skip action 11, since A is true. Conditions D and E can be ignored.
16) Perform action 12, which is unconditional.

The use of dated special actions within logical blocks requires caution. For instance, for actions 9 and 10 in the above example, it is possible that the value of **tfish** changes between April 29 and May 1 such that one of the actions is performed while the other is not, even though they have the same logical conditions. The user must make sure that this is the intended result.

Another situation requiring care is a Special Action that alters one of the variables that define the logical conditions upon which that action depends. For instance, if action 4 above changed the value of the UVQUAN **tstage** to 6224.0 by altering its base variable, then actions 5 and 6 will still not be executed that interval, since Condition C is not re-evaluated until the following interval.

Global Workspace Variables

In many cases, relatively complicated events can be implemented using logical conditions and variable action quantities. However, sometimes multiple-stage calculations must be performed, requiring storage of intermediate results. Such results may be stored in an array of temporary ("scratch") variables called the Global Workspace. It is called Global because the variables are independent of any HSPF operation (PERLND, RCHRES, etc.), but Special Actions can address them as if they were in the OSV of every operation in the run.

Global Workspace variables are stored in an array named WORKSP(1-999), which may be used directly. However, it is recommended that these variables be declared as UVNAMEs, so that more mnemonic names can be assigned to them.

Global Workspace Variables as a Target

```
***                 <addrss>-------               <addrss>-------
***             cnt    or              act       or              act
***kwrd>  <unam>< > <vari><1><2><3> <frc> <  >    <vari><1><2><3> <frc> <  >
  UVNAME  TEMP    1 WORKSP 22         1.0

***                                    <-addr->              <uvqn>
***optyp range dc ds yr  mo da hr mn d t   vari  s1 s2 s3 ac  value    tc ts num
  <****><-><--><>< ><--><-><-><-><-><><>  <----><-><-><-><-><--------> <> < >< >
  GENER   1                            TEMP             =      25.0
```

The above example creates the variable name TEMP that can be used as a target for Special Actions. Since it is not associated with any single operation, the operation given in the action line specifies the point in the interval that the action occurs. The action will occur when the operation GENER 1 performs its Special Actions.

Accessing the Value Stored in Global Workspace Variables

```
***                          <addrss>-------
***                             or                        lc ls ac as agfn
***kwrd> <uqnm> <oper> <#> <vari><1><2><3><t><multfact> <>< > <>< > <  >
  UVQUAN temp   GLOBAL     WORKSP 22
  UVQUAN temp4  GLOBAL     WORKSP 22                4.0       DY  1 AVER
```

The value stored in a Global Workspace variable can only be accessed by making it the base variable of one or more UVQUANs, as if it were an OSV variable. In the example, “temp” returns the latest value placed in TEMP (above), while “temp4” returns the running daily average of TEMP, multiplied by four.

Global Workspace variables and their pipes are always initialized to zero at the start of the run. Once they are set, they keep their value from interval to interval until changed again. They can only be changed or accessed via Special Actions.

Special Actions Block Input Formats

Action Line

```
         1         2         3         4         5         6         7         8
----+----0----+----0----+----0----+----0----+----0----+----0----+----0----+----0

                                          <addrss>-------   ----<uvqn>
               dc ds                   d t   or                   or   tc ts num
  <oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
```

Symbol	Format	Def	Min	Max	Definition/Comment
<oper>	A6	-	-	-	Operation type - valid values are PERLND, IMPLND, RCHRES, PLTGEN, or GENER
<f>	I3	-	-	-	First operation to act upon
<-l>	I4	-	-	-	Last operation to act upon, 0 or blank means first operation only
dc	A2	MI	MI	DY	Code specifying time units of deferral of action when an applicable logic condition fails. Valid values are: MI – minute; HR – hour; DY - day. Case sensitive.
ds	I3	0	0	-	Number of such intervals to defer the action
<yr>	I4	0	0	-	Year action will be performed; if the date is left blank, then the action is performed every interval of the run.
<m>	1X,I2	1	1	12	Month action is performed
<d>	1X,I2	1	1	31	Day action is performed
<h>	1X,I2	0	0	24	Hour action is performed
<m>	1X,I2	0	0	60	Minute action is performed
d	I2	0	0	50	Index number of "DISTRB" line; blank if none.
t	I2	3	2	4	Type of variable to act on: 2-INTEGER, 3-REAL, 4-DOUBLE PRECISION
<vari>	A6	-	-	-	Name of variable to act upon; case-sensitive
<1> <2><3>	3A3	-	-	-	Subscripts for variable name; blank if none May be 2-character CATEGORY tag if applicable. Otherwise, must be integer.
<addrss>	I8	-	-	-	Memory location (in the OSV) of variable; this is an optional method to specify the variable. Numerical addresses are version-specific and are rarely used.
<a>	A3	-	-	-	Action code; can be specified as either index number of action (#) or character identifier (ch) of the action:

#	ch	effect	#	ch	effect
1	=	T= A	2	+=	T= T+A
3	-=	T= T- A	4	*=	T= T*A
5	/=	T= T/A	6	MIN	T= Min(T,A)
7	MAX	T= Max(T,A)	8	ABS	T= Abs(A)
9	INT	T= Int(A)	10	^=	T= T^A
11	LN	T= Ln(A)	12	LOG	T= Log10(A)
13	MOD	T= Mod(T,A)			

where T is current value of target variable and A is action value. Character identifiers are not case-sensitive.

Action Line (continued)

Symbol	Format	Def	Min	Max	Definition/Comment
<value>	F10.0	0.0	-	-	"Value" of the action to be taken (numerical constant)
<uvqn>	A6	-	-	-	Name of User-defined variable quantity containing the "value" of the action
tc	A2	MI	MI	YR	Code specifying time units of "repeat" interval. Valid values are: MI - minute; HR – hour; DY - day; MO - month; YR – year. Case sensitive
ts	I3	1	1	-	Number of “tc” intervals to skip before repeating action
num	I3	1	1	-	Maximum number of times to perform action

Distribution Line

```
         1         2         3         4         5         6         7         8
----+----0----+----0----+----0----+----0----+----0----+----0----+----0----+----0

         ds  ct tc ts
  <kwrd>< > < > <> < > <dff>  <frc><frc><frc><frc><frc><frc><frc><frc><frc><frc>
```

Symbol	Format	Def	Min	Max	Definition/Comment
<kwrd>	A6	-	-	-	Keyword (DISTRB); defines current line as a "Distribution" line
ds	I3	-	1	50	Index number; corresponds to the value specified on the action line
ct	I3	-	1	10	Number of separate actions or applications to divide the total application
tc	A2	MI	MI	YR	Code specifying time units of the interval between separate applications or actions. Valid values are: MI - minute; HR – hour; DY - day; MO - month; YR – year. Case sensitive
ts	I3	-	1	-	Number of such intervals between separate applications
<dff>	A5	SKIP	-	-	Deferral flag; indicates how to treat deferral of the action under a conditional situation. Valid values are SKIP, SHIFT, ACCUM (case sensitive).
<frc>	10F5.2	0.0	-	-	Fractions/multipliers for each of the separate applications. There should be “ct” values present, and they need not sum to one.

User-defined Variable Name Line

```
         1         2         3         4         5         6         7         8
----+----0----+----0----+----0----+----0----+----0----+----0----+----0----+----0

                    <addrss>-------               <addrss>-------
                cnt    or                act         or                  act
  <kwrd>  <unam>< > <vari><1><2><3> <frc> <  >    <vari><1><2><3> <frc> <  >
```

Symbol	Format	Def	Min	Max	Definition/Comment
<kwrd>	A6	-	-	-	Keyword (UVNAME); defines current line as a "User defined Variable Name" line (case-sensitive)
<unam>	A6	-	-	-	User-defined variable name (case-sensitive)
cnt	I3	-	1	-	Number of OSV variables included in aggregate group

The following inputs repeat (cnt) times, two per line.

<vari>	A6	-	-	-	OSV variable name (from Variable Name Library)
<1> <2><3>	3A3	-	-	-	Subscripts for variable name, blank if none. May be a 2-character CATEGORY tag if applicable. Otherwise, it must be integer
<addrss>	I8	-	-	-	Memory location (in the OSV) of variable; this is an optional method to specify the variable. Numerical addresses are version-specific and are rarely used.
<frc>	F5.2	0.0	-	-	Multiplier to action value for corresponding OSV variable.
act	A4	QUAN	-	-	Operation code; QUAN, MOVT, MOV1, MOV2 (case sensitive) QUAN: Normal quantity use Action Line action code Others mix each pair of targets A and B using frc_A frc_B is ignored. MOVT: $A_1 = frc_A*(A_0+B_0)$; $B_1 = (1-frc_A)*(A_0+B_0)$ MOV1: $A_1 = frc_A*A_0$; $B_1 = (1-frc_A)*A_0+B_0$ MOV2: $A_1 = frc_A*B_0$; $B_1 = (1-frc_A)*B_0+A_0$

User-defined Variable Quantity Line

```
         1         2         3         4         5         6         7         8
----+----0----+----0----+----0----+----0----+----0----+----0----+----0----+----0

                           <addrss>-------
                              or                          lc ls ac as agfn
  <kwrd> <uqnm> <oper> <#> <vari><1><2><3><t><multfact> <>< > <>< > <  >
```

Symbol	Format	Def	Min	Max	Definition/Comment
<kwrd>	A6	-	-	-	Keyword (UVQUAN); defines current line as a "User-defined Variable Quantity" line
<uqnm>	A6	-	-	-	User-defined variable quantity name (case-sensitive)
<oper>	A6	-	-	-	Operation type of the base variable (PERLND, RCHRES, etc)
<#>	I3	-	1	-	Operation ID number of the base variable
<vari>	A6	-	-	-	Name of base variable; see Variable Name Library (Appendix A)
<1><2><3>	3A3	-	-	-	Subscripts for variable name, blank if none. May be a 2-character CATEGORY tag, if applicable. Otherwise, must be integer
<addrss>	I8	-	-	-	Memory location (in the OSV) of variable; this is an optional method to specify the variable. Numerical addresses are version-specific, and are rarely used.
<t>	I2	3	2	4	Type of variable (2-INTEGER, 3-REAL, 4-DOUBLE PRECISION)
<multfact>	F10.0	1.0	-	-	Multiplier to apply to base variable
lc	A2	MI	MI	DY	Code specifying time units of the lag period to apply to the base variable. Valid values are: MI – minute; HR – hour; DY - day. Case sensitive.
ls	I3	0	0	-	Number of “lc” intervals to lag the base variable
ac	A2	MI	MI	DY	Code specifying time units of the period to aggregate base variable. Valid values are: MI – minute; HR – hour; DY - day. Case sensitive.
as	I3	1	1	-	Number of “ac” intervals to aggregate the base variable
agfn	A4	SUM	-	-	Transformation function to use for aggregation of base variable. Valid values are SUM, AVER, MAX, MIN.

Conditional Line (free format)

```
         1         2         3         4         5         6         7         8
----+----0----+----0----+----0----+----0----+----0----+----0----+----0----+----0

  IF ( ( <quan> <comp> <quan> ) <logop> ( <quan> <comp> <quan> ) ) THEN
    ...
  ELSE IF ( <quan> <comp> <quan> ) THEN
    ...
  ELSE
    ...
  END IF
```

Symbol	Format***	Definition/Comment
IF	-	Keyword specifying the beginning of a logical condition
<quan>	free(10)	May be either a UVQUAN name (format up to A6) or a numeric value (format up to F10.0).
<comp>	free(2)	Comparison operator. Valid values and their definitions: = equal /= not equal > greater than >= greater than or equal < less than <= less than or equal
<logop>	free(3)	Logical operator: AND or OR.
THEN	-	Keyword specifying the end of a logical condition
ELSE IF	-	Keyword specifying that the following Special Actions are an alternative to the previous IFs and ELSE IFs, provided that the additional condition is also satisfied. Exactly one space must occur between the two words.
ELSE	-	Keyword specifying that the following Special Actions are an alternative to previous IFs and ELSE IFs
END IF	-	Keyword specifying the end of a logical block. Exactly one space must occur between the two words.

*** free(N) denotes that the field may be any length up to N characters, and may appear in any column, subject to the maximum line length of 80 characters.

Output Levels

The effects of Special Actions can be seen indirectly in the simulation results, but most users will want clearer confirmation that the Special Actions worked as intended, at least while "debugging" a UCI file under development. Therefore, Special Actions can produce output that is written to the Run Interpreter Output File (often referred to as the "echo" file), which is specified as MESSU in the FILES block of the UCI file. The amount of output produced is controlled by two parameters on the third line of the GLOBAL block. The Run Interpreter Output Level appears in columns 26-30, and the Special Action Output Level is in columns 31-35.

```
GLOBAL
  Special Actions Case Study #1 - Simple parameter changes
  START       1992              END    1992
  RUN INTERP OUTPUT LEVEL    3    2
  RESUME     0 RUN     1                   UNIT SYSTEM     1
END GLOBAL
```

Run Interpreter Output Level

As the Run Interpreter processes the UCI file, it "echoes" some or all of the data it finds into a plain ASCII file. This allows the user to verify that the program's interpretation of the input is the same as what was intended. The amount of information generated by all sections of the Run Interpreter is controlled by the Run Interpreter Output Level, which can vary from 0 (the default) to 10, with increasing output as the level increases. The levels relevant to Special Actions are described below.

```
FOUND SPEC-ACTIONS
 FOUND END SPEC-ACTIONS
```

0: The Run Interpreter reports only whether it finds the block delimiters SPEC-ACTIONS and END SPEC-ACTIONS.

```
PROCESSING SPEC-ACTIONS BLOCK
 FINISHED PROCESSING SPEC-ACTIONS BLOCK
```

1-2: The Run Interpreter also reports when it starts and completes the processing of the SPEC-ACTIONS block.

```
 USER-DEFINED VARIABLE NAMES
  UVNAME OPTYP VNAME  S1 S2 S3  ADDR ACT    FRAC
  TMFL       0 WORKSP 90  0  0   -90   0 1.00000
  FERTN5     1 SAMAD   0  0  0  4713   0 0.50000
  FERTN5     1 UAMAD   0  0  0  4721   0 0.50000

 USER-DEFINED VARIABLE QUANTITIES
  NAME OPTYP OPTNO OPNO  ADDR TYP  MULTIPLY LAGIVL AGGIVL AGGCD
month      4     1    1    19   2  1.00          0      1     1
tmfl       0     0    0   -90   3  1.00          0      1     1

DISTRIBUTIONS
   INDEX TSTEP CTCODE TCODE CDEFFG DEFFG  CNT FRACTIONS
       1     1     DY     4  ACCUM     3   10  0.20000 0.20000 0.20000 0.20000 0.20000 0.00000 0.00000

 ACTION DEFINITIONS
   OPERATION       DEFERRAL DATE AND TIME     TYPE  DIST VARIABLE SUBSCRPTS   ADDR   ACT      VALUE
   TYPE     #   # STEP CODE YEAR/MO/DY HR:MN  CODE       NAME   #1 #2 #3           CODE
   GENER    1   1    0   MI 1989  7 31 24  0     3     0 TMFL                   -90  =      70.000
   GENER    1   1    0   MI 1989  8 15 24  0     3     0 TMFL                   -90  =      50.000
  IF: NESTING LEVEL  1
       1( month      =     1.0000  )  1 THEN
  IF: NESTING LEVEL  2
       1( tmfl       >    10.0000  )  1 THEN
   GENER    1   1    0   MI 1989  7 31 24  0     3     0 JUL_DA                  -2  =    0.0000E+00
  END IF: NESTING LEVEL  1

  END IF: NESTING LEVEL  1

 USER-DEFINED VARIABLE QUANTITIES - POINTERS AND PIPE
  NAME    POS  LEN       VALUE
  tmfl      1 1176 0.00000
  month  1177 1176          12
```

3-10: The echo file contains detailed information on each line processed in the SPEC-ACTIONS block. The above example shows the output produced by each type of input line.

Special Action Output Level

```
 COMMENCING EXECUTION
```

The Run Interpreter Output File also contains several types of messages that are generated during the execution of the run, as opposed to the interpretation phase. These are headed by the aboveline. Runtime error and warning messages, if any, are found below the header line, interspersed with any messages regarding the execution of Special Actions.

```
***                                       addr or              uvq or
***                                      <------>              <---->
*** opt foplop dcdts  yr mo dy hr mn d t   vnam  s1 s2 s3 ac quantity  tc  ts rp
  <****><-><--><><-><--> <> <> <> <><><>  <----><-><-><-><-><--------> <> <-><->
  GENER   1         1992  1  1            LMINQ            =     200.0

  GENER   1                               LMUPRO           =    mudem
  GENER   1                               LMUPRO         MIN    lmusto

  GENER   1                               LFWPRO           =     100.0
  GENER   1                               LFWPRO         MIN    lfwsto

  GENER   1                               LPROP            =    lmupro
  GENER   1                               LPROP           +=    lfwpro

IF (lprop < lminq) THEN
 *** need additional release
  GENER   1                               LNEED            =    lminq
  GENER   1                               LNEED           -=    lprop

 *** try to satisfy from fish water first
  GENER   1                               LFWPRO          +=    lneed
  GENER   1                               LFWPRO         MIN    lfwsto

 *** recalculate total proposed release from Lake
  GENER   1                               LPROP            =    lmupro
  GENER   1                               LPROP           +=    lfwpro

 IF (lprop < lminq) THEN
  *** still need more water
  GENER   1                               LNEED            =    lminq
  GENER   1                               LNEED           -=    lprop

 *** try to satisfy from municipal water
  GENER   1                               LMUPRO          +=    lneed
  GENER   1                               LMUPRO         MIN    lmusto

 *** recalculate total proposed release from Lake
  GENER   1                               LPROP            =    lmupro
  GENER   1                               LPROP           +=    lfwpro
 END IF
END IF

  GENER   1                               K       1        =    lmupro
  GENER   2                               K       1        =    lfwpro
```

The Special Actions generate output depending on the Special Action Output Level set in the GLOBAL block. The levels are cumulative. The following examples are based on the above UCI lines.

The resulting cumulative output for each value of the Special Action Output Level is:

```
```

0: No output generated

```
SPEC-ACT: GENER     1 AT 1992/ 1/ 1 24: 0
IF (lprop < lminq) THEN       181
          CONDITION IS TRUE
 IF (lprop < lminq) THEN       194
          CONDITION IS FALSE
```

1: For each interval during which a Special Action occurs, the operation, date, and time are identified. Also, each Condition is echoed with its approximate line number in the UCI file, followed by its logical value.

```
SPEC-ACT: GENER     1 AT 1992/ 1/ 1 24: 0
   LMINQ               ORIG:   0.0000E+00          RESET TO =    2.0000E+02
   LMUPRO              ORIG:   0.0000E+00          RESET TO =    2.0000E+01
   LPROP               ORIG:   0.0000E+00          RESET TO =    2.0000E+01
IF (lprop < lminq) THEN       181
          CONDITION IS TRUE
   LNEED               ORIG:   0.0000E+00          RESET TO =    2.0000E+02
   LNEED               ORIG:   2.0000E+02  -     2.0000E+01 =    1.8000E+02
   LFWPRO              ORIG:   0.0000E+00  +     1.8000E+02 =    1.8000E+02
   LPROP               ORIG:   2.0000E+01  +     1.8000E+02 =    2.0000E+02
 IF (lprop < lminq) THEN       194
          CONDITION IS FALSE
```

2: (Default) Each action is also echoed, with the action quantity and the original and new values of the target variable. Also, if an action is deferred, the message includes the fraction that is being deferred (if a Distribution is being used) or the new date when the action will be retried (if it is undistributed).

```
SPEC-ACT: GENER     1 AT 1992/ 1/ 1 24: 0
   LMINQ               ORIG:   0.0000E+00          RESET TO =    2.0000E+02
   LMUPRO              ORIG:   0.0000E+00          RESET TO =    2.0000E+01
   LPROP               ORIG:   0.0000E+00          RESET TO =    2.0000E+01
IF (lprop < lminq) THEN       181
          lprop :   1.2000E+02 <  lminq :   2.0000E+02 TRUE
          CONDITION IS TRUE
   LNEED               ORIG:   0.0000E+00          RESET TO =    2.0000E+02
   LNEED               ORIG:   2.0000E+02  -     2.0000E+01 =    1.8000E+02
   LFWPRO              ORIG:   0.0000E+00  +     1.8000E+02 =    1.8000E+02
   LPROP               ORIG:   2.0000E+01  +     1.8000E+02 =    2.0000E+02
IF (lprop < lminq) THEN       194
          lprop :   2.0000E+02 <  lminq :   2.0000E+02 FALSE
          CONDITION IS FALSE
```

3: When the logical conditions are evaluated, the values of each quantity and the results of each comparison are echoed. These can be reviewed to determine why a given action occurred or was skipped.

```
SPEC-ACT: GENER     1 AT 1992/ 1/ 1 24: 0
   LMINQ                ORIG:   0.0000E+00          RESET TO =    2.0000E+02
   LMUPRO               ORIG:   0.0000E+00          RESET TO =    2.0000E+01
   LPROP                ORIG:   0.0000E+00          RESET TO =    2.0000E+01
IF (lprop < lminq) THEN       181
          lprop :   1.2000E+02 <  lminq :   2.0000E+02 TRUE
          CONDITION IS TRUE
   LNEED                ORIG:   0.0000E+00          RESET TO =    2.0000E+02
   LNEED                ORIG:   2.0000E+02  -     2.0000E+01 =    1.8000E+02
   LFWPRO               ORIG:   0.0000E+00  +     1.8000E+02 =    1.8000E+02
   LPROP                ORIG:   2.0000E+01  +     1.8000E+02 =    2.0000E+02
IF (lprop < lminq) THEN       194
          lprop :   2.0000E+02 <  lminq :   2.0000E+02 FALSE
          CONDITION IS FALSE
    SPECIAL ACTION SKIPPED - CONDITION FALSE
    SPECIAL ACTION SKIPPED - CONDITION FALSE
    SPECIAL ACTION SKIPPED - CONDITION FALSE
```

4: Every time a Special Action is skipped because of a false logical condition, a message is echoed. This ensures that every action line produces output confirming that it has been considered.

5-8: Currently unused.

9-10: Provide large amounts of output that are only useful during code modification efforts.

Case Studies

The best way to learn how to make effective use of HSPF Special Actions is to analyze examples of actual applications. In order to illustrate a wide range of Special Actions, three SPEC-ACTIONS blocks are shown and described in detail in this section. The entire UCI file for each case study can be found in Appendix C. Case Study A demonstrates a simple parameter change to account for a process HSPF doesn't consider. Case Study B uses additional input line types to execute a variety of agricultural operations. Case Study C performs reservoir operation using a relatively complex set of logical conditions in conjunction with Global Workspace variables.

Case Study A. Simple Parameter Changes

```
SPEC-ACTIONS
***                                         <addrss>-------   ----<uvqn>
***            dc ds               d t        or                   or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
*** Spring Thaw
  PERLND  1         1992/04/15            INFILT           =      0.10 YR   1 10
*** Beginning of Growing Season
  PERLND  1         1992/04/29 12         INFILT           =      0.13 YR   1 10
*** End of Growing Season
  PERLND  1         1992/08/25            INFILT           =      0.10 YR   1 10
*** Winter Frozen Ground
  PERLND  1         1992/12/02            INFILT           =      0.05 YR   1 10
END SPEC-ACTIONS
```

The simplest use of Special Actions is to unconditionally change the value of a parameter or state variable at a specific point in time. In this example, the PWATER parameter INFILT (infiltration capacity) is adjusted seasonally to reflect either human intervention or natural processes not otherwise simulated in HSPF. The actions are repeated each year for ten years.

INFILT is given a nominal value of 0.10. This value is reduced to 0.05 to account for frozen ground during the winter, and increased to 0.13 due to the loosening of soil by tillage during the growing season. The nominal value is reset during spring and fall. The entire cycle is set to repeat for up to ten years. The reduction for frozen ground could have also been modeled directly by one of two possible methods in PWATER instead of by Special Actions, but these methods require simulation of soil temperature using section PSTEMP or simulation of ice in the snowpack using section SNOW. Special Actions can be used as a simpler alternative. The increase in INFILT due to soil tillage is not generally required, but may sometimes be necessary, especially at smaller scales.

Case Study B. Agricultural Operations

When the agri-chemical modules of PERLND (PEST, NITR, PHOS) are used to model agricultural areas, fertilizer and pesticide applications, as well as tillage operations and other “events” related to soil chemicals and erosion, are specified using Special Actions. Beginning with HSPF Version 11, it is also possible to apply chemicals to the surface and upper soil layers by using the Atmospheric Deposition input timeseries. However, Special Actions are more flexible, and will generally require less effort to construct than timeseries data sets.

Description

This example contains one PERLND, which represents a land use, with a winter cover crop and a summer cash crop. The cover crop is plowed under in the spring before the cash crop is planted. Fertilizer and manure are applied in yearly cycles to both crops. A pesticide is used on the summer crop only. Dry field conditions are required for efficient tillage and chemical applications.

The timing of events and the application rates of chemicals are not necessarily intended to represent realistic cropping practices in any given area. The actions were chosen with the intent of demonstrating as many features as possible in a relatively short SPEC-ACTIONS block. These features include repeated actions, distributions, logical conditions, deferred actions (plain and distributed), UVNAMEs, and UVQUANs. The entire SPEC-ACTIONS block follows in sections, with each section followed by an explanation of its purpose.

Declaring UVQUANs, UVNAMEs, and DISTRBs

```
SPEC-ACTIONS
*** User-Defined Variable Quantity Lines
***                        <addrss>-------
***                           or                        lc ls ac as agfn
***kwrd> <uqnm> <oper> <#> <vari><1><2><3><t><multfact> <>< > <>< > <  >
  UVQUAN surwat PERLND   1 SURS
```

If the fields are too wet, farmers generally must wait for drier conditions before tillage and chemical applications. To allow for this fact, the UVQUAN “surwat” is defined based on the PERLND variable SURS, which represents the surface storage of water at the end of each interval. The action lines that perform many of the tillage events or chemical applications are conditional on this value, and are deferred daily until the surface drains sufficiently.

```
*** Distribution Lines
***      ds  ct tc ts
***kwrd>< > < > <> < > <dff>  <frc><frc><frc><frc><frc><frc><frc><frc><frc><frc>
*** Daily distribution over five days, with five extra days to make up any
    missed fraction. ***
  DISTRB  1  10 DY   1 ACCUM    .20  .20  .20  .20  .20    0    0    0    0    0
```

Farmers do not apply fertilizers and pesticides all on the same day throughout the basin. A simple way to model this is to distribute an application over several consecutive days by using the DISTRB function. The deferral code ACCUM is specified so that if a day is skipped because of rain, the next day's application will be increased to compensate. The days with zero fractions at the end of the distribution are added so that if the fifth day is rained out, HSPF will make several extra attempts to complete the application.

```
*** User-Defined Variable Name Lines
***                 <addrss>-------              <addrss>-------
***             cnt    or              act        or                   act
***kwrd>  <unam>< > <vari><1><2><3> <frc> <  >    <vari><1><2><3> <frc> <  >
*** Manure 50%/50% surface/upper as tons/ac.  Multipliers give lb/ac of N or P.
  UVNAME  MANURE  8 SAMAD           1.82 QUAN    UAMAD           1.82 QUAN
                    SORGN           2.73 QUAN    UORGN           2.73 QUAN
                    SP4AD           .675 QUAN    UP4AD           .675 QUAN
                    SORGP           .675 QUAN    UORGP           .675 QUAN

*** Nitrogen Fertilizer 50%/50% surface/upper as lbs N/acre
  UVNAME  FERTN5  4 SAMAD           .375 QUAN    UAMAD           .375 QUAN
                    SNO3            .125 QUAN    UNO3            .125 QUAN

*** Nitrogen Fertilizer 10%/90% surface/upper as lbs N/acre
  UVNAME  FERTN1  4 SAMAD           .075 QUAN    UAMAD           .675 QUAN
                    SNO3            .025 QUAN    UNO3            .225 QUAN

*** Phosphorus Fertilizer 10%/90% surface/upper as lbs P/acre
  UVNAME  FERTP1  2 SP4AD             .1 QUAN    UP4AD             .9 QUAN
```

Next, a series of UVNAMEs are declared for manure and various kinds of fertilizer. The "fractions" given for MANURE are actually multipliers that convert from tons of manure to pounds of nutrient as N or P. The fertilizer UVNAMEs are defined by straightforward fractions of the pounds of N or P that occur in each form. Whenever one of these UVNAMEs is invoked in an action, the “quantity” in the action will be multiplied by these factors to generate the total application in units of pounds per acre.

```
*** Incorporation of cover crop by moldboard plow - Assumes 6.4% of upper layer
    storages remain on surface, while surface storages are completely ***
    incorporated into the upper layer. ***
    Soil mass ratio= (0.39*74.9)/(5.61*81.2) = .064 ***
    See Table-type SOIL-DATA. ***
  UVNAME  INCORP 14 SAMAD            .07 MOV2    UAMAD
                    SNO3             .07 MOV2    UNO3
                    SAMSU            .07 MOV2    UAMSU
                    SORGN            .07 MOV2    UORGN
                    SP4AD            .07 MOV2    UP4AD
                    SP4SU            .07 MOV2    UP4SU
                    SORGP            .07 MOV2    UORGP
  UVNAME  PLANT   8 SPLTN              1 QUAN    UPLTN              1 QUAN
                    LPLTN              1 QUAN    APLTN              1 QUAN
                    SPLTP              1 QUAN    UPLTP              1 QUAN
                    LPLTP              1 QUAN    APLTP              1 QUAN
```

The next entries use UVNAME operation codes. The first UVNAME (INCORP) is intended to represent plowing under the entire surface layer, incorporating it into the upper layer, while leaving a fraction of the upper layer on the surface. The fraction is based on the relative soil depths of the two layers. The final UVNAME (PLANT) is used to set all of the layer-derived plant N and P storages to zero at harvest time, by invoking the UVNAME with a single action line.

Action and Condition Lines

```
*** Action Lines
***                                         <addrss>-------   ----<uvqn>
***            dc ds                 d t       or                    or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >

                 *** Winter Cover Crop ***

IF (surwat = 0.0) THEN
  *** Planting of winter cover crop
  PERLND  1    DY  11984 10 15 12         DETS             =       1.0 YR   1  8

  *** Manure (as N+P) Application- 50% Surface, 50% Upper - Split 3 times
      during the fall and winter on cover crop - tons/acre ***
  PERLND  1    DY  11984 10 20 12         MANURE          +=      0.80 YR   1  8
  PERLND  1    DY  11984 12 20 12         MANURE          +=      0.80 YR   1  8
  PERLND  1    DY  11984  2 20 12         MANURE          +=      0.80 YR   1  8
END IF
```

At the end of the declarations, the action lines begin, with condition lines inserted as needed. First, the winter planting process disturbs the soil, leaving behind one ton/acre of detached sediment (DETS), regardless of the initial storage. During the fall and winter, manure is applied in three separate applications at the rate of 0.8 tons/acre (wet). This results in the addition of 8.74 lb/acre of adsorbed ammonia, 13.10 lb/acre of organic N, and 3.24 lb/acre each of phosphate and organic P. All of these amounts are divided equally between the surface and upper layers. These actions are conditional on there being no water standing on the surface at noon on the application date. If standing water is present, the event is deferred on a daily basis until the condition (dry surface) becomes true.

```
*** Incorporate winter cover crop with moldboard plow
  PERLND  1         1984  4 13 12         DETS             =       3.0 YR   1  8
  PERLND  1         1984  4 13 12         PLANT            =       0.0 YR   1  8
  PERLND  1         1984  4 13 12         INCORP           =           YR   1  8
  *** Reset Organic N and P storages to simulate return of plant N and P from
      residue and roots ***
  PERLND  1         1984  4 13 12         SORGN            =      80.0 YR   1  8
  PERLND  1         1984  4 13 12         UORGN            =     200.0 YR   1  8
  PERLND  1         1984  4 13 12         LORGN            =     800.0 YR   1  8
  PERLND  1         1984  4 13 12         SORGP            =      20.0 YR   1  8
  PERLND  1         1984  4 13 12         UORGP            =      40.0 YR   1  8
  PERLND  1         1984  4 13 12         LORGP            =      25.0 YR   1  8
```

In the spring, the entire crop is plowed under. The detached sediment (DETS) is set to 3.0 tons/acre, the plant N and P are reset to zero via the UVNAME called PLANT, and the organic N and P storages are reset to simulate the return of the plant material to the soil. The action line that refers to the UVNAME INCORP needs no action value, since the UVNAME operation code doesn't require one. The action code on this line is ignored for the same reason (although a valid one must still be supplied to avoid an error condition).

```
*** Summer Crop ***

IF (surwat = 0.0) THEN
  *** Planting of Summer Crop
  PERLND  1    DY  11984  4 15 12         DETS             =       1.0 YR   1  8

  *** N and P Fertilizer applied - 10% Surface, 90% Upper
  PERLND  1         1984  4 20 12    1    FERTN1          +=     48.98 YR   1  8
  PERLND  1         1984  4 20 12    1    FERTP1          +=     22.31 YR   1  8

  *** Tillage Operation ***
  PERLND  1    DY  11984  5 12 12         DETS             =       1.5 YR   1  8

  *** MANURE Application Split 3 times during the season - tons/acre
  PERLND  1    DY  11984  5 15 12         MANURE          +=      2.77 YR   1  8
  PERLND  1    DY  11984  7  1 12         MANURE          +=      2.77 YR   1  8
  PERLND  1    DY  11984  8 15 12         MANURE          +=      2.77 YR   1  8

  *** Pesticide applied - 100% Surface adsorbed storage - 2.5 lb/ac spread over
      3 weeks ***
  PERLND  1    DY  11984  6  5 12         SPS     2  1    +=     0.625 YR   1  8
  PERLND  1    DY  11984  6 13 12         SPS     2  1    +=     1.250 YR   1  8
  PERLND  1    DY  11984  6 20 12         SPS     2  1    +=     0.625 YR   1  8

  *** N Fertilizer applied - 50% Surface, 50% Upper
  PERLND  1         1984  6 15 12    1    FERTN5          +=     48.85 YR   1  8
END IF
```

Next, the summer cash crop is modeled. The chemical applications and tillage are conditional on the soil surface being dry. Plowing and manure applications occur in the same manner as in winter. Additional nitrogen fertilizer and pesticide are also applied. FERTN1 and FERTP1 are UVNAMEs that represent nitrogen and phosphorus fertilizers, respectively, that are applied so that 90% of the nutrients immediately reach the upper soil zone. SPS(2,1) is the storage of adsorbed ammonia on the surface of the soil. Note that every action line that is conditional is deferred (or distributed with a deferral code of ACCUM), so that applications will not be missed because of wet weather.

```
*** Set pesticide decay rate high to reflect high volatilization at application
  PERLND  1         1984  6  5            SPSPM   8  1     =      0.12 YR   1  8
*** Reduce pesticide decay rate to reflect less volatilization later in season
  PERLND  1         1984  6 30            SPSPM   8  1     1      0.06 YR   1  8
```

Pesticide degradation is modeled in HSPF by using a constant first-order rate. Special Actions are used to reset this parameter to reflect distinct decay processes with different rates that dominate at different times.

```
*** Harvest Summer crop
  PERLND  1         1984  9 30 12         PLANT            =       0.0 YR   1  8
  *** Reset Organic N and P storages to simulate return of plant N and P from
      residue and roots ***
  PERLND  1         1984  9 30 12         SORGN            =      80.0 YR   1  8
  PERLND  1         1984  9 30 12         UORGN            =     200.0 YR   1  8
  PERLND  1         1984  9 30 12         LORGN            =     800.0 YR   1  8
  PERLND  1         1984  9 30 12         SORGP            =      20.0 YR   1  8
  PERLND  1         1984  9 30 12         UORGP            =      40.0 YR   1  8
  PERLND  1         1984  9 30 12         LORGP            =      25.0 YR   1  8
END SPEC-ACTIONS
```

Finally, the summer crop is harvested, causing a return of the plant residue to organic nitrogen and phosphorus, in the same manner as the winter crop.

Case Study C. Reservoir Operations and Basin Management

Reservoir operations can be exceedingly complex, particularly when a basin contains more than one reservoir, or a reservoir is managed for multiple benefits (e.g., flood control, municipal water supply, irrigation, and minimum environmental flows). All of these except irrigation are explicitly included in this example.

Description

The basin consists of two multi-purpose reservoirs, operating in parallel, upstream of a river that is modeled as two free-flowing stream reaches. The first reservoir is a large natural lake with a gated weir controlling the releases into the upper river reach. The second is a smaller reservoir on a dammed tributary that also feeds into the upper reach. The upper reach has a diversion for consumptive municipal use. The land surface of the entire basin (375,000 acres) is modeled by a single PERLND representing a large forest.

There are three primary demands on the system. First, the municipal diversion demand is an annual cycle ranging from 20 to 60 cfs. This cycle is input as a daily timeseries. Second, a minimum target flow is established for fish at the outflow of the lower river reach. The target varies according to the season, and may be reduced if the total storage of water reserved for fish flows (comprising all water that is not earmarked for municipal use) in the two reservoirs drops too low. Finally, flood control space is reserved in the smaller reservoir during the winter and spring.

This separation of municipal water and fish water is handled by declaring Water Categories in the CATEGORY block of the UCI file. Two Categories are declared: municipal water and fish water. Each Category has a two-character identifying "tag", which is used throughout the UCI as an array subscript to specify which Category is referred to by a given quantity. The tags used in this example are "mu" for municipal water and "fw" for fish water.

The municipal demand is supplied entirely by the large lake, with 20 percent of the inflow owned by the municipal utility company, based on legal agreements. The water is released from the lake according to the aforementioned annual schedule, and diverted upon reaching the bottom of the upper river reach. The smaller reservoir never contains any municipal water.

The smaller reservoir maintains an empty flood control pool of 15,000 acre-feet from December 1st to March 31st. The maximum allowable storage is slowly decreased over two months from October 1st to November 30th, and any excess water above that storage is drawn down each day during that time. The reservoir is allowed to refill during the spring snowmelt season from April 1st to May 31st as the maximum allowable storage is slowly increased; during this time, any reservoir releases for target fish flows are curtailed.

Both reservoirs are operated to maintain the target fish in the lower stream reach. If the natural downstream inflows are enough to satisfy the target, then neither reservoir makes releases above required minimums. When additional water is needed, the lake makes releases of fish water, up to that day's inflow. If the target is still not met, the smaller reservoir releases water unless it falls below a minimum desired storage or it is filling in the spring. Finally, any remaining shortfall is met by further lake releases.

There is also a minimum flow requirement at the outlet from each reservoir. The minimum requirement for the large lake varies seasonally, while that for the smaller reservoir is constant year round, but is reduced if the storage falls below a desired level.

A last constraint on reservoir releases is imposed to reduce releases by both reservoirs when the upper river reach approaches a flood stage of 500 cfs. The total of the daily downstream inflow plus the fish releases from the two reservoirs must not exceed this flood flow.

Approach to Implementation

In this model, the end result of the SPEC-ACTIONS block will be a set of three timeseries that are input to the reservoirs (as COTDGT - the Category outflow demand) to determine the releases of each applicable Category of water. Most of the Special Action calculations are performed using Global Workspace variables. These were presented in the Overview of Components and Usage, but because they are complex and because they are not expected to be needed by the majority of HSPF users, the discussion there remained brief. Before the details of the case study itself are reviewed, the methods for using Global Workspace variables are examined in more detail.

Creating Output Timeseries Using the GENER Utility Operation

```
***                                       <addrss>-------   ----<uvqn>
***            dc ds                d t     or                   or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
  RCHRES  1                               COTDGT  1 fw     =      10.0
```

As discussed in the section on HSPF Program Structure, an input timeseries cannot be directly altered by Special Actions, since the value is obtained every interval from the INPAD **after** the Special Actions are performed. Therefore, an action such as this does not produce the desired effect.

```
SPEC-ACTIONS
[variable declarations]
 . . .
***                                       <addrss>-------   ----<uvqn>
***            dc ds                d t     or                   or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
*** Set flood stage for Reach 3 (municipal area)
  GENER   1         1992  1  1            FLOOD            =     500.0

*** Set minimum flows for lake - varies seasonally
*** Initial value
  GENER   1         1992  1  1            LMINQ            =      50.0
*** Summer
  GENER   1         1992  4  1            LMINQ            =      70.0 YR   1 10
*** Winter
  GENER   1         1992 10  1            LMINQ            =      50.0 YR   1 10

 . . .
[further computations omitted which define lmupro, lfwpro, and rfwpro
 based on flood, lminq, etc.]
 . . .
  GENER   1                               K       1        =    lmupro
  GENER   2                               K       1        =    lfwpro
  GENER   3                               K       1        =    rfwpro
END SPEC-ACTIONS

NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #        <Name> # #<-factor->strg <Name>   #   #        <Name> # #  ***
GENER    1 OUTPUT TIMSER                    RCHRES   1     EXTNL  COTDGT 1mu
GENER    2 OUTPUT TIMSER                    RCHRES   1     EXTNL  COTDGT 1fw
GENER    3 OUTPUT TIMSER                    RCHRES   2     EXTNL  COTDGT 1fw
END NETWORK
```

However, the GENER operation, which performs mathematical transformations on timeseries, includes an option for creating a constant timeseries A=K, where K is an input parameter. Special Actions can be used to reset the value of K to any desired value, with the resulting timeseries being passed to the appropriate target via the NETWORK block in the UCI file. Here, the three GENER operations each produce a demand timeseries, which are then transferred to the reaches in the NETWORK block.

The UVQUANs “lmupro”, “lfwpro”, and “rfwpro,” which are used to set the final timeseries K values, represent the current values of Global Workspace variables LMUPRO, LFWPRO, and RFWPRO, which in turn represent the proposed releases to meet downstream demands. They are calculated earlier in the SPEC-ACTIONS block, largely as the result of preliminary computations, the first few of which are shown above, using other Workspace variables like FLOOD and LMINQ.

Whereas Special Actions that target OSV variables are executed just before the operation containing that variable, actions that target Workspace variables may be executed at any point in the operation sequence established in the OPN SEQUENCE block of the UCI. The chosen operation is specified on the action line itself. Thus, the first action above, which sets the Workspace variable FLOOD to 500, is executed just before GENER 1. In fact, to ensure that they occur together in the order they appear in the UCI file, all of the action lines that perform these scratch calculations are executed by GENER 1. At the end of the SPEC-ACTIONS block, all of the output timeseries are created by setting the respective K values for all three GENERs equal to the computed demands.

Reading Input Timeseries into Special Actions via the COPY Utility Operation

```
EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member-> ***
<Name>   # <Name> # tem strg<-factor->strg <Name>   #   #        <Name> # # ***
WDM    137 FLOW     ENGL                   COPY     1     INPUT  MEAN   1
END EXT SOURCES

SPEC-ACTIONS
 . . .
***                        <addrss>-------
***                           or                         lc ls ac as agfn
***kwrd> <uqnm> <oper> <#> <vari><1><2><3><t><multfact> <>< > <>< > <  >
  UVQUAN mudem  COPY     1 MEAN    1
 . . .
END SPEC-ACTIONS
```

Not only does this SPEC-ACTIONS block create timeseries, it also must read the timeseries that represents the municipal water demand. To accomplish this, the input is read from the external file (a WDM file in this case) and passed into a “dummy” COPY operation (one with no output timeseries connections in the NETWORK or EXT TARGETS blocks). This places the current value of the input timeseries into the convenient OSV variable MEAN(1), which can in turn be used as the base variable of the UVQUAN “mudem.” Up to 40 timeseries can be handled this way by one COPY operation.

The Importance of Operation Order

```
OPN SEQUENCE
    INGRP              INDELT 24:00
      PERLND       1
      COPY         1
      GENER        1
      GENER        2
      RCHRES       1
      GENER        3
      RCHRES       2
      RCHRES       3
      RCHRES       4
    END INGRP
END OPN SEQUENCE
```

A look at the OPN SEQUENCE block helps point out the significance of operation order. First, the PERLND operation generates the inflows to the stream reaches. Next, the dummy COPY operation reads the municipal demand timeseries, as discussed above. Because these two operations do not share any timeseries, they could as easily occur in the opposite order.

The COPY 1 operation provides timeseries input to the Workspace computations, which are executed at the beginning of GENER 1. Therefore, COPY 1 must be placed prior to GENER 1 in the OPN SEQUENCE block.

The Special Actions for GENER 1 then perform all of the Workspace computations, which result in the storage of three timeseries of releases in separate Workspace variables. The three GENERs then take these three results and turn them into output timeseries for RCHRES via the last three Action lines. Each GENER must occur in OPN SEQUENCE before the RCHRES operation that receives its output. Thus, GENERs 1 and 2, which compute the releases for the large lake (Reach 1) are executed, followed by the RCHRES itself, and likewise GENER 3 for the small reservoir (Reach 2) and its GENER. Finally, the last two RCHRESs representing the downstream river are executed.

There is some flexibility in this operation order. The dummy COPY 1 could have appeared first, since it doesn't depend on anything that PERLND 1 does. However, it **must** appear before GENER 1, which depends on the timeseries being passed to it. Likewise, the GENERs could have all appeared before any of the RCHRESs, since GENER 3 doesn't depend on anything that happens in RCHRES 1. However, the timeseries transfers are made more efficient by placing each source operation immediately before its target when possible.

Complete Special Actions Block

In this example, Special Actions are used to extend the capabilities of HSPF so that it can implement a fairly complex set of reservoir operation policies. The use of nested logical conditions as well as Global Workspace variables make it possible.

The complete SPEC-ACTIONS block is described in the following pages. Table 2 contains names and defintions for all of the UVQUANs, both those based on orkspace UVNAME variables as well as those based on RCHRES, PERLND, and COPY OSV variables.

Table 2. Case Study 3 – UVQUAN definitions

Name	Base	Type	Definition	Units
lminq	Workspace	Real	Lake (Reach 1) minimum required flow	cfs
lprop	Workspace	Real	Total proposed lake release	cfs
lfwpro	Workspace	Real	Proposed Fish water release from lake	cfs
lmupro	Workspace	Real	Proposed Municipal water release from lake	cfs
lneed	Workspace	Real	Needed additional release from lake to meet demands	cfs
rmaxst	Workspace	Real	Maximum allowable storage in reservoir (Reach 2)	cfs
rminq	Workspace	Real	Reservoir minimum flow	cfs
rfwpro	Workspace	Real	Proposed Fish water release from reservoir	cfs
rneed	Workspace	Real	Needed additional release from reservoir to meet demands	cfs
rdraw	Workspace	Real	Reservoir release for winter drawdown	cfs
ravail	Workspace	Real	Reservoir storage of fish water above	cfs
rfilfg	Workspace	Integer	Flag indicating whether reservoir is filling in spring	-
flood	Workspace	Real	Flood flow at upstream Reach 3	cfs
ftarhi	Workspace	Real	Target fish flows at downstream Reach 4 for high storage	cfs
ftarlo	Workspace	Real	Target fish flows at downstream Reach 4 for low storage	cfs
ftarg	Workspace	Real	Current target fish flows at downstream Reach 4	cfs
favail	Workspace	Real	Total available fish water stored in lake or reservoir	ac-ft
fneed	Workspace	Real	Current shortfall below FTARG at Reach 4	cfs
maxrel	Workspace	Real	Maximum total fish release from both lake and reservoir without violating flood flow limits	cfs
totpro	Workspace	Real	Total proposed release from lake	cfs
lfwsto	OSV	Real	Storage of Fish water in lake	cfs
lfwstv	OSV	Real	Storage of Fish water in lake	ac-ft
lmusto	OSV	Real	Storage of Municipal water in lake	cfs
lwinf	OSV	Real	Inflow of fish water into lake	cfs
month	OSV	Integer	Month of year	-
mudem	OSV	Real	Municipal water demand timeseries	cfs
natdin	OSV	Real	Natural downstream inflow in river	cfs
rfwsto	OSV	Real	Storage of Fish water in reservoir	cfs
rfwstv	OSV	Real	Storage of Fish water in reservoir	ac-ft
rstor	OSV	Real	Total storage in reservoir	ac-ft

Declaring UVQUANs, UVNAMEs, DISTRBs, and Global Workspace Variables

```
SPEC-ACTIONS
*** User-Defined Target Variable Names
***                 <addrss>-------                <addrss>-------
***             cnt    or                 act        or                 act
***kwrd>  <unam>< > <vari><1><2><3> <frc> <  >    <vari><1><2><3> <frc> <  >
  UVNAME  LMINQ   1 WORKSP 11         1.0 QUAN
  UVNAME  LPROP   1 WORKSP 12         1.0 QUAN
  UVNAME  LFWPRO  1 WORKSP 13         1.0 QUAN
  UVNAME  LMUPRO  1 WORKSP 14         1.0 QUAN
  UVNAME  LNEED   1 WORKSP 15         1.0 QUAN

  UVNAME  RMAXST  1 WORKSP 21         1.0 QUAN
  UVNAME  RMINQ   1 WORKSP 22         1.0 QUAN
  UVNAME  RFWPRO  1 WORKSP 23         1.0 QUAN
  UVNAME  RNEED   1 WORKSP 24         1.0 QUAN
  UVNAME  RDRAW   1 WORKSP 25         1.0 QUAN
  UVNAME  RAVAIL  1 WORKSP 26         1.0 QUAN
  UVNAME  RFILFG  1 WORKSP 27         1.0 QUAN

  UVNAME  FLOOD   1 WORKSP 31         1.0 QUAN
  UVNAME  FTARHI  1 WORKSP 32         1.0 QUAN
  UVNAME  FTARLO  1 WORKSP 33         1.0 QUAN
  UVNAME  FTARG   1 WORKSP 34         1.0 QUAN
  UVNAME  FAVAIL  1 WORKSP 35         1.0 QUAN
  UVNAME  FNEED   1 WORKSP 36         1.0 QUAN
  UVNAME  MAXREL  1 WORKSP 37         1.0 QUAN
  UVNAME  TOTPRO  1 WORKSP 38         1.0 QUAN

*** User-Defined Variable Quantity Lines
***                        <addrss>-------
***                           or                         lc ls ac as agfn
***kwrd> <uqnm> <oper> <#> <vari><1><2><3><t><multfact> <>< > <>< > <  >
  UVQUAN lminq  GLOBAL     WORKSP 11
  UVQUAN lprop  GLOBAL     WORKSP 12
  UVQUAN lfwpro GLOBAL     WORKSP 13
  UVQUAN lmupro GLOBAL     WORKSP 14
  UVQUAN lneed  GLOBAL     WORKSP 15


  UVQUAN rmaxst GLOBAL     WORKSP 21
  UVQUAN rminq  GLOBAL     WORKSP 22
  UVQUAN rfwpro GLOBAL     WORKSP 23
  UVQUAN rneed  GLOBAL     WORKSP 24
  UVQUAN rdraw  GLOBAL     WORKSP 25          .50416667
                *** RDRAW is in units of ac-ft.  Convert rdraw to cfs.
  UVQUAN ravail GLOBAL     WORKSP 26          .50416667
                *** RAVAIL is in units of ac-ft. Convert ravail to cfs.
  UVQUAN rfilfg GLOBAL     WORKSP 27        2

  UVQUAN flood  GLOBAL     WORKSP 31
  UVQUAN ftarhi GLOBAL     WORKSP 32
  UVQUAN ftarlo GLOBAL     WORKSP 33
  UVQUAN ftarg  GLOBAL     WORKSP 34
  UVQUAN favail GLOBAL     WORKSP 35                           DY  2 AVER
  UVQUAN fneed  GLOBAL     WORKSP 36
  UVQUAN maxrel GLOBAL     WORKSP 37
  UVQUAN totpro GLOBAL     WORKSP 38
```

At the beginning of the Special Actions block, a series of Global Workspace variables are declared, first as UVNAMEs, and then as UVQUANs. Notice that some of the UVQUANs have multipliers that result in units conversions. Close attention must be paid to the units of the variables throughout this example. Also, note that the UVQUAN “rfilfg” is declared as an integer (type "2"), and that “favail” contains the two-day average of the values assigned to the UVNAME FAVAIL, not just its current value.

```
***                         <addrss>-------
***                            or                          lc ls ac as agfn
***kwrd> <uqnm> <oper> <#> <vari><1><2><3><t><multfact> <>< > <>< > <  >
  UVQUAN month  COPY     1 MON              2
  UVQUAN mudem  COPY     1 MEAN    1
  UVQUAN lfwinf PERLND   1 PERO               6302.
  UVQUAN natdin PERLND   1 PERO               6302.
                *** PERO is in units of inches/day.  Using a tributary area of
                *** 150,000 acres for both basins, convert to cfs.
```

Next in the Special Actions, several more UVQUANs are defined, based on OSV variables. The first one, "month", simply gives the current month of the simulation (January = 1, etc.) The base (OSV) variable, MON, is available from any of the operations in the run, but it is important to use an operation that executes prior to any Special Actions that refer to the UVQUAN (in this case GENER 1). Special Actions occur **before** the date and time are updated, so if **"**month" were based on MON from GENER 1, any Special Action that is executed by GENER 1 would always be one interval behind. Note that "month" could also be based on MON from PERLND 1, since it also occurs before GENER 1.

The UVQUAN "mudem" contains the value of the municipal demand timeseries being passed to the COPY operation. UVQUANs "lfwinf" and "natdin" represent respectively the inflow of fish water into the lake and the natural downstream inflow to the river below the reservoirs. Each of the two basins has a drainage area of 150,000 acres. The variable PERO, in PERLND, which represents the total outflow from the land segment, is converted from inches to cubic feet per second using the multiplication factor (6302.).

```
***                         <addrss>-------
***                            or                          lc ls ac as agfn
***kwrd> <uqnm> <oper> <#> <vari><1><2><3><t><multfact> <>< > <>< > <  >
  UVQUAN lfwsto RCHRES   1 CVOL   fw        4 1.1574E-5
                *** CVOL is in units of ft3.  Convert lfwsto to cfs.
  UVQUAN lfwstv RCHRES   1 CVOL   fw        4 2.2957E-5
                *** CVOL is in units of ft3.  Convert lfwstv to ac-ft.
  UVQUAN lmusto RCHRES   1 CVOL   mu        4 1.1574E-5
                *** CVOL is in units of ft3.  Convert lmusto to cfs.

  UVQUAN rstor  RCHRES   2 VOL              4 2.2957E-5
                *** VOL is in units of ft3.  Convert rstor to ac-ft.
  UVQUAN rfwsto RCHRES   2 CVOL   fw        4 1.1574E-5
                *** CVOL is in units of ft3.  Convert rfwsto to cfs.
  UVQUAN rfwstv RCHRES   2 CVOL   fw        4 2.2957E-5
                *** CVOL is in units of ft3.  Convert rfwstv to ac-ft.
```

The last group of UVQUANs is the Category storages and total water storages in the reservoirs. The internal units (cubic feet) are converted to either acre-feet or cfs by a multiplication factor. Multiple UVQUANs are required in order to refer to the same base variable in different units (e.g., lfwsto and lfwstv). This can be useful for Global Workspace variables as well.

Action and Condition Lines

Now we are ready to look at the action lines. Generally, the dated Special Actions that set constant and seasonal values occur first, followed by undated conditional actions which perform the daily operations. Note that whenever dated and undated actions are intermixed, they are executed in the order in which they appear in the UCI file.

```
********************************************************************************
*** Begin Operating Logic ******************************************************
********************************************************************************
*** =============== Constants and Seasonal Values ===========================
***                                       <addrss>-------   ----<uvqn>
***          dc ds                d t      or                    or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
*** Set flood stage for Reach 3 (municipal area)
  GENER   1         1992  1  1            FLOOD            =     500.0
```

First, a Workspace variable called FLOOD is set to represent the flow at flood stage for the downstream control point at RCHRES 3. The action is dated the first interval of the run. This value does not change at any time during the run. Technically, the Workspace variable is unnecessary, as we could simply use the number 500.0 whenever needed, but named constants may make the SPEC-ACTIONS block more readable.

```
*** Set minimum flows for lake - varies seasonally
*** Initial value
  GENER   1         1992  1  1            LMINQ            =      50.0
*** Summer
  GENER   1         1992  4  1            LMINQ            =      70.0 YR   1 10
*** Winter
  GENER   1         1992 10  1            LMINQ            =      50.0 YR   1 10

*** Set seasonal fish flow targets for high and low fish storage
*** Initial values
  GENER   1         1992  1  1            FTARHI           =     200.0
  GENER   1         1992  1  1            FTARLO           =     100.0
*** Spring
  GENER   1         1992  2  1            FTARHI           =     250.0 YR   1 10
  GENER   1         1992  2  1            FTARLO           =     150.0 YR   1 10
*** Summer-Winter
  GENER   1         1992  6  1            FTARHI           =     200.0 YR   1 10
  GENER   1         1992  6  1            FTARLO           =     100.0 YR   1 10
```

Next, several dated Special Actions are used to set seasonal values for the minimum required lake release (LMINQ) and high and low values for target fish flow in RCHRES 4 (FTARHI and FTARLO). Notice that initial values are required, and repeat codes are used to continue the cycle over multiple years.

```
*** Maximum reservoir storage for winter flood control space
    plus filling season flag ***
*** Initial values
  GENER   1         1992  1  1            RMAXST           =   10000.0
  GENER   1         1992  1  1         2  RFILFG           =         0

*** Springtime filling season is April and May - set flag at start
  GENER   1         1992  4  1         2  RFILFG           =         1 YR   1 10
IF (month = 4 OR month = 5) THEN
 *** During April and May, there is a daily increase in allowable storage of
 *** 1/61st of total fill of 15,000 acre-feet.
  GENER   1                               RMAXST          +=     245.9
END IF

*** Summer - turn off filling flag for reservoir and set high max storage
  GENER   1         1992  6  1         2  RFILFG           =         0 YR   1 10
  GENER   1         1992  6  1            RMAXST           =   25000.0 YR   1 10

*** Fall Drawdown
IF (month = 10 OR month = 11) THEN
 *** During October and November, there is a daily reduction in allowable
 *** storage of 1/61st of total drawdown of 15,000 acre-feet.
  GENER   1                               RMAXST          -=     245.9
END IF

*** Winter
  GENER   1         1992 12  1            RMAXST           =   10000.0 YR   1 10
```

The last seasonal values to be determined are the maximum allowable storage for the smaller reservoir and a flag that is turned on only during the reservoir's filling season. The actions that define the flag must specify that the target is integer (type "2"). The maximum storage value is altered by a combination of dated and undated actions that define an annual curve that rises in the spring and drops during autumn, while remaining constant in summer and winter.

Daily Operations

The remainder of the SPEC-ACTIONS block concerns itself with daily operations, which depend upon many quantities, including the runoff into the reaches, the storage in the reservoirs, and the input municipal demand, as well as the values established above. All of the actions are undated, since their logical conditions are checked on every interval of the run (which has a one-day time step).

```
*** ============== Daily operations ==========================================
*** Proposed releases are calculated based on municipal and fish demands.  These
*** releases are adjusted as needed to meet minimum flow, maximum flow, and
*** maximum storage requirements.
*** ========================================================================
***                                       <addrss>-------   ----<uvqn>
***            dc ds               d t     or                    or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
*** ------------------- Municipal Release -------------------------------------
*** Lake releases municipal demand based on input timeseries
*** -----------------------------------------------------------------------
  GENER   1                               LMUPRO           =    mudem
```

First, the current day's proposed municipal release is set equal to the input demand (mudem) and stored in a Global Workspace variable (LMUPRO), which may later be modified before it is passed to the GENER output timeseries.

```
*** ------------------ Fish Releases ----------------------------------------
*** Total needed fish releases are calculated based on seasonal target, total
*** storage of category "fw", and the flow at the gage for Reach 4.  They are
*** also limited by flood stage at Reach 3.
*** Fish releases are allocated according to priority: 1) Lake fish water up
*** to inflow; 2) Reservoir fish water; 3) Lake fish water above inflow
*** -----------------------------------------------------------------------
*** Determine whether to use high or low fish flow target based on total
*** storage of fish water.

*** First find how much total fish water is available in both sources

  GENER   1                               FAVAIL          =    lfwstv
  GENER   1                               FAVAIL         +=    rfwstv

IF (favail >= 150000.) THEN
 *** more than 150,000. acre-feet storage, so use high target
  GENER   1                               FTARG           =    ftarhi
ELSE
 *** less than 150,000. acre-feet storage, so use low target
  GENER   1                               FTARG           =    ftarlo
END IF

*** Determine fish release limit for downstream flood control by
*** subtraction natural inflows and necessary municipal releases
*** from flooding limit.  Last line sets negative release to zero.
  GENER   1                               MAXREL          =    flood
  GENER   1                               MAXREL         -=    natdin
  GENER   1                               MAXREL         -=    lmupro
  GENER   1                               MAXREL        MAX       0.0

*** Then calculate total needed for fish releases as fish target
*** minus downstream inflow, and bracketed by zero and maximum
  GENER   1                               FNEED           =    ftarg
  GENER   1                               FNEED          -=    natdin
  GENER   1                               FNEED         MAX       0.0
  GENER   1                               FNEED         MIN    maxrel

*** Lake fish water proposed release - up to inflow if needed
IF (fneed <= 0.0) THEN
 *** none needed
  GENER   1                               LFWPRO          =       0.0
ELSE
 *** make further release from Lake fish water up to storage and
 *** decrement remaining need
  GENER   1                               LFWPRO          =    fneed
  GENER   1                               LFWPRO        MIN    lfwinf
  GENER   1                               FNEED          -=    lfwpro
END IF
```

The computation of releases for fish from the two water bodies requires more complicated logic. First, the amount of available fish water FAVAIL is summed and compared against a threshold of 150,000 acre feet to determine whether there is enough to attempt to meet the higher target FTARHI rather than the low target FTARLO. The resulting chosen target is saved in the variable FTARG. Next, the maximum safe fish release MAXREL is figured by starting with the flood-stage flow at Reach 3, and then subtracting both the downstream, uncontrolled flow “natdin” and the required municipal release “lmupro”. If the downstream reach is already flooding, then the maximum release is set to zero by the MIN action.

Then the actual need for fish flows (FNEED) above the natural inflow is computed as the target “ftarg” minus the natural flow “natdin.” This time, the municipal water is not counted, since it will be diverted from Reach 3 before it reaches the fish habitat areas downstream in Reach 4. The need is immediately bracketed by MIN and MAX actions that ensure that the release remains in the range from zero to the maximum safe release. If there is a remaining need for fish flows, the lake may release up to its current inflow of fish water, called “lfwinf.” Finally, the amount of this release is subtracted from the remaining need, if any.

```
*** Reservoir fish water proposed release
IF (rfilfg = 0) THEN
 *** not in filling season - allowed to make fish releases
 IF (fneed <= 0.0) THEN
  *** none needed
  GENER   1                            RFWPRO           =       0.0
 ELSE
  *** make further release from Reservoir fish water

  *** compute available amount over minimum desired storage
  GENER   1                            RAVAIL           =    rfwstv
  GENER   1                            RAVAIL          -=    5000.0
  GENER   1                            RAVAIL         MAX       0.0

  *** now compute release
  GENER   1                            RFWPRO           =    fneed
  GENER   1                            RFWPRO         MIN    ravail
  GENER   1                            FNEED           -=    rfwpro
 END IF
END IF

*** Lake fish water proposed release - above inflow
IF (fneed > 0.0) THEN
 *** make further release from Lake fish water
  GENER   1                            LFWPRO          +=    fneed
  GENER   1                            LFWPRO         MIN    lfwsto
END IF
```

Now, possible additional fish water releases from both sources are computed. If the reservoir is not in the process of filling in the spring (in which case “rfilfg” is set to one), then it can make a supplemental fish release as long as it does not dip below the minimum desired storage of 5,000 acre-feet. Thus, if there is any remaining fish need to satisfy, then any fish water available above this storage in the reservoir, up to that need, will be released. Again, FNEED is updated to account for the new water. If additional fish needs still remain, then the lake will make a further release beyond its current inflow, up to the total amount of fish water in its storage.

```
*** ---------- Adjust lake releases for minimum flow --------------------------
*** Make additional releases as needed to raise the total proposed release to
*** meet minimum flow requirements.
*** -------------------------------------------------------------------------
***                                    <addrss>-------   ----<uvqn>
***          dc ds                d t     or                     or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
  GENER   1                            LPROP            =    lmupro
  GENER   1                            LPROP           +=    lfwpro

IF (lprop < lminq) THEN
 *** need additional release
  GENER   1                            LNEED            =    lminq
  GENER   1                            LNEED           -=    lprop

 *** try to satisfy from fish water first
  GENER   1                            LFWPRO          +=    lneed
  GENER   1                            LFWPRO         MIN    lfwsto

 *** recalculate total proposed release from Lake
  GENER   1                            LPROP            =    lmupro
  GENER   1                            LPROP           +=    lfwpro

 IF (lprop < lminq) THEN
  *** still need more water
  GENER   1                            LNEED            =    lminq
  GENER   1                            LNEED           -=    lprop

 *** try to satisfy from municipal water
  GENER   1                            LMUPRO          +=    lneed
  GENER   1                            LMUPRO         MIN    lmusto
```

```
 *** recalculate total proposed release from Lake
  GENER   1                                LPROP            =    lmupro
  GENER   1                                LPROP           +=    lfwpro
 END IF
END IF
```

Next, the total lake release is computed and checked against the seasonal minimum flow requirement. If it is too low, additional fish water, and municipal water if necessary, are released. Note that minimum flows are not reduced during downstream flood conditions.

```
*** ---------- Adjust reservoir releases for maximum storage -------------------
*** If the reservoir storage is above the maximum storage, additional releases
*** are made to draw the level down.
*** ---------------------------------------------------------------------------
***                                       <addrss>-------   ----<uvqn>
***            dc ds                 d t     or                   or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
IF (rstor > rmaxst) THEN
 *** draw down reservoir

 *** compute excess storage
  GENER   1                                RDRAW            =    rstor
  GENER   1                                RDRAW           -=    rmaxst

 IF (rdraw > rfwpro) THEN
  *** must release additional water
  GENER   1                                RNEED            =    rdraw
  GENER   1                                RNEED           -=    rfwpro
  GENER   1                                RFWPRO          +=    rneed
  GENER   1                                RFWPRO         MIN    rfwsto
  *** check new total releases against maximum
  GENER   1                                TOTPRO           =    lprop
  GENER   1                                TOTPRO          +=    rfwpro
  IF (totpro > maxrel) THEN
   *** reduce drawdown
  GENER   1                                RFWPRO           =    maxrel
  GENER   1                                RFWPRO          -=    lprop
  END IF
 END IF
END IF
```

Then the reservoir is drawn down, if it is above the maximum allowable storage, by releasing the excess, again subject to the flooding limit.

```
*** ---------- Adjust reservoir releases for minimum flow ---------------------
*** Make additional releases as needed to raise the total proposed release to
*** meet minimum flow requirements.
*** -------------------------------------------------------------------------
***                                       <addrss>-------   ----<uvqn>
***            dc ds                d t     or                    or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
IF (rstor >= 5000.0) THEN
 *** reservoir storage is high enough to release high minimum
  GENER   1                               RMINQ            =      10.0
ELSE
 *** release low minimum
  GENER   1                               RMINQ            =       5.0
END IF

IF (rfwpro < rminq) THEN
 *** need additional release
  GENER   1                               RNEED            =    rminq
  GENER   1                               RNEED           -=    rfwpro
 *** make additional release up to total fish storage in reservoir
  GENER   1                               RFWPRO          +=    rneed
  GENER   1                               RFWPRO         MIN    rfwsto
END IF
```

Next, the adjusted reservoir release is checked for minimum flow in a similar manner as the lake release. The process is simpler here, since only one Category is present. Also, the minimum flow is reduced if the storage is below the minimum desired level.

```
*******************************************************************************
*** Pass final values for proposed releases to GENER operations.
*******************************************************************************
***                                       <addrss>-------   ----<uvqn>
***            dc ds                d t     or                    or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
  GENER   1                               K       1        =    lmupro
  GENER   2                               K       1        =    lfwpro
  GENER   3                               K       1        =    rfwpro

END SPEC-ACTIONS
```

Finally, the proposed releases are passed to the GENER operations, which create the output timeseries needed for output demands of RCHRES 1 and 2.

Selected References

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

Aqua Terra Consultants. 1996. HSPF Data Structure: The Operation Status Vector (OSV). Written communication,. Aqua Terra Consultants, Mountain View, CA.

Appendix A. Special Action Variable Library

The Special Action Variable Library lists the names of all of the OSV variables that HSPF recognizes in the SPEC-ACTIONS block. It contains definitions, internal units, the type (real, integer, or double precision) and an indication of whether the variable is a valid target of Special Actions. All of the variables listed, even if not classified as valid Special Action targets, may be used as sources, or base variables, of user-defined variable quantities. The program has its own internal copy of the Library, against which it checks the name given in the action line. Definitions of selected abreviations used in this section can be found in table A.1. Tables A.2 – A.33 contain the Special Action Variable Library, broken down by HSPF operations.

Table A.1 Abbreviations used in Special Action Variable Library.

Found in Column	Abbrev	Description
Type	C	Character variable
	I	Integer variable
	R	Single-precision real variable
	D	Double-precision variable
Class	DT	Date and time
	IT	Input timeseries
	OP	Option flag
	PM	Parameter
	ST	State variable
	FX	Output flux
SA Target Category	YES	Acts normally as a Special Action Target.
	NO	Has no effect if used as a Special Action Target, generally because the calculations in the current interval are independent of the previous value.
	INT	Intermittently calculated (i.e., not every interval). Acts as a NO in the intervals it is calculated, and as a YES in the intervals it is not. For example, for those parameters that vary monthly, the current value is re-computed at the first interval of the day. If the run has an hourly interval, and a Special Action targets the current value in the middle of the day, the new value will remain for the rest of the day. However, if the Special Action occurs in the first interval, it will have no effect. If that same parameter does not vary monthly (because of a flag setting), then it acts as a YES at all times. If it is an input timeseries, (because of a flag setting), then it acts as a NO at all times. The calculation interval is given in the variable definition for all INTs.
	OP	Changing an option flag with a Special Action usually requires that values for other variables be supplied or changed, or that different input timeseries be available. A thorough understanding of the situation is necessary. For example, if a constant parameter is changed to monthly by setting its corresponding monthly variable flag, then all 12 monthly values must be set at the same time with Special Actions, even if values are present in the UCI, since the monthly table is ignored when the flag is initially set for a single value.
	NO!	May cause serious errors if used as a Special Action Target.
Miscellaneous	ivl	Interval (time step) of the run
	LS	Land segment (i.e., a PERLND or IMPLND operation)
	PLS	Pervious land segment (i.e., a PERLND operation)
	ILS	Impervious land segment (i.e., an IMPLND operation)

Table A.2. PERLND General Section

Variable Name	Type	Class	SA	Definition
YR	I	DT	NO!	the year (four digits)
MON	I	DT	NO!	calendar month
DAY	I	DT	NO!	day of the month
HR	I	DT	NO!	hour of the day (internal convention)
MIN	I	DT	NO!	minute in the hour (internal convention)

Table A.3. PERLND and IMPLND ATEMP Section

[Internal unit system is English, regardless of external unit system. Units of "in" means inches of water equivalent except as noted.]

Variable Name	Type	Class	SA	Definition	English Units
AIRTMP	R	ST	NO	estimated air temp on the LS at the end of the current interval	F
ELDAT	R	PM	YES	difference in elevation between LS and air temp gage	ft
GATMP	R	IT	NO	air temp at the gage	F
LAPSE(24)	R	PM	YES	assumed dry air lapse rate for each hour of the day	F/ft

Table A.4. PERLND and IMPLND SNOW Section

[Internal unit system is English, regardless of external unit system. Units of "in" means inches of water equivalent except as noted.]

Variable Name	Type	Class	SA	Definition	English Units
ALBEDO	R	ST	NO	albedo of the pack	
CCFACT	R	PM	YES	parameter for condensation & convection snowmelt	
COMPCT	R	ST	NO	unit rate of increase of RDENPF	/ivl
COVIND	R	PM	YES	max value of PACKF required to ensure complete areal snow cover	in
COVINX	R	ST	YES	current PACKF required to get complete areal cover of snow	in
DEWTMP	R	ST	NO	estimated dewpoint temp on LS	F
DRYFG	I	ST	NO	ON means zero precip in one or more consecutive intervals	
DTMPG	R	IT	NO	dewpoint at the gage	F
DULL	R	ST	YES	dullness index for pack -- used to estimate albedo	
GMELTR	R	ST	NO	current rate of ground melt	in/ivl
ICEFG	I	OP	OP	ON means ice formation at the base of the pack will be simulated	
LAT	R	PM	YES	latitude of the LS -- positive for N hemisphere	deg
MELEV	R	PM	YES	mean elevation of LS above sea level	ft
MELT	R	FX	NO	water equivalent melted from the pack	in/ivl
MGMELT	R	PM	YES	max rate of melt by ground heat at pack temp = 32 deg F	in/ivl
MNEGHS	R	ST	NO	max negative heat storage -- water equivalent	in
MOSTHT	R	ST	NO	sum of heat flux rates for condensation, convection & radiation	in/ivl
MWATER	R	PM	YES	max water content of the pack	in water/in
NEGHT	R	ST	NO	potential rate of cooling of pack	in/ivl
NEGHTS	R	ST	YES	negative heat storage in the pack	in
PACK	R	ST	NO	total moisture stored in the pack	in
PACKF	R	ST	YES	frozen contents of pack	in
PACKI	R	ST	YES	ice in the pack	in
PACKW	R	ST	YES	liquid water held in the pack	in
PACKWC	R	ST	NO	liquid water holding capacity of the pack	in water/in
PAKTMP	R	ST	NO	mean temp of the pack	F
PDEPTH	R	ST	YES	depth of the pack (actual, not water equivalent)	in snowpack

Table A.4. PERLND and IMPLND SNOW Section

[Internal unit system is English, regardless of external unit system. Units of “in” means inches of water equivalent except as noted.]

Variable Name	Type	Class	SA	Definition	English Units
PRAIN	R	FX	NO	rainfall entering the pack (averaged over entire LS)	in/ivl
PREC	R	IT	NO	precip on the PLS, unadjusted	in/ivl
RAINF	R	FX	NO	rainfall	in/ivl
RAINFG	I	ST	NO	ON means its raining	
RDCSN	R	PM	YES	relative density of cold (below 0 F) new snow	in/in snow
RDENPF	R	ST	NO	relative density of frozen contents of pack, i.e. PACKF/PDEPTH	
RDNSN	R	ST	NO	Relative density of new-fallen snow under current conditions	
SHADE	R	PM	YES	fraction of LS which is shaded by, e.g., forest cover	
SKYCLR	R	ST	YES	fraction of sky which is clear	
SNOCOV	R	ST	YES	fraction of LS covered by pack during interval	
SNOEVP	R	PM	YES	parameter for snow evaporation	
SNOFFG	I	ST	NO	ON means its snowing	
SNOTMP	R	ST	NO	air temp below which precip will be modeled as snow	F
SNOWCF	R	PM	YES	snow catch correction factor	
SNOWE	R	FX	NO	evaporation from PACKF	in/ivl
SNOWEP	R	ST	NO	potential rate of evap from PACKF	in/ivl
SNOWF	R	FX	NO	snowfall	in/ivl
SOLRAD	R	IT	NO	solar radiation on the LS	ly/ivl
SVP(40)	R	PM	YES	saturation vapor pressure of water, at 5 deg F intervals, starting at -95 deg F	mbar
TSNOW	R	PM	YES	air temp at which snowfall can occur under saturated conditions	F
VAP	R	ST	NO	vapor pressure	mbar
WINMOV	R	IT	NO	wind movement on the LS	mi/ivl
WYIELD	R	FX	NO	water released from the pack to the land surface	in/ivl
XLNMLT	R	ST	YES	remaining possible increment to ice storage	in

Table A.5. PERLND PWATER Section

[Internal unit system is English, regardless of external unit system.]

Variable Name	Type	Class	SA	Definition	English Units
AGWET	R	FX	NO	ET from active groundwater storage	in/ivl
AGWETP	R	PM	YES	parameter governing ET from active groundwater	
AGWI	R	FX	NO	active ground water inflow (excluding any lateral inflow)	in/ivl
AGWLI	R	IT	NO	active ground water lateral inflow	in/ivl
AGWO	R	FX	NO	active ground water outflow	in/ivl
AGWS	R	ST	YES	active groundwater storage	in
BASET	R	FX	NO	ET from baseflow	in/ivl
BASETP	R	PM	YES	parameter governing ET from baseflow	
CEPE	R	FX	NO	evap from interception storage	in/ivl
CEPO	R	FX	NO	interception outflow	in/ivl
CEPS	R	ST	YES	interception storage	in
CEPSC	R	ST	INT	current value of interception storage capacity (daily or constant)	in
CEPSCM(12)	R	PM	YES	interception storage capacity at the start of each calendar month	in
CSNOFG	I	OP	OP	ON means effects of snow are considered in this RUN	
DEC	R	ST	NO	variable used in overland flow recession constant	complex
DEEPFR	R	PM	YES	fraction of groundwater inflow going to deep groundwater storage	
FOREST	R	PM	YES	fraction of PLS covered by forest which transpires in winter	
FSMSFG	I	ST	YES	ON means this is the first interval with surface moisture supply after one or more intervals with none	

Table A.5. PERLND PWATER Section

[Internal unit system is English, regardless of external unit system.]

Variable Name	Type	Class	SA	Definition	English Units
FZG	R	PM	YES	if IFFCFG = 1: coefficient for PACKI (if IFFCFG = 2: unused)	/in
FZGL	R	PM	YES	if IFFCFG = 1: lower limit of INFFAC; if IFFCFG = 2: INFFAC if LGTEMP is at or below freezing	
GWVS	R	ST	YES	index to groundwater slope	in
IFFCFG	I	OP	OP	1 means infiltration adjustment for frozen ground is based on PACKI; 2 means based on lower layer soil temp	
IFWI	R	FX	NO	interflow inflow (excluding any lateral inflow)	in/ivl
IFWK1	R	ST	NO	1st derived interflow routing parameter	
IFWK2	R	ST	NO	2nd derived interflow routing parameter	
IFWLI	R	IT	NO	interflow lateral inflow	in/ivl
IFWO	R	FX	NO	interflow outflow	in/ivl
IFWS	R	ST	YES	interflow storage	in
IGWI	R	FX	NO	inflow to inactive (deep) groundwater	in/ivl
INFEXP	R	PM	YES	exponent in infiltration equation	
INFFAC	R	ST	INT	infiltration factor to account for frozen ground (hourly)	
INFIL	R	FX	NO	infiltration	in/ivl
INFILD	R	PM	YES	ratio of max to mean infiltration	
INFILT	R	PM	YES	infiltration parameter	in/ivl
INTFW	R	ST	INT	current value of the interflow inflow parameter (daily or constant)	
INTFWM(12)	R	PM	YES	value of interflow inflow parameter at the start of each calendar month	
INTGRL(10)	R	PM	YES	table of integral of upper zone function	
IRC	R	ST	INT	current value of the interflow recession constant (daily or constant)	/d
IRCM(12)	R	PM	YES	value of interflow recession const at the start of each calendar month	/d
KGW	R	PM	YES	groundwater outflow parameter	/ivl
KVARY	R	PM	YES	parameter to make active groundwater storage/outflow relation nonlinear	/in
LSUR	R	PM	YES	length of the overland flow plane	ft
LZET	R	FX	NO	ET from the lower zone	in/ivl
LZETP	R	ST	INT	current value of lower zone ET parameter (daily or constant)	
LZETPM(12)	R	PM	YES	value of lower zone ET parameter at the start of each calendar month	
LZFRAC	R	ST	INT	fraction of IPERC taken by lower zone (calculated when ABS(LZRAT-RLZRAT) > 0.02)	
LZI	R	FX	NO	lower zone inflow	in/ivl
LZS	R	ST	YES	lower zone storage	in
LZSN	R	PM	YES	lower zone nominal storage	in
NSUR	R	ST	INT	current value of Manning's n for the overland flow plane (daily or constant)	complex
NSURM(12)	R	PM	YES	Manning's n for overland flow at the start of each calendar month	complex
PERC	R	FX	NO	percolation from the upper to the lower zone	in/ivl
PERO	R	FX	NO	total outflow from PLS	in/ivl
PERS	R	ST	NO	total water stored in the PLS	in
PET	R	FX	NO	PET on the PLS, adjusted for snow cover and air temp	in/ivl
PETADJ	R	ST	INT	PET factor to account for snow cover & air temp (hourly)	
PETINP	R	IT	NO	potential evapotranspiration on the PLS (input)	in/ivl
PETMAX	R	PM	YES	air temp below which PET is arbitrarily reduced	F
PETMIN	R	PM	YES	air temp below which PET is arbitrarily adjusted to zero	F
RLZRAT	R	ST	INT	reference value for LZRAT -- used to decide when to update LZFRAC (same as LZFRAC)	
RPARM	R	ST	INT	current value of max lower zone ET opportunity on PLS	in/ivl
RTOPFG	I	OP	OP	selects surface routing algorithm (0,1)	
SLSUR	R	PM	YES	slope of the overland flow plane	

Table A.5. PERLND PWATER Section

[Internal unit system is English, regardless of external unit system.]

Variable Name	Type	Class	SA	Definition	English Units
SMSFG	I	ST	YES	ON means there is surface moisture supply (MSUPY>0)	
SRC	R	ST	NO	variable used in overland flow routing	complex
SUPY	R	FX	NO	precip or (rain + snowpack water yield)	in/ivl
SURI	R	FX	NO	surface inflow (including any lateral inflow)	in/ivl
SURLI	R	IT	NO	surface lateral inflow	in/ivl
SURO	R	FX	NO	surface outflow	in/ivl
SURS	R	ST	YES	surface (overland flow) storage	in
SURSS	R	ST	NO	surface storage at the start of the interval	in
TAET	R	FX	NO	total actual ET	in/ivl
UZET	R	FX	NO	ET from the upper zone	in/ivl
UZFG	I	OP	OP	selects upper zone inflow function (0,1)	
UZI	R	FX	NO	upper zone inflow	in/ivl
UZRA(10)	R	PM	YES	table of upper zone function	
UZS	R	ST	YES	upper zone storage	in
UZSN	R	ST	INT	current value of upper zone nominal storage capacity (daily or constant)	in
UZSNM(12)	R	PM	YES	UZSN at the start of each calendar month	in
VCSFG	I	OP	OP	ON means interception storage capacity varies through the year	
VIFWFG	I	OP	OP	ON means INTFW (interflow inflow parameter) varies through the year	
VIRCFG	I	OP	OP	ON means interflow recession constant varies through the year	
VLEFG	I	OP	OP	ON means lower zone ET parameter varies through the year	
VNNFG	I	OP	OP	ON means Manning’s n for overland flow varies through the year	
VUZFG	I	OP	OP	ON means UZSN varies through the year	

Table A.6. PERLND SEDMNT Section

[Internal unit system is English, regardless of external unit system.]

Variable Name	Type	Class	SA	Definition	English Units
SLSED	R	IT	NO	lateral input of sediment to the surface	tons/ac/ivl
CRVFG	I	OP	OP	ON means erosion related cover is allowed to vary throughout the year	
VSIVFG	I	OP	OP	ON means net vertical sediment input is allowed to vary throughout the year	
SDOPFG	I	OP	OP	selects algorithm for removal of sediment from the surface (0,1)	
SMPF	R	PM	YES	supporting management practice factor	
KRER	R	PM	YES	coefficient in soil splash equation	complex
JRER	R	PM	YES	exponent of rainfall intensity in soil splash equation	complex
AFFIX	R	PM	YES	unit rate of attachment of detached sediment to soil matrix on non-precip days	/d
KSER	R	PM	YES	coefficient in detached sediment washoff equation	complex
JSER	R	PM	YES	exponent of surface runoff outflow in sediment washoff equation	complex
KGER	R	PM	YES	coefficient in scouring equation	complex
JGER	R	PM	YES	exponent of surface runoff outflow in scouring equation	complex
COVERM(12)	R	PM	YES	value of erosion related cover constant at the start of each calendar month	
NVSIM(12)	R	PM	YES	net vertical sediment input at the start of each month	tons/ac/ivl
DRYDFG	I	ST	YES	ON means precip did not occur during the previous day	
DETS	R	ST	YES	detached sediment storage	tons/ac
STCAP	R	ST	YES	sediment transport capacity by surface runoff	tons/ac/ivl
COVER	R	ST	INT	erosion related cover constant (daily or constant)	
WSSD	R	FX	NO	washoff of detached sediment	tons/ac/ivl
SCRSD	R	FX	NO	scour of matrix soil	tons/ac/ivl

Table A.6. PERLND SEDMNT Section

[Internal unit system is English, regardless of external unit system.]

Variable Name	Type	Class	SA	Definition	English Units
SOSED	R	FX	NO	total removal of soil and sediment	tons/ac/ivl
DET	R	FX	NO	quantity of sediment detached from soil matrix by rainfall	tons/ac/ivl
NVSI	R	FX	INT	net vertical sediment input (daily or constant)	tons/ac/ivl

Table A.7. PERLND PSTEMP Section

[Internal unit system is Metric, regardless of external unit system.]

Variable Name	Type	Class	SA	Definition	Metric Units
AIRTC	R	ST	NO	air temp at end of current interval	C
AIRTCS	R	ST	NO	(Centigrade) air temp at start of current interval	C
ASLT	R	ST	INT	y-intercept for surface layer temp regression equation (daily or constant)	C
ASLTM(12)	R	PM	YES	value of ASLT at start of each calendar month	C
BSLT	R	ST	INT	slope for surface layer temp regression equation (daily or constant)	
BSLTM(12)	R	PM	YES	value of BSLT at start of each calendar month	
LGTMP	R	ST	NO	lower layer and groundwater temp	C
LGTP1	R	ST	INT	if TSOPFG= 1, temp of lower layer and groundwater if TSOPFG= 0 or 2, smoothing factor for lower layer/groundwater temp calculation (daily or constant)	C
LGTP1M(12)	R	PM	YES	value of LGTP1 at start of each calendar month	See LGTP1
LGTP2	R	ST	INT	if TSOPFG= 1, not used if TSOPFG= 0, mean difference between lower layer/gw temp and air temp if TSOPFG= 2, mean difference between lower layer/gw temp and upper layer temp (daily or constant)	 C C
LGTP2M(12)	R	PM	YES	value of LGTP2 at start of each calendar month (only used if TSOPFG= 0 or 2)	See LGTP2
LGTVFG	I	OP	OP	ON means lower layer and gw temp parameters are allowed to vary throughout the year	
SLTMP	R	ST	NO	surface layer soil temp	C
SLTVFG	I	OP	OP	ON means surface layer temp parameters are allowed to vary throughout the year	
TSOPFG	I	OP	OP	0 - all subsurface temps are calculated using mean departure from air temp plus smoothing factor 1 - upper layer temp is based on regression, lower layer and gw temps are based on monthly values 2 - same as 0, except that lower layer and gw temp uses mean departure from upper layer temp instead of air temp	
ULTMP	R	ST	NO	upper layer soil temp	C
ULTP1	R	ST	INT	if TSOPFG= 1, y-intecept for the upper layer temp regression equation if TSOPFG= 0 or 2, smoothing factor for upper layer temp calculation (daily or constant)	C
ULTP1M(12)	R	PM	YES	value of ULTP1 at start of each calendar month	See ULTP1
ULTP2	R	ST	INT	if TSOPFG= 1,slope for upper layer temp regression equation if TSOPFG= 0 or 2, difference between mean upper layer temp and mean water temp (daily or constant)	C/C C
ULTP2M(12)	R	PM	YES	value of ULTP2 at start of each calendar month	See ULTP2
ULTVFG	I	OP	OP	ON means upper layer temp parameters are allowed to vary throughout the year	

Table A.8. PERLND PWTGAS Section

[Internal unit system is Metric, regardless of external unit system.]

Variable Name	Type	Class	SA	Definition	Metric Units
ACO2P	R	ST	INT	concentration of CO2 in active groundwater (daily or constant)	mg/l
ACO2PM(12)	R	PM	YES	CO2 conc in active gw at the start of each calendar month	mg/l
ADOXP	R	ST	INT	concentration of DO in active groundwater (daily or constant)	mg/l
ADOXPM(12)	R	PM	YES	DO conc in active gw at the start of each calendar month	mg/l
AOCO2	R	ST	NO	concentration of CO2 in active gw outflow	mg/l
AOCO2M	R	FX	NO	flux of CO2 in active gw outflow	mg.in/l/ivl
AODOX	R	ST	NO	concentration of DO in active gw outflow	mg/l
AODOXM	R	FX	NO	flux of DO in active gw outflow	mg.in/l/ivl
AOHT	R	FX	NO	heat energy in active gw outflow	C.in/ivl
AOTMP	R	ST	NO	active groundwater outflow temp	C
ELEVGC	R	PM	YES	correction factor for elevation above sea level (used in dissolved gases calc)	complex
GCVFG	I	OP	OP	ON means active groundwater CO2 conc is allowed to vary throughout the year	
GDVFG	I	OP	OP	ON means active groundwater DO conc is allowed to vary throughout the year	
ICO2P	R	ST	INT	concentration of CO2 in interflow (daily or constant)	mg/l
ICO2PM(12)	R	PM	YES	CO2 conc in interflow at the start of each calendar month	mg/l
ICVFG	I	OP	OP	ON means interflow CO2 conc is allowed to vary throughout the year	
IDOXP	R	ST	INT	concentration of DO in interflow (daily or constant)	mg/l
IDOXPM(12)	R	PM	YES	DO conc in interflow at the start of each calendar month	mg/l
IDVFG	I	OP	OP	ON means interflow DO conc is allowed to vary throughout the year	
IOCO2	R	ST	NO	concentration of CO2 in interflow outflow	mg/l
IOCO2M	R	FX	NO	flux of CO2 in interflow outflow	mg.in/l/ivl
IODOX	R	ST	NO	concentration of DO in interflow outflow	mg/l
IODOXM	R	FX	NO	flux of DO in interflow outflow	mg.in/l/ivl
IOHT	R	FX	NO	heat energy in interflow outflow	C.in/ivl
IOTMP	R	ST	NO	interflow outflow temp	C
POCO2M	R	FX	NO	flux of CO2 in total outflow from PLS	mg.in/l/ivl
PODOXM	R	FX	NO	flux of DO in total outflow from PLS	mg.in/l/ivl
POHT	R	FX	NO	heat energy in total outflow from PLS	C.in/ivl
SOCO2	R	ST	NO	concentration of CO2 in surface outflow	mg/l
SOCO2M	R	FX	NO	flux of CO2 in surface outflow	mg.in/l/ivl
SODOX	R	ST	NO	concentration of DO in surface outflow	mg/l
SODOXM	R	FX	NO	flux of DO in surface outflow	mg.in/l/ivl
SOHT	R	FX	NO	heat energy in surface outflow	C.in/ivl
SOTMP	R	ST	NO	surface outflow temp	C

Table A.9. PERLND PQUAL Section

[Internal unit system is a combination of English units and the user-specified unit “qty” (QTYID in Table-Type QUAL-PROPS), regardless of external unit system.]

Variable Name	Type	Class	SA	Definition	Units
ACQOP(7)	R	ST	INT	accumulation rate of QUALOF (daily or constant)	qty/ac/d
ACQOPM(12,7)	R	PM	YES	accumulation rate of each QUALOF, at the start of each calendar month	qty/ac/d
AOQC(7)	R	ST	INT	concentration of QUALGW in groundwater (daily or constant)	qty/ac/in
AOQCM(12,7)	R	PM	YES	concentration of QUALGW in groundwater outflow at the start of each calendar month	qty/ac/in
AOQUAL(7)	R	FX	NO	outflow of QUALGW with groundwater	qty/ac/ivl
IOQC(7)	R	ST	INT	concentration of QUALIF in interflow outflow (daily or constant)	qty/ac/in
IOQCM(12,7)	R	PM	YES	concentration of QUALIF in interflow outflow at the start of each calendar month	qty/ac/in
IOQUAL(7)	R	FX	NO	outflow of QUALIF in interflow	qty/ac/ivl
POQC(10)	R	ST	NO	concentration of QUAL in the total outflow from the pervious land segment	qty/ac/in
POQUAL(10)	R	FX	NO	total outflow of QUAL from the pervious land segment	qty/ac/ivl
POTFS(7)	R	ST	INT	scour potency factor (daily or constant)	qty/ton
POTFSM(12,7)	R	PM	YES	scour potency factor at the start of each calendar month	qty/ton
POTFW(7)	R	ST	INT	washoff potency factor (daily or constant)	qty/ton
POTFWM(12,7)	R	PM	YES	washoff potency factor at the start of each calendar month	qty/ton
PQACNM(12,10)	R	PM	YES	wet atmospheric deposition conc in precip at start of calendar month	qty/ac/in
PQADDR(10)	R	FX	NO	dry atmospheric deposition flux	qty/ac/ivl
PQADFG(20)	I	OP	OP	atmospheric deposition flags: -1 = timeseries, 0 = none, >0 = MONTH-DATA table number. Odd subscripts are for dry deposition, even for wet deposition. Flag must be zero if QUAL is not a QUALOF.	
PQADWT(10)	R	FX	NO	wet atmospheric deposition flux	qty/ac/ivl
PQAFXM(12,10)	R	PM	YES	dry atmospheric deposition flux at the start of each calendar month	qty/ac/ivl
REMQOM(12,7)	R	PM	YES	unit removal rate of each QUALOF, at the start of each calendar month	/d
REMQOP(7)	R	ST	INT	unit removal rate of QUALOF (daily or constant)	/d
SCRQS(7)	R	FX	NO	removal of QUALSD by association with scour of matrix soil	qty/ac/ivl
SOQC(10)	R	ST	NO	concentration of QUAL in the surface runoff	qty/ac/in
SOQO(7)	R	FX	NO	washoff of QUALOF from the surface	qty/ac/ivl
SOQOC(7)	R	ST	NO	concentration of QUALOF in the surface runoff	qty/ac/in
SOQS(7)	R	FX	NO	total outflow of QUALSD from the surface	qty/ac/ivl
SOQUAL(10)	R	FX	NO	total outflow of QUAL from the surface	qty/ac/ivl
SQO(7)	R	ST	YES	storage of QUALOF on the surface	qty/ac
VAQCFG(7)	I	OP	OP	ON means conc of QUALGW is allowed to vary throughout the year	
VIQCFG(7)	I	OP	OP	ON means conc of QUALIF is allowed to vary throughout the year	
VPFSFG(7)	I	OP	OP	ON means scour potency factors are allowed to vary throughout the year	
VPFWFG(7)	I	OP	OP	ON means washoff potency factors are allowed to vary throughout the year	
VQOFG(7)	I	OP	OP	ON means the accumulation rate and limiting storage (hence, removal rate) for QUALOF vary throughout the year	
WASHQS(7)	R	FX	NO	removal of QUALSD by association with detached sediment washoff	qty/ac/ivl
WSFAC(7)	R	PM	YES	susceptibility of each QUALOF to washoff, at the start of each calendar month	/in

Table A.10. PERLND MSTLAY Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
CFINMA	R	PM	YES	conversion factor from inches of water to mass/area of water	lb/ac/in	kg/ha/in
FRAC(8)	R	ST	NO	fractional fluxes: 1) FSO- surface outflow 2) FSP- surface percolation 3) FII- interflow inflow 4) FUP- upper percolation 5) FIO- interflow outflow 6) FLP- lower percolation to active groundwater 7) FLDP- lower percolation to inactive groundwater 8) FAO- active groundwater outflow	/ivl	/ivl
LLPF	R	PM	YES	factor used to reduce solute percolation (leaching) from the lower layer to both the active and inactive groundwater when LZS <(LZSN*LLPF)		
MST(5)	R	ST	NO	soil moisture storages: 1) SMSTM- surface layer 2) UMSTM- upper layer 3) ILSTM- interflow storage 4) LMSTM- lower layer 5) AMSTM- active groundwater	lb/ac	kg/ha
SLMPF	R	PM	YES	factor used to reduce solute percolation (leaching) from the surface layer to the upper layer		
ULPF	R	PM	YES	factor used to reduce solute percolation (leaching) from the upper layer principal storage to the lower layer when UZS < (UZSN*ULPF)		

Table A.11. PERLND PEST Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
ACVFG(3)	I	ST	YES	Same as SCVFG, for active groundwater layer		
ADOPFG(3)	I	OP	OP	adsorption/desorption option flag: 1 = first order kinetics, 2 = single value Freundlich isotherm method, 3 = non-single value Freundlich isotherm method		
ALSM	R	PM	YES	groundwater layer mass	lb/ac	kg/ha
APS(3,3)	R	ST	YES	active groundwater layer storages (same structure as SPS)	lb/ac	kg/ha
APSPM(8,3)	R	PM	YES	active groundwater layer parameters (same structure as SPSPM)		
AXJCT(3)	R	ST	INT	Same as SXJCT, for active groundwater layer		
AXST(3)	R	ST	INT	Same as SXST, for active groundwater layer	ppm	ppm
DEGPS(5,3)	R	FX	NO	degraded pesticide fluxes: pesticide # is second subscript, first subscript is: 1) SDEGPS- surface layer 2) UDEGPS- upper layer 3) LDEGPS- lower layer 4) ADEGPS- active groundwater layer 5) TDEGPS- total	lb/ac/ivl	kg/ha/ivl
GPSPM(8,3)				general parameters		
GPSPM(8,3)	C	PM	NO	1-5) PESTID- character ID		
GPSPM(8,3)	R	PM	YES	6) THDSPS- temp correction for first order desorption		
GPSPM(8,3)	R	PM	YES	7) THADPS- temp correction for first order adsorption		

Table A.11. PERLND PEST Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
GPSPM(8,3)	R	PM	YES	8) CMAX- max solubility	ppm	ppm
IPS(3)	R	ST	YES	upper layer interflow storage (IPSSU) for each pesticide	lb/ac	kg/ha
ITMXPS(3)	I	PM	YES	maximum number of iterations that the Freundlich solution technique is allowed		
LCVFG(3)	I	ST	YES	Same as SCVFG, for lower layer		
LLSM	R	PM	YES	lower layer soil mass	lb/ac	kg/ha
LPS(3,3)	R	ST	YES	lower layer storages (same structure as SPS)	lb/ac	kg/ha
LPSPM(8,3)	R	PM	YES	lower layer parameters (same structure as SPSPM)		
LXJCT(3)	R	ST	INT	Same as SXJCT, for lower layer		
LXST(3)	R	ST	INT	Same as SXST, for lower layer	ppm	ppm
PEACNM(12,3,3)	R	PM	YES	wet atmospheric deposition conc in precip at start of calendar month	lb/ac/in	kg/ha/mm
PEADDR(3,3)	R	FX	NO	dry atmospheric deposition flux	lb/ac/ivl	kg/ha/ivl
PEADFG(18)	I	OP	OP	atmospheric deposition flags: -1 = timeseries, 0 = none, >0 = MONTH-DATA table number. Odd subscripts are for dry deposition, even for wet deposition. 1-2,3-4,5-6) Crystalline, adsorbed, solution for pesticide #1, etc.		
PEADWT(3,3)	R	FX	NO	wet atmospheric deposition flux	lb/ac/ivl	kg/ha/ivl
PEAFXM(12,3,3)	R	PM	YES	dry atmospheric deposition flux at the start of each calendar month	lb/ac/ivl	kg/ha/ivl
POPST(3)	R	FX	NO	total outflow of pesticide	lb/ac/ivl	kg/ha/ivl
SCVFG(3)	I	ST	YES	ON means curve #1 (solely adsorption curve) was used last in the non-single value method for the surface layer		
SDPS(2,3)	R	FX	NO	sediment associated fluxes - pesticide # is second subscript, first subscript is: 1) SDPSY- removal of crystalline pesticide 2) SDPSA- removal of adsorbed pesticide	lb/ac/ivl	kg/ha/ivl
SLME	R	PM	YES	amount of surface layer soil in tons/acre	tons/ac	tons/ac
SLSM	R	PM	YES	surface layer soil mass	lb/ac	kg/ha
SOSDPS(3)	R	FX	NO	outflow of sediment-associated pesticide	lb/ac/ivl	kg/ha/ivl
SPS(3,3)	R	ST	YES	surface layer storages: pesticide # is second subscript, first subscript is: 1) SPSCY- crystalline pesticide 2) SPSAD- adsorbed pesticide 3) SPSSU- solution pesticide	lb/ac	kg/ha
SPSPM(8,3)	R	PM	YES	surface layer parameters		
SPSPM(8,3)				1) SKDSPS- first order desorption rate	/ivl	/ivl
SPSPM(8,3)				2) SKADPS- first order pesticide adsorption rate	/ivl	/ivl
SPSPM(8,3)				3) SXFIX- pesticide fixed capacity	ppm	ppm
SPSPM(8,3)				4) SXMAX- maximum adsorption capacity	ppm	ppm
SPSPM(8,3)				5) SKF1- single value Freundlich K	complex	complex
SPSPM(8,3)				6) SN1I- 1/SN1		
SPSPM(8,3)				7) SN2I- 1/SN2		
SPSPM(8,3)				8) SDGCON- first order pesticide decay rate	/d	/d

Table A.11. PERLND PEST Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
SSPSS(3,3)	R	FX	NO	fluxes of solution pesticide in subsoil: pesticide # is second subscript, first subscript is: 1) LPPSS- percolation from lower layer to active groundwater storage 2) LDPPSS- deep percolation from the lower layer to inactive groundwater 3) AOPSS- active groundwater outflow	lb/ac/ivl	kg/ha/ivl
SXJCT(3)	R	ST	INT	adsorbed conc where curve #1 joins #2 in the non-single value Freundlich method, for surface layer (calc when adsorbed conc changes direction)	ppm	ppm
SXST(3)	R	ST	INT	adsorbed concentration in surface layer at beginning of interval - used in non-single value Freundlich method (calc when adsorbed conc changes direction)	ppm	ppm
TOPST(3)	R	FX	NO	total outflow of pesticide	lb/ac/ivl	kg/ha/ivl
TOTPST(3)	R	ST	NO	total pesticide in storage	lb/ac	kg/ha
TPS(3,3)	R	ST	NO	total storages by species (same structure as SPS)	lb/ac	kg/ha
TSPSS(5,3)	R	FX	NO	fluxes of solution pesticide in topsoil: pesticide # is second subscript, first subscript is: 1) SOPSS- surface outflow 2) SPPSS- percolation from surface to upper layer principal storage 3) UPPSS- percolation from upper layer principal to lower layer storage 4) IIPSS- inflow from upper layer principal to interflow storage 5) IOPSS- interflow outflow	lb/ac/ivl	kg/ha/ivl
UCVFG(3)	I	ST	YES	Same as SCVFG, for upper layer		
ULSM	R	PM	YES	upper layer soil mass	lb/ac	kg/ha
UPS(3,3)	R	ST	YES	upper layer principal storages (same structure as SPS)	lb/ac	kg/ha
UPSPM(8,3)	R	PM	YES	upper layer parameters (same structure as SPSPM)		
UXJCT(3)	R	ST	INT	same as SXJCT, for upper layer		
UXST(3)	R	ST	INT	same as SXST, for upper layer	ppm	ppm

Table A.12. PERLND NITR Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
AAMAD	R	ST	YES	adsorbed ammonium storage in active groundwater layer	lb/ac	kg/ha
AAMSU	R	ST	YES	solution ammonium storage in active groundwater layer	lb/ac	kg/ha
AANUFM(12)	R	PM	YES	same as SANUFM, for active groundwater layer		
AANUTF	R	ST	INT	above-ground plant uptake fraction for active groundwater layer (daily or constant)		
ACSIAM	R	PM	YES	half-saturation constant for active groundwater layer ammonia immobilization	mg/l	mg/l
ACSINI	R	PM	YES	half-saturation constant for active groundwater layer nitrate immobilization	mg/l	mg/l
ACSUAM	R	PM	YES	half-saturation constant for active groundwater layer ammonia uptake	mg/l	mg/l
ACSUNI	R	PM	YES	half-saturation constant for active groundwater layer nitrate uptake	mg/l	mg/l

Table A.12. PERLND NITR Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
AGKPRN	R	ST	INT	first order above-ground plant return rate (daily or constant)	/ivl	/ivl
AGPLTN	R	ST	YES	above-ground plant N storage	lb/ac	kg/ha
AKADAM	R	PM	YES	first order ammonium adsorption rate for active groundwater layer	/ivl	/ivl
AKAM	R	PM	YES	first order ammonification of organic N rate for active groundwater layer	/ivl	/ivl
AKDNI	R	PM	YES	first order denitrification rate for active groundwater layer	/ivl	/ivl
AKDSAM	R	PM	YES	first order ammonium desorption rate for active groundwater layer	/ivl	/ivl
AKF1AM	R	PM	YES	single value Freundlich K for ammonium for active groundwater layer	complex	complex
AKIAMM(12)	R	PM	YES	same as SKINIM, for active groundwater layer ammonia	/ivl	/ivl
AKIMAM	R	PM	YES	first order ammonium immobilization rate for active groundwater layer	/ivl	/ivl
AKIMNI	R	PM	YES	first order nitrate immobilization rate for active groundwater layer	/ivl	/ivl
AKINIM(12)	R	PM	YES	same as SKINIM, for active groundwater layer nitrate	/ivl	/ivl
AKLON	R	PM	YES	labile partition coefficient for active groundwater layer		
AKNI	R	PM	YES	first order nitrification rate for active groundwater layer	/ivl	/ivl
AKONLR	R	PM	YES	first order labile/refractory conversion rate for active groundwater layer	/ivl	/ivl
AKPLN	R	ST	INT	plant uptake rate for NO3 and NH4 for active groundwater layer (daily or constant)	/ivl	/ivl
AKPLNM(12)	R	PM	YES	same as SKPLNM, for active groundwater layer	/ivl	/ivl
AKPRBN	R	ST	INT	first order plant return rate for active groundwater layer (daily or constant)	/ivl	/ivl
AKRBNM(12)	R	PM	YES	same as SKRBNM, for active groundwater layer	/ivl	/ivl
AKRON	R	PM	YES	refractory partition coefficient for active groundwater layer		
AKSIAM	R	ST	INT	maximum ammonia immobilization rate for saturation kinetics for active gw layer (daily or constant)	/ivl	/ivl
AKSINI	R	ST	INT	maximum nitrate immobilization rate for saturation kinetics for active gw layer (daily or constant)	/ivl	/ivl
AKSUAM	R	ST	INT	maximum ammonia uptake rate for saturation kinetics for active gw layer (daily or constant)	/ivl	/ivl
AKSUNI	R	ST	INT	maximum nitrate uptake rate for saturation kinetics for active gw layer (daily or constant)	/ivl	/ivl
AKUAMM(12)	R	PM	YES	same as SKUNIM, for active groundwater layer ammonia	/ivl	/ivl
AKUNIM(12)	R	PM	YES	same as SKUNIM, for active groundwater layer nitrate	/ivl	/ivl
AKVOL	R	PM	YES	first order rate for active GW layer	/ivl	/ivl
ALPNFG	I	OP	OP	ON means above-ground and litter compartments are simulated		
AMIMB(5)	R	FX	NO	immobilization fluxes 1) SAMIMB- surface layer 2) UAMIMB- upper layer 3) LAMIMB- lower layer 4) AAMIMB- active groundwater 5) TAMIMB- total	lb/ac/ivl	kg/ha/ivl

Table A.12. PERLND NITR Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
AMNIT(5)	R	FX	NO	nitrification fluxes 1) SAMNIT- surface layer 2) UAMNIT- upper layer 3) LAMNIT- lower layer 4) AAMNIT- active groundwater 5) TAMNIT- total	lb/ac/ivl	kg/ha/ivl
AMUPA(5)	R	FX	NO	above-ground ammonia uptake fluxes 1) SAMUPA- surface layer 2) UAMUPA- upper layer 3) LAMUPA- lower layer 4) AAMUPA- active groundwater 5) TAMUPA- total	lb/ac/ivl	kg/ha/ivl
AMUPB(5)	R	FX	NO	below-ground ammonia uptake fluxes 1) SAMUPB- surface layer 2) UAMUPB- upper layer 3) LAMUPB- lower layer 4) AAMUPB- active groundwater 5) TAMUPB- total	lb/ac/ivl	kg/ha/ivl
AMVOFG	I	OP	OP	ON means ammonia volatilization is simulated		
AMVOL(5)	R	FX	NO	ammonia volatilization fluxes 1) SAMVOL- surface layer 2) UAMVOL- upper layer 3) LAMVOL- lower layer 4) AAMVOL- active groundwater 5) TAMVOL- total	lb/ac/ivl	kg/ha/ivl
AN1IAM	R	PM	YES	1/N1 for ammonium for active groundwater layer		
ANDFC	R	ST	YES	yield-based plant uptake deficit for active groundwater layer	lb/ac	kg/ha
ANO3	R	ST	YES	nitrate storage in active groundwater layer	lb/ac	kg/ha
ANRXF(16)	R	FX	INT	active groundwater layer reaction fluxes (recalc same as SNRFX) 1) AADSAM- current adsorption flux for ammonium 2) ADESAM- current desorption flux for ammonium 3) AAMMIF- current ammonification flux 4) AIMMAM- current immobilization flux for ammonium 5) AUTAM- current below-ground plant uptake flux for ammonium 6) AIMMNI- current immobilization flux of nitrate 7) AUTNI- current below-ground plant uptake flux for nitrate 8) ANITRF- current nitrification flux 9) ADENI- current denitrification flux 10) AAMVO- current ammonia volatilization flux 11) ARFON- current labile-to-refractory organic N flux 12) APRETL- current plant return flux to labile organic N 13) APRETR- current plant return flux to refractory organic N 14) AUTAMA- current above-ground plant uptake flux for ammonium 15) AUTNIA- current above-ground plant uptake flux for nitrate 16) ANFIX- current nitrogen fixation flux	lb/ac/ivl	kg/ha/ivl
ANUPTG	R	ST	INT	yield-based nitrogen uptake target for active groundwater layer (daily or constant)	lb/ac/ivl	kg/ha/ivl
ANUPTM(12)	R	PM	YES	fraction of monthly N uptake target for active groundwater layer		

Table A.12. PERLND NITR Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
APLON/AORGN	R	ST	YES	particulate labile organic N storage in active groundwater layer	lb/ac	kg/ha
APLTN	R	ST	YES	plant nitrogen storage in active groundwater layer	lb/ac	kg/ha
APNUTG	R	ST	INT	same as SPNUTG, for active groundwater layer	lb/ac/d	kg/ha/d
APRON	R	ST	YES	particulate refractory organic N storage in active groundwater layer	lb/ac	kg/ha
ASLON	R	ST	YES	solution labile organic N storage in active groundwater layer	lb/ac	kg/ha
ASRON	R	ST	YES	solution refractory organic N storage in active groundwater layer	lb/ac	kg/ha
ATHNLR	R	PM	YES	labile/refractory conversion temperature correction factor for active groundwater layer		
AXFIXA	R	PM	YES	fixed capacity for ammonium for active groundwater layer	ppm	ppm
AXMAXA	R	PM	YES	maximum adsorption capacity of ammonium for active groundwater layer	ppm	ppm
BGNPRF	R	ST	INT	plant return refractory fraction (daily or constant)		
BIVLN	I	ST	YES	counter used to determine when bio-chemical reactions are to be done		
BNPRFM(12)	R	PM	YES	refractory fraction of below-ground plant N return at the start of each calendar month	/ivl	/ivl
BNUMN	I	PM	YES	the number of ivls per biochemical timestep for nitrogen		
CIVLN	I	ST	YES	counter used to determine when chemical reactions are to be done		
CMAXAM	R	PM	YES	maximum solubility of ammonium in water	ppm	ppm
CNUMN	I	PM	YES	the number of ivls per chemical timestep for nitrogen		
CRPDAT(4,3)	I	OP	OP	planting and harvesting dates for each possible crop season		
CRPDAY(13,3)	I	OP	OP	number of days in month for each possible crop season (Month 13 is leap year February)		
CRPFRC(13,3)	R	OP	OP	fraction of monthly plant uptake allocated to each crop, based on crop days (Month 13 is leap year February)		
DENIF(5)	R	FX	NO	denitrification fluxes 1) SDENIF- surface layer 2) UDENIF- upper layer 3) LDENIF- lower layer 4) ADENIF- acitve groundwater 5) TDENIF- total	lb/ac/ivl	kg/ha/ivl
FIXNFG	I	OP	OP	ON means that if NUPTFG= 1 then nitrogen fixation is simulated		
FORAFG	I	OP	OP	adsorption/desorption option flag for ammonium 0 means: use first order temperature dependent kinetics 1 means: use single value Freundlich isotherm method		
IAMSU	R	ST	YES	solution ammonium storage in interflow	lb/ac	kg/ha
INH3	R	FX	NO	Special Action input of ammonia	lb/ac/ivl	kg/ha/ivl
INO3	R	FX	NO	Special Action input of nitrate	lb/ac/ivl	kg/ha/ivl
INO3	R	ST	YES	nitrate storage in interflow	lb/ac	kg/ha
IORN	R	FX	NO	Special Action input of organic N	lb/ac/ivl	kg/ha/ivl
ISLON	R	ST	YES	solution labile organic N storage in interflow	lb/ac	kg/ha
ISRON	R	ST	YES	solution refractory organic N storage in interflow	lb/ac	kg/ha
ITMAXA	I	PM	YES	maximum number of iterations that the Freundlich method is allowed for ammonium		

Table A.12. PERLND NITR Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
KRANM(12)	R	PM	YES	first order above-ground plant N return rate at the start of each calendar month	/ivl	/ivl
LAMAD	R	ST	YES	adsorbed ammonium storage in lower layer	lb/ac	kg/ha
LAMSU	R	ST	YES	solution ammonium storage in lower layer	lb/ac	kg/ha
LANUFM(12)	R	PM	YES	same as SANUFM, for lower layer		
LANUTF	R	ST	INT	above-ground plant uptake fraction for lower layer (daily or constant)		
LCSIAM	R	PM	YES	half-saturation constant for lower layer ammonia immobilization	mg/l	mg/l
LCSINI	R	PM	YES	half-saturation constant for lower layer nitrate immobilization	mg/l	mg/l
LCSUAM	R	PM	YES	half-saturation constant for lower layer ammonia uptake	mg/l	mg/l
LCSUNI	R	PM	YES	half-saturation constant for lower layer nitrate uptake	mg/l	mg/l
LINPRF	R	ST	INT	litter return refractory fraction (daily or constant)		
LITTRN	R	ST	YES	litter compartment N storage	lb/ac	kg/ha
LKADAM	R	PM	YES	first order ammonium adsorption rate for lower layer	/ivl	/ivl
LKAM	R	PM	YES	first order ammonification of organic N rate for lower layer	/ivl	/ivl
LKDNI	R	PM	YES	first order denitrification rate for lower layer	/ivl	/ivl
LKDSAM	R	PM	YES	first order ammonium desorption rate for lower layer	/ivl	/ivl
LKF1AM	R	PM	YES	single value Freundlich K for ammonium for lower layer	complex	complex
LKIAMM(12)	R	PM	YES	same as SKINIM, for lower layer ammonia	/ivl	/ivl
LKIMAM	R	PM	YES	first order ammonium immobilization rate for lower layer	/ivl	/ivl
LKIMNI	R	PM	YES	first order nitrate immobilization rate for lower layer	/ivl	/ivl
LKINIM(12)	R	PM	YES	same as SKINIM, for lower layer nitrate	/ivl	/ivl
LKLON	R	PM	YES	labile partition coefficient for lower layer		
LKNI	R	PM	YES	first order nitrification rate for lower layer	/ivl	/ivl
LKONLR	R	PM	YES	first order labile/refractory conversion rate for lower layer	/ivl	/ivl
LKPLN	R	ST	INT	plant uptake rate for NO3 and NH4 for lower layer (daily or constant)	/ivl	/ivl
LKPLNM(12)	R	PM	YES	same as SKPLNM, for lower layer	/ivl	/ivl
LKPRBN	R	ST	INT	first order plant return rate for lower layer (daily or constant)	/ivl	/ivl
LKRBNM(12)	R	PM	YES	same as SKRBNM, for lower layer	/ivl	/ivl
LKRON	R	PM	YES	refractory partition coefficient for lower layer		
LKSIAM	R	ST	INT	maximum ammonia immobilization rate for saturation kinetics for lower layer (daily or constant)	/ivl	/ivl
LKSINI	R	ST	INT	maximum nitrate immobilization rate for saturation kinetics for lower layer (daily or constant)	/ivl	/ivl
LKSUAM	R	ST	INT	maximum ammonia uptake rate for saturation kinetics for lower layer (daily or constant)	/ivl	/ivl
LKSUNI	R	ST	INT	maximum nitrate uptake rate for saturation kinetics for lower layer (daily or constant)	/ivl	/ivl
LKUAMM(12)	R	PM	YES	same as SKUNIM, for lower layer ammonia	/ivl	/ivl
LKUNIM(12)	R	PM	YES	same as SKUNIM, for lower layer nitrate	/ivl	/ivl
LKVOL	R	PM	YES	first order rate for lower layer	/ivl	/ivl
LN1IAM	R	PM	YES	1/N1 for ammonium for lower layer		
LNDFC	R	ST	YES	yield-based plant uptake deficit for lower layer	lb/ac	kg/ha

Table A.12. PERLND NITR Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
LNO3	R	ST	YES	nitrate storage in lower layer	lb/ac	kg/ha
LNPRFM(12)	R	PM	YES	refractory fraction of for litter N return at the start of each calendar month	/ivl	/ivl
LNRXF(16)	R	FX	INT	lower layer reaction fluxes (recalc same as SNRFX) 1) LADSAM- current adsorption flux for ammonium 2) LDESAM- current desorption flux for ammonium 3) LAMMIF- current ammonification flux 4) LIMMAM- current immobilization flux for ammonium 5) LUTAM- current below-ground plant uptake flux for ammonium 6) LIMMNI- current immobilization flux of nitrate 7) LUTNI- current below-ground plant uptake flux for nitrate 8) LNITRF- current nitrification flux 9) LDENI- current denitrification flux 10) LAMVO- current ammonia volatilization flux 11) LRFON- current labile-to-refractory organic N flux 12) LPRETL- current plant return flux to labile organic N 13) LPRETR- current plant return flux to refractory organic N 14) LUTAMA- current above-ground plant uptake flux for ammonium 15) LUTNIA- current above-ground plant uptake flux for nitrate 16) LNFIX- current nitrogen fixation flux	lb/ac/ivl	kg/ha/ivl
LNUPTG	R	ST	INT	yield-based nitrogen uptake target for lower layer (daily or constant)	lb/ac/ivl	kg/ha/ivl
LNUPTM(12)	R	PM	YES	fraction of monthly N uptake target for lower layer		
LPLON/LORGN	R	ST	YES	particulate labile organic N storage in lower layer	lb/ac	kg/ha
LPLTN	R	ST	YES	plant nitrogen storage in lower layer	lb/ac	kg/ha
LPNUTG	R	ST	INT	same as SPNUTG, for lower layer	lb/ac/d	kg/ha/d
LPRON	R	ST	YES	particulate refractory organic N storage in lower layer	lb/ac	kg/ha
LSLON	R	ST	YES	solution labile organic N storage in lower layer	lb/ac	kg/ha
LSRON	R	ST	YES	solution refractory organic N storage in lower layer	lb/ac	kg/ha
LTHNLR	R	PM	YES	labile/refractory conversion temperature correction factor for lower layer		
LXFIXA	R	PM	YES	fixed capacity for ammonium for lower layer	ppm	ppm
LXMAXA	R	PM	YES	maximum adsorption capacity of ammonium for lower layer	ppm	ppm
NCRP	I	OP	OP	number of crop seasons per year for yield-based plant uptake		
NFIXFX(5)	R	FX	NO	nitrogen fixation fluxes 1) SFIXN- surface layer 2) UFIXN- upper layer 3) LFIXN- lower layer 4) AFIXN- active groundwater 5) TFIXN- total	lb/ac/ivl	kg/ha/ivl
NH4UTF	R	PM	YES	ammonium fraction of total N plant uptake		
NIACNM(12,3,2)	R	PM	YES	wet atmospheric deposition concentration in precip at start of calendar month	lb/ac/in	kg/ha/mm
NIADDR(3,2)	R	FX	NO	dry atmospheric deposition flux: nitrate, ammonia, and particulate labile organic N to surface and upper layers	lb/ac/ivl	kg/ha/ivl

Table A.12. PERLND NITR Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
NIADFG(12)	I	OP	OP	atmospheric deposition flags: -1 = timeseries, 0 = none, >0 = MONTH-DATA table number. Odd subscripts are for dry deposition, even for wet deposition. 1-2,3-4,5-6) Nitrate, ammonia, and particulate labile organic N to the surface layer; 7-8,9-10,11-12) Same to upper layer		
NIADWT(3,2)	R	FX	NO	wet atmospheric deposition flux: nitrate, ammonia, and particulate labile organic N to surface and upper layers	lb/ac/ivl	kg/ha/ivl
NIAFXM(12,3,2)	R	PM	YES	dry atmospheric deposition flux at the start of each calendar month	lb/ac/ivl	kg/ha/ivl
NIIMB(5)	R	FX	NO	nitrate immobilization fluxes 1) SNIIMB- surface layer 2) UNIIMB- upper layer 3) LNIIMB- lower layer 4) ANIIMB- active groundwater 5) TNIIMB- total	lb/ac/ivl	kg/ha/ivl
NIUPA(5)	R	FX	NO	above-ground nitrate uptake fluxes 1) SNIUPA- surface layer 2) UNIUPA- upper layer 3) LNIUPA- lower layer 4) ANIUPA- active groundwater 5) TNIUPA- total	lb/ac/ivl	kg/ha/ivl
NIUPB(5)	R	FX	NO	below-ground nitrate uptake fluxes 1) SNIUPB- surface layer 2) UNIUPB- upper layer 3) LNIUPB- lower layer 4) ANIUPB- active groundwater 5) TNIUPB- total	lb/ac/ivl	kg/ha/ivl
NMXRAT	R	PM	YES	ratio of maximum uptake to target uptake for nitrogen		
NO3UTF	R	PM	YES	nitrate fraction of total N plant uptake		
NUPTFG	I	OP	OP	nitrogen plant uptake option flag 0 means: use first order temperature dependent kinetics 1 means: use yield-based algorithm 2 means: use saturation kinetics for plant uptake AND immobilization -2 means: same as 2, but use same parameters for all four layers		
NUPTFM(12)	R	PM	YES	monthly fraction of total annual yield-based N uptake target		
NUPTGT	R	PM	YES	total annual yield-based plant uptake target of nitrogen	lb/ac	kg/ha
ORNMN(5)	R	FX	NO	mineralization fluxes 1) SORNMN- surface layer 2) UORNMN- upper layer 3) LORNMN- lower layer 4) AORNMN- active groundwater 5) TORNMN- total	lb/ac/ivl	kg/ha/ivl
PONH4	R	FX	NO	total outflow of ammonium from the PLS	lb/ac/ivl	kg/ha/ivl
PONITR	R	FX	NO	total outflow of nitrogen from the PLS	lb/ac/ivl	kg/ha/ivl
PONO3	R	FX	NO	total outflow of nitrate from the PLS	lb/ac/ivl	kg/ha/ivl
POORN	R	FX	NO	total outflow of organic N from the PLS	lb/ac/ivl	kg/ha/ivl

Table A.12. PERLND NITR Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
REFRON(5)	R	FX	NO	labile-to-refractory organic N conversion fluxes 1) SREFON- surface layer 2) UREFON- upper layer 3) LREFON- lower layer 4) AREFON- active groundwater 5) TREFON- total	lb/ac/ivl	kg/ha/ivl
RETAGN	R	FX	NO	return of above-ground plant N to litter compartment	lb/ac/ivl	kg/ha/ivl
RTLBN(5)	R	FX	NO	above-ground plant N return to particulate labile organic N fluxes 1) SRTLBN- surface layer 2) URTLBN- upper layer 3) LRTLBN- lower layer 4) ARTLBN- active groundwater 5) TRTLBN- total	lb/ac/ivl	kg/ha/ivl
RTLLN(3)	R	FX	NO	litter N return to particulate labile organic N fluxes 1) SRTLLN- surface layer 2) URTLLN- upper layer 3) TRTLLN- total	lb/ac/ivl	kg/ha/ivl
RTRBN(5)	R	FX	NO	above-ground plant N return to particulate refractory organic N fluxes 1) SRTRBN- surface layer 2) URTRBN- upper layer 3) LRTRBN- lower layer 4) ARTRBN- active groundwater 5) TRTRBN- total	lb/ac/ivl	kg/ha/ivl
RTRLN(3)	R	FX	NO	litter N return to particulate refractory organic N fluxes 1) SRTRLN- surface layer 2) URTRLN- upper layer 3) TRTRLN- total	lb/ac/ivl	kg/ha/ivl
SAMAD	R	ST	YES	adsorbed ammonium storage in surface layer	lb/ac	kg/ha
SAMSU	R	ST	YES	solution ammonium storage in surface layer	lb/ac	kg/ha
SANUFM(12)	R	PM	YES	above-ground plant uptake fraction for surface layer at the start of each calendar month		
SANUTF	R	ST	INT	above-ground plant uptake fraction for surface layer (daily or constant)		
SCSIAM	R	PM	YES	half-saturation constant for surface layer ammonia immobilization	mg/l	mg/l
SCSINI	R	PM	YES	half-saturation constant for surface layer nitrate immobilization	mg/l	mg/l
SCSUAM	R	PM	YES	half-saturation constant for surface layer ammonia uptake	mg/l	mg/l
SCSUNI	R	PM	YES	half-saturation constant for surface layer nitrate uptake	mg/l	mg/l
SEDN(3)	R	FX	NO	sediment associated fluxes 1) SDLORN- removal of labile organic N on/with sediment 2) SDAMA- removal of adsorbed ammonia on/with sediment 3) SDRORN- removal of refractory organic N on/with sediment	lb/ac/ivl	kg/ha/ivl
SKADAM	R	PM	YES	first order ammonium adsorption rate for surface layer	/ivl	/ivl
SKAM	R	PM	YES	first order ammonification of organic N rate for surface layer	/ivl	/ivl
SKDNI	R	PM	YES	first order denitrification rate for surface layer	/ivl	/ivl
SKDSAM	R	PM	YES	first order ammonium desorption rate for surface layer	/ivl	/ivl
SKF1AM	R	PM	YES	single value Freundlich K for ammonium for surface layer	complex	complex

Table A.12. PERLND NITR Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
SKIAMM(12)	R	PM	YES	same as SKINIM, for surface layer ammonia	/ivl	/ivl
SKIMAM	R	PM	YES	first order ammonium immobilization rate for surface layer	/ivl	/ivl
SKIMNI	R	PM	YES	first order nitrate immobilization rate for surface layer	/ivl	/ivl
SKINIM(12)	R	PM	YES	Maximum nitrate immobilization rate for saturation kinetics for surface layer at the start of each calendar month	/ivl	/ivl
SKLON	R	PM	YES	labile partition coefficient for surface layer		
SKNI	R	PM	YES	first order nitrification rate for surface layer	/ivl	/ivl
SKONLR	R	PM	YES	first order labile/refractory conversion rate for surface layer	/ivl	/ivl
SKPLN	R	ST	INT	plant uptake rate for NO3 and NH4 for surface layer (daily or constant)	/ivl	/ivl
SKPLNM(12)	R	PM	YES	first order N plant uptake rate for surface layer at the start of each calendar month	/ivl	/ivl
SKPRBN	R	ST	INT	first order plant return rate for surface layer (daily or constant)	/ivl	/ivl
SKPRLN	R	ST	INT	first order litter return rate to surface layer (daily or constant)	/ivl	/ivl
SKRBNM(12)	R	PM	YES	first order below-ground plant N return rate for surface layer at the start of each calendar month	/ivl	/ivl
SKRLNM(12)	R	PM	YES	first order litter N return rate for surface layer at the start of each calendar month	/ivl	/ivl
SKRON	R	PM	YES	refractory partition coefficient for surface layer		
SKSIAM	R	ST	INT	maximum ammonia immobilization rate for saturation kinetics for surface layer (daily or constant)	/ivl	/ivl
SKSINI	R	ST	INT	maximum nitrate immobilization rate for saturation kinetics for surface layer (daily or constant)	/ivl	/ivl
SKSUAM	R	ST	INT	maximum ammonia uptake rate for saturation kinetics for surface layer (daily or constant)	/ivl	/ivl
SKSUNI	R	ST	INT	maximum nitrate uptake rate for saturation kinetics for surface layer (daily or constant)	/ivl	/ivl
SKUAMM(12)	R	PM	YES	same as SKUNIM, for surface layer ammonia	/ivl	/ivl
SKUNIM(12)	R	PM	YES	maximum nitrate uptake rate for saturation kinetics for surface layer at the start of each calendar month	/ivl	/ivl
SKVOL	R	PM	YES	first order rate for surface layer	/ivl	/ivl
SN1IAM	R	PM	YES	1/N1 for ammonium for surface layer		
SNDFC	R	ST	YES	yield-based plant uptake deficit for surface layer	lb/ac	kg/ha
SNO3	R	ST	YES	nitrate storage in surface layer	lb/ac	kg/ha

Table A.12. PERLND NITR Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
SNRXF(16)	R	FX	INT	surface layer reaction fluxes 1) SADSAM- current adsorption flux for ammonium (every CNUMN intervals) 2) SDESAM- current desorption flux for ammonium (every CNUMN intervals) 3) SAMMIF- current ammonification flux (every BNUMN intervals) 4) SIMMAM- current immobilization flux for ammonium (every BNUMN intervals) 5) SUTAM- current below-ground plant uptake flux for ammonium (every BNUMN intervals) 6) SIMMNI- current immobilization flux of nitrate (every BNUMN intervals) 7) SUTNI- current below-ground plant uptake flux for nitrate (every BNUMN intervals) 8) SNITRF- current nitrification flux (every BNUMN intervals) 9) SDENI- current denitrification flux (every BNUMN intervals) 10) SAMVO- current ammonia volatilization flux (every BNUMN intervals) 11) SRFON- current labile-to-refractory organic N flux (every BNUMN intervals) 12) SPRETL- current plant return flux to labile organic N (every BNUMN intervals) 13) SPRETR- current plant return flux to refractory organic N (every BNUMN intervals) 14) SUTAMA- current above-ground plant uptake flux for ammonium (every BNUMN intervals) 15) SUTNIA- current above-ground plant uptake flux for nitrate (every BNUMN intervals) 16) SNFIX- current nitrogen fixation flux (every BNUMN intervals)	lb/ac/ivl	kg/ha/ivl
SNUPTG	R	ST	INT	yield-based nitrogen uptake target for surface layer (daily or constant)	lb/ac/ivl	kg/ha/ivl
SNUPTM(12)	R	PM	YES	fraction of monthly N uptake target for surface layer		
SOSEDN	R	FX	NO	surface outflow of sediment associated N	lb/ac/ivl	kg/ha/ivl
SPLON/SORGN	R	ST	YES	particulate labile organic N storage in surface layer	lb/ac	kg/ha
SPLTN	R	ST	YES	plant nitrogen storage in surface layer	lb/ac	kg/ha
SPNUTG	R	ST	INT	yield-based N uptake target from surface layer for last day of previous month (daily or constant)	lb/ac/d	kg/ha/d
SPRON	R	ST	YES	particulate refractory organic N storage in surface layer	lb/ac	kg/ha
SSAMS(3)	R	FX	NO	fluxes of solution ammonium in the subsoil layers 1) LPAMS- percolation from lower layer to active groundwater 2) LDPAMS- deep percolation from lower layer to inactive groundwater 3) AOAMS- active groundwater outflow of solution ammonium	lb/ac/ivl	kg/ha/ivl
SSLON	R	ST	YES	solution labile organic N storage in surface layer	lb/ac	kg/ha
SSNO3(3)	R	FX	NO	fluxes of nitrate in the subsoil layers 1) LPNO3- percolation from lower layer to active groundwater storage 2) LDPNO3- deep percolation from the lower layer to inactive groundwater 3) AONO3- active groundwater outflow	lb/ac/ivl	kg/ha/ivl
SSRON	R	ST	YES	solution refractory organic N storage in surface layer	lb/ac	kg/ha

Table A.12. PERLND NITR Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
SSSLN(3)	R	FX	NO	fluxes of solution labile organic N in the subsoil layers 1) LPSLN- percolation from lower layer to active groundwater 2) LDPSLN- deep percolation from lower layer to inactive groundwater 3) AOSLN- active groundwater outflow	lb/ac/ivl	kg/ha/ivl
SSSRN(3)	R	FX	NO	fluxes of solution refractory organic N in the subsoil layers 1) LPSRN- percolation from lower layer to active groundwater 2) LDPSRN- deep percolation from lower layer to inactive groundwater 3) AOSRN- active groundwater outflow	lb/ac/ivl	kg/ha/ivl
STHNLR	R	PM	YES	labile/refractory conversion temperature correction factor for surface layer		
SXFIXA	R	PM	YES	fixed capacity for ammonium for surface layer	ppm	ppm
SXMAXA	R	PM	YES	maximum adsorption capacity of ammonium for surface layer	ppm	ppm
TAMAD	R	ST	NO	total adsorbed ammonium storage	lb/ac	kg/ha
TAMSU	R	ST	NO	total solution ammonium storage	lb/ac	kg/ha
THKADA	R	PM	YES	temp coefficient for first order ammonia adsorption		
THKAM	R	PM	YES	temp coefficient for first order organic N ammonification		
THKDNI	R	PM	YES	temp coefficient for first order denitrification of NO3		
THKDSA	R	PM	YES	temp coefficient for first order ammonia desorption		
THKIMA	R	PM	YES	temp coefficient for first order ammonia immobilization		
THKIMN	R	PM	YES	temp coefficient for first order N immobilization		
THKNI	R	PM	YES	temp coefficient for first order nitrification		
THPLN	R	PM	YES	temp coefficient for first order plant uptake of ammonium and nitrate		
THVOL	R	PM	YES	temp correction coefficient		
TNDFC	R	ST	NO	total deficit yield-based plant uptake	lb/ac	kg/ha
TNO3	R	ST	NO	total nitrate storage	lb/ac	kg/ha
TOTNIT	R	ST	NO	total nitrogen stored in the PLS	lb/ac	kg/ha
TPLON/TORGN	R	ST	NO	total particulate labile organic N storage	lb/ac	kg/ha
TPLTN	R	ST	NO	total plant nitrogen storage	lb/ac	kg/ha
TPRON	R	ST	NO	total particulate refractory organic N storage	lb/ac	kg/ha
TRFVOL	R	PM	YES	reference temperature for correction	C	C
TSAMS(5)	R	FX	NO	fluxes of solution ammonium in the topsoil layers 1) SOAMS- surface outflow 2) SPAMS- percolation from surface to upper layer principal storage 3) UPAMS- percolation from upper layer principal to lower layer 4) IIAMS- flow from upper layer principal to interflow storage 5) IOAMS- interflow storage outflow	lb/ac/ivl	kg/ha/ivl
TSLON	R	ST	NO	total solution labile organic N storage	lb/ac	kg/ha

Table A.12. PERLND NITR Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
TSNO3(5)	R	FX	NO	fluxes of nitrate in the topsoil layers 1) SONO3- surface outflow 2) SPNO3- percolation from surface to upper layer principal storage 3) UPNO3- percolation from upper layer principal to lower layer storage 4) IINO3- flow from upper layer principal to interflow storage 5) IONO3- interflow storage outflow	lb/ac/ivl	kg/ha/ivl
TSRON	R	ST	NO	total solution refractory organic N storage	lb/ac	kg/ha
TSSLN(5)	R	FX	NO	fluxes of solution labile organic N in the topsoil layers 1) SOSLN- surface outflow 2) SPSLN- percolation from surface to upper layer principal storage 3) UPSLN- percolation from upper layer principal to lower layer 4) IISLN- flow from upper layer principal to interflow storage 5) IOSLN- interflow storage outflow	lb/ac/ivl	kg/ha/ivl
TSSRN(5)	R	FX	NO	fluxes of solution refractory organic N in the topsoil layers 1) SOSRN- surface outflow 2) SPSRN- percolation from surface to upper layer principal storage 3) UPSRN- percolation from upper layer principal to lower layer 4) IISRN- flow from upper layer principal to interflow storage 5) IOSRN- interflow storage outflow	lb/ac/ivl	kg/ha/ivl
UAMAD	R	ST	YES	adsorbed ammonium storage in upper layer	lb/ac	kg/ha
UAMSU	R	ST	YES	solution ammonium storage in upper layer	lb/ac	kg/ha
UANUFM(12)	R	PM	YES	same as SANUFM, for upper layer		
UANUTF	R	ST	INT	above-ground plant uptake fraction for upper layer (daily or constant)		
UCSIAM	R	PM	YES	half-saturation constant for upper layer ammonia immobilization	mg/l	mg/l
UCSINI	R	PM	YES	half-saturation constant for upper layer nitrate immobilization	mg/l	mg/l
UCSUAM	R	PM	YES	half-saturation constant for upper layer ammonia uptake	mg/l	mg/l
UCSUNI	R	PM	YES	half-saturation constant for upper layer nitrate uptake	mg/l	mg/l
UKADAM	R	PM	YES	first order ammonium adsorption rate for upper layer	/ivl	/ivl
UKAM	R	PM	YES	first order ammonification of organic N rate for upper layer	/ivl	/ivl
UKDNI	R	PM	YES	first order denitrification rate for upper layer	/ivl	/ivl
UKDSAM	R	PM	YES	first order ammonium desorption rate for upper layer	/ivl	/ivl
UKF1AM	R	PM	YES	single value Freundlich K for ammonium for upper layer	complex	complex
UKIAMM(12)	R	PM	YES	same as SKINIM, for upper layer ammonia	/ivl	/ivl
UKIMAM	R	PM	YES	first order ammonium immobilization rate for upper layer	/ivl	/ivl
UKIMNI	R	PM	YES	first order nitrate immobilization rate for upper layer	/ivl	/ivl
UKINIM(12)	R	PM	YES	same as SKINIM, for upper layer nitrate	/ivl	/ivl
UKLON	R	PM	YES	labile partition coefficient for upper layer		
UKNI	R	PM	YES	first order nitrification rate for upper layer	/ivl	/ivl

Table A.12. PERLND NITR Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
UKONLR	R	PM	YES	first order labile/refractory conversion rate for upper layer	/ivl	/ivl
UKPLN	R	ST	INT	plant uptake rate for NO3 and NH4 for upper layer (daily or constant)	/ivl	/ivl
UKPLNM(12)	R	PM	YES	same as SKPLNM, for upper layer	/ivl	/ivl
UKPRBN	R	ST	INT	first order plant return rate for upper layer (daily or constant)	/ivl	/ivl
UKPRLN	R	ST	INT	first order litter return rate to upper layer (daily or constant)	/ivl	/ivl
UKRBNM(12)	R	PM	YES	Same as SKRBNM, for upper layer	/ivl	/ivl
UKRLNM(12)	R	PM	YES	same as SKRLNM, for upper layer	/ivl	/ivl
UKRON	R	PM	YES	refractory partition coefficient for upper layer		
UKSIAM	R	ST	INT	maximum ammonia immobilization rate for saturation kinetics for upper layer (daily or constant)	/ivl	/ivl
UKSINI	R	ST	INT	maximum nitrate immobilization rate for saturation kinetics for upper layer (daily or constant)	/ivl	/ivl
UKSUAM	R	ST	INT	maximum ammonia uptake rate for saturation kinetics for upper layer (daily or constant)	/ivl	/ivl
UKSUNI	R	ST	INT	maximum nitrate uptake rate for saturation kinetics for upper layer (daily or constant)	/ivl	/ivl
UKUAMM(12)	R	PM	YES	same as SKUNIM, for upper layer ammonia	/ivl	/ivl
UKUNIM(12)	R	PM	YES	same as SKUNIM, for upper layer nitrate	/ivl	/ivl
UKVOL	R	PM	YES	first order rate for upper layer	/ivl	/ivl
UN1IAM	R	PM	YES	1/N1 for ammonium for upper layer		
UNDFC	R	ST	YES	yield-based plant uptake deficit for upper layer	lb/ac	kg/ha
UNO3	R	ST	YES	nitrate storage in upper layer	lb/ac	kg/ha
UNRXF(16)	R	FX	INT	upper layer reaction fluxes (recalc same as SNRFX) 1) UADSAM- current adsorption flux for ammonium 2) UDESAM- current desorption flux for ammonium 3) UAMMIF- current ammonification flux 4) UIMMAM- current immobilization flux for ammonium 5) UUTAM- current below-ground plant uptake flux for ammonium 6) UIMMNI- current immobilization flux of nitrate 7) UUTNI- current below-ground plant uptake flux for nitrate 8) UNITRF- current nitrification flux 9) UDENI- current denitrification flux 10) UAMVO- current ammonia volatilization flux 11) URFON- current labile-to-refractory organic N flux 12) UPRETL- current plant return flux to labile organic N 13) UPRETR- current plant return flux to refractory organic N 14) UUTAMA- current above-ground plant uptake flux for ammonium 15) UUTNIA- current above-ground plant uptake flux for nitrate 16) UNFIX- current nitrogen fixation flux	lb/ac/ivl	kg/ha/ivl
UNUPTG	R	ST	INT	yield-based nitrogen uptake target for upper layer (daily or constant)	lb/ac/ivl	kg/ha/ivl
UNUPTM(12)	R	PM	YES	fraction of monthly N uptake target for upper layer		
UPLON/UORGN	R	ST	YES	particulate labile organic N storage in upper layer	lb/ac	kg/ha
UPLTN	R	ST	YES	plant nitrogen storage in upper layer	lb/ac	kg/ha

Table A.12. PERLND NITR Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
UPNUTG	R	ST	INT	same as SPNUTG, for upper layer	lb/ac/d	kg/ha/d
UPRON	R	ST	YES	particulate refractory organic N storage in upper layer	lb/ac	kg/ha
USLON	R	ST	YES	solution labile organic N storage in upper layer	lb/ac	kg/ha
USRON	R	ST	YES	solution refractory organic N storage in upper layer	lb/ac	kg/ha
UTHNLR	R	PM	YES	labile/refractory conversion temperature correction factor for upper layer		
UXFIXA	R	PM	YES	fixed capacity for ammonium for upper layer	ppm	ppm
UXMAXA	R	PM	YES	maximum adsorption capacity of ammonium for upper layer	ppm	ppm
VNPRFG	I	OP	OP	ON means that plant return parameters for nitrogen vary throughout the year		
VNUTFG	I	OP	OP	ON means plant uptake rates for nitrogen vary throughout the year		
WILTPT(4)	R	PM	YES	wilting point for yield-based plant uptake for each soil layer	in	in

Table A.13. PHOS Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
AKADP	R	PM	YES	first order phosphate adsorption rate for active groundwater layer	/ivl	/ivl
AKDSP	R	PM	YES	first order phosphate desorption rate for active groundwater layer	/ivl	/ivl
AKF1P	R	PM	YES	single value Freundlich K for phosphate for active groundwater layer	complex	complex
AKIMP	R	PM	YES	first order phosphate immobilization rate for active groundwater layer	/ivl	/ivl
AKMP	R	PM	YES	first order organic P mineralization rate for active groundwater layer	/ivl	/ivl
AKPLP	R	ST	INT	groundwater layer plant uptake rate (daily or constant)	/ivl	/ivl
AKPLPM(12)	R	PM	YES	same as SKPLPM, for active groundwater layer	/ivl	/ivl
AN1IP	R	PM	YES	1/N1 for phosphate for active groundwater layer		
AORGP	R	ST	YES	organic phosphorus storage in active groundwater layer	lb/ac	kg/ha
AP4AD	R	ST	YES	adsorbed phosphate storage in active groundwater layer	lb/ac	kg/ha
AP4SU	R	ST	YES	solution phosphate storage in active groundwater layer	lb/ac	kg/ha
APDFC	R	ST	YES	yield-based plant uptake deficit for active groundwater layer	lb/ac	kg/ha
APLTP	R	ST	YES	plant phosphorus derived from active groundwater layer	lb/ac	kg/ha
APPUTG	R	ST	INT	same as SPPUTG, for active groundwater layer	lb/ac/d	kg/ha/d
APRXF(5)	R	FX	INT	Active groundwater layer reaction fluxes (recalc same as SPRFX) 1) AADP4- current adsorption flux for phosphate 2) ADSP4- current desorption flux for phosphate 3) AMZOP- current mineralization flux for organic P 4) AIMP4- current immobilization flux for phosphate 5) AUTP4- current plant uptake flux for phosphate	lb/ac/ivl	kg/ha/ivl

Table A.13. PHOS Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
APUPTG	R	ST	INT	yield-based nitrogen uptake target for active gw layer (daily or constant)	lb/ac/ivl	kg/ha/ivl
APUPTM(12)	R	PM	YES	same as SPUPTM, for active groundwater layer		
AXFIXP	R	PM	YES	phosphate fixed capacity for active groundwater layer	ppm	ppm
AXMAXP	R	PM	YES	maximum adsorptive capacity of phosphate for active groundwater layer	ppm	ppm
BIVLP	I	ST	YES	counter used to determine when bio-chemical reactions are to be done		
BNUMP	I	PM	YES	the number of ivls per biochemical timestep for phosphorus		
CIVLP	I	ST	YES	counter used to determine when chemical reactions are to be done		
CMAXP	R	PM	YES	maximum solubility of phosphate in water	ppm	ppm
CNUMP	I	PM	YES	the number of ivls per chemical timestep for phosphorus		
FORPFG	I	OP	OP	adsorption/desorption option flag for phosphate 0 means: use first order temperature dependent kinetics; 1 means: single value Freundlich isotherm		
IORP	R	FX	NO	Special-Action input of organic P		
IP4SU	R	ST	YES	solution phosphate	lb/ac	kg/ha
IPO4	R	FX	NO	Special-Action input of phosphate		
ITMAXP	I	PM	YES	maximum number of iterations for Freundlich solution for phosphate		
LKADP	R	PM	YES	first order phosphate adsorption rate for lower layer	/ivl	/ivl
LKDSP	R	PM	YES	first order phosphate desorption rate for lower layer	/ivl	/ivl
LKF1P	R	PM	YES	single value Freundlich K for phosphate for lower layer	complex	complex
LKIMP	R	PM	YES	first order phosphate immobilization rate for lower layer	/ivl	/ivl
LKMP	R	PM	YES	first order organic P mineralization rate for lower layer	/ivl	/ivl
LKPLP	R	ST	INT	lower layer plant uptake rate (daily or constant)	/ivl	/ivl
LKPLPM(12)	R	PM	YES	same as SKPLPM, for lower layer	/ivl	/ivl
LN1IP	R	PM	YES	1/N1 for phosphate for lower layer		
LORGP	R	ST	YES	organic phosphorus storage in lower layer	lb/ac	kg/ha
LP4AD	R	ST	YES	adsorbed phosphate storage in lower layer	lb/ac	kg/ha
LP4SU	R	ST	YES	solution phosphate storage in lower layer	lb/ac	kg/ha
LPDFC	R	ST	YES	yield-based plant uptake deficit for lower layer	lb/ac	kg/ha
LPLTP	R	ST	YES	plant phosphorus derived from lower layer	lb/ac	kg/ha
LPPUTG	R	ST	INT	same as SPPUTG, for lower layer	lb/ac/d	kg/ha/d
LPRXF(5)	R	FX	INT	lower layer reaction fluxes (recalc same as SPRFX) 1) LADP4- current adsorption flux for phosphate 2) LDSP4- current desorption flux for phosphate 3) LMZOP- current mineralization flux for organic P 4) LIMP4- current immobilization flux for phosphate 5) LUTP4- current plant uptake flux for phosphate	lb/ac/ivl	kg/ha/ivl
LPUPTG	R	ST	INT	yield-based nitrogen uptake target for lower layer (daily or constant)	lb/ac/ivl	kg/ha/ivl
LPUPTM(12)	R	PM	YES	same as SPUPTM, for lower layer		
LXFIXP	R	PM	YES	phosphate fixed capacity for lower layer	ppm	ppm
LXMAXP	R	PM	YES	maximum adsorptive capacity of phosphate for lower layer	ppm	ppm

Table A.13. PHOS Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
ORPMN(5)	R	FX	NO	mineralization fluxes 1) SORPMN- surface layer 2) UORPMN- upper layer 3) LORPMN- lower layer 4) AORPMN- active groundwater 5) TORPMN- total	lb/ac/ivl	kg/ha/ivl
P4IMB(5)	R	FX	NO	immobilization fluxes 1) SP4IMB- surface layer 2) UP4IMB- upper layer 3) LP4IMB- lower layer 4) AP4IMB- active groundwater 5) TP4IMB- total	lb/ac/ivl	kg/ha/ivl
PHACNM(12,2,2)	R	PM	YES	atmospheric deposition concentration in precip at start of calendar month	lb/ac/in	kg/ha/mm
PHADDR(2,2)	R	FX	NO	dry atmospheric deposition flux	lb/ac/ivl	kg/ha/ivl
PHADFG(8)	I	OP	OP	atmospheric deposition flags: -1 = timeseries, 0 = none, >0 = MONTH-DATA table number. Odd subscripts are for dry deposition, even for wet deposition. 1-2,3-4) phosphate and organic P to the surface layer; 5-6,7-8) Same to upper layer		
PHADWT(2,2)	R	FX	NO	wet atmospheric deposition flux	lb/ac/ivl	kg/ha/ivl
PHAFXM(12,2,2)	R	PM	YES	atmospheric deposition flux at start of calendar month	lb/ac/ivl	kg/ha/ivl
PMXRAT	R	PM	YES	ratio of maximum uptake to target uptake for phosphorus		
POPHOS	R	FX	NO	total outflow of phosphorus from the PLS	lb/ac/ivl	kg/ha/ivl
PUPTFG	I	OP	OP	phosphorus plant uptake option flag - 0 means: use first order temperature dependent kinetics; 1 means: use yield-based algorithm		
PUPTFM(12)	R	PM	YES	monthly fraction of total annual yield-based P uptake target		
PUPTGT	R	PM	YES	total annual yield-based plant uptake target of phosphorus	lb/ac	kg/ha
SEDP(2)	R	FX	NO	sediment associated fluxes 1) SDORP- removal of organic P on/with sediment 2) SDP4A- removal of adsorbed phosphate on/with sediment	lb/ac/ivl	kg/ha/ivl
SKADP	R	PM	YES	first order phosphate adsorption rate for surface layer	/ivl	/ivl
SKDSP	R	PM	YES	first order phosphate desorption rate for surface layer	/ivl	/ivl
SKF1P	R	PM	YES	single value Freundlich K for phosphate for surface layer	complex	complex
SKIMP	R	PM	YES	first order phosphate immobilization rate for surface layer	/ivl	/ivl
SKMP	R	PM	YES	first order organic P mineralization rate for surface layer	/ivl	/ivl
SKPLP	R	ST	INT	surface layer plant uptake rate (daily or constant)	/ivl	/ivl
SKPLPM(12)	R	PM	YES	first order phosphate plant uptake rate for the surface layer at the start of each calendar month	/ivl	/ivl
SN1IP	R	PM	YES	1/N1 for phosphate for surface layer		
SORGP	R	ST	YES	organic phosphorus storage in surface layer	lb/ac	kg/ha
SOSEDP	R	FX	NO	surface outflow of sediment associated phosphorus	lb/ac/ivl	kg/ha/ivl
SP4AD	R	ST	YES	adsorbed phosphate storage in surface layer	lb/ac	kg/ha
SP4SU	R	ST	YES	solution phosphate storage in surface layer	lb/ac	kg/ha

Table A.13. PHOS Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
SPDFC	R	ST	YES	yield-based plant uptake deficit for surface layer	lb/ac	kg/ha
SPLTP	R	ST	YES	plant phosphorus derived from surface layer	lb/ac	kg/ha
SPPUTG	R	ST	INT	yield-based P uptake target from surface layer for last day of previous month (daily or constant)	lb/ac/d	kg/ha/d
SPRXF(5)	R	FX	INT	surface layer reaction fluxes 1) SADP4- current adsorption flux for phosphate (every CNUMN intervals) 2) SDSP4- current desorption flux for phosphate (every CNUMN intervals) 3) SMZOP- current mineralization flux for organic P (every BNUMN intervals) 4) SIMP4- current immobilization flux for phosphate (every BNUMN intervals) 5) SUTP4- current plant uptake flux for phosphate (every BNUMN intervals)	lb/ac/ivl	kg/ha/ivl
SPUPTG	R	ST	INT	yield-based nitrogen uptake target for surface layer (daily or constant)	lb/ac/ivl	kg/ha/ivl
SPUPTM(12)	R	PM	YES	fraction of monthly P uptake target for surface layer		
SSP4S(3)	R	FX	NO	fluxes of solution phosphate in subsoil layers 1) LPP4S- percolation from lower layer to active groundwater storage 2) LDPP4S- deep percolation from the lower layer to inactive groundwater 3) AOP4S- active groundwater outflow	lb/ac/ivl	kg/ha/ivl
SXFIXP	R	PM	YES	phosphate fixed capacity for surface layer	ppm	ppm
SXMAXP	R	PM	YES	maximum adsorptive capacity of phosphate for surface layer	ppm	ppm
THKADP	R	PM	YES	temp coefficient for first order phosphate adsorption		
THKDSP	R	PM	YES	temp coefficient for first order phosphate desorption		
THKIMP	R	PM	YES	temp coefficient for first order phosphate immobilization		
THKMP	R	PM	YES	temp coefficient for first order phosphate mineralization		
THPLP	R	PM	YES	temp coefficient for first order plant uptake of phosphate		
TORGP	R	ST	NO	total organic phosphorus storage	lb/ac	kg/ha
TOTPHO	R	ST	NO	total phosphorus stored in the PLS	lb/ac	kg/ha
TP4AD	R	ST	NO	total adsorbed phosphate storage	lb/ac	kg/ha
TP4SU	R	ST	NO	total solution phosphate storage	lb/ac	kg/ha
TPDFC	R	ST	NO	total yield-based plant uptake deficit	lb/ac	kg/ha
TPLTP	R	ST	NO	total plant phosphorus	lb/ac	kg/ha
TSP4S(5)	R	FX	NO	fluxes of solution phosphate in topsoil layers 1) SOP4S- surface outflow 2) SPP4S- percolation from surface to upper layer principal storage 3) UPP4S- percolation from upper layer principal to lower layer 4) IIP4S- flow from upper layer principal to interflow storage 5) IOP4S- interflow outflow	lb/ac/ivl	kg/ha/ivl
UKADP	R	PM	YES	first order phosphate adsorption rate for upper layer	/ivl	/ivl
UKDSP	R	PM	YES	first order phosphate desorption rate for upper layer	/ivl	/ivl
UKF1P	R	PM	YES	single value Freundlich K for phosphate for upper layer	complex	complex

Table A.13. PHOS Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
UKIMP	R	PM	YES	first order phosphate immobilization rate for upper layer	/ivl	/ivl
UKMP	R	PM	YES	first order organic P mineralization rate for upper layer	/ivl	/ivl
UKPLP	R	ST	INT	upper layer plant uptake rate (daily or constant)	/ivl	/ivl
UKPLPM(12)	R	PM	YES	same as SKPLPM, for upper layer	/ivl	/ivl
UN1IP	R	PM	YES	1/N1 for phosphate for upper layer		
UORGP	R	ST	YES	organic phosphorus storage in upper layer	lb/ac	kg/ha
UP4AD	R	ST	YES	adsorbed phosphate storage in upper layer	lb/ac	kg/ha
UP4SU	R	ST	YES	solution phosphate storage in upper layer	lb/ac	kg/ha
UPDFC	R	ST	YES	yield-based plant uptake deficit for upper layer	lb/ac	kg/ha
UPLTP	R	ST	YES	plant phosphorus derived from upper layer	lb/ac	kg/ha
UPPUTG	R	ST	INT	same as SPPUTG, for upper layer	lb/ac/d	kg/ha/d
UPRXF(5)	R	FX	INT	upper layer reaction fluxes (recalc same as SPRFX) 1) UADP4- current adsorption flux for phosphate 2) UDSP4- current desorption flux for phosphate 3) UMZOP- current mineralization flux for org. P 4) UIMP4- current immobilization flux for phosphate 5) UUTP4- current plant uptake flux for phosphate	lb/ac/ivl	kg/ha/ivl
UPUPTG	R	ST	INT	yield-based nitrogen uptake target for upper layer (daily or constant)	lb/ac/ivl	kg/ha/ivl
UPUPTM(12)	R	PM	YES	same as SPUPTM, for upper layer		
UXFIXP	R	PM	YES	phosphate fixed capacity for upper layer	ppm	ppm
UXMAXP	R	PM	YES	maximum adsorptive capacity of phosphate for upper layer	ppm	ppm
VPUTFG	I	OP	OP	ON means plant uptake reaction rates for phosphorus vary throughout the year		

Table A.14. PERLND TRACER Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
ATRSU	R	ST	YES	tracer in active groundwater layer	lb/ac	kg/ha
ITRSU	R	ST	YES	tracer in interflow storage	lb/ac	kg/ha
LTRSU	R	ST	YES	tracer in lower layer storage	lb/ac	kg/ha
POTRS	R	FX	NO	total outflow of tracer from the PLS	lb/ac/ivl	kg/ha/ivl
SSTRS(3)	R	FX	NO	fluxes of tracer in the subsoil layers 1) LPTRS- percolation from lower layer to active groundwater storage 2) LDPTRS- deep percolation from lower layer to inactive groundwater 3) AOTRS- active groundwater outflow	lb/ac/ivl	kg/ha/ivl
STRSU	R	ST	YES	tracer in surface layer storage	lb/ac	kg/ha
TRACNM(12,2)	R	PM	YES	wet atmospheric deposition concentration in precip at start of calendar month	lb/ac/in	kg/ha/mm
TRADDR(2)	R	FX	NO	dry atmospheric deposition flux	lb/ac/ivl	kg/ha/ivl

Table A.14. PERLND TRACER Section

[Internal unit system is unit system specified by the user in the GLOBAL block.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
TRADFG(4)	I	OP	OP	atmospheric deposition flags: -1 = timeseries, 0 = none, >0 = MONTH-DATA table number. Odd subscripts are for dry deposition, even for wet deposition. 1-2) surface layer; 3-4) upper layer		
TRADWT(2)	R	FX	NO	wet atmospheric deposition flux	lb/ac/ivl	kg/ha/ivl
TRAFXM(12,2)	R	PM	YES	dry atmospheric deposition flux at the start of each calendar month	lb/ac/ivl	kg/ha/ivl
TRSU	R	ST	NO	total tracer stored in the PLS	lb/ac	kg/ha
TSTRS(5)	R	FX	NO	fluxes of tracer in the topsoil 1) SOTRS- surface outflow 2) SPTRS- percolation from surface to upper layer principal storage 3) UPTRS- percolation from upper layer principal to lower layer storage 4) IITRS- flow from upper layer principal to interflow storage 5) IOTRS- interflow outflow	lb/ac/ivl	kg/ha/ivl
UTRSU	R	ST	YES	tracer in upper layer principal storage	lb/ac	kg/ha

Table A.15. IMPLND GENERAL Section

Variable Name	Type	Class	SA	Definition
YR	I	DT	NO!	the year (four digits)
MON	I	DT	NO!	calendar month
DAY	I	DT	NO!	day of the month
HR	I	DT	NO!	hour of the day (internal convention)
MIN	I	DT	NO!	minute in the hour (internal convention)

IMPLND ATEMP and SNOW Sections – Same as for PERLND. See Tables A.3 and A.4

Table A.16. IMPLND IWATER Section

[Internal unit system is English, regardless of external unit system.]

Variable Name	Type	Class	SA	Definition	English Units
CSNOFG	I	OP	OP	ON means effects of snow are considered in this RUN; OFF means they are not	
DEC	R	ST	NO	variable used in overland flow routing	complex
FSMSFG	I	ST	YES	ON means this is the first interval with surface moisture supply after one or more intervals without	
IMPEV	R	FX	NO	actual ET from the ILS	in/ivl
IMPS	R	ST	NO	total water stored in the ILS	in
LSUR	R	PM	YES	length of the overland flow plane	ft
NSUR	R	ST	INT	current value of Manning's n for the overland flow plane (daily or constant)	complex

Table A.16. IMPLND IWATER Section

[Internal unit system is English, regardless of external unit system.]

Variable Name	Type	Class	SA	Definition	English Units
NSURM(12)	R	PM	YES	Manning's n for the overland flow plane at the start of each calendar month	complex
PET	R	FX	NO	PET on the ILS, adjusted for snow and air temp	in/ivl
PETADJ	R	ST	INT	PET factor to account for snow cover & air temp (hourly)	
PETINP	R	IT	NO	potential ET on the ILS (input)	in/ivl
PETMAX	R	PM	YES	air temp below which PET is arbitrarily reduced	F
PETMIN	R	PM	YES	air temp below which PET is arbitrarily adjusted to zero	F
RETO	R	FX	NO	retention outflow	in/ivl
RETS	R	ST	YES	retention storage	in
RETSC	R	ST	INT	current value of retention storage capacity (daily or constant)	in
RETSCM(12)	R	PM	YES	retention storage capacity at the start of each calendar month	in
RTLIFG	I	OP	OP	On means surface lateral inflow is subject to retention	
RTOPFG	I	OP	OP	selects surface routing algorithm (0,1)	
SLSUR	R	PM	YES	slope of the overland flow plane	
SMSFG	I	ST	YES	ON means there is surface moisture supply (MSUPY>0)	
SRC	R	ST	NO	variable used in overland flow routing	complex
SUPY	R	FX	NO	precip or (rain + snowpack water yield)	in/ivl
SURI	R	FX	NO	surface inflow	in/ivl
SURLI	R	IT	NO	surface lateral inflow	in/ivl
SURO	R	FX	NO	surface outflow	in/ivl
SURS	R	ST	YES	surface (overland flow) storage	in
VNNFG	I	OP	OP	ON means Manning's n for overland flow varies through the year	
VRSFG	I	OP	OP	ON means retention storage capacity varies through the year	

Table A.17. IMPLND SOLIDS Section

[Internal unit system is English, regardless of external unit system.]

Variable Name	Type	Class	SA	Definition	English Units
ACCSDM(12)	R	PM	YES	accumulation rate of solids at the start of each month	tons/ac/d
ACCSDP	R	ST	INT	current value of accumulation rate of solids (daily or constant)	tons/ac/d
DRYDFG	I	ST	YES	ON means precip did not occur during the previous day	
JEIM	R	PM	YES	exponent of surface runoff outflowin solids washoff equation	complex
KEIM	R	PM	YES	coefficent in solids washoff equation	complex
REMSDM(12)	R	PM	YES	unit-rate removal of solids at the start of each month	/d
REMSDP	R	ST	INT	current value of unit-rate removal of solids (daily or constant)	/d
SDOPFG	I	OP	OP	selects algorithm for removal of sediment from the surface (0,1)	
SLDS	R	ST	YES	solids storage	tons/ac
SLSLD	R	IT	NO	lateral input of solids	tons/ac/ivl
SOSLD	R	FX	NO	solids removed by washoff	tons/ac/ivl
VASDFG	I	OP	OP	ON means accumulation rate of solids is allowed to vary throughout the year	
VRSDFG	I	OP	OP	ON means unit-rate of removal of solids is allowed to vary throughout the year	

Table A.18. IMPLND IWTGAS Section

[Internal unit system is English, regardless of external unit system.]

Variable Name	Type	Class	SA	Definition	English Units
AIRTC	R	ST	NO	air temp at end of current interval	C
AWTF	R	ST	INT	y-intercept for water temperature regression equation (daily or constant)	C
AWTFM(12)	R	PM	YES	value of AWTF at start of each calendar month	C
BWTF	R	ST	INT	slope for water temperature regression equation (daily or constant)	none
BWTFM(12)	R	PM	YES	value of BWTF at start of each calendar month	
ELEVGC	R	PM	YES	correction factor for elevation above sea level (used in dissolved gases calc)	complex
SOCO2	R	ST	NO	concentration of CO2 in surface outflow	mg C/l
SOCO2M	R	FX	NO	flux of CO2 in surface outflow	mg C.in/l/ivl
SODOX	R	ST	NO	concentration of DO in surface outflow	mg/l
SODOXM	R	FX	NO	flux of DO in surface outflow	mg.in/l/ivl
SOHT	R	FX	NO	heat energy in surface outflow, relative to freezing point	C.in/ivl
SOTMP	R	ST	NO	surface outflow temp	C
WTFVFG	I	OP	OP	ON means water temperature regression parameters are allowed to vary throughout the year	

Table A.19. IMPLND IQUAL Section

[Internal unit system is a combination of English units and the user-specified “qty” (QTYID in Table-Type QUAL-PROPS), regardless of external unit system.]

Variable Name	Type	Class	SA	Definition	English Units
ACQOP(7)	R	ST	INT	accumulation rate of QUALOF (daily or constant)	qty/ac/d
ACQOPM(12,7)	R	PM	YES	accumulation rate of each QUALOF, at the start of each calendar month	qty/ac/d
IQACNM(12,10)	R	PM	YES	wet atmospheric deposition concentration in precip at start of calendar month	qty/ac/in
IQADDR(10)	R	FX	NO	dry atmospheric deposition flux	qty/ac/ivl
IQADFG(20)	I	OP	OP	atmospheric deposition flags: -1 = timeseries, 0 = none, >0 = MONTH-DATA table number. Odd subscripts are for dry deposition, even for wet deposition. Flag must be zero if QUAL is not a QUALOF.	
IQADWT(10)	R	FX	NO	wet atmospheric deposition flux	qty/ac/ivl
IQAFXM(12,10)	R	PM	YES	dry atmospheric deposition flux at the start of each calendar month	qty/ac/ivl
POTFW(7)	R	ST	INT	washoff potency factor (daily or constant)	qty/ton
POTFWM(12,7)	R	PM	YES	washoff potency factor at the start of each calendar month	qty/ton
REMQOM(12,7)	R	PM	YES	unit removal rate of each QUALOF, at the start of each calendar month	/d
REMQOP(7)	R	ST	INT	unit removal rate of QUALOF (daily or constant)	/d
SOQC(10)	R	ST	NO	concentration of QUAL in the surface runoff	qty/ac/in
SOQO(7)	R	FX	NO	washoff of QUALOF from the surface	qty/ac/ivl
SOQOC(7)	R	ST	NO	concentration of QUALOF in the surface runoff	qty/ac/in
SOQS(7)	R	FX	NO	outflow of QUALSD from the surface	qty/ac/ivl
SOQUAL(10)	R	FX	NO	total outflow of QUAL from the surface	qty/ac/ivl
SQO(7)	R	ST	YES	storage of QUALOF on the surface	qty/ac
VPFWFG(7)	I	OP	OP	ON means washoff potency factors are allowed to vary throughout the year	
VQOFG(7)	I	OP	OP	ON means the accumulation rate and limiting storage (hence, removal rate) vary throughout the year	
WSFAC(7)	R	PM	YES	susceptibility of each QUALOF to washoff	/in

Table A.20. RCHRES GENERAL Section

Variable Name	Type	Class	SA	Definition
YR	I	DT	NO!	the year (four digits)
MON	I	DT	NO!	calendar month
DAY	I	DT	NO!	day of the month
HR	I	DT	NO!	hour of the day (internal convention)
MIN	I	DT	NO!	minute in the hour (internal convention)

Table A.21. RCHRES HYDR Section

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
AKAPPA	R	PM	YES	Karman constant		
AUX1FG	I	OP	OP	ON means DEP, STAGE, SAREA, AVDEP, HRAD, and TWID will be computed		
AUX2FG	I	OP	OP	ON means AVVEL and AVSECT will be computed		
AUX3FG	I	OP	OP	ON means TAU and USTAR will be computed		
AVDEP	R	ST	NO	average depth (volume/surf area)	ft	m
AVSECT	R	ST	NO	mean cross section area (VOL/LEN)	ft2	m2
AVVEL	R	ST	NO	average flow velocity (RO/VOL)	ft/s	m/s
CDFVOL(5,100)	R	ST	YES	cumulative deficit in g(t) category demand	ft3	m3
CEVAP	I	OP	OP	if > 0, the category number for evap; if <= 0, absolute value is the number of categories in HYDR-CEVAP		
CEVAPC(20)	I	PM	YES	category numbers for evaporation		
CEVAPC(20)	I	PM	YES	category priorities for evaporation		
CEVAPF(20)	R	PM	YES	category fractions for evaporation		
CFVOL(5)	I	OP	OP	if > 0, the category number for f(vol) flow for each exit if <= 0, absolute value is the number of categories in HYDR-CFVOL for each exit		
CFVOLC(20,5)	I	PM	YES	category numbers for f(vol) flows		
CFVOLF(20,5)	R	PM	YES	category fractions for f(vol) flows		
CFVOLP(20,5)	I	PM	YES	category priorities for f(vol) flows		
CIVOL(100)	R	IT	NO	volume of inflow of each category entering through gate INFLO	ft3/ivl	m3/ivl
CO(5,100)	R	ST	NO	outflow rates of each category from exit at end of interval	ft3/s	m3/s
COGTC(20)	I	PM	YES	category numbers for g(t) demands		
COGTE(20)	I	PM	YES	exit of category g(t) demands		
COGTP(20)	R	PM	YES	category priorities for g(t) demands		
COKS	R	PM	YES	complement of KS (1.0-KS)		
COLIND(5)	R	IT	NO	indicates which (pair of) columns in RCHTAB are used to evaluate f(VOL)		
CONVF	R	ST	INT	current value of f(VOL) adjustment factor (daily or constant)		
CONVFM(12)	R	PM	YES	f(VOL) adjustment factors for the start of each calendar month		
COREL(5,100)	R	IT	NO	g(t) component of category release	ft3/s	m3/s
COTDGT(5,100)	R	IT	NO	g(t) component of category demand	ft3/s	m3/s
COVOL(5,100)	R	FX	NO	volumes of outflow of each category	ft3/ivl	m3/ivl
CPREC	I	OP	OP	if > 0, the category number for precip; if <= 0, absolute value is the number of categories specified in HYDR-CPREC		

Table A.21. RCHRES HYDR Section

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
CPRECC(20)	I	PM	YES	category numbers for precipitation		
CPRECF(20)	R	PM	YES	category fractions for precipitation		
CRO(100)	R	ST	NO	total rate of outflow of each category from RCHRES at end of interval	ft3/s	m3/s
CROVOL(100)	R	FX	NO	total volume of outflow of each category	ft3/ivl	m3/ivl
CVOL(100)	D	ST	YES	volume of each category in the RCHRES at end of interval	ft3	m3
DB50	R	PM	YES	median diameter of bed material	ft	m
DELTH	R	PM	YES	drop in the energy line along the length of this RCHRES	ft	m
DEP	R	ST	NO	depth, at specified location	ft	m
FACTA1	R	PM	YES	1.0/(COKS*DELTS)	/s	/s
FUNCT(5)	I	OP	OP	flag indicating which function to use in combining the components of an outflow demand: 1 means use Min(f(VOL),g(t)) 2 means use Max(f(VOL),g(t)) 3 means use f(VOL)+g(t)		
GAM	R	PM	YES	unit weight of water	lb/ft3	kg/m3
GRAV	R	PM	YES	acceleration due to gravity	ft/sec2	m/sec2
HRAD	R	ST	NO	hydraulic radius	ft	m
IVOL	R	IT	NO	volume of inflow entering through gate INFLO	ft3/ivl	m3/ivl
KS	R	PM	YES	weighting factor for hydraulic routing		
LEN	R	PM	YES	length of the reach	ft	m
NCOGT	I	OP	OP	number of g(t) category demands in HYDR-CDEMAND		
NCOLS	I	OP	OP	no of 'cols' in RCHTAB		
NODFV	I	OP	OP	no of outflow demands in this reach which have a f(VOL) component		
NODGT	I	OP	OP	no of outflow demands in this reach which have a g(t) component		
NROWS	I	OP	OP	no of 'rows' in RCHTAB		
O(5)	R	ST	YES	outflow rates from each exit at end of interval	ft3/s	m3/s
ODFVFG(5)	I	OP	OP	if 0, this outflow demand does not have a f(VOL) component if >0, this outflow demand does have a f(VOL) component -- value is column no in RCHTAB containing f(VOL). if <0, this outflow demand does have a f(VOL) component – absolute value is the element of array COLIND( ) which indicates the (pair) of columns in RCHTAB to be used for evaluation of f(VOL)		
ODGTFG(5)	I	OP	OP	if 0, outflow demand does not have a g(t) component. if >0, outflow demand does have a g(t) component -- value is the element of array OUTDGT( ) which contains the component		
OS(5)	R	ST	NO	outflow rates from each exit at start of interval	ft3/s	m3/s
OUTDGT(5)	R	IT	NO	g(t) component of outflow demand	ft3/s	m3/s
OVOL(5)	R	FX	NO	volumes of outflow	ft3/ivl	m3/ivl
POTEV	R	IT	NO	potential evap from the RCHRES	ft/ivl	m/ivl
PREC	R	IT	NO	precipitation on surface of RCHRES	ft/ivl	m/ivl
PRSUPY	R	FX	NO	volume of water contributed by precip on surface of RCHRES	ft3/ivl	m3/ivl

Table A.21. RCHRES HYDR Section

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
RCHTAB(100)	R	PM	YES	table containing geometric and hydraulic properties of the reach. Each row of NCOLS members contains: Depth Surface area Volume f(Vol)(NCOLS-3)	 ft ft2 ft3 ft3/s	 m m2 m3 m3/s
RO	R	ST	YES	total rate of outflow at end of interval	ft3/s	m3/s
ROS	R	ST	NO	total rate of outflow at start of interval	ft3/s	m3/s
ROVOL	R	FX	NO	total volume of outflow	ft3/ivl	m3/ivl
ROWPT	I	ST	YES	points to row of RCHTAB last in use		
SAREA	R	ST	NO	surface area	ft2	m2
SLOPE	R	PM	YES	slope of the RCHRES (DELTH/LEN)		
STAGE	R	ST	NO	stage, at specified location	ft	m
STCOR	R	PM	YES	Depth+STCOR= Stage	ft	m
TAU	R	ST	NO	bed shear stress	lb/ft2	kg/m2
TWID	R	ST	NO	mean top width (surf area/length)	ft	m
USTAR	R	ST	NO	shear velocity	ft/s	m/s
VCONFG	I	OP	OP	ON means f(VOL) outflow demand components are multiplied by a factor which is allowed to vary through the year		
VOL	D	ST	YES	volume of water in the RCHRES at end of interval	ft3	m3
VOLEV	R	FX	NO	volume of water lost by evaporation	ft3/ivl	m3/ivl
VOLS	D	ST	YES	volume of water in the RCHRES at start of current interval	ft3	m3

Table A.22. RCHRES ADCALC Section

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
CRRAT	R	PM	YES	critical value of ratio of mean flow time through RCHRES to simulation interval		
EOVOL(5)	R	FX	NO	fluxes for individual exit gates, based on conditions at end of interval	ft3/ivl	m3/ivl
EROVOL	R	FX	NO	total flux, based on conditions at end of interval	ft3/ivl	m3/ivl
SOVOL(5)	R	FX	NO	fluxes for individual exit gates, based on conditions at start of interval	ft3/ivl	m3/ivl
SROVOL	R	FX	NO	total flux, based on conditions at start of interval	ft3/ivl	m3/ivl

Table A.23. RCHRES CONS Section

[Internal unit system is a combination of the selectedexternal unit system and the user-specified units “conc” and “qty” (CONCID and QTYID in Table-Type CONS-DATA.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
CCONV(10)	R	PM	YES	factors to convert from qty/vol to conc units: conc= CCONV* qty/vol (in English system, vol is ft3) (in Metric system, vol is m3)		
COACNM(12,10)	R	PM	YES	wet atmospheric deposition concentration in precip at start of calendar month	conc	conc
COADDR(10)	R	FX	NO	dry atmospheric deposition flux	conc.ft3/ivl	conc.m3/ivl

Table A.23. RCHRES CONS Section

[Internal unit system is a combination of the selectedexternal unit system and the user-specified units “conc” and “qty” (CONCID and QTYID in Table-Type CONS-DATA.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
COADFG(20)	I	OP	OP	atmospheric deposition flags for each constituent: -1 = timeseries, 0 = none, >0 = MONTH-DATA table number. Odd subscripts are for dry deposition, even for wet deposition.		
COADWT(10)	R	FX	NO	wet atmospheric deposition flux	conc.ft3/ivl	conc.m3/ivl
COAFXM(12,10)	R	PM	YES	dry atmospheric deposition flux at the start of each calendar month	conc.ft3/ft2/ivl	conc.m3/m2/ivl
CON(10)	D	ST	YES	conservative constituent concentrations	conc	conc
ICON(10)	R	IT	NO	inflow of conservative constituents	conc.ft3/ivl	conc.m3/ivl
OCON(5,10)	R	FX	NO	outflow of conservative constits	conc.ft3/ivl	conc.m3/ivl
RCON(10)	D	ST	NO	storage at end of current interval	conc.ft3	conc.m3
ROCON(10)	R	FX	NO	total outflow of conservative constituents	conc.ft3/ivl	conc.m3/ivl

Table A.24. RCHRES HTRCH Section

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
AIRTMP	R	ST	NO	air temp at the RCHRES	C	C
BEDFLG	I	OP	OP	flag indicating bed exchange algorithm: 0 - none, 1 - single layer, 2 - two-layer, 3 – Jobson		
CFPRES	R	PM	YES	pressure correction factor for conductive-convective heat transport.		
CFSAEX	R	PM	YES	fraction of RCHRES surface area exposed to radiation		
CLOUD	R	IT	NO	cloud cover	tenths	tenths
DELH(100)	R	PM	YES	sediment-to-water heat flux per deg change in water temp for previous TSTOP intervals (BEDFLG=3)	kcal/m2/C	kcal/m2/C
DELTT(100)	R	ST	NO	water temp changes for previous TSTOP intervals (BEDFLG=3)	C	C
DEWTMP	R	IT	NO	Dewpoint	C	C
ELDAT	R	PM	YES	difference in elev. between RCHRES and air temp gage (+ if RCHRES is > gage)	ft	ft
ELEV	R	PM	YES	mean RCHRES elevation	ft	ft
GATMP	R	IT	NO	air temperature at the gage	C	C
HTEXCH	R	FX	NO	total heat exchange w/ atmosphere	C.ft3/ivl	C.m3/ivl
IHEAT	R	IT	NO	inflow of thermal energy	C.ft3/ivl	C.m3/ivl
KATRAD	R	PM	YES	longwave radiation coefficient	complex	complex
KCOND	R	PM	YES	conduction-convection coefficient	complex	complex
KEVAP	R	PM	YES	evaporation coefficient	complex	complex
KGRND	R	PM	YES	heat conduction coefficient between mud layer and ground (BEDFLG=2)	kcal/m2/C/ivl	kcal/m2/C/ivl
KMUD	R	PM	YES	heat conduction coefficient between water and ground (BEDFLG=1) or mud (BEDFLG=2)	kcal/m2/C/ivl	kcal/m2/C/ivl
LAPSE(24)	R	PM	YES	value of the assumed dry air lapse rate for each hour of the day	C/ft	C/ft
MUDDEP	R	PM	YES	depth of mud layer (BEDFLG=2)	m	m
OHEAT(5)	R	FX	NO	outflow of thermal energy	C.ft3/ivl	C.m3/ivl

Table A.24. RCHRES HTRCH Section

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
QBED	R	FX	NO	bed heat exchange	C.ft3/ivl	C.m3/ivl
QCON	R	FX	NO	heat exchange by conduction and convection	C.ft3/ivl	C.m3/ivl
QEVAP	R	FX	NO	heat removal by evaporation	C.ft3/ivl	C.m3/ivl
QLONGW	R	FX	NO	exchange of longwave radiation	C.ft3/ivl	C.m3/ivl
QPREC	R	FX	NO	heat input in precipitation	C.ft3/ivl	C.m3/ivl
QSOLAR	R	FX	NO	input of solar radiation	C.ft3/ivl	C.m3/ivl
QTOTAL	R	FX	NO	total heat exchange	C.ft3/ivl	C.m3/ivl
RHEAT	R	ST	YES	storage at end of current interval	C.ft3	C.m3
ROHEAT	R	FX	NO	total outflow of thermal energy	C.ft3/ivl	C.m3/ivl
SOLRAD	R	IT	NO	solar radiation	Ly/ivl	Ly/ivl
TGFLG	I	OP	OP	flag indicating source of ground temp: 1 means a timeseries either input or computed, 2 means a single user-supplied value, 3 means 12 user-supplied values (one for each month)		
TGRND	R	ST	INT	current ground temperature (BEDFLG=1 or 2) (daily, constant, or timeseries)	C	C
TGRNDM(12)	R	PM	YES	monthly values of ground temperature (BEDFLG=1 or 2, TGFLG=3)	C	C
TMUD	R	ST	YES	current mud temp (BEDFLG=2)	C	C
TMUDDT	R	ST	YES	slope of mud temp curve (BEDFLG=2)	C	C
TSTOP	I	OP	OP	number of intervals for Jobson method		
TW	R	ST	NO	water temperature	C	C
WIND	R	IT	NO	wind movement	m/ivl	m/ivl

Table A.25. RCHRES SEDTRN Section

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
BEDDEP	R	ST	NO	bed depth	ft	m
BEDWID	R	PM	YES	width of bed for purpose of estimating bed thickness	ft	m
BEDWRN	R	PM	YES	bed sediment depth which, if exceeded, will result in warning message	ft	m
DB50E	R	PM	YES	DB50 in English units (for Toffaleti method)	ft	ft
DB50M	R	PM	YES	DB50 in metric units (for Colby method)	mm	mm
DEPSCR(4)	R	FX	NO	deposition/scour fluxes (positive for deposition, negative for scour): 1) sand, 2) silt, 3) clay, 4) total	mg.ft3/l/ivl	mg.m3/l/ivl
ISED(3)	R	IT	NO	inflow of sediment: 1) sand, 2) silt, 3) clay	mg.ft3/l/ivl	mg.m3/l/ivl
OSED(5,4)	R	FX	NO	outflow by exit	mg.ft3/l/ivl	mg.m3/l/ivl
POR	R	PM	YES	porosity of the bed sediment		
ROSED(4)	R	FX	NO	total outflow from RCHRES	mg.ft3/l/ivl	mg.m3/l/ivl
RSED(10)	R	ST	NO	sediment storages: 1-3) suspended sand, silt, clay;| 4-6) bed sand, silt, clay; 7-9) total sand, silt, clay; 10) total sediment	mg.ft3/l	mg.m3/l
RSSED(3)	D	ST	NO	total storage of 1) sand, 2) silt, and 3) clay	mg.ft3/l	mg.m3/l
SANDFG	I	OP	OP	method used to compute sandload: 1-Colby, 2-Toffaleti, 3-Input power function		

Table A.25. RCHRES SEDTRN Section

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
SDPM(6,3)	R	PM	YES	sediment parameters: second subscript is:1) sand, 2) silt, 3) clay; first subscript is: 1) D- particle diameter 2) W- particle settling velocity in still water 3) RHO- particle density 4) KSAND- for sand- coefficient in input power function TAUCD- for silt, clay- critical shear stress for deposition 5) EXPSND- for sand- exponent in input power function TAUCS- for silt, clay- critical shear stress for scour 6) (unused)- for sand M- for silt, clay- erodibility coefficient	 ft m/ivl gm/cm3 lb/ft2 complex lb/ft2 complex kg/m2/ivl	 m m/ivl gm/cm3 kg/m2 complex kg/m2 complex kg/m2/ivl
SSED(4)	R	ST	YES	concentrations in suspension: 1) sand, 2) silt, 3) clay, 4) total	mg/l	mg/l
WSANDE	R	PM	YES	W for sand in English units for Toffaleti method	ft/s	ft/s

Table A.26. RCHRES GQUAL Section

[Internal unit system is a combination of the selected external unit system and the user-specified units “concu” and “qty” (CONCID and QTYID in Table-Type GQ-QALDATA). Last subscript selects qual.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
ADDCPM(4,3)	R	PM	YES	decay parameters for adsorbed material: 1) KSUSP- decay rate on suspended sediment 2) THSUSP- temp correction coefficient for suspended sediment 3) KBED- decay rate on bed sediment 4) THBED- temp correction coefficient for bed sediment	 /ivl /ivl	 /ivl /ivl
ADPM(6,3,3)	R	PM	YES	Adsorption/desorption parameters for each qual: 1st subscript selects: 1-3) suspended sand, silt, clay; 4-6) bed sand, silt, clay 2nd subscript selects: 1) KA- distribution coefficient 2) K- transfer rate between adsorbed and desorbed states 3) THK- temp correction coefficient	 l/mg /ivl	 l/mg /ivl
ADQAL(7,3)	R	FX	NO	adsorption/desorption to/from: 1-3) suspended sand, silt, clay; 4-6) bed sand, silt, clay; 7) total	concu.ft3/l/ivl	concu.m3/l/ivl
ALPH(18)	R	PM	YES	base light absorption coefficients for clear water for 18 wavelengths of light	/cm	/cm
BIO(3)	R	IT	NO	concentration of biomass causing biodegradation for each qual	mg biomass/l	mg biomass/l
BIOM(12,3)	R	PM	YES	monthly values of biomass which biodegrades qual	mg/l	mg/l
BIOPM(2,3)	R	PM	YES	biodegradation parameters: 1) BIOCON- second order biodegradation rate constant 2) THBIO- temp correction factor	 l/mg/ivl	 l/mg/ivl
C(3,3,6)	R	PM	YES	matrix for specifying production of daughter compounds: C(I,J,K) means the amount of I produced per unit of J decomposed through decay process K (matrix must be upper triangular with zeros on diagonal)	concu I/concu J	concu I/concu J

Table A.26. RCHRES GQUAL Section

[Internal unit system is a combination of the selected external unit system and the user-specified units "concu" and "qty" (CONCID and QTYID in Table-Type GQ-QALDATA). Last subscript selects qual.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
CFGAS(3)	R	PM	YES	ratio of volatization rate of qual to oxygen reaeration rate		
CINV(3)	R	PM	YES	1.0/CONV(I)		
CLD	R	ST	INT	cloud cover (daily, constant, or timeseries)	tenths	tenths
CLDFG	I	OP	OP	source of cloud cover data when GQALFG(3)=1: code same as TEMPFG.		
CLDM(12)	R	PM	YES	monthly values of cloud cover	tenths	tenths
CONV(3)	R	PM	YES	factor to convert from qty/vol to concentration units: concu/l= CONV*qty/vol, where vol is in ft3 or m3		
DAUGFG(3)	I	OP	OP	indicates whether or not a qual is a daughter compound		
DDQAL(7,3)	R	FX	NO	decay of dissolved qual	concu.ft3/l/ivl	concu.m3/l/ivl
DEL(18)	R	PM	YES	increments to ALPH for phytoplankton-laden water for 18 wavelengths of light	l/mg/cm	l/mg/cm
DQAL(3)	R	ST	YES	concentration of dissolved qual	concu/l	concu/l
DSQAL(4,3)	R	FX	NO	deposition & scour of qual (with sediment): 1-3) on sand, silt, clay; 4) total	concu.ft3/l/ivl	concu.m3/l/ivl
FACT1	R	PM	YES	CFSAEX*DELT60/24	d/ivl	d/ivl
GAMM(18)	R	PM	YES	increments to ALPH for sediment-laden water for 18 wavelengths of light	l/mg/cm	l/mg/cm
GDAUFG(6)	I	OP	OP	indicates whether or not any qual is a daughter product through each of the 6 possible decay processes		
GENPM(2,3)	R	PM	YES	general first order decay parameters: 1) FSTDEC- first order decay rate 2) THFST- temp correction factor	/ivl	/ivl
GQACNM(12,3)	R	PM	YES	wet atmospheric deposition concentration in precip at start of calendar month	concu/l	concu/l
GQADDR(3)	R	FX	NO	dry atmospheric deposition flux of qual	concu.ft3/l/ivl	concu.m3/l/ivl
GQADFG(6)	I	OP	OP	atmospheric deposition flags for each qual: -1 = timeseries, 0 = none, >0 = MONTH-DATA table number. Odd subscripts are for dry deposition, even for wet deposition.		
GQADWT(3)	R	FX	NO	wet atmospheric deposition flux of qual	concu.ft3/l/ivl	concu.m3/l/ivl
GQAFXM(12,3)	R	PM	YES	dry atmospheric deposition flux at the start of each calendar month	concu.ft3/ l.ft2.ivl	concu.m3/ l.m2.ivl
GQALFG(7)	I	OP	OP	indicates whether or not any of the quals undergoes the 6 possible decay processes or is sediment-associated		
GQPM2(7,3)	I	OP	OP	daughter process flag: 1-6) indicate whether or not this qual is a "daughter" product through each of the 6 possible decay processes: 1) hydrolysis 2) oxidation 3) photolysis 4) volatilization 5) biodegradation 6) general first order decay 7) source of biomass data for qual I when QALFG(5,I)= 1: code same as TEMPFG.		

Table A.26. RCHRES GQUAL Section

[Internal unit system is a combination of the selected external unit system and the user-specified units “concu” and “qty” (CONCID and QTYID in Table-Type GQ-QALDATA). Last subscript selects qual.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
HYDPM(4,3)	R	PM	YES	hydrolysis parameters: 1) KA- second order acid rate constant 2) KB- second order base rate constant 3) KN- first order rate for neutral reaction 4) THHYD- temp correction parameter	 /ivl /ivl /ivl	 /ivl /ivl /ivl
IDQAL(3)	R	IT	NO	inflow of dissolved qual	concu.ft3/l/ivl	concu.m3/l/ivl
ISQAL(3,3)	R	IT	NO	inflow of qual (2nd subscript) on sand, silt, and clay (1st subscript)	concu.ft3/l/ivl	concu.m3/l/ivl
KCLD(18)	R	PM	YES	efficiency of cloud cover in intercepting light, for 18 wavelengths of light		
LAT	I	PM	YES	latitude of the RCHRES when GQALFG(3)=1; positive for northern hemisphere		
LIT(18,4)	R	PM	YES	light intensity for each of 18 wavelengths of light; second subscript selects season: 1) spring: Mar-May (Sep-Nov if LAT < 0) 2) summer: Jun-Aug (Dec-Feb if LAT < 0) 3) fall: Sep-Nov (Mar-May if LAT < 0) 4) winter: Dec-Feb (Jun-Aug if LAT < 0)	mEinstein/ cm2/d	mEinstein/ cm2/d
LITFG	I	ST	YES	indicates whether or not a new set of light data will be required next time step		
LSET	I	ST	YES	indicates current set of light data being used		
ODQAL(5,3)	R	FX	NO	outflows of dissolves quals thru individual exits	concu.ft3/l/ivl	concu.m3/l/ivl
OSQAL(5,3,3)	R	FX	NO	outflow of qual thru individual exits; second subscript selects: 1) sand, 2) silt, 3) clay	concu.ft3/l/ivl	concu.m3/l/ivl
PDQAL(3)	R	FX	NO	input from decay of parent compounds	concu.ft3/l/	concu.m3/l/
PHFLAG	I	OP	OP	source of the pH data when GQALFG(1)=1: code same as TEMPFG.		
PHOTPM(20,3)	R	PM	YES	other photolysis parameters for each qual 1-18) molar absorption coefficients for 18 wavelengths of light 19) quantum yield in air-saturated pure water 20) temp correction coefficient	mole/Einstein	mole/Einstein
PHVAL	R	IT	NO	value of water pH		
PHVALM(12)	R	PM	YES	monthly pH values		
PHY	R	ST	INT	phytoplankton concentration (as biomass) (daily, constant, or timeseries)	mg/l	mg/l
PHYM(12)	R	PM	YES	monthly values of phytoplankton concentration	mg/l	mg/l
PHYTFG	I	OP	OP	source of phytoplankton data when GQALFG(3)=1: code same as TEMPFG.		
QALFG(7,3)	I	OP	OP	qual process flags: 1-6) indicates which of the 6 decay processes are active for each qual; 7) indicates whether or not the qual is sediment-associated		
QALGFG(3)	I	OP	OP	indicates whether or not a qual undergoes any of the 6 decay processes		
RDQAL(3)	R	ST	NO	storage of dissolved qual	concu.ft3/l	concu.m3/l
ROC	R	IT	NO	concentration of free radical oxygen	mole/l	mole/l
ROCM(12)	R	PM	YES	monthly values for free radical oxygen	moles/l	moles/l
RODQAL(3)	R	FX	NO	total outflow of dissolved qual	concu.ft3/l/ivl	concu.m3/l/ivl
ROSQAL(4,3)	R	FX	NO	total outflow of adsorbed qual: 1-3) on sand, silt, clay; 4) total	concu.ft3/l/ivl	concu.m3/l/ivl

Table A.26. RCHRES GQUAL Section

[Internal unit system is a combination of the selected external unit system and the user-specified units “concu” and “qty” (CONCID and QTYID in Table-Type GQ-QALDATA). Last subscript selects qual.]

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
ROXFG	I	OP	OP	source of free radical oxygen data when GQALFG(2)=1: code same as TEMPFG.		
ROXPM(2,3)	R	PM	YES	oxidation parameters: 1) KOX- rate parameter 2) THOX- temp correction parameter	moles/l/ivl	moles/l/ivl
RRQAL(3)	R	ST	NO	total storage of qual in RCHRES	concu.ft3/l	concu.m3/l
RSQAL(12,3)	R	ST	NO	storage of qual on sediment: 1-3) on suspended sand, silt, clay 4) total in suspension 5-7) on bed sand, silt, clay 8) total in bed 9-11) total on sand, silt, clay 12) total on sediment	concu.ft3/l	concu.m3/l
SDCNC	R	ST	INT	total suspended sediment concentration (daily, constant, or timeseries)	mg/l	mg/l
SDCNCM(12)	R	PM	YES	monthly values of sediment concentration	mg/l	mg/l
SDFG	I	OP	OP	source of sediment concentration data when GQALFG(3)=1: code same as TEMPFG.		
SQAL(6,3)	R	ST	YES	concentration of qual on: 1-3) suspended sand, silt, clay= 4-6) bed sand, silt, clay	concu/mg	concu/mg
SQDEC(7,3)	R	FX	NO	decay of qual on: 1-3) suspended sand, silt, clay; 4-6) bed sand, silt, clay; 7) total	concu.ft3/l/ivl	concu.m3/l/ivl
TEMPFG	I	OP	OP	source of water temperature data: 1 means a timeseries either input or computed, 2 means a single user-supplied value, 3 means 12 user-supplied values (monthly)		
TEMPM(12)	R	PM	YES	monthly water temp values	C	C
TWAT	R	ST	INT	water temperature (daily, constant, or timeseries)	C	C

Table A.27. RCHRES RQUAL Section

Variable Name	Type	Class	SA	Definition	Units
AVDEPE	R	PM	YES	average depth in English units	ft
AVVELE	R	PM	YES	average velocity in English units	ft/s
BENRFG	I	OP	OP	if ON, benthal influences are enabled	
DEPCOR	R	PM	YES	conversion factor from bottom surface area to volume	m2/l
SCRFAC	R	PM	YES	scour factor in effect for interval	
SCRMUL	R	PM	YES	multiplier to increase benthal releases during scouring	
SCRVEL	R	PM	YES	velocity above which effect of scouring on benthal release rates is considered	ft/s

Table A.28. RCHRES OXRX Section

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
BALBOD	R	FX	NO	benthic algae death	mg.ft3/l/ivl	mg.m3/l/ivl
BALDOX	R	FX	NO	benthic algae growth/respiration	mg.ft3/l/ivl	mg.m3/l/ivl
BENDOX	R	FX	NO	benthal oxygen demand	mg.ft3/l/ivl	mg.m3/l/ivl
BENOD	R	PM	YES	benthal oxygen demand (with unlimited DO concentration at 20 Deg C)	mg/m2/ivl	mg/m2/ivl

Table A.28. RCHRES OXRX Section

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
BNRBOD	R	FX	NO	benthal release	mg.ft3/l/ivl	mg.m3/l/ivl
BOD	R	ST	YES	biochemical oxygen demand concentration	mg/l	mg/l
BODDOX	R	FX	NO	BOD decay	mg.ft3/l/ivl	mg.m3/l/ivl
BODOX	R	FX	NO	oxygen required to satisfy BOD decay	mg/l/ivl	mg/l/ivl
BRBOD(2)	R	PM	YES	benthal BOD release parameters: 1) release in fully aerobic conditions; 2) increment to release under anaerobic conditions	mg/m2/ivl	mg/m2/ivl
CFOREA	R	PM	YES	correction factor for reaeration coefficient for lakes		
DECBOD	R	FX	NO	decay	mg.ft3/l/ivl	mg.m3/l/ivl
DENBOD	R	FX	NO	denitrification	mg.ft3/l/ivl	mg.m3/l/ivl
DOX	R	ST	YES	dissolved oxygen concentration	mg/l	mg/l
EXPOD	R	PM	YES	exponent multiplier for DO concentration in benthal oxygen demand equation		
EXPRED	R	PM	YES	exponent to depth used in calculation of reaeration coefficient		
EXPREL	R	PM	YES	exponent multiplier for DO concentration in benthal BOD release equation		
EXPREV	R	PM	YES	exponent to velocity used in calculation of reaeration coefficient		
IBOD	R	IT	NO	inflow of biochem oxygen demand	mg.ft3/l/ivl	mg.m3/l/ivl
IDOX	R	IT	NO	inflow of dissolved oxygen	mg.ft3/l/ivl	mg.m3/l/ivl
KBOD20	R	PM	YES	unit BOD decay rate at 20 deg C	/ivl	/ivl
KODSET	R	PM	YES	rate of BOD settling	ft/ivl	ft/ivl
KOREA	R	FX	NO	gas reaeration coefficient	/ivl	/ivl
NITDOX	R	FX	NO	nitrification	mg.ft3/l/ivl	mg.m3/l/ivl
OBOD(5)	R	FX	NO	outflow of biochem oxygen demand	mg.ft3/l/ivl	mg.m3/l/ivl
ODOX(5)	R	FX	NO	outflow of dissolved oxygen	mg.ft3/l/ivl	mg.m3/l/ivl
PHYBOD	R	FX	NO	phytoplankton death	mg.ft3/l/ivl	mg.m3/l/ivl
PHYDOX	R	FX	NO	phytoplankton growth/respiration	mg.ft3/l/ivl	mg.m3/l/ivl
RBOD	R	ST	NO	biochemical oxygen demand mass		
RDOX	R	ST	NO	dissolved oxygen mass		
READOX	R	FX	NO	aeration	mg.ft3/l/ivl	mg.m3/l/ivl
REAK	R	PM	YES	empirical constant for equation used to calculate reaeration coefficient	/hr	/hr
REAKT	R	PM	YES	empirical constant in Tsivoglou's equation for reaeration (escape coefficient)	/ft	/ft
REAMFG	I	OP	OP	indicates method used to calculate reaeration coefficient: 1 means Tsivoglou method is used; 2 means Owens, Churchill, or O'Connor-Dobbins method is used depending on velocity and depth of water; 3 means coefficient is calculated as a constant power function of velocity and/or depth; user inputs exponents for velocity and depth and an empirical constant (REAK)		
ROBOD	R	FX	NO	total outflow of biochemical oxygen demand	mg.ft3/l/ivl	mg.m3/l/ivl
RODOX	R	FX	NO	total outflow of dissolved oxygen	mg.ft3/l/ivl	mg.m3/l/ivl
SATDO	R	ST	NO	dissolved oxygen saturation concentration	mg/l	mg/l
SNKBOD	R	FX	NO	sinking	mg.ft3/l/ivl	mg.m3/l/ivl
SUPSAT	R	PM	YES	allowable dissolved oxygen supersaturation (expressed as multiple of SATDO)		

Table A.28. RCHRES OXRX Section

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
TCBEN	R	PM	YES	temperature correction coefficient for benthal oxygen demand		
TCBOD	R	PM	YES	temp correction coefficient for BOD decay	complex	complex
TCGINV	R	PM	YES	temperature correction coefficient for surface gas invasion	complex	complex
ZOOBOD	R	FX	NO	zooplankton death	mg.ft3/l/ivl	mg.m3/l/ivl
ZOODOX	R	FX	NO	zooplankton respiration	mg.ft3/l/ivl	mg.m3/l/ivl

Table A.29. RCHRES NUTRX Section

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
ADNH4(4)	R	FX	NO	adsorption (+) or desorption of NH4 to sand, silt, clay, total	mg.ft3/l/ivl	mg.m3/l/ivl
ADNHFG	I	OP	OP	if ON, ammonia adsorption is simulated		
ADNHPM(3)	R	PM	YES	Partition coefficients for adsorption of NH4 to sand, silt, and clay	l/mg	l/mg
ADPO4(4)	R	FX	NO	adsorption (+) or desorption (-) of PO4 to sand, silt, clay, total	mg.ft3/l/ivl	mg.m3/l/ivl
ADPOFG	I	OP	OP	if ON, phosphate adsorption is simulated		
ADPOPM(3)	R	PM	YES	Partition coefficients for adsorption of PO4 to sand, silt, and clay	l/mg	l/mg
AMVFG	I	OP	OP	if ON, ammonia vaporization is enabled		
ANAER	R	PM	YES	concentration of dissolved oxygen below which anaerobic condition exists	mg/l	mg/l
BALNO3	R	FX	NO	Benthic algae growth/respiration	mg.ft3/l/ivl	mg.m3/l/ivl
BALPO4	R	FX	NO	Benthal algae growth/respiration	mg.ft3/l/ivl	mg.m3/l/ivl
BALTAM	R	FX	NO	Benthic algae growth/respiration	mg.ft3/l/ivl	mg.m3/l/ivl
BNH4(3)	R	PM	YES	bed concentration of ammonia on bed sediment: 1) sand, 2) silt, 3) clay	mg/mg	mg/mg
BNRPO4	R	FX	NO	Benthal release	mg.ft3/l/ivl	mg.m3/l/ivl
BNRTAM	R	FX	NO	Benthal release	mg.ft3/l/ivl	mg.m3/l/ivl
BODNO3	R	FX	NO	BOD decay	mg.ft3/l/ivl	mg.m3/l/ivl
BODPO4	R	FX	NO	BOD decay	mg.ft3/l/ivl	mg.m3/l/ivl
BODTAM	R	FX	NO	BOD decay	mg.ft3/l/ivl	mg.m3/l/ivl
BPCNTC	R	PM	YES	percentage, by weight, of biomass which is carbon		
BPO4(3)	R	PM	YES	bed concentration of phosphate on bed sediment: 1) sand, 2) silt, 3) clay	mg/mg	mg/mg
BRPO4(2)	R	PM	YES	benthal phosphate release rates under: 1) aerobic or 2) anaerobic conditions	mg/m2/ivl	mg/m2/ivl
BRTAM(2)	R	PM	YES	benthal ammonia release rates under: 1) aerobic conditions 2) anaerobic conditions	mg/m2/ivl	mg/m2/ivl
CVBN	R	PM	YES	conversion from milligrams biomass to milligrams nitrogen	mg/mg	mg/mg
CVBO	R	PM	YES	conversion from milligrams biomass to milligrams oxygen	mg/mg	mg/mg
CVBP	R	PM	YES	conversion from milligrams biomass to milligrams phosphorus	mg/mg	mg/mg
CVBPC	R	PM	YES	conversion from biomass expressed as phosphorus to carbon equivalency	moles/mole	moles/mole
CVBPN	R	PM	YES	conversion from biomass expressed as phosphorus to nitrogen equivalency	moles/mole	moles/mole

Table A.29. RCHRES NUTRX Section

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
CVOC	R	PM	YES	conversion from milligrams oxygen to milligrams carbon	mg/mg	mg/mg
CVON	R	PM	YES	conversion from milligrams oxygen to milligrams nitrogen	mg/mg	mg/mg
CVOP	R	PM	YES	conversion from milligrams oxygen to milligrams phosphorus	mg/mg	mg/mg
DECCO2	R	FX	NO	amount of CO2 produced by BOD decay	mg/l/ivl	mg/l/ivl
DENFG	I	OP	OP	if ON, denitrification is enabled		
DENNO3	R	FX	NO	Denitrification	mg.ft3/l/ivl	mg.m3/l/ivl
DENOXT	R	PM	YES	threshold DO concentration for denitrification	mg/l	mg/l
DSNH4(4)	R	FX	NO	Amount of NH4 entering the water column due to scour (+) or deposition (-) of sand, silt, clay, total	mg.ft3/l/ivl	mg.m3/l/ivl
DSPO4(4)	R	FX	NO	Amount of PO4 entering the water column due to scour (+) or deposition (-) of sand, silt, clay, total	mg.ft3/l/ivl	mg.m3/l/ivl
EXPNVG	R	PM	YES	Exponent to gas layer mass transfer equation for NH3 volatilization		
EXPNVL	R	PM	YES	Exponent to liquid layer mass transfer equation for NH3 volatilization		
INO2	R	IT	NO	inflow of nitrite (as N)	mg.ft3/l/ivl	mg.m3/l/ivl
INO3	R	IT	NO	inflow of nitrate (as N)	mg.ft3/l/ivl	mg.m3/l/ivl
IPO4	R	IT	NO	inflow of dissolved phosphate (as P)	mg.ft3/l/ivl	mg.m3/l/ivl
ISNH4(3)	R	IT	NO	inflow of ammonium on sand, silt, and clay	mg.ft3/l/ivl	mg.m3/l/ivl
ISPO4(3)	R	IT	NO	inflow of ortho-phosphate on sand, silt, and clay	mg.ft3/l/ivl	mg.m3/l/ivl
ITAM	R	IT	NO	inflow of dissolved total ammonia (as N)	mg.ft3/l/ivl	mg.m3/l/ivl
KNO220	R	PM	YES	unit oxidation rate of nitrite to nitrate at 20 degrees C	/ivl	/ivl
KNO320	R	PM	YES	unit denitrification rate of nitrate 20 degrees C	/ivl	/ivl
KTAM20	R	PM	YES	unit oxidation rate of ammonia to nitrite at 20 degrees C	/ivl	/ivl
NH3	R	ST	YES	Dissolved concentration of NH3	mg/l	mg/l
NH4	R	ST	YES	Dissolved concentration of NH4	mg/l	mg/l
NITNO2	R	FX	NO	Nitrification	mg.ft3/l/ivl	mg.m3/l/ivl
NITNO3	R	FX	NO	Nitrification	mg.ft3/l/ivl	mg.m3/l/ivl
NITTAM	R	FX	NO	Nitrification	mg.ft3/l/ivl	mg.m3/l/ivl
NO2	R	ST	YES	Dissolved concentration of NO2	mg/l	mg/l
NO2FG	I	OP	OP	if ON, nitrite is simulated		
NO3	R	ST	YES	Dissolved concentration of NO3	mg/l	mg/l
NUACNM(12,3)	R	PM	YES	wet atmospheric deposition concentration in precip at start of calendar month	mg/l	mg/l
NUADDR(3)	R	FX	NO	dry atmospheric deposition flux	mg.ft3/l/ivl	mg.m3/l/ivl
NUADFG(6)	I	OP	OP	atmospheric deposition flags: -1 = timeseries, 0 = none, >0 = MONTH-DATA table number Odd subscripts are for dry deposition, even for wet deposition. 1-2,3-4,5-6) for nitrate, ammonia, phosphate.		
NUADWT(3)	R	FX	NO	wet atmospheric deposition flux	mg.ft3/l/ivl	mg.m3/l/ivl
NUAFXM(12,3)	R	PM	YES	dry atmospheric deposition flux at the start of each calendar month	mg.ft3/ l/ft2/ivl	mg.m3/l/m2/ivl
ONO2(5)	R	FX	NO	Outflow of dissolved NO2 thru indiv exits	mg.ft3/l/ivl	mg.m3/l/ivl
ONO3(5)	R	FX	NO	Outflow of dissolved NO3 thru indiv exits	mg.ft3/l/ivl	mg.m3/l/ivl
OPO4(5)	R	FX	NO	Outflow of dissolved PO4 thru indiv exits	mg.ft3/l/ivl	mg.m3/l/ivl

Table A.29. RCHRES NUTRX Section

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
OSNH4(5,3)	R	FX	NO	Outflow of adsorbed NH4 on sand, silt, clay through individual exits	mg.ft3/l/ivl	mg.m3/l/ivl
OSPO4(5,3)	R	FX	NO	Outflow of adsorbed PO4 on sand, silt, clay through individual exits	mg.ft3/l/ivl	mg.m3/l/ivl
OTAM(5)	R	FX	NO	Outflow of dissolved TAM thru indiv exits	mg.ft3/l/ivl	mg.m3/l/ivl
PHYNO3	R	FX	NO	Phytoplankton growth/respiration	mg.ft3/l/ivl	mg.m3/l/ivl
PHYPO4	R	FX	NO	Phytoplankton growth/respiration	mg.ft3/l/ivl	mg.m3/l/ivl
PHYTAM	R	FX	NO	Phytoplankton growth/respiration	mg.ft3/l/ivl	mg.m3/l/ivl
PO4	R	ST	YES	Dissolved concentration of PO4	mg/l	mg/l
PO4FG	I	OP	OP	if ON, ortho-phosphorus is simulated		
RNH3	R	ST	NO	Storage of dissolved NH3	mg.ft3/l	mg.m3/l
RNH4	R	ST	NO	Storage of dissolved NH4	mg.ft3/l	mg.m3/l
RNO2	R	ST	NO	Storage of dissolved NO2	mg.ft3/l	mg.m3/l
RNO3	R	ST	NO	Storage of dissolved NO3	mg.ft3/l	mg.m3/l
RONO2	R	FX	NO	total outflow of nitrite (as nitrogen)	mg.ft3/l/ivl	mg.m3/l/ivl
RONO3	R	FX	NO	total outflow of nitrate (as nitrogen)	mg.ft3/l/ivl	mg.m3/l/ivl
ROPO4	R	FX	NO	total outflow of phosphate (as phosphorus)	mg.ft3/l/ivl	mg.m3/l/ivl
ROSNH4(4)	R	FX	NO	Total outflow of adsorbed NH4 on sand, silt, clay, and total	mg.ft3/l/ivl	mg.m3/l/ivl
ROSPO4(4)	R	FX	NO	Total outflow of adsorbed PO4 on sand, silt, clay, and total	mg.ft3/l/ivl	mg.m3/l/ivl
ROTAM	R	FX	NO	total outflow of ammonia (as nitrogen)	mg.ft3/l/ivl	mg.m3/l/ivl
RPO4	R	ST	NO	Storage of dissolved PO4	mg.ft3/l	mg.m3/l
RRNO2	R	ST	NO	Total storage of NO2 in reach	mg.ft3/l	mg.m3/l
RRNO3	R	ST	NO	Total storage of NO3 in reach	mg.ft3/l	mg.m3/l
RRPO4	R	ST	NO	Total storage of PO4 in reach	mg.ft3/l	mg.m3/l
RRTAM	R	ST	NO	Total storage of TAM in reach	mg.ft3/l	mg.m3/l
RSNH4(12)	R	ST	NO	Storage of adsorbed NH4 1-3) suspended sand, silt, clay; 4) total suspended; 5-7) bed sand, silt, clay; 8) total bed; 9-11) total sand, silt, clay; 12) total on sediment	mg.ft3/l	mg.m3/l
RSPO4(12)	R	ST	NO	Storage of adsorbed PO4 1-3) suspended sand, silt, clay; 4) total suspended; 5-7) bed sand, silt, clay; 8) total bed; 9-11) total sand, silt, clay; 12) total on sediment	mg.ft3/l	mg.m3/l
RTAM	R	ST	NO	Storage of dissolved TAM (includes NH3, NH4)	mg.ft3/l	mg.m3/l
SNH4(3)	R	ST	YES	Concentration of NH4 on sand, silt, clay	mg/mg	mg/mg
SPO4(3)	R	ST	YES	Concentration of PO4 on sand, silt, clay	mg/mg	mg/mg
TAM	R	ST	YES	Dissolved concentration of TAM (incl. NH3, NH4)	mg/l	mg/l
TAMFG	I	OP	OP	if ON, total ammonia is simulated		
TCDEN	R	PM	YES	temp correction coefficient for denitrification	complex	complex
TCNIT	R	PM	YES	temp correction coefficient for nitrification	complex	complex
VOLNH3	R	FX	NO	Volatilization	mg.ft3/l/ivl	mg.m3/l/ivl
ZOONO3	R	FX	NO	Zooplankton death/respiration	mg.ft3/l/ivl	mg.m3/l/ivl
ZOOPO4	R	FX	NO	Zooplankton death/respiration	mg.ft3/l/ivl	mg.m3/l/ivl
ZOOTAM	R	FX	NO	Zooplankton death/respiration	mg.ft3/l/ivl	mg.m3/l/ivl

Table A.30. RCHRES PLANK Section

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
ALDH	R	PM	YES	high algal unit death rate	/ivl	/ivl
ALDL	R	PM	YES	low algal unit death rate	/ivl	/ivl
ALNPR	R	PM	YES	fraction of nitrogen requirements for phytoplankton growth satisfied by nitrate		
ALR20	R	PM	YES	algal unit respiration rate at 20 deg C	/ivl	/ivl
AMRFG	I	OP	OP	if ON, ammonia retardation nitrogen limited growth is enabled		
BALCLA	R	ST	NO	benthic algae population (as chlorophyll a)	ug/m2	ug/m2
BALCO2	R	FX	NO	amount of CO2 taken up or released by net benthic algae growth	mg/l/ivl	mg/l/ivl
BALFG	I	OP	OP	if ON, benthic algae are simulated		
BENAL	R	ST	YES	benthic algae concentration (as biomass)	mg/m2	mg/m2
CFBALG	R	PM	YES	ratio of benthic algal to phytoplankton growth rates		
CFBALR	R	PM	YES	ratio of benthic algal to phytoplankton respiration rates		
CLALDH	R	PM	YES	chlorophyll "a" concentration above which high algal death rate occurs	ug/l	ug/l
CMMLT	R	PM	YES	radiation Michaelis-Menten constant for light limited growth	Ly/min	Ly/min
CMMN	R	PM	YES	nitrate Michaelis-Menten constant for nitrogen limited growth	mg/l	mg/l
CMMNP	R	PM	YES	nitrate Michaelis-Menten constant for phosphorus limited growth	mg/l	mg/l
CMMP	R	PM	YES	phosphate Michaelis-Menten constant for phosphorus limited growth	mg/l	mg/l
CVBC	R	PM	YES	conversion from milligrams biomass to milligrams carbon	mg/mg	mg/mg
CVBCL	R	PM	YES	conversion from milligrams biomass to micrograms chlorophyll a	ug/mg	ug/mg
CVNRBO	R	PM	YES	conversion from milligrams biomass to milligrams oxygen, times NONREF	mg/mg	mg/mg
CVPB	R	PM	YES	conversion factor from micromoles P to milligrams biomass	mg/umole	mg/umole
DECFG	I	OP	OP	if ON, linkage between carbon dioxide and phytoplankton growth is decoupled		
EXTB	R	PM	YES	base extinction coefficient for light	/ft	/ft
IORC	R	IT	NO	inflow of organic carbon (ORC)	mg.ft3/l/ivl	mg.m3/l/ivl
IORN	R	IT	NO	inflow of organic nitrogen (ORN)	mg.ft3/l/ivl	mg.m3/l/ivl
IORP	R	IT	NO	inflow of organic phosphorus (ORP)	mg.ft3/l/ivl	mg.m3/l/ivl
IPHYTO	R	IT	NO	inflow of phytoplankton	mg.ft3/l/ivl	mg.m3/l/ivl
IZOO	R	IT	NO	inflow of zooplankton	mg.ft3/l/ivl	mg.m3/l/ivl
LITSED	R	PM	YES	multiplication factor to sediment concentration for light extinction	l/mg/ft	l/mg/ft
MALGR	R	PM	YES	maximum unit algal growth rate	/ivl	/ivl
MBAL	R	PM	YES	max benthic algae density (as biomass)	mg/m2	mg/m2
MXSTAY	R	PM	YES	concentration of plankton not subject to advection at very low flow	mg/l	mg/l
MZOEAT	R	PM	YES	max zooplankton unit ingestion rate	mg/mg/ivl	mg/mg/ivl
NALDH	R	PM	YES	inorganic N concentration below which high algal death rate occurs (as N)	mg/l	mg/l
NONREF	R	PM	YES	nonrefractory fraction of algae and zooplankton biomass	mg/mg	mg/mg

Table A.30. RCHRES PLANK Section

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
NSFG	I	OP	OP	if ON, ammonia is included as part of available N supply in N limited growth calculations		
OORC(5)	R	FX	NO	outflow of ORC	mg.ft3/l/ivl	mg.m3/l/ivl
OORN(5)	R	FX	NO	outflow of ORN	mg.ft3/l/ivl	mg.m3/l/ivl
OORP(5)	R	FX	NO	outflow of ORP	mg.ft3/l/ivl	mg.m3/l/ivl
OPHYT(5)	R	FX	NO	outflow of phytoplankton	mg.ft3/l/ivl	mg.m3/l/ivl
ORC	R	ST	YES	dead refractory organic carbon	mg/l	mg/l
OREF	R	PM	YES	outflow at which concentration of plankton not subject to advection is midway between SEED and MXSTAY	ft3/s	m3/s
ORN	R	ST	YES	dead refractory organic nitrogen	mg/l	mg/l
ORP	R	ST	YES	dead refractory organic phosphorus	mg/l	mg/l
OXALD	R	PM	YES	increment to phytoplankton unit death rate due to anaerobic conditions	/ivl	/ivl
OXZD	R	PM	YES	increment to unit zooplankton death rate due to anaerobic conditions	/ivl	/ivl
OZOO(5)	R	FX	NO	outflow of zooplankton	mg.ft3/l/ivl	mg.m3/l/ivl
PALDH	R	PM	YES	inorganic P concentration below which high algal death rate occurs (as P)	mg/l	mg/l
PHYCLA	R	ST	NO	phytoplankton concentration (as chlorophyll a)	ug/l	ug/l
PHYCO2	R	FX	NO	amount of CO2 taken up or released by net phytoplankton growth	mg/l/ivl	mg/l/ivl
PHYFG	I	OP	OP	if ON, phytoplankton are simulated		
PHYSET	R	PM	YES	rate of phytoplankton settling	ft/ivl	ft/ivl
PHYTO	R	ST	YES	phytoplankton concentration (as biomass)	mg/l	mg/l
PLACNM(12,3)	R	PM	YES	wet atmospheric deposition concentration in precip at start of calendar month	mg/l	mg/l
PLADDR(3)	R	FX	NO	dry atmospheric deposition flux	mg.ft3/l/ivl	mg.m3/l/ivl
PLADFG(6)	I	OP	OP	atmospheric deposition flags: -1 = timeseries, 0 = none, >0 = MONTH-DATA table number. Odd subscripts are for dry deposition, even for wet deposition. 1-2,3-4,5-6) for organic N, organic P, organic C		
PLADWT(3)	R	FX	NO	wet atmospheric deposition flux	mg.ft3/l/ivl	mg.m3/l/ivl
PLAFXM(12,3)	R	PM	YES	dry atmospheric deposition flux at the start of each calendar month	mg.ft3/l/ft2/ivl	mg.m3/l/m2/ivl
POTBOD	R	ST	NO	potential biochem oxygen demand	mg/l	mg/l
RATCLP	R	PM	YES	ratio of chlorophyll "a" content of biomass to phosphorus content		
REFSET	R	PM	YES	rate of settling for dead refractory organics	ft/ivl	ft/ivl
ROORC	R	FX	NO	total outflow of ORC	mg.ft3/l/ivl	mg.m3/l/ivl
ROORN	R	FX	NO	total outflow of ORN	mg.ft3/l/ivl	mg.m3/l/ivl
ROORP	R	FX	NO	total outflow of ORP	mg.ft3/l/ivl	mg.m3/l/ivl
ROPHYT	R	FX	NO	total outflow of phytoplankton	mg.ft3/l/ivl	mg.m3/l/ivl
ROZOO	R	FX	NO	total outflow of zooplankton	mg.ft3/l/ivl	mg.m3/l/ivl
SDLTFG	I	OP	OP	if ON, influence of sediment washload on light extinction is simulated		
SEED	R	PM	YES	minimum concentration of plankton not subject to advection	mg/l	mg/l
TALGRH	R	PM	YES	temp above which algal growth ceases	C	C
TALGRL	R	PM	YES	temp below which algal growth ceases	C	C
TALGRM	R	PM	YES	temperature below which algal growth is retarded	C	C

Table A.30. RCHRES PLANK Section

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
TCZFIL	R	PM	YES	temperature correction coefficient for zooplankton filtering	complex	complex
TCZRES	R	PM	YES	temperature correction coefficient for zooplankton respiration	complex	complex
TORC	R	ST	NO	total organic carbon	mg/l	mg/l
TORN	R	ST	NO	total organic nitrogen	mg/l	mg/l
TORP	R	ST	NO	total organic phosphorus	mg/l	mg/l
ZCO2	R	FX	NO	amount of CO2 released by zooplankton respiration	mg/l/ivl	mg/l/ivl
ZD	R	PM	YES	natural zooplankton unit death rate	/ivl	/ivl
ZEXDEL	R	PM	YES	fraction of nonrefractory zooplankton excretion which is immediately decomposed when ingestion rate > MZOEAT		
ZFIL20	R	PM	YES	zooplankton filtering rate at 20 deg C	l/mg(zoo)/ivl	l/mg(zoo)/ivl
ZFOOD	I	PM	YES	quality of zooplankton food		
ZOMASS	R	PM	YES	average weight of zooplankton organism	mg/org	mg/org
ZOO	R	ST	YES	zooplankton	mg/l	mg/l
ZOOFG	I	OP	OP	if ON, zooplankton are simulated		
ZRES20	R	PM	YES	zooplankton unit respiration rate at 20 deg C	/ivl	/ivl

Table A.31. RCHRES PHCARB Section

Variable Name	Type	Class	SA	Definition	English Units	Metric Units
ALKCON	I	OP	OP	number of the conservative constituent which is alkalinity		
BENCO2	R	FX	NO	benthal release of CO2 (as C)	mg/l/ivl	mg/l/ivl
BRCO2(2)	R	PM	YES	benthal release of CO2 under 1) aerobic conditions; 2) anaerobic conditions	mg/m2/ivl	mg/m2/ivl
CFCINV	R	PM	YES	ratio of carbon dioxide invasion rate to oxygen reaeration rate		
CO2	R	ST	YES	carbon dioxide (as carbon)	mg/l	mg/l
ICO2	R	IT	NO	inflow of carbon dioxide (as carbon)	mg.ft3/l/ivl	mg.m3/l/ivl
ITIC	R	IT	NO	inflow of total inorganic carbon	mg.ft3/l/ivl	mg.m3/l/ivl
OCO2(5)	R	FX	NO	outflow of carbon dioxide (as C)	mg.ft3/l/ivl	mg.m3/l/ivl
OTIC(5)	R	FX	NO	outflow of inorganic carbon	mg.ft3/l/ivl	mg.m3/l/ivl
PH	R	ST	YES	pH		
PHCNT	I	PM	YES	maximum number of iterations to pH solution		
ROCO2	R	FX	NO	total outflow of carbon dioxide (as carbon)	mg.ft3/l/ivl	mg.m3/l/ivl
ROTIC	R	FX	NO	total outflow of total inorganic carbon	mg.ft3/l/ivl	mg.m3/l/ivl
TIC	R	ST	YES	total inorganic carbon	mg/l	mg/l

PLTGEN - NO VARIABLE NAMES ARE AVAILABLE IN PLTGEN - NUMERICAL ADDRESSES ONLY

DISPLY - SPECIAL ACTIONS NOT IMPLEMENTED FOR DISPLY

DURANL - SPECIAL ACTIONS NOT IMPLEMENTED FOR DURANL

MUTSIN - SPECIAL ACTIONS NOT IMPLEMENTED FOR MUTSIN

Table A.32. COPY Operation

Variable Name	Type	Class	SA	Definition
YR	I	DT	NO!	the year (four digits)
MON	I	DT	NO!	calendar month
DAY	I	DT	NO!	day of the month
HR	I	DT	NO!	hour of the day (internal convention)
MIN	I	DT	NO!	minute in the hour (internal convention)
POINT(20)	R	IT	NO	current values of point-valued timeseries (PTVAL)
MEAN(20)	R	IT	NO	current values of mean-valued timeseries (MNVAL)

Table A.33. GENER Operation

Variable Name	Type	Class	SA	Definition
YR	I	DT	NO!	the year (four digits)
MON	I	DT	NO!	calendar month
DAY	I	DT	NO!	day of the month
HR	I	DT	NO!	hour of the day (internal convention)
MIN	I	DT	NO!	minute in the hour (internal convention)
OPCODE	I	OP	OP	operation code: 1) C= ABS(A) 2) C= SQRT(A) 3) C= TRUNC(A) 4) C= CEIL(A) 5) C= FLOOR(A) 6) C= LOGE(A) 7) C= LOG10(A) 8) C= K(1)+ K(2)*A+ K(3)*(A**2) + etc. 9) C= K**A 10) C= A**K 11) C= A+K 12) C= SIN(A) 13) C= COS(A) 14) C= TAN(A) 15) C= SUM(A) 16) C= A+B 17) C= A-B 18) C= A*B 19) C= A/B 20) C= MAX(A,B) 21) C= MIN(A,B) 22) C= A**B 23) C= cumulative departure of A below B 24) C= K 25) C= Max (A,K) 26) C= Min (A,K)
NTERMS	I	OP	OP	number of terms in power function
K(7)	R	PM	YES	Coefficients in power function: C = K(1) + K(2)*A + K(3)*(A**2) + etc.
SUM	R	ST	YES	for storing SUM of timeseries

Appendix B. Special Action Accumulators

Special Actions that increment certain storages (i.e., the action code is "2" or "+="), also increment a corresponding accumulator in the program, so that the output file (specified in the GEN-INFO table) shows the total input of these constituents. This accumulation has no effect on the simulation - it merely provides information in the output file.

Beginning in version 11, when Special Actions are used in PERLND to increment the storage of nitrate, ammonia, or organic N in NITR, or phosphate or organic P in PHOS, a corresponding accumulator variable in the PERLND OSV is also incremented so that the printed fluxes in the output file contain the total input flux of each constituent due to Special Actions. These particular constituents were chosen because they are the most common Special Action targets that do not have an input timeseries available. Future versions of HSPF may add accumulators for other Special Action inputs.

The accumulators are listed below in Table B.1, along with the list of Special Action targets that cause them to be incremented.

Table B.1. Special Action Accumulators

Operation ←		Name	Definition	Special Action targets that cause Accumulator to be incremented
Type	Section			[* The _ORGN names are equivalent to the _PLON names. Both refer to particulate labile organic N.]
PERLND	NITR	INO3	Total input of nitrate to all soil layers	SNO3, UNO3, LNO3, ANO3
		INH3	Total input of ammonia (dissolved and particulate) to all soil layers	SAMAD, UAMAD, LAMAD, AAMAD SAMSU, UAMSU, LAMSU, AAMSU
		IORN	Total input of all forms of organic N to all soil layers	SPLON, UPLON, LPLON, APLON (SORGN, UORGN, LORGN, AORGN)* SPRON, UPRON, LPRON, APRON SSLON, USLON, LSLON, ASLON SSRON, USRON, LSRON, ASRON
	PHOS	IPO4	Total input of phosphate (dissolved and particulate) to all soil layers	SP4AD, UP4AD, LP4AD, AP4AD SP4SU, UP4SU, LP4SU, AP4SU
		IORP	Total input of organic P to all soil layers	SORGP, UORGP, LORGP, AORGP

Appendix C. Case Study UCI Files

Case Study A. Simple Parameter Changes

```
RUN

GLOBAL
  Special Actions Case Study #1 - Simple parameter changes
  START       1992              END    1992
  RUN INTERP OUTPUT LEVEL    3    2
  RESUME     0 RUN     1                   UNIT SYSTEM     1
END GLOBAL

FILES
<FILE>  <UN#>***<----FILE NAME-------------------------------------------------->
WDM        21   case.wdm
MESSU      22   case1.ech
           30   case1.out
END FILES

OPN SEQUENCE
    INGRP               INDELT 00:30
      PERLND       1
    END INGRP
END OPN SEQUENCE

SPEC-ACTIONS
***                                       <addrss>-------   ----<uvqn>
***           dc ds                d t     or                    or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
*** Spring Thaw
  PERLND  1         1992/04/15            INFILT           =      0.10 YR   1 10
*** Beginning of Growing Season
  PERLND  1         1992/04/29 12         INFILT           =      0.13 YR   1 10
*** End of Growing Season
  PERLND  1         1992/08/25            INFILT           =      0.10 YR   1 10
*** Winter Frozen Ground
  PERLND  1         1992/12/02            INFILT           =      0.05 YR   1 10
END SPEC-ACTIONS

PERLND
  ACTIVITY
    <PLS >          Active Sections (1=Active; 0=Inactive)             ***
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
    1                  1
  END ACTIVITY

  PRINT-INFO
    <PLS >          Print-flags                                    *** PIVL  PYR
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC       ***
    1                  4                                                      12
  END PRINT-INFO

  GEN-INFO
    <PLS ><-------Name------->        Unit-systems   Printer ***
    # -  #                            t-series Engl Metr ***
                                        in  out          ***
    1     Cropland                       1    1   30
  END GEN-INFO

  *** Section PWATER ***

  PWAT-PARM1
    <PLS >  PWATER variable monthly parameter value flags    ***
    # -  # CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE IFFC ***
    1         0    0    0    1    1    1    0    0    1    1
  END PWAT-PARM1

  PWAT-PARM2
    <PLS > ***  PWATER input info: Part 2
           ***  INFILT here reflects frozen ground conditions on Jan 1
```

```
          ***  Nominal value is 0.10.  See SPEC-ACTIONS block
    # -  # ***FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
    1         0.000        8.0     0.050      350.     0.010       0.5      0.98
  END PWAT-PARM2

  PWAT-PARM3
    <PLS > ***  PWATER input info: Part 3
    # -  # ***PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
    1           40.        35.       2.0       2.0      0.10       0.0      0.08
  END PWAT-PARM3

  PWAT-PARM4
    <PLS >     PWATER input info: Part 4                                  ***
    # -  #     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP ***
    1                     0.01       0.1       1.0      0.60
  END PWAT-PARM4

  MON-INTERCEP
    <PLS>   Only required if VCSFG=1 in PWAT-PARM1                        ***
    # -  #  Interception storage capacity at start of each month          ***
            JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1      0.04 0.04 0.03 0.03 0.03 0.03 0.10 0.17 0.19 0.14 0.05 0.04
  END MON-INTERCEP

  MON-UZSN
    <PLS>   Only required if VUZFG=1 in PWAT-PARM1                        ***
    # -  #  Upper zone storage at start of each month                     ***
            JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1       0.4  0.4  0.4  0.4  1.6  1.1  1.1  1.3  1.3  1.3  1.1  0.9
  END MON-UZSN

  MON-MANNING
    <PLS >  Only required if VNNFG=1 in PWAT-PARM1                        ***
    # -  #  Manning's n for overland flow at start of each month          ***
            JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1      0.30 0.30 0.30 0.30 0.27 0.25 0.25 0.25 0.25 0.25 0.35 0.33
  END MON-MANNING

  MON-LZETPARM
    <PLS >  Only required if VLEFG=1 in PWAT-PARM1                        ***
    # -  #  Lower zone ET parameter at start of each month                ***
            JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1      0.20 0.20 0.20 0.23 0.23 0.25 0.60 0.80 0.75 0.50 0.30 0.20
  END MON-LZETPARM

  PWAT-STATE1
    <PLS > *** Initial conditions at start of simulation
    # -  # ***  CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
    1           0.05       0.0      0.15       0.0       4.0      0.05      0.05
  END PWAT-STATE1
END PERLND

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   # <Name> # tem strg<-factor->strg <Name>   #   #        <Name> # #  ***
WDM     39 PREC     ENGLZERO               PERLND   1     EXTNL  PREC
WDM     41 EVAP     ENGL        .7    DIV  PERLND   1     EXTNL  PETINP
END EXT SOURCES

END RUN
```

Case Study B. Agricultural Operations

```
RUN

GLOBAL
  Special Actions Case Study #2 - Agricultural Operations
  START       1984              END    1991
  RUN INTERP OUTPUT LEVEL    3    4
  RESUME     0 RUN     1                   UNIT SYSTEM     1
END GLOBAL

FILES
<FILE>  <UN#>***<----FILE NAME-------------------------------------------------->
WDM        24   case.wdm
MESSU      25   case2.ech
           90   case2.out
END FILES

OPN SEQUENCE
    INGRP              INDELT 01:00
      PERLND       1
    END INGRP
END OPN SEQUENCE

SPEC-ACTIONS

*** User-Defined Variable Quantity Lines
***                        <addrss>-------
***                           or                         lc ls ac as agfn
***kwrd> <uqnm> <oper> <#> <vari><1><2><3><t><multfact> <>< > <>< > <  >
  UVQUAN surwat PERLND   1 SURS

*** Distribution Lines
***      ds  ct tc ts
***kwrd>< > < > <> < > <dff>  <frc><frc><frc><frc><frc><frc><frc><frc><frc><frc>
*** Daily distribution over five days, with five extra days to make up any
    missed fraction. ***
  DISTRB  1  10 DY   1 ACCUM    .20  .20  .20  .20  .20    0    0    0    0    0

*** User-Defined Variable Name Lines
***                 <addrss>-------              <addrss>-------
***             cnt    or               act        or                 act
***kwrd>  <unam>< > <vari><1><2><3> <frc> <  >    <vari><1><2><3> <frc> <  >
*** Manure 50%/50% surface/upper as tons/ac.  Multipliers give lb/ac of N or P.
  UVNAME  MANURE  8 SAMAD            1.82 QUAN    UAMAD            1.82 QUAN
                    SORGN            2.73 QUAN    UORGN            2.73 QUAN
                    SP4AD            .675 QUAN    UP4AD            .675 QUAN
                    SORGP            .675 QUAN    UORGP            .675 QUAN

*** Nitrogen Fertilizer 50%/50% surface/upper as lbs N/acre
  UVNAME  FERTN5  4 SAMAD            .375 QUAN    UAMAD            .375 QUAN
                    SNO3             .125 QUAN    UNO3             .125 QUAN

*** Nitrogen Fertilizer 10%/90% surface/upper as lbs N/acre
  UVNAME  FERTN1  4 SAMAD            .075 QUAN    UAMAD            .675 QUAN
                    SNO3             .025 QUAN    UNO3             .225 QUAN

*** Phosphorus Fertilizer 10%/90% surface/upper as lbs P/acre
  UVNAME  FERTP1  2 SP4AD              .1 QUAN    UP4AD              .9 QUAN

*** Incorporation of cover crop by moldboard plow - Assumes 6.4% of upper layer
    storages remain on surface, while surface storages are completely ***
    incorporated into the upper layer. ***
    Soil mass ratio= (0.39*74.9)/(5.61*81.2) = .064 ***
    See Table-type SOIL-DATA. ***
  UVNAME  INCORP 14 SAMAD            .064 MOV2    UAMAD
                    SNO3             .064 MOV2    UNO3
                    SAMSU            .064 MOV2    UAMSU
                    SORGN            .064 MOV2    UORGN
                    SP4AD            .064 MOV2    UP4AD
                    SP4SU            .064 MOV2    UP4SU
                    SORGP            .064 MOV2    UORGP
```

```
  UVNAME  PLANT   8 SPLTN               1 QUAN    UPLTN             1 QUAN
                    LPLTN               1 QUAN    APLTN             1 QUAN
                    SPLTP               1 QUAN    UPLTP             1 QUAN
                    LPLTP               1 QUAN    APLTP             1 QUAN

*** Action Lines
***                                       <addrss>-------   ----<uvqn>
***            dc ds                 d t    or                    or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >

                 *** Winter Cover Crop ***

IF (surwat = 0.0) THEN
  *** Planting of winter cover crop
  PERLND  1    DY  11984 10 15 12         DETS             =       1.0 YR   1  8

  *** Manure (as N+P) Application- 50% Surface, 50% Upper - Split 3 times
      during the fall and winter on cover crop ***
  PERLND  1    DY  11984 10 20 12         MANURE          +=      9.52 YR   1  8
  PERLND  1    DY  11984 12 20 12         MANURE          +=      9.52 YR   1  8
  PERLND  1    DY  11984  2 20 12         MANURE          +=      9.52 YR   1  8
END IF

  *** Incorporate winter cover crop with moldboard plow
  PERLND  1         1984  4 13 12         DETS             =       3.0 YR   1  8
  PERLND  1         1984  4 13 12         PLANT            =       0.0 YR   1  8
  PERLND  1         1984  4 13 12         INCORP           =           YR   1  8
  *** Reset Organic N and P storages to simulate return of plant N and P from
      residue and roots ***
  PERLND  1         1984  4 13 12         SORGN            =      80.0 YR   1  8
  PERLND  1         1984  4 13 12         UORGN            =     200.0 YR   1  8
  PERLND  1         1984  4 13 12         LORGN            =     800.0 YR   1  8
  PERLND  1         1984  4 13 12         SORGP            =      20.0 YR   1  8
  PERLND  1         1984  4 13 12         UORGP            =      40.0 YR   1  8
  PERLND  1         1984  4 13 12         LORGP            =      25.0 YR   1  8

                 *** Summer Crop ***

IF (surwat = 0.0) THEN
  *** Planting of Summer Crop
  PERLND  1    DY  11984  4 15 12         DETS             =       1.0 YR   1  8

  *** N and P Fertilizer applied - 10% Surface, 90% Upper
  PERLND  1         1984  4 20 12    1    FERTN1          +=     48.98 YR   1  8
  PERLND  1         1984  4 20 12    1    FERTP1          +=     22.31 YR   1  8

  *** Tillage Operation ***
  PERLND  1    DY  11984  5 12 12         DETS             =       1.5 YR   1  8

  *** MANURE Application Split 3 times during the season
  PERLND  1    DY  11984  5 15 12         MANURE          +=     33.12 YR   1  8
  PERLND  1    DY  11984  7  1 12         MANURE          +=     33.12 YR   1  8
  PERLND  1    DY  11984  8 15 12         MANURE          +=     33.12 YR   1  8

  *** Pesticide applied - 100% Surface adsorbed storage - 2.5 lb/ac spread over
      3 weeks ***
  PERLND  1    DY  11984  6  5 12         SPS     2  1    +=     0.625 YR   1  8
  PERLND  1    DY  11984  6 13 12         SPS     2  1    +=     1.250 YR   1  8
  PERLND  1    DY  11984  6 20 12         SPS     2  1    +=     0.625 YR   1  8

  *** N Fertilizer applied - 50% Surface, 50% Upper
  PERLND  1         1984  6 15 12    1    FERTN5          +=     48.85 YR   1  8
END IF

*** Set pesticide decay rate high to reflect high volatilization at application
  PERLND  1         1984  6  5            SPSPM   8  1     =      0.12 YR   1  8
*** Reduce pesticide decay rate to reflect less volatilization later in season
  PERLND  1         1984  6 30            SPSPM   8  1     1      0.06 YR   1  8

  *** Harvest Summer crop
  PERLND  1         1984  9 30 12         PLANT            =       0.0 YR   1  8
  *** Reset Organic N and P storages to simulate return of plant N and P from
      residue and roots ***
  PERLND  1         1984  9 30 12         SORGN            =      80.0 YR   1  8
  PERLND  1         1984  9 30 12         UORGN            =     200.0 YR   1  8
  PERLND  1         1984  9 30 12         LORGN            =     800.0 YR   1  8
```

```
  PERLND  1          1984  9 30 12         SORGP            =       20.0 YR   1  8
  PERLND  1          1984  9 30 12         UORGP            =       40.0 YR   1  8
  PERLND  1          1984  9 30 12         LORGP            =       25.0 YR   1  8
END SPEC-ACTIONS

PERLND
  ACTIVITY
    #    # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC   ***
    1         1    0    1    1    1    1    1    1    1    1    1    0
  END ACTIVITY

  PRINT-INFO
    #    # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC PIVL***PY
    1         5         5    5    5    5    5    5    5    4    4             12
  END PRINT-INFO

  GEN-INFO
    #    #      NAME                       IN  OUT ENGL METR  ***
    1     HIGH TILL CROPLAND                1    1   90    0
  END GEN-INFO

  ATEMP-DAT
    ELEVATION DIFFERENCE BETWEEN GAGE AND PLS ***
    #    #     ELDAT    AIRTMP ***
    1         -592.0      32.1
  END ATEMP-DAT

  PWAT-PARM1
    #    # CSNO RTOP UZFG  VCS  VUZ  NVV VIFW VIRC  VLE  ***
    1         0    1    1    1    1    1    0    0    1
  END PWAT-PARM1

  PWAT-PARM2
    #    # ***FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY      AGWR
    1          0.000     8.000    0.0300      300.   0.07000     0.000     0.985
  END PWAT-PARM2

  PWAT-PARM4
    #    #     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP  ***
    1           0.00     0.800     0.090     1.000     0.600     0.420
  END PWAT-PARM4

  MON-INTERCEP
    #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
    1     0.0300.0300.0300.0300.0150.0600.1200.1430.1350.1050.0500.040
  END MON-INTERCEP

  MON-UZSN
    #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
    1     0.3000.3000.3000.3000.2800.2500.2500.2500.2500.3000.3000.300
  END MON-UZSN

  MON-MANNING
    #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
    1      .100 .100 .100 .080 .080 .080 .080 .090 .090 .100 .100 .100
  END MON-MANNING

  MON-LZETPARM
    #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
    1     0.1000.1000.1000.1000.2500.5500.5500.5500.4500.2500.1500.100
  END MON-LZETPARM

  PWAT-STATE1
    #    # ***  CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
    1          0.000     0.000     1.500     0.000     7.900     1.006     0.000
  END PWAT-STATE1

  SED-PARM1
    #    #  CRV VSIV SDOP  ***
    1         1    0    1
  END SED-PARM1

  SED-PARM2
    #    #      SMPF      KRER      JRER     AFFIX     COVER      NVSI  ***
    1          1.000     0.320     2.000     0.010     0.000     1.000
  END SED-PARM2
```

```
SED-PARM3
  #    #      KSER      JSER      KGER      JGER  ***
  1           0.75     2.000     0.000     2.000
END SED-PARM3

MON-COVER
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
  1      .230 .220 .150 .170 .280 .500 .750 .930 .930 .320 .290 .240
END MON-COVER

SED-STOR
  #    #      DETS  ***
  1           0.70
END SED-STOR

PSTEMP-PARM1
  #    # SLTV ULTV LGTV TSOP  ***
  1         1    1    1    1
END PSTEMP-PARM1

PSTEMP-PARM2
  #    #      ASLT      BSLT     ULTP1     ULTP2     LGTP1     LGTP2  ***
  1           32.0      0.95      32.0      0.90      32.0       0.0
END PSTEMP-PARM2

MON-ASLT
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
  1      33.9 33.9 37.5 43.0 49.6 55.8 59.8 59.8 53.5 44.8 40.0 35.7
END MON-ASLT

MON-BSLT
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
  1      0.50 0.50 0.50 0.50 0.50 0.50 0.50 0.50 0.50 0.50 0.50 0.50
END MON-BSLT

MON-ULTP1
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
  1      34.6 34.6 40.7 50.7 62.4 74.0 81.2 81.2 69.7 53.2 45.2 37.7
END MON-ULTP1

MON-ULTP2
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
  1      0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10
END MON-ULTP2

MON-LGTP1
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
  1      50.0 50.0 52.0 54.0 56.0 58.0 60.0 62.0 58.0 55.0 52.0 50.0
END MON-LGTP1

PSTEMP-TEMPS
  #    #     AIRTC     SLTMP     ULTMP     LGTMP  ***
  1           32.0      32.0      32.0      49.0
END PSTEMP-TEMPS

PWT-PARM1
  #    #  IDV  ICV  GDV  GCV  ***
  1         1    0    1    0
END PWT-PARM1

PWT-PARM2
  #    #      ELEV     IDOXP     ICO2P     ADOXP     ACO2P  ***
  1          1880.      8.80      0.00      8.80      0.00
END PWT-PARM2

MON-IFWDOX
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
  1      12.7 12.7 11.2 9.70 7.40 6.50 5.50 5.50 6.00 8.40 9.40 11.6
END MON-IFWDOX

MON-GRNDDOX
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
  1      12.0 12.0 11.0 10.0 7.50 5.50 4.50 4.00 4.50 7.50  9.0 10.0
END MON-GRNDDOX
```

```
  PWT-GASES
    #    #     SODOX     SOCO2     IODOX     IOCO2     AODOX     AOCO2  ***
    1          14.5       0.0      12.7       0.0      10.0       0.0
  END PWT-GASES

  NQUALS
    #    # NQAL  ***
    1        1
  END NQUALS

  QUAL-PROPS
    #    #<--QUALID-->    QTID  QSD VPFW VPFS  QSO  VQO QIFW VIQC QAGW VAQC  ***
    1             BOD     LBS    1    2    0    0    0    1    4    1    4
  END QUAL-PROPS

  MON-POTFW
    #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
    1      184. 184. 230. 230. 230. 230. 345. 345. 345. 345. 345. 184.
  END MON-POTFW

  MON-IFLW-CONC
    #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
    1      11.0 11.0 11.0 11.0 11.0 11.0 11.0 11.0 11.0 11.0 11.0 11.0
  END MON-IFLW-CONC

  MON-GRND-CONC
    #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
    1      5.50 5.50 5.50 5.50 5.50 5.50 5.50 5.50 5.50 5.50 5.50 5.50
  END MON-GRND-CONC

  MST-PARM
    <PLS > FACTORS USED TO ADJUST SOLUTE LEACHING RATES ***
    #    #     SLMPF      ULPF      LLPF   ***
    1            0.9       3.0       1.5
  END MST-PARM

  SOIL-DATA
    <PLS > SOIL LAYER DEPTHS AND BULK DENSITIES  ***
    # -  #           DEPTHS (IN)               BULK DENSITY (LB/FT3) ***
           SURFACE   UPPER   LOWER GROUNDW SURFACE   UPPER   LOWER GROUNDW   ***
    1         0.39    5.61   41.30     60.    74.9    81.2    84.3    90.5
  END SOIL-DATA

  PEST-FLAGS
    <PLS >  Options for simulation of up to 3 different pesticides ***
    # -  # NPST MAX ITERATIONS ADSORP OPTION                       ***
              PST1 PST2 PST3 PST1 PST2 PST3                        ***
    1        1   20              1
  END PEST-FLAGS

  PEST-ID
    <PLS >                     ***
    # -  #<--Pesticide Name--> ***
    1     Pesticide #1
  END PEST-ID

  PEST-FIRSTPM      SURFACE LAYER
    <PLS >First-order parms (/day) ***
    # -  #     KDSPS     KADPS     ***
    1            .02       .05
  END PEST-FIRSTPM

  PEST-FIRSTPM      UPPER LAYER
    <PLS >First-order parms (/day) ***
    # -  #     KDSPS     KADPS     ***
    1            .02       .05
  END PEST-FIRSTPM

  PEST-FIRSTPM      LOWER LAYER
    <PLS >First-order parms (/day) ***
    # -  #     KDSPS     KADPS     ***
    1            .02       .05
  END PEST-FIRSTPM

  PEST-FIRSTPM      GROUNDWATER LAYER
    <PLS >First-order parms (/day) ***
```

```
  # -  #     KDSPS     KADPS     ***
  1           .02       .05
END PEST-FIRSTPM

PEST-DEGRAD
  <PLS >  Pesticide degradation rates (/day)     ***
  # -  #   SURFACE     UPPER     LOWER   GROUNDW ***
  1          0.06     0.045      0.04      0.04
END PEST-DEGRAD

NIT-FLAGS
  <PLS > NITROGEN FLAGS   ***
  # -  # VNUT FORA ITMX BNUM CNUM NUPT FIXN AMVO ALPN VNPR ***
  1              1  100    3    1    1         1
END NIT-FLAGS

NIT-AD-FLAGS
           Atmospheric Deposition Flags ***
               NO3            NH3            ORGN    ***
  <PLS >    sur    upp     sur    upp     sur    upp ***
  # -  #   F  C   F  C    F  C   F  C    F  C   F  C ***
  1       -1  0   0  0   -1  0   0  0   -1  0   0  0
END NIT-AD-FLAGS

SOIL-DATA2
  <PLS >    SWILTP    UWILTP    LWILTP    AWILTP ***
  # -  #   (IN/IN)   (IN/IN)   (IN/IN)   (IN/IN) ***
  1          0.01      0.02      0.05      0.18
END SOIL-DATA2

CROP-DATES
  <PLS >              CROP 1            CROP 2            CROP 3    ***
  # -  # NCRP     PM PD   HM HD     PM PD   HM HD     PM PD   HM HD ***
  1         2     10 15    4 13      4 15    9 30
END CROP-DATES

NIT-YIELD
  <PLS >    NUPTGT    NMXRAT ***
  # -  #   (LB/AC)           ***
  1         145.00       2.0
END NIT-YIELD

MON-NUPT-FR1
  <PLS >  Monthly fractions for plant uptake target                  ***
  # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1       .01  .04  .09 .115 .135 .145  .15  .14 .095  .05 .025 .005
END MON-NUPT-FR1

MON-NUPT-FR2
  <PLS >  Monthly fractions for plant uptake target from surface     ***
  # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1       .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01
END MON-NUPT-FR2

MON-NUPT-FR2
  <PLS >  Monthly fractions for plant uptake target from upper       ***
  # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1       .56  .56  .65  .65  .65  .65  .60  .55  .50  .45  .56  .56
END MON-NUPT-FR2

MON-NUPT-FR2
  <PLS >  Monthly fractions for plant uptake target from lower       ***
  # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1       .43  .43  .34  .34  .34  .34  .39  .44  .49  .54  .43  .43
END MON-NUPT-FR2

MON-NUPT-FR2
  <PLS >  Monthly fractions for plant uptake target from active gw   ***
  # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1        .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0
END MON-NUPT-FR2

NIT-FSTGEN
  <PLS > UPT-FRAC.<----  TEMP-PARMS(THETA)              >***
  #    #  NO3  NH4  PLN KDSA KADA KIMN  KAM KDNI  KNI KIMA***
  1       0.8  0.2 1.07 1.05 1.05 1.07 1.07 1.07 1.05 1.07
```

```
END NIT-FSTGEN

NIT-FSTPM
  <PLS >*** NITROGEN FIRST-ORDER RATES FOR SURFACE LAYER (/DAY)
  #    #***  KDSAM     KADAM     KIMNI       KAM      KDNI       KNI     KIMAM
  1                               .0      .001        .0       10.       5.0
END NIT-FSTPM

NIT-FSTPM
  <PLS >*** NITROGEN FIRST-ORDER RATES FOR UPPER LAYER (/DAY)
  #    #***  KDSAM     KADAM     KIMNI       KAM      KDNI       KNI     KIMAM
  1                               .0    .00015      .000       5.0       2.0
END NIT-FSTPM

NIT-FSTPM
  <PLS >*** NITROGEN FIRST-ORDER RATES FOR LOWER LAYER (/DAY)
  #    #***  KDSAM     KADAM     KIMNI       KAM      KDNI       KNI     KIMAM
  1                               .0    .00015      .005       3.0        .2
END NIT-FSTPM

NIT-FSTPM
  <PLS >*** NITROGEN FIRST-ORDER RATES FOR GROUNDWATER LAYER (/DAY)
  #    #***  KDSAM     KADAM     KIMNI       KAM      KDNI       KNI     KIMAM
  1                               .0       0.0      .030       .50        .0
END NIT-FSTPM

NIT-CMAX
  <PLS >     MAXIMUM SOLUBILITY OF AMMONIUM      ***
  #    #     CMAX                                ***
            (PPM)                                ***
  1          5000.
END NIT-CMAX

NIT-SVALPM        SURFACE
  NITROGEN SINGLE VALUE FREUNDLICH ADSORPTION/DESORPTION PARAMTERS ***
  <PLS >      XFIX        K1        N1***
  #    #     (PPM)                    ***
  1             5.       1.0      1.50
END NIT-SVALPM

NIT-SVALPM        UPPER
  NITROGEN SINGLE VALUE FREUNDLICH ADSORPTION/DESORPTION PARAMETERS ***
  <PLS >      XFIX        K1        N1***
  #    #     (PPM)                    ***
  1             5.       1.0      1.20
END NIT-SVALPM

NIT-SVALPM        LOWER
  NITROGEN SINGLE VALUE FREUNDLICH ADSORPTOIN/DESORPTION PARAMETERS ***
  <PLS >      XFIX        K1        N1***
  #    #     (PPM)                    ***
  1             .7       0.5      1.20
END NIT-SVALPM

NIT-SVALPM        GROUNDWATER
  NITROGEN SINGLE VALUE FREUNDLICH ADSORPTION/DESORPTION PARAMETERS ***
  <PLS >      XFIX        K1        N1***
  #    #     (PPM)                    ***
  1             .3       0.5      1.10
END NIT-SVALPM

NIT-AMVOLAT
  <PLS >     SKVOL     UKVOL     LKVOL     AKVOL     THVOL    TRFVOL ***
  #    #    (/day)    (/day)    (/day)    (/day)       (-)   (deg C) ***
  1            0.0       0.0       0.0         0      1.07       20.
END NIT-AMVOLAT

NIT-STOR1         SURFACE
  <PLS >INITIAL STORAGE OF N FORMS IN SURFACE LAYER LB/AC ***
  #    #      ORGN      AMAD      AMSU       NO3      PLTN***
  1            80.      1.00      0.03       0.3        .0
END NIT-STOR1

NIT-STOR1         UPPER
  <PLS >INITIAL STORAGE OF N FORMS IN UPPER LAYER LB/AC ***
  #    #      ORGN      AMAD      AMSU       NO3      PLTN***
```

```
  1          200.       5.0       0.5       2.0        .0
END NIT-STOR1

NIT-STOR1        LOWER LAYER
  <PLS >INITIAL STORAGE OF N FORMS IN LOWER LAYER LB/AC ***
  #    #      ORGN      AMAD      AMSU       NO3      PLTN***
  1          800.       5.0       1.0        8.        .0
END NIT-STOR1

NIT-STOR1        GROUNDWATER LAYER
  <PLS >INITIAL STORAGE OF N FORMS IN GROUNDWATER LAYER LB/AC ***
  #    #      ORGN      AMAD      AMSU       NO3      PLTN***
  1          600.      6.00      0.50       1.0        .0
END NIT-STOR1

PHOS-FLAGS
         PHOSPHOROUS FLAGS ***
  <PLS > VPUT FORP ITMX BMUM CNUM PUPT ***
  # -  #                              ***
  1             1  100    3    1    1
END PHOS-FLAGS

PHOS-AD-FLAGS
           Atmospheric Deposition Flags ***
               PO4           ORGP        ***
  <PLS >    sur    upp     sur    upp     ***
  # -  #   F  C   F  C    F  C   F  C     ***
  1       -1  0   0  0   -1  0   0  0
END PHOS-AD-FLAGS

MON-PHOSUPT
  <PLS > PLANT UPTAKE OF PHOSPHOROUS IN SURFACE LAYER (/DAY) ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1       .25  .25  .25  .35  1.0  1.5  1.5  1.5  1.5  1.2  .25  .25
END MON-PHOSUPT

MON-PHOSUPT
  <PLS > PLANT UPTAKE OF PHOSPHOROUS IN UPPER LAYER (/DAY) ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1       .25  .25  .25  .35  1.2  3.5  4.5  4.5  4.5  4.5  .55  .25
END MON-PHOSUPT

MON-PHOSUPT
  <PLS > PLANT UPTAKE OF PHOSPHOROUS IN LOWER LAYER (/DAY) ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1       .15  .15  .15  .35  .90  5.2  6.0  6.0  6.0  6.0  .15  .15
END MON-PHOSUPT

PHOS-YIELD
  <PLS >    PUPTGT    PMXRAT ***
  # -  #   (LB/AC)           ***
  1          25.00       1.8
END PHOS-YIELD

MON-PUPT-FR1
  <PLS >  Monthly fractions for plant uptake target                  ***
  # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1       .01  .04  .09 .115 .135 .145  .15  .14 .095  .05 .025 .005
END MON-PUPT-FR1

MON-PUPT-FR2
  <PLS >  Monthly fractions for plant uptake target from surface     ***
  # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1       .05  .05  .05  .05  .05  .05  .05  .05  .05  .05  .05  .05
END MON-PUPT-FR2

MON-PUPT-FR2
  <PLS >  Monthly fractions for plant uptake target from upper       ***
  # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1       .80  .80  .80  .80  .80  .80  .80  .80  .80  .80  .80  .80
END MON-PUPT-FR2

MON-PUPT-FR2
  <PLS >  Monthly fractions for plant uptake target from lower       ***
  # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1       .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15
```

```
END MON-PUPT-FR2

MON-PUPT-FR2
  <PLS >  Monthly fractions for plant uptake target from active gw   ***
  # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1        .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0
END MON-PUPT-FR2

PHOS-FSTGEN
  <PLS > TEMPERATURE CORRECTION PARAMETERS FOR PHOSPHOROUS REACTIONS ***
  #    #     THPLP    THKDSP    THKADP    THKIMP     THKMP           ***
  1           1.07                          1.07       1.05
END PHOS-FSTGEN

PHOS-FSTPM
  <PLS > PHOSPHOROUS FIRST-ORDER RATES FOR SURFACE LAYER (/DAY)    ***
  #    #      KDSP      KADP      KIMP       KMP                   ***
  1                               10.0     .0007
END PHOS-FSTPM

PHOS-FSTPM
  <PLS > PHOSPHOROUS FIRST-ORDER RATES FOR UPPER LAYER (/DAY)      ***
  #    #      KDSP      KADP      KIMP       KMP                   ***
  1                               2.00    .00003
END PHOS-FSTPM

PHOS-FSTPM
  <PLS > PHOSPHOROUS FIRST-ORDER RATES FOR LOWER LAYER (/DAY)      ***
  #    #      KDSP      KADP      KIMP       KMP                   ***
  1                               .100    .00005
END PHOS-FSTPM

PHOS-FSTPM
  <PLS > PHOSPHOROUS FIRST-ORDER RATES FOR GROUNDWATER LAYER (/DAY)    ***
  #    #      KDSP      KADP      KIMP       KMP                       ***
  1                                 0.      0.00
END PHOS-FSTPM

PHOS-CMAX
  <PLS > MAXIMUM SOLUBILITY OF PHOSPHATE   ***
  #    #      CMAX                         ***
             (PPM)                         ***
  1           50.0
END PHOS-CMAX

PHOS-SVALPM        SURFACE
  <PLS >      XFIX       K1        N1***
  #    #     (PPM)                   ***
  1            25.        5.      1.50
END PHOS-SVALPM

PHOS-SVALPM        UPPER
  <PLS >      XFIX       K1        N1***
  #    #     (PPM)                   ***
  1            15.        5.      1.50
END PHOS-SVALPM

PHOS-SVALPM        LOWER
  <PLS >      XFIX       K1        N1***
  #    #     (PPM)                   ***
  1            10.        5.      1.50
END PHOS-SVALPM

PHOS-SVALPM        GROUNDWATER
  <PLS >      XFIX       K1        N1***
  #    #     (PPM)                   ***
  1            12.        6.      1.50
END PHOS-SVALPM

PHOS-STOR1
  <PLS > INITIAL PHOSPHOROUS STORAGE IN SURFACE LAYER LB/AC ***
  #    #      ORGP      P4AD      P4SU      PLTP            ***
  1            20.      2.00      0.00        0.
END PHOS-STOR1

PHOS-STOR1
```

```
    <PLS > INITIAL PHOSPHOROUS STORAGE IN UPPER LAYER LB/AC   ***
    #    #      ORGP      P4AD      P4SU      PLTP            ***
    1            40.      28.0      1.00        0.
  END PHOS-STOR1

  PHOS-STOR1
    <PLS > INITIAL PHOSPHOROUS STORAGE IN LOWER LAYER LB/AC   ***
    #    #      ORGP      P4AD      P4SU      PLTP            ***
    1            25.     130.0       1.5        0.
  END PHOS-STOR1

  PHOS-STOR1
    <PLS > INITIAL PHOSPHOROUS STORAGE IN GROUNDWATER LAYER LB/AC ***
    #    #      ORGP      P4AD      P4SU      PLTP                ***
    1            15.      210.      01.0        0.
  END PHOS-STOR1
END PERLND

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member-> ***
<Name>   # <Name> # tem strg<-factor->strg <Name>   #   #        <Name> # # ***
WDM    105 HPRC  10 ENGLZERO          SAME PERLND   1     EXTNL  PREC
WDM     40 EVAP     ENGLZERO     0.86 DIV  PERLND   1     EXTNL  PETINP
WDM     49 ATMP     ENGL              SAME PERLND   1     EXTNL  GATMP
WDM    541 NH4X     ENGL              DIV  PERLND   1     EXTNL  NIADFX 2 1
WDM    542 NO3X     ENGL              DIV  PERLND   1     EXTNL  NIADFX 1 1
WDM    543 NO3X     ENGL              DIV  PERLND   1     EXTNL  NIADFX 1 1
WDM    545 ORGN     ENGL              DIV  PERLND   1     EXTNL  NIADFX 3 1
WDM    544 PO4X     ENGL              DIV  PERLND   1     EXTNL  PHADFX 1 1
WDM    546 ORGP     ENGL              DIV  PERLND   1     EXTNL  PHADFX 2 1
END EXT SOURCES

END RUN
```

Case Study C. Reservoir Operations

```
RUN

GLOBAL
  Special Actions Case Study #3 - Basin Management
  START       1992              END    1993
  RUN INTERP OUTPUT LEVEL    3    4
  RESUME     0 RUN     1                   UNIT SYSTEM     1
END GLOBAL

FILES
<ftyp>  <fun>***<-----------------fname----------------------------------------->
MESSU      25   case3.ech
WDM        26   case.wdm
            2   case3.out
END FILES

OPN SEQUENCE
    INGRP              INDELT 24:00
      PERLND       1
      COPY         1
      GENER        1
      GENER        2
      RCHRES       1
      GENER        3
      RCHRES       2
      RCHRES       3
      RCHRES       4
    END INGRP
END OPN SEQUENCE

CATEGORY
   <> <-----name-----> ***
   fw fish & wildlife
   mu municipal
END CATEGORY

SPEC-ACTIONS

*** User-Defined Target Variable Names
***                 <addrss>-------                <addrss>-------
***             cnt    or              act        or                act
***kwrd>  <unam>< > <vari><1><2><3> <frc> <  >    <vari><1><2><3> <frc> <  >
  UVNAME  LMINQ   1 WORKSP 11         1.0 QUAN
  UVNAME  LPROP   1 WORKSP 12         1.0 QUAN
  UVNAME  LFWPRO  1 WORKSP 13         1.0 QUAN
  UVNAME  LMUPRO  1 WORKSP 14         1.0 QUAN
  UVNAME  LNEED   1 WORKSP 15         1.0 QUAN

  UVNAME  RMAXST  1 WORKSP 21         1.0 QUAN
  UVNAME  RMINQ   1 WORKSP 22         1.0 QUAN
  UVNAME  RFWPRO  1 WORKSP 23         1.0 QUAN
  UVNAME  RNEED   1 WORKSP 24         1.0 QUAN
  UVNAME  RDRAW   1 WORKSP 25         1.0 QUAN
  UVNAME  RAVAIL  1 WORKSP 26         1.0 QUAN
  UVNAME  RFILFG  1 WORKSP 27         1.0 QUAN

  UVNAME  FLOOD   1 WORKSP 31         1.0 QUAN
  UVNAME  FTARHI  1 WORKSP 32         1.0 QUAN
  UVNAME  FTARLO  1 WORKSP 33         1.0 QUAN
  UVNAME  FTARG   1 WORKSP 34         1.0 QUAN
  UVNAME  FAVAIL  1 WORKSP 35         1.0 QUAN
  UVNAME  FNEED   1 WORKSP 36         1.0 QUAN
  UVNAME  MAXREL  1 WORKSP 37         1.0 QUAN
  UVNAME  TOTPRO  1 WORKSP 38         1.0 QUAN

*** User-Defined Variable Quantity Lines
***                        <addrss>-------
***                           or                         lc ls ac as agfn
***kwrd> <uqnm> <oper> <#> <vari><1><2><3><t><multfact> <>< > <>< > <  >
  UVQUAN lminq  GLOBAL     WORKSP 11
```

```
  UVQUAN lprop  GLOBAL     WORKSP 12
  UVQUAN lfwpro GLOBAL     WORKSP 13
  UVQUAN lmupro GLOBAL     WORKSP 14
  UVQUAN lneed  GLOBAL     WORKSP 15

  UVQUAN rmaxst GLOBAL     WORKSP 21
  UVQUAN rminq  GLOBAL     WORKSP 22
  UVQUAN rfwpro GLOBAL     WORKSP 23
  UVQUAN rneed  GLOBAL     WORKSP 24
  UVQUAN rdraw  GLOBAL     WORKSP 25          .50416667
               *** RDRAW is in units of ac-ft.  Convert rdraw to cfs.
  UVQUAN ravail GLOBAL     WORKSP 26          .50416667
               *** RAVAIL is in units of ac-ft. Convert ravail to cfs.
  UVQUAN rfilfg GLOBAL     WORKSP 27        2

  UVQUAN flood  GLOBAL     WORKSP 31
  UVQUAN ftarhi GLOBAL     WORKSP 32
  UVQUAN ftarlo GLOBAL     WORKSP 33
  UVQUAN ftarg  GLOBAL     WORKSP 34
  UVQUAN favail GLOBAL     WORKSP 35                          DY  2 AVER
  UVQUAN fneed  GLOBAL     WORKSP 36
  UVQUAN maxrel GLOBAL     WORKSP 37
  UVQUAN totpro GLOBAL     WORKSP 38

***                        <addrss>-------
***                           or                         lc ls ac as agfn
***kwrd> <uqnm> <oper> <#> <vari><1><2><3><t><multfact> <>< > <>< > <  >
  UVQUAN month  COPY     1 MON              2
  UVQUAN mudem  COPY     1 MEAN    1

  UVQUAN lfwinf PERLND   1 PERO               6302.0833
  UVQUAN natdin PERLND   1 PERO               6302.0833
               *** PERO is in units of inches/day.  Using a tributary area of
               *** 150,000 acres, convert to cfs.

  UVQUAN lfwsto RCHRES   1 CVOL   fw        4 1.1574E-5
               *** CVOL is in units of ft3.  Convert lfwsto to cfs.
  UVQUAN lfwstv RCHRES   1 CVOL   fw        4 2.2957E-5
               *** CVOL is in units of ft3.  Convert lfwstv to ac-ft.
  UVQUAN lmusto RCHRES   1 CVOL   mu        4 1.1574E-5
               *** CVOL is in units of ft3.  Convert lmusto to cfs.

  UVQUAN rstor  RCHRES   2 VOL              4 2.2957E-5
               *** VOL is in units of ft3.  Convert rstor to ac-ft.
  UVQUAN rfwsto RCHRES   2 CVOL   fw        4 1.1574E-5
               *** CVOL is in units of ft3.  Convert rfwsto to cfs.
  UVQUAN rfwstv RCHRES   2 CVOL   fw        4 2.2957E-5
               *** CVOL is in units of ft3.  Convert rfwstv to ac-ft.

********************************************************************************
*** Begin Operating Logic ******************************************************
********************************************************************************

*** ================ Constants and Seasonal Values ============================
***                                       <addrss>-------   ----<uvqn>
***            dc ds                 d t     or                  or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
*** Set flood stage for Reach 3 (municipal area)
  GENER   1        1992  1  1             FLOOD            =     500.0

*** Set minimum flows for lake - varies seasonally
*** Initial value
  GENER   1        1992  1  1             LMINQ            =      50.0
*** Summer
  GENER   1        1992  4  1             LMINQ            =      70.0 YR   1 10
*** Winter
  GENER   1        1992 10  1             LMINQ            =      50.0 YR   1 10

*** Set seasonal fish flow targets for high and low fish storage
*** Initial values
  GENER   1        1992  1  1             FTARHI           =     200.0
  GENER   1        1992  1  1             FTARLO           =     100.0
*** Spring
  GENER   1        1992  2  1             FTARHI           =     250.0 YR   1 10
  GENER   1        1992  2  1             FTARLO           =     150.0 YR   1 10
*** Summer-Winter
```

```
  GENER   1         1992  6  1            FTARHI           =     200.0 YR   1 10
  GENER   1         1992  6  1            FTARLO           =     100.0 YR   1 10

*** Maximum reservoir storage for winter flood control space
    plus filling season flag ***
*** Initial values
  GENER   1         1992  1  1            RMAXST           =   10000.0
  GENER   1         1992  1  1         2  RFILFG           =         0

*** Springtime filling season is April and May - set flag at start
  GENER   1         1992  4  1         2  RFILFG           =         1 YR   1 10
IF (month = 4 OR month = 5) THEN
 *** During April and May, there is a daily increase in allowable storage of
 *** 1/61st of total fill of 15,000 acre-feet.
  GENER   1                               RMAXST          +=     245.9
END IF

*** Summer - turn off filling flag for reservoir and set high max storage
  GENER   1         1992  6  1         2  RFILFG           =         0 YR   1 10
  GENER   1         1992  6  1            RMAXST           =   25000.0 YR   1 10

*** Fall Drawdown
IF (month = 10 OR month = 11) THEN
 *** During October and November, there is a daily reduction in allowable
 *** storage of 1/61st of total drawdown of 15,000 acre-feet.
  GENER   1                               RMAXST          -=     245.9
END IF

*** Winter
  GENER   1         1992 12  1            RMAXST           =   10000.0 YR   1 10

*** ============= Daily operations ==========================================
*** Proposed releases are calculated based on municipal and fish demands.  These
*** releases are adjusted as needed to meet minimum flow, maximum flow, and
*** maximum storage requirements.
*** ========================================================================
***                                       <addrss>-------   ----<uvqn>
***          dc ds                 d t      or                    or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
*** ------------------ Municipal Release -----------------------------------
*** Lake releases municipal demand based on input timeseries
*** ------------------------------------------------------------------------
  GENER   1                               LMUPRO           =    mudem

*** ------------------ Fish Releases ---------------------------------------
*** Total needed fish releases are calculated based on seasonal target, total
*** storage of category "fw", and the flow at the gage for Reach 4.  They are
*** also limited by flood stage at Reach 3.
*** Fish releases are allocated according to priority: 1) Lake fish water up
*** to inflow; 2) Reservoir fish water; 3) Lake fish water above inflow
*** ------------------------------------------------------------------------
*** Determine whether to use high or low fish flow target based of total
*** storage of fish water

*** First find how much total fish water is available in both sources

  GENER   1                               FAVAIL           =    lfwstv
  GENER   1                               FAVAIL          +=    rfwstv

IF (favail >= 150000.) THEN
 *** more than 150,000. acre-feet storage, so use high target
  GENER   1                               FTARG            =    ftarhi
ELSE
 *** less than 150,000. acre-feet storage, so use low target
  GENER   1                               FTARG            =    ftarlo
END IF

*** Determine fish release limit for downstream flood control by
*** subtraction natural inflows and necessary municipal releases
*** from flooding limit.  Last line sets negative release to zero.
  GENER   1                               MAXREL           =    flood
  GENER   1                               MAXREL          -=    natdin
  GENER   1                               MAXREL          -=    lmupro
  GENER   1                               MAXREL         MAX       0.0

*** Then calculate total needed for fish releases as fish target
```

```
*** minus downstream inflow, and bracketed by zero and maximum
  GENER   1                             FNEED             =    ftarg
  GENER   1                             FNEED            -=    natdin
  GENER   1                             FNEED           MAX       0.0
  GENER   1                             FNEED           MIN    maxrel

*** Lake fish water proposed release - up to inflow if needed
IF (fneed <= 0.0) THEN
 *** none needed
  GENER   1                             LFWPRO            =       0.0
ELSE
 *** make further release from Lake fish water up to storage and
 *** decrement remaining need
  GENER   1                             LFWPRO            =    fneed
  GENER   1                             LFWPRO          MIN    lfwinf
  GENER   1                             FNEED            -=    lfwpro
END IF

*** Reservoir fish water proposed release
IF (rfilfg = 0) THEN
 *** not in filling season - allowed to make fish releases
 IF (fneed <= 0.0) THEN
  *** none needed
  GENER   1                             RFWPRO            =       0.0
 ELSE
  *** make further release from Reservoir fish water

  *** compute available amount over minimum desired storage
  GENER   1                             RAVAIL            =    rfwstv
  GENER   1                             RAVAIL           -=    5000.0
  GENER   1                             RAVAIL          MAX       0.0

  *** now compute release
  GENER   1                             RFWPRO            =    fneed
  GENER   1                             RFWPRO          MIN    ravail
  GENER   1                             FNEED            -=    rfwpro
 END IF
END IF

*** Lake fish water proposed release - above inflow
IF (fneed > 0.0) THEN
 *** make further release from Lake fish water
  GENER   1                             LFWPRO           +=    fneed
  GENER   1                             LFWPRO          MIN    lfwsto
END IF

*** ---------- Adjust lake releases for minimum flow --------------------------
*** Make additional releases as needed to raise the total proposed release to
*** meet minimum flow requirements.
*** ---------------------------------------------------------------------------
***                                     <addrss>-------   ----<uvqn>
***            dc ds                 d t    or                   or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
  GENER   1                             LPROP             =    lmupro
  GENER   1                             LPROP            +=    lfwpro

IF (lprop < lminq) THEN
 *** need additional release
  GENER   1                             LNEED             =    lminq
  GENER   1                             LNEED            -=    lprop

 *** try to satisfy from fish water first
  GENER   1                             LFWPRO           +=    lneed
  GENER   1                             LFWPRO          MIN    lfwsto

 *** recalculate total proposed release from Lake
  GENER   1                             LPROP             =    lmupro
  GENER   1                             LPROP            +=    lfwpro

 IF (lprop < lminq) THEN
  *** still need more water
  GENER   1                             LNEED             =    lminq
  GENER   1                             LNEED            -=    lprop

 *** try to satisfy from municipal water
  GENER   1                             LMUPRO           +=    lneed
```

```
  GENER   1                               LMUPRO         MIN    lmusto

 *** recalculate total proposed release from Lake
  GENER   1                               LPROP            =    lmupro
  GENER   1                               LPROP           +=    lfwpro
 END IF
END IF

*** ---------- Adjust reservoir releases for maximum storage -------------------
*** If the reservoir storage is above the maximum storage, additional releases
*** are made to draw the level down.
*** ---------------------------------------------------------------------------
***                                       <addrss>-------   ----<uvqn>
***            dc ds                 d t     or                  or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
IF (rstor > rmaxst) THEN
 *** draw down reservoir

 *** compute excess storage
  GENER   1                               RDRAW            =    rstor
  GENER   1                               RDRAW           -=    rmaxst

 IF (rdraw > rfwpro) THEN
  *** must release additional water
  GENER   1                               RNEED            =    rdraw
  GENER   1                               RNEED           -=    rfwpro
  GENER   1                               RFWPRO          +=    rneed
  GENER   1                               RFWPRO         MIN    rfwsto
  *** check new total releases against maximum
  GENER   1                               TOTPRO           =    lprop
  GENER   1                               TOTPRO          +=    rfwpro
  IF (totpro > maxrel) THEN
   *** reduce drawdown
  GENER   1                               RFWPRO           =    maxrel
  GENER   1                               RFWPRO          -=    lprop
  END IF
 END IF
END IF

*** ---------- Adjust reservoir releases for minimum flow ----------------------
*** Make additional releases as needed to raise the total proposed release to
*** meet minimum flow requirements.
*** ---------------------------------------------------------------------------
***                                       <addrss>-------   ----<uvqn>
***            dc ds                 d t     or                  or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
IF (rstor >= 5000.0) THEN
 *** reservoir storage is high enough to release high minimum
  GENER   1                               RMINQ            =      10.0
ELSE
 *** release low minimum
  GENER   1                               RMINQ            =       5.0
END IF

IF (rfwpro < rminq) THEN
 *** need additional release
  GENER   1                               RNEED            =    rminq
  GENER   1                               RNEED           -=    rfwpro
 *** make additional release up to total fish storage in reservoir
  GENER   1                               RFWPRO          +=    rneed
  GENER   1                               RFWPRO         MIN    rfwsto
END IF

*******************************************************************************
*** Pass final values for proposed releases to GENER operations.
*******************************************************************************

***                                       <addrss>-------   ----<uvqn>
***            dc ds                 d t     or                  or   tc ts num
***oper><f><-l><>< ><yr><m><d><h><m><><>  <vari><1><2><3><a><-value--> <> < >< >
  GENER   1                               K       1        =    lmupro
  GENER   2                               K       1        =    lfwpro
  GENER   3                               K       1        =    rfwpro

END SPEC-ACTIONS
```

```
PERLND
  ACTIVITY
    <PLS >          Active Sections (1=Active, 0=Inactive)             ***
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
    1              1    1
  END ACTIVITY

  PRINT-INFO
    <PLS >          Print-flags                                    *** PIVL  PYR
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC       ***
    1              4    4                                                1   12
  END PRINT-INFO

  GEN-INFO
    <PLS ><-------Name------->        Unit-systems   Printer ***
    # -  #                                t-series Engl Metr ***
                                           in  out           ***
    1      KESTREL FOREST                   1    1    2    0
  END GEN-INFO

  *** Section SNOW ***

  ICE-FLAG
    <PLS >  0= Ice formation not simulated, 1= Simulated ***
    # -  #ICEFG                                          ***
    1        0
  END ICE-FLAG

  SNOW-PARM1
    <PLS >  Snow input info: Part 1                              ***
    # -  #       LAT     MELEV     SHADE    SNOWCF    COVIND ***
    1            42.     1800.       0.0      1.45       0.5
  END SNOW-PARM1

  SNOW-PARM2
    <PLS >  Snow input info: Part 2                                        ***
    # -  #     RDCSN     TSNOW    SNOEVP    CCFACT    MWATER    MGMELT ***
    1           0.12       32.      0.05       0.5      0.08    0.0001
  END SNOW-PARM2

  SNOW-INIT1
    <PLS >  Initial snow conditions: Part 1                                ***
    # -  #  PACKSNOW   PACKICE PACKWATER    RDENPF      DULL    PAKTMP ***
    1            1.4       0.2       0.1       0.2      375.      27.5
  END SNOW-INIT1

  SNOW-INIT2
    <PLS >  Initial snow conditions: Part 2 ***
    # -  #    COVINX    XLNMLT    SKYCLR    ***
    1           0.50       0.0       1.0
  END SNOW-INIT2

  *** Section PWATER ***

  PWAT-PARM1
    <PLS >  PWATER variable monthly parameter value flags ***
    # -  # CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE    ***
    1         0    1    1    1    0    0    0    0    0
  END PWAT-PARM1

  PWAT-PARM2
    <PLS > ***  PWATER input info: Part 2
    # -  # ***FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
    1          0.000     4.000      0.06      200.   0.22000     0.000     0.985
  END PWAT-PARM2

  PWAT-PARM3
    <PLS > ***  PWATER input info: Part 3
    # -  # ***PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
    1            40.       35.       2.0       2.0       0.0       0.0       0.0
  END PWAT-PARM3

  PWAT-PARM4
    <PLS >     PWATER input info: Part 4                                   ***
    # -  #     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP ***
    1           0.00     1.000     0.350     3.000     0.750     0.400
```

```
  END PWAT-PARM4

  MON-INTERCEP
    <PLS>   Only required if VCSFG=1 in PWAT-PARM1                    ***
    # -  #  Interception storage capacity at start of each month      ***
            JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
    1      .060 .060 .060 .100 .160 .160 .160 .160 .160 .100 .060 .060
  END MON-INTERCEP

  PWAT-STATE1
    <PLS > *** Initial conditions at start of simulation
    # -  # ***  CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
    1          0.000     0.000     0.500     0.000     4.000     0.500     0.000
  END PWAT-STATE1
END PERLND

RCHRES
  ACTIVITY
    RCHRES  Active Sections (1=Active; 0=Inactive)           ***
    # -  # HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG ***
    1    4    1
  END ACTIVITY

  PRINT-INFO
    RCHRES  Print-flags                                               ***
    # -  # HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK   PH PIVL  PYR ***
    1    4    4                                              1   12
  END PRINT-INFO

  GEN-INFO
    RCHRES<-------Name------->Nexit   Unit Systems   Printer      ***
    # -  #                              t-series  Engl Metr LKFG ***
                                          in  out                 ***
    1     LAKE SERRA              2         1    1    2    0    1
    2     ADDISON RESERVOIR       2         1    1    2    0    1
    3     UPPER KEITH RIVER       2         1    1    2    0    0
    4     LOWER KEITH RIVER       1         1    1    2    0    0
  END GEN-INFO

  HYDR-PARM1
    RCHRES  Flags for HYDR section                           ***
    # -  #  VC A1 A2 A3  ODFVFG for each     ODGTFG for each *** FUNCT  for each
            FG FG FG FG  possible   exit     possible   exit *** possible   exit
                1  2  3    1  2  3  4  5       1  2  3  4  5 ***
    1           1             4                1
    2           1             4                1
    3           1             4                1
    4           1          4
  END HYDR-PARM1

  HYDR-PARM2
    RCHRES ***
    # -  #  DSN FTBN       LEN     DELTH     STCOR        KS ***
    1              1      21.9                           0.0
    2              2       1.7                           0.0
    3              3       3.4                           0.0
    4              4       5.6                           0.0
  END HYDR-PARM2

  HYDR-INIT
          Initial conditions for HYDR section      ***
  RCHRES         VOL  CAT Initial value  of COLIND *** initial  value  of OUTDGT
    # -  #     ac-ft      for each possible   exit *** for  each  possible  exit
                           EX1  EX2  EX3  EX4  EX5 ***   EX1  EX2  EX3  EX4  EX5
    1        400000.    2       4.0
    2         10000.   fw       4.0
    3            16.   fw       4.0
    4            16.   fw  4.0
  END HYDR-INIT

  HYDR-CINIT
*** RCHRES  Category Fractions for Precipitation
*** # -  #   c  frac   c  frac   c  frac   c  frac   c  frac   c  frac   c  frac
    1       fw   0.8  mu   0.2
  END HYDR-CINIT
```

```
  HYDR-CATEGORY
       Categories specified for Outflows, Precipitation and Evaporation ***
    RCHRES Categories associated with:                                  ***
    # -  # prec evap  fv1  fv2  fv3  fv4  fv5   gt                      ***
    1        fw   fw        fw                   2
    2        fw   fw        fw                   1
    3        fw   fw        fw                   1
    4        fw   fw
  END HYDR-CATEGORY

  HYDR-CDEMAND
  Category Priorities and Initial Values for G(T) Demands  ***
           c x  Priority  COTDGT   c x  Priority  COTDGT ***
    RCHRES      (yyyy/mm/dd) (cfs)      (yyyy/mm/dd) (cfs) ***
    # -  #  <><> <--> <> <> <---->  <><> <--> <> <> <----> ***
    1       fw 1               50.  mu 1              20.
    2       fw 1               10.
    3       mu 1              200.
  END HYDR-CDEMAND
  *** Note: COTDGT of 200. cfs for Reach 3, Exit 1 is the maximum diversion
  *** capacity.  No input timeseries is provided for this demand, so the
  *** value will remain constant.  The result is that ALL municipal water
  *** entering Reach 3 will be diverted, up to the capacity.  Any excess will
  *** continue downstream.
END RCHRES

COPY
  TIMESERIES
    # -  #  NPT  NMN ***
    1             1
  END TIMESERIES
END COPY

GENER
  OPCODE
    #    # OPCD ***
    1    3   24
  END OPCODE

  PARM
    #    #         K ***
    1    3        0.
  END PARM
END GENER

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member-> ***
<Name>   # <Name> # tem strg<-factor->strg <Name>   #   #        <Name> # # ***
WDM     39 PREC     ENGLZERO               PERLND   1     EXTNL  PREC
WDM     39 PREC     ENGL                   RCHRES   1   4 EXTNL  PREC
WDM    123 ATMP     ENGL              AVER PERLND   1     ATEMP  AIRTMP
WDM     41 EVAP     ENGL        .7         PERLND   1     EXTNL  PETINP
WDM     41 EVAP     ENGL        .7         RCHRES   1   4 EXTNL  POTEV
WDM     42 WIND     ENGL                   PERLND   1     EXTNL  WINMOV
WDM     46 SOLR     ENGL                   PERLND   1     EXTNL  SOLRAD
WDM    126 DEWP     ENGL                   PERLND   1     EXTNL  DTMPG
WDM    135 CLDC     ENGL                   PERLND   1     EXTNL  CLOUD
WDM    137 FLOW     ENGL                   COPY     1     INPUT  MEAN   1
END EXT SOURCES

SCHEMATIC
<-Source->                <--Area-->       <-Target->  <ML->  ***
<Name>   #                <-factor->       <Name>   #      #  ***
PERLND   1                   150000.       RCHRES   1      3
PERLND   1                    75000.       RCHRES   2      4
PERLND   1                   100000.       RCHRES   3      4
PERLND   1                    50000.       RCHRES   4      4

RCHRES   1                                 RCHRES   3      1
RCHRES   2                                 RCHRES   3      1
RCHRES   3                                 RCHRES   4      2
END SCHEMATIC

MASS-LINK
  MASS-LINK        1
<Srce>     <-Grp> <-Member-><--Mult-->     <Targ>         <-Grp> <-Member-> ***
```

```
<Name>     <Name> <Name> # #<-factor->     <Name>         <Name> <Name> # # ***
RCHRES     ROFLOW                         RCHRES         INFLOW
  END MASS-LINK    1

  MASS-LINK        2
<Srce>     <-Grp> <-Member-><--Mult-->     <Targ>         <-Grp> <-Member-> ***
<Name>     <Name> <Name> # #<-factor->     <Name>         <Name> <Name> # # ***
RCHRES     OFLOW        2                 RCHRES         INFLOW
  END MASS-LINK    2

  MASS-LINK        3
<Srce>     <-Grp> <-Member-><--Mult-->     <Targ>         <-Grp> <-Member-> ***
<Name>     <Name> <Name> # #<-factor->     <Name>         <Name> <Name> # # ***
PERLND     PWATER PERO      0.06666667     RCHRES         EXTNL  CIVOL fw
PERLND     PWATER PERO      0.01666667     RCHRES         EXTNL  CIVOL mu
  END MASS-LINK    3

  MASS-LINK        4
<Srce>     <-Grp> <-Member-><--Mult-->     <Targ>         <-Grp> <-Member-> ***
<Name>     <Name> <Name> # #<-factor->     <Name>         <Name> <Name> # # ***
PERLND     PWATER PERO      0.08333333     RCHRES         EXTNL  CIVOL fw
  END MASS-LINK    4
END MASS-LINK

NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #        <Name> # #<-factor->strg <Name>   #   #        <Name> # #  ***
GENER    1 OUTPUT TIMSER                   RCHRES   1     EXTNL  COTDGT 1mu
GENER    2 OUTPUT TIMSER                   RCHRES   1     EXTNL  COTDGT 1fw
GENER    3 OUTPUT TIMSER                   RCHRES   2     EXTNL  COTDGT 1fw
END NETWORK

FTABLES
  FTABLE      1
 ROWS COLS ***
   25    4
     DEPTH      AREA    VOLUME     DISCH ***
      (FT)   (ACRES)   (AC-FT)     (CFS) ***
       0.0    119950     0.000      0.00
       1.0    120370    120160      0.00
       1.5    120540    180380      0.00
       2.0    120710    240700      0.00
       2.5    120870    301090      0.00
       3.0    121020    361570      0.00
       3.4    121130    410000      0.00
       3.7    121210    446350      0.00
       4.0    121270    482720      0.00
       4.3    121340    519110     17.00
       4.7    121420    567660    109.00
       5.0    121480    604100    211.00
       5.3    121540    640550    336.00
       5.7    121620    689180    375.00
       6.0    121680    725680    450.00
       6.3    121740    762190    600.00
       6.7    121830    810900    800.00
       7.0    121900    847470   1000.00
       7.5    122020    908450   1300.00
       8.0    122160    969490   1650.00
       8.5    122530   1030630   2050.00
       9.0    122900   1092020   2450.00
       9.5    123040   1153510   2850.00
      10.0    123140   1215050   3250.00
      10.5    123230   1276640   3500.00
  END FTABLE  1
  FTABLE      2
 ROWS COLS ***
   25    4
     DEPTH      AREA    VOLUME     DISCH ***
      (FT)   (ACRES)   (AC-FT)     (CFS) ***
       0.0       0.0       0.0      0.00
       8.0       4.0      17.0      0.00
      18.0      24.0     143.0      0.00
      28.0      47.0     491.0      0.00
      33.0      66.0     770.0      0.00
      38.0      86.0    1148.0      0.00
      38.6      89.0    1201.0      0.00
```

```
      43.0     109.0    1633.0      0.00
      48.0     132.0    2230.0      0.00
      53.0     157.0    2948.0      0.00
      58.0     182.0    3791.0      0.00
      63.0     212.0    4771.0      0.00
      68.0     242.0    5901.0      0.00
      73.0     274.0    7187.0      0.00
      78.0     307.0    8636.0      0.00
      83.0     352.0   10278.0      0.00
      88.0     398.0   12147.0      0.00
      93.0     451.0   14262.0      0.00
      98.0     504.0   16643.0      0.00
     103.0     559.0   19294.0      0.00
     108.0     614.0   22220.0      0.00
     113.0     674.0   25434.0      0.00
     118.0     734.0   28949.0    117.00
     123.0     818.0   32806.0    638.00
     138.0    1069.0   46936.0   2345.00
  END FTABLE  2
  FTABLE      3
 Rows Cols ***
   18    4
     DEPTH      AREA    VOLUME     DISCH ***
      (FT)   (ACRES)   (AC-FT)     (CFS) ***
       0.0     0.000     0.000      0.00
       2.3     2.339     0.369      1.00
       3.1     7.223     3.849     17.00
       3.7    13.243     8.954     46.00
       4.5    20.406    20.509    138.00
       5.3    24.510    36.397    318.00
       6.3    27.225    58.513    666.00
       7.5    29.836    90.116   1302.00
       8.3    31.797   113.364   1847.00
       9.1    33.356   138.003   2486.00
       9.9    34.756   163.636   3208.00
      10.9    36.283   197.485   4258.00
      11.9    37.368   233.321   5482.00
      13.1    39.329   278.197   7136.00
      14.3    42.080   325.800   8993.00
      15.5    43.339   373.742  11009.00
      16.9    45.015   432.516  13643.00
      18.5    47.576   498.040  16671.00
  END FTABLE  3
  FTABLE      4
 Rows Cols ***
   18    4
     DEPTH      AREA    VOLUME     DISCH ***
      (FT)   (ACRES)   (AC-FT)     (CFS) ***
       0.0     0.000     0.000      0.00
       2.3     2.339     0.369      1.00
       3.1     7.223     3.849     17.00
       3.7    13.243     8.954     46.00
       4.5    20.406    20.509    138.00
       5.3    24.510    36.397    318.00
       6.3    27.225    58.513    666.00
       7.5    29.836    90.116   1302.00
       8.3    31.797   113.364   1847.00
       9.1    33.356   138.003   2486.00
       9.9    34.756   163.636   3208.00
      10.9    36.283   197.485   4258.00
      11.9    37.368   233.321   5482.00
      13.1    39.329   278.197   7136.00
      14.3    42.080   325.800   8993.00
      15.5    43.339   373.742  11009.00
      16.9    45.015   432.516  13643.00
      18.5    47.576   498.040  16671.00
  END FTABLE  4
END FTABLES

END RUN
```