Documentation of Conversion of the MODFLOW Streamflow-Routing (STR) Package To MODFLOW-2005

This documentation describes the changes to the Streamflow-Routing (STR) Package (Prudic, 1989) to convert it to work with MODFLOW-2005. See Chapter 9 of Harbaugh (2005) for further information about the MODFLOW-2005 program. The modified code is designated version 7, and this code has the same functionality as version 6 of this package, which is the version used in MODFLOW-2000. Version 6 added the capability to define input data using parameters. The input for version 7 is the same as for version 6. Input instructions are included at the end of this documentation.

1. Fortran module GWFSTRMODULE was created to store the shared data for the STR Package; GWFSTRMODULE incorporates the capability to support Local grid Refinement. The following table describes the data.

Variable Name	Size	Description
MXSTRM	Scalar	The sum of the reaches used to define parameters and the maximum number of active reaches in a stress period
NSTREM	Scalar	The number of stream reaches active in a stress period
NSS	Scalar	The number of stream segments
NTRIB	Scalar	The number of stream tributaries that can connect to one segment
NDIV	Scalar	Diversion flag – positive indicates diversions are allowed
ICALC	Scalar	Stage calculation flag – positive value indicates stream stage is calculated
ISTCB1	Scalar	Flag and file unit for writing stream seepage into the Listing File
ISTCB2	Scalar	Flag and file unit for writing streamflow into an unformatted file
IPTFLG	Scalar	Stream print flag
CONST	Scalar	A constant value used in calculating stream stage
NPSTR	Scalar	The number of stream parameters
ISTRPB	Scalar	The maximum number of active reaches in a stress period plus 1. ISTRPB is the value of the 2nd index of STRM and ISTRM at which parameter data begins
STRM	11,MXSTRM	A list of real-number values for each stream reach
ARTRIB	NSS	The streamflow from the last reach of a segment
ISTRM	5,MXSTRM	A list of integer values for each stream reach
ITRBAR	NSS,NTRIB	The connecting tributaries for each segment
IDIVAR	NSS	The upstream segment from which a diversion segment diverts water
NDFGAR	NSS	The number of tributaries connecting to each segment

2. All subroutines were changed to designate 2 for the process version and 7 for the package version: GWF2STR7.

3. Subroutines GWF2STR7ALP and GWF2STR7RPPD were combined and renamed GWF2STR7AR.

4. GWF2STR7AR was modified to use ALLOCATE statements to reserve memory for the data in GWFSTRMODULE rather than reserving space in the RX and IR arrays used by MODFLOW-2000.

5. Subroutine arguments that are contained in Fortran modules were replaced with USE statements in all subroutines.

6. Subroutine GWF2STR7DA was created to deallocate memory.

7. To support the Local Grid Refinement capability, subroutine SGWF2STR7PNT was created to set pointers to a grid, and subroutine SGWF2STR7PSV was created to save the pointers for a grid. The grid number, IGRID,

was added as a subroutine argument to all of the primary subroutines, and subroutines SGWF2STR7PSV and SGWF2STR7PNT are called as appropriate.

Input Instructions for STR7

Input to the modified version of the Streamflow-Routing (STR) Package is read from the file that has file type "STR" in the MODFLOW name file. Optional variables are shown in brackets. Variables are free format if the option "FREE" is specified in the Basic Package input file; otherwise, most variables are read with the indicated fixed format.

FOR EACH SIMULATION

0. [#Text]

Item 0 is optional -- "#" must be in column 1. Item 0 can be repeated multiple times.

1. [***PARAMETER*** NPSTR MXL]

This optional record is read with free format; it must start with the word "PARAMETER".

2. MXACTS NSS NTRIB NDIV ICALC CONST ISTCB1 ISTCB2 [Option]
I10 I10 I10 I10 I10 F10.0 I10 I10 Free

3. [PARNAM PARTYP Parval NLST [***INSTANCES*** NUMINST]]

Item 3 is read with free format. If PARNAM is to be a time-varying parameter, the keyword "INSTANCES" and a value for NUMINST must be entered.

4a. [INSTNAM]

Item 4a is read only if PARNAM is time varying. NUMINST repetitions of Item 4 (parts a and b) are read. After each repetition of Item 4a, NLST repetitions of Item 4b are read.

4b. [Layer Row Col Seg Reach Flow Stage Condfact Sbot Stop [xyz]]
I5 I5 I5 I5 I5 F15.0 F10.0 F10.0 F10.0 F10.0 Free

NLST repetitions of Item 4b are required. The NLST repetitions of Item 4b follow each repetition of Item 4a when PARNAM is time varying. Repeat Items 3 and 4 for each of NPSTR parameters.

FOR EACH STRESS PERIOD

5. ITMP IRDFLG IPTFLG
I10 I10 I10

6. Layer Row Col Seg Reach Flow Stage Cond Sbot Stop [xyz]
I5 I5 I5 I5 I5 F15.0 F10.0 F10.0 F10.0 F10.0 Free

Item 6 is repeated ITMP times if NPSTR=0. If ITMP<0, Item 6 records are used from the previous stress period.

7. [Pname [Iname]]

Item 7 is repeated ITMP times if NPSTR>0. Free format is used. Iname is read if Pname is a time-varying parameter.

[Note that either Item 6 or Item 7 may be read, but not both.]

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8. Width    Slope    Rough
   F10.0    F10.0    F10.0
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Item 8 is read only if ICALC > 0, in which case Item 8 is repeated for every stream reach. The records must be is the same order as the stream reaches.

```
9.  Itrib(NTRIB)
     10I5
```

Item 9 is read only if NTRIB > 0, in which case Item 9 is repeated NSS times in sequential order of the segments. Each record contains NTRIB values.

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10.  Iupseg
       I10
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Item 10 is read only if NDIV>0, in which case Item 10 is repeated NSS times in sequential order of the segments.

Explanation of Variables Read by the STR Package

Text - is a character variable (199 characters) that starts in column 2. Any characters can be included in Text. The "#" character must be in column 1. Text is printed when the file is read.

NPSTR - is the number of stream parameters that will be defined.

MXL - is the maximum number of stream reaches that will be defined using parameters. MXL must equal or exceed the sum of NLST x NUMINST for all parameters.

MXACTS - is the maximum number of stream reaches that will be in use during any stress period. MXACTS includes reaches that are defined using parameters as well as reaches that are defined without using parameters.

NSS - is the number of stream segments

NTRIB - is the number of stream tributaries that can connect to one segment. The program is currently dimensioned so that NTRIB cannot exceed 10.

NDIV - is a flag, which when positive, specifies that diversions from segments are to be simulated.

ICALC - is a flag, which when positive, specifies that stream stages in reaches are to be calculated.

CONST - is a constant value used in calculating stream stage in reaches. It is specified whenever ICALC is greater than 0. This constant is 1.486 for flow units of cubic feet per second and 1.0 for units of cubic meters per second. The constant must be multiplied by 86,400 when using time units of days in the simulation.

ISTCB1 - is a flag and a unit number for the option to write seepage between the stream reaches and model cells into the list file or an unformatted (binary) file.

If ISTCB1>0, it is the unit number to which seepage between each stream reach and the corresponding model cell will be saved whenever the variable ICBCFL in the Output Control Option is set.
If ISTCB1=0, seepage between each stream reach and the corresponding model cell will not be written into any file.

If ISTCB1<0, streamflow for each reach and seepage between each stream reach and the corresponding models cell will be written into the LIST file whenever the variable ICBCFL in the Output Control Option is set.

ISTCB2 - is a flag and a unit number for the option to store streamflow out of each reach in an unformatted (binary) file.

If ISTCB2 > 0, it is the unit number to which streamflow in each stream reach will be saved whenever the variable ICBCFL in the Output Control Option is set.
If ISTCB2 ≤ 0, streamflow in each stream reach will not be stored in a disk file.

Option—is the following optional character value.
"AUXILIARY abc" or "AUX abc"—defines an auxiliary variable, named "abc", which will be read for each reach as part of Items 4 and 6. Up to 20 variables can be specified, each of which must be preceded by "AUXILIARY" or "AUX." These variables will not be used by the Ground-Water Flow Process, but they will be available for use by other processes.

PARNAM – is the name of a parameter. This name can consist of 1 to 10 characters and is not case sensitive. That is, any combination of the same characters with different case will be equivalent.

PARTYP - is the type of parameter to be defined. For the STR Package, the only allowed parameter type is STR, which defines values of streambed conductance.

Parval - is the parameter value. This parameter value may be overridden by a value in the Parameter Value File.

NLST - is the number of stream reaches that are included in each instance defined for the parameter.

INSTANCES – is an optional keyword that designates a parameter as time varying. The keyword is case-insensitive; that is, it may be entered in any combination of upper- and lower-case letters. If ***INSTANCES*** is present, it must be followed by a value for NUMINST. If ***INSTANCES*** is absent, PARNAM is non-time-varying and NUMINST should not be present.

NUMINST – is the number of instances that are included in the definition of a time-varying parameter, where each instance is a list of stream reaches and associated properties. If the keyword ***INSTANCES*** is present, NUMINST must be present. If the keyword ***INSTANCES*** is absent, NUMINST should not be present.

INSTNAM – is the name of an instance associated with the parameter PARNAM specified in the corresponding Item 3. The name can consist of 1 to 10 characters and is not case sensitive. That is, any combination of the same characters with different case will be equivalent. Names entered for INSTNAM must be unique for any given parameter, but names may be reused for instances associated with different parameters.

Layer - is the layer number of the stream reach.

Row - is the row number of the stream reach.

Col - is the column number of the stream reach.

Seg - is a number assigned to a group of reaches. Segments must be numbered in downstream order and are read into the program in sequential order.

Reach - is a sequential number in a segment that begins with 1 for the farthest upstream reach and continues in downstream order to the last reach in the segment. Reaches must be read in sequentially because the order in which reaches are read determines the order of connection.

Flow - is the streamflow entering a segment. This value is used only for the first reach of each segment. The value should be specified as either 0 or blank when the reach number (Reach) is not 1. When the inflow to the first reach of a segment is the sum of the outflow from upstream tributary segments, Flow should be specified as -1. When the segment is a diversion, the Flow for the first reach is the amount to divert; however, there will be no diversion if the segment from which the diversion is obtained contains less than the value of Flow.

Stage - is the stream stage. The value of Stage is not used if ICALC>0.

Condfact - is the factor used to calculate streambed hydraulic conductance from the parameter value. The conductance is the product of Condfact and the parameter value.

Sbot -is the elevation of the bottom of the streambed.

Stop - is the elevation of the top of the streambed. The value of Stop is used if the option to calculate stream stage is active (ICALC>0) or when the streambed has zero flow.

[xyz]—represents the values of the auxiliary variables for a stream reach that have been defined in Item 2. The values of auxiliary variables must be present in each repetition of Items 4 and 6 if they are defined in Item 2. The values must be specified in the order used to define the variables in Item 2.

ITMP - is a flag and a counter. Its meaning depends on whether or not stream parameters are being used.

If STR parameters are being used (NPSTR>0), ITMP is the number of stream parameters being used in the current stress period.

IF STR parameters are not being used (NPSTR=0), ITMP is the number of stream reaches for which data will be read in the current stress period. If ITMP < 0, STR data from the preceding stress period will be reused.

IRDFLG - is a flag, which when positive, suppresses printing of the stream input data for a stress period. The input data are printed if IRDFLG is 0 and ICBCFL in the Output Control Option is set.

IPTFLG - is a flag, which when positive, suppresses printing of stream results for a stress period. Results are printed if IPTFLG is 0, ICBCFL in the Output Control Option is set, and ISTCB1 < 0.

Cond - is the streambed hydraulic conductance.

Pname - is the name of a parameter that is being used in the current stress period. ITMP parameter names will be read. They must be specified in an order that meets the downstream ordering requirements for Seg and Reach.

Iname – is an instance name that is read only if Pname is a time-varying parameter. Multiple instances of the same time-varying parameter are not allowed in a stress period.

Width - is the width of the stream channel. It is read only when stream stage is calculated (ICALC>0).

Slope - is the slope of the stream channel. It is read only when stream stage is calculated (ICALC>0).

Rough - is Manning's roughness coefficient. It is read only when stream stage is calculated (ICALC>0).

Itrib - contains the segment number for each tributary that flows into a segment. NTRIB values are read for each segment. Unused values of Itrib should be set to 0. Itrib records are read only when NTRIB>0.

Iupseg - is the number of the upstream segment from which water is diverted. If the segment is not a diversion, Iupseg should be specified as 0. Iupseg records are read only when NDIV>0.

REFERENCES

Harbaugh, A.W., 2005, MODFLOW-2005,the U.S. Geological Survey modular ground-water model—the Ground-Water Flow Process: U.S. Geological Survey Techniques and Methods 6-A16, variously p.

Prudic, D.E., 1989, Documentation of a computer program to simulate stream-aquifer relations using a modular, finite-difference, ground-water flow model: U.S. Geological Survey Open-File Report 88-729, 113 p.