

Input and output instructions for the Agricultural Water Use (AG) Package for GSFLOW

The AG was developed for GSFLOW to simulate irrigation and water use by cultivated and natural plants. The AG Package works with the Streamflow-Routing (SFR2) and the Unsaturated Flow (UZF1) Packages and includes capabilities for simulating pumping wells like the WELL Package. Input required for simulating agricultural diversions, supplementary pumping, irrigation, and demand calculations are all specified within the AG Package input file. All exchanges between different packages (SFR2, UZF1, and AG) are calculated within the AG Package; however, the SFR2 and UZF1 Packages must be active to use their capabilities in conjunction with the AG Package. Diversion segments must be specified within the SFR2 Package to apply diverted water as irrigation. All data for supplementary and irrigation wells is specified within the AG Package input file; the AG Package calculates and applies its own boundary conditions to the groundwater flow equation for representing irrigation and/or supplementary wells.

The AG Package is activated by specifying a file type of “AG” within the MODFLOW-NWT Name file. The AG input file contains 4 different blocks of data, including 1) Options, 2) Time series, 3) Segment and Well Lists, and 4) Stress Period. Stress period data is used to vary agricultural practices during a simulation represented mechanically as the connectivity between segments and irrigation cells, supplemental wells and diversion segments, and wells and irrigation cells, as well as other input values that control agricultural water use.

Block 1: Simulation options

AG Package character variables can be specified in any order and must be preceded and followed by the character variables OPTIONS and END, respectively.

Item 1: OPTIONS

Item 2: [NOPRINT]		
[IRRIGATION_DIVERSION	Numirrdiversions	Maxcellsdiversion]
[IRRIGATION_WELL	Numirrwwells	Maxcellswell]
[SUPPLEMENTAL_WELL	Numsupwells	Maxdiversions]
[MAXWELL	Nummaxwell]	
[TABFILES	Numtab	Maxval]
[PHIRAMP]		
[ETDEMAND]		
[TRIGGER]		
[TIMESERIES_DIVERSION]		
[TIMESERIES_WELL]		
[TIMESERIES_DIVERSIONET]		
[TIMESERIES_WELLET]		
[DIVERSIONLIST	Unit_diversionlist]	
[WELLLIST	Unit_welllist]	
[WELLIRRLLIST	Unit_wellirrlist]	
[DIVERSIONIRRLLIST	Unit_diversionirrlist]	
[WELLCBC	Unitcbc]	

Item 3: END

OPTIONS Character variable specified to indicate the beginning of the key word options.

NOPRINT Character variable that suppresses the printing of well lists.

IRRIGATION_DIVERSION An optional character variable. When IRRIGATION_DIVERSION is specified, the option to use surface water (SW) for irrigation is activate.

Numirrdiversions	An optional integer variable. When IRRIGATION_DIVERSION is specified, the integer variable Numirrdiversions also is specified. Numirrdiversions is the maximum number of SFR2 diversion segments in any stress period that will be used for irrigation.
Maxcellsdiversion	An optional integer variable. When IRRIGATION_DIVERSION is specified, the integer variable Maxcellsdiversion also is specified. Maxcellsdiversion is the maximum number of MODFLOW cells or PRMS HRUs that will receive irrigation from a single SFR2 diversion segment in any stress period.
IRRIGATION_WELL	An optional character variable. When IRRIGATION_WELL is specified, the option to use groundwater for irrigation is activate.
Numirrwells	An optional integer variable. When IRRIGATION_WELL is specified, the integer variable Numirrwells also is specified. Numirrwells is the maximum number of AG wells in any stress period that will be used for irrigation.
Maxcellswell	An optional integer variable. When IRRIGATION_WELL is specified, the integer variable Maxcellswell also is specified. Maxcellswell is the maximum number of MODFLOW cells or PRMS HRUs that will receive irrigation from a single AG well in any stress period.
SUPPLEMENTAL_WELL	An optional character variable. When SUPPLEMENTAL_WELL is specified, the option to simulate supplemental groundwater for irrigation is active. The AG Package calculates supplemental GW pumping using the difference between the irrigation demand and the surface water diversion.
Numsupwells	An optional integer variable. When SUPPLEMENTAL_WELL is specified, the integer variable Numsupwells also is specified. Numsupwells is the maximum number of supplemental wells in any stress period that will pump groundwater.
Maxdiversions	An optional integer variable. When SUPPLEMENTAL_WELL is specified, the integer variable Maxdiversions also is specified. Maxdiversions is the maximum number of SFR2 diversion segments that are supplemented by a well.
MAXWELL	An optional character variable. If IRRIGATION_WELL or SUPPLEMENTAL_WELL is specified then MAXWELL also is specified. MAXWELL is included to indicate that the maximum number of unique supplemental and irrigation wells used during a simulation (Nummaxwell) also will be read.
Nummaxwell	The maximum number of unique supplemental and irrigation wells used during a simulation.
TABFILES	An optional character variable. TABFILES is included in order set pumping rates using time series input files.
Maxval	An integer variable equal to the maximum number of values specified for any TABFILE.
PHIRAMP	An optional character variable. PHIRAMP is included to specify the smoothing interval used to change negative pumping rates to zero when the groundwater cell dewater. This variable only is used when the Newton Solver is active.
ETDEMAND	An optional character variable. ETDEMAND is included in order to activate automatic calculation of the net irrigation water requirement.

TRIGGER	An optional character variable. TRIGGER is included to activate the irrigation trigger option.
TIMESERIES_DIVERSION	An optional character variable that activates the option for outputting diversions flow rates for specified SFR2 segments used for irrigation. Additional details are specified in the time series data input.
TIMESERIES_WELL	An optional character variable for outputting well pumping rates for specified wells used for irrigation. Additional details are specified in the time series data input.
TIMESERIES_DIVERSIONET	An optional character variable for outputting irrigation applied to all cells/HRUs supplied by 1 or more specified diversion segments. Additional details are specified in the time series data input.
TIMESERIES_WELLET	An optional character variable for outputting irrigation applied to all cells/HRUs supplied by 1 or more specified wells. Additional details are specified in the time series data input.
DIVERSIONLIST	An optional character variable for outputting a list of all diversion segments and diversion amounts used for irrigation in the AG Package when "SAVE BUDGET" or a non-zero value for ICBCFL is specified in Output Control.
Unit_diversionlist	An optional integer variable that is the file unit number to which DIVERSIONLIST output is written. This unit number must correspond to a file of type Data specified in the MODFLOW Name file. A negative value indicates output will be written to the LIST file.
WELLLIST	An optional character variable for outputting a list of all active wells in the AG Package and pumped amounts when "SAVE BUDGET" or a non-zero value for ICBCFL is specified in Output Control.
Unit_welllist	An optional integer variable that is the file unit number to which WELLLIST output is written. This unit number must correspond to a file of type Data specified in the MODFLOW Name file. A negative value indicates output will be written to the LIST file.
WELLIRRLIST	An optional character variable for outputting a list of MODFLOW cells or PRMS HRUs that are irrigated by AG wells and the irrigated amounts when "SAVE BUDGET" or a non-zero value for ICBCFL is specified in Output Control.
Unit_wellirrlist	An optional integer variable that is the file unit number to which WELLIRRLIST output is written. This unit number must correspond to a file of type Data specified in the MODFLOW Name file. A negative value indicates output will be written to the LIST file.
DIVERSIONIRRLIST	An optional character variable for outputting a list of MODFLOW cells or PRMS HRUs irrigated by irrigation segments and the irrigated amounts when "SAVE BUDGET" or a non-zero value for ICBCFL is specified in Output Control.
Unit_diversionirrlist	An optional integer variable that is the file unit number to which DIVERSIONIRRLIST output is written. This unit number must correspond to a file of type Data specified in the

WELLCBC	An optional character variable for outputting cell-by-cell flow terms when "SAVE BUDGET" or a non-zero value for ICBCFL is specified in Output Control.
Unit_cbc	An optional integer variable that is the file unit number to which cell-by-cell unformatted list output is written. This unit number must correspond to a file of type Data(binary) specified in the MODFLOW Name file.
END	Character variable specified to indicate the end of the character options.

Time series data can be written to separate formatted output files for selected SFR segments and AG wells used for irrigation. These files are of type “Data” and must be included in the MODFLOW Name file. Time series data are read only if time series character variables are specified in the character options section.

Item 5: [DIVERSION Segmentnum₁ Unit_diversion₁]
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 .
 .
 [DIVERSION Segmentnum_{numtimeseriesdiversion} Unit_diversion_{numtimeseriesdiversion}]

Item 6: [DIVERSIONET Segmentnum₁ Unit_diversionet₁]
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 .
 .
 [DIVERSIONET Segmentnum_{numtimeseriesdiversionet} Unit_diversionet_{numtimeseriesdiversionet}]

Item 7: [WELL Wellnum₁ Unit_well₁]
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 .
 .
 [WELL Wellnum_{numtimeserieswell} Unit_well_{numtimeserieswell}]

Item 8: [WELLET Welletnum Unit_wellet]
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 .
 .
 [WELLET Wellnum_{numtimeserieswellet} Unit_wellet_{numtimeserieswellet}]

Item 9: [WELLALL Unitwellall]

Item 10: [WELLETALL Unitwelletall]

Item 11: [END]

TIME SERIES Character variable specified to indicate the beginning of the time series data block.

DIVERSION Character variable indicating that irrigation information for a diversion will be written to a time series output file.

Segmentnum Integer variable that is the SFR2 segment number.

Unitdiversion Integer variable that is the formatted output file unit number.

DIVERSIONET Character variable indicating that crop ET for all cells/HRUs irrigated by a diversion will be written to a time series output file.

Segmentnum Integer variable that is the SFR2 segment number.

Unitdiversionet Integer variable that is the formatted output file unit number.

WELL Character variable indicating that irrigation information for a well will be written to a time series output file.

Wellnum Integer variable that is the AG well number.

Unitwell Integer variable that is the formatted output file unit number. This file is of type “Data” and is included in the MODFLOW Name file.

WELLET Character variable indicating that evapotranspiration information for a well will be written to a time series output file.

Welletnum Integer variable that is the AG well number.

Unitwellet Integer variable that is the formatted output file unit number. This file is of type “Data” and is included in the MODFLOW Name file.

WELLETALL Character variable indicating that evapotranspiration information summed for all wells will be written to a time series output file.

Unitwelletall Integer variable that is the formatted output file unit number. This file is of type “Data” and is included in the MODFLOW Name file.

WELLALL Character variable indicating that irrigation information summed for all wells will be written to a time series output file.

Unitwellall Integer variable that is the formatted output file unit number. This file is of type “Data” and is included in the MODFLOW Name file.

END Character variable specified to indicate the end of the time series data block.

Block 3: Segment and Well lists

SFR segments used for irrigation during any stress period of a simulation must be listed within the SEGMENT LIST data block. Maximum segment diversion rates can be set for each time step using SFR TABFILES, and maximum diversion rates can be set for each stress period using the SFR input variable Q.

Item 12: [SEGMENT LIST]

Item 13: [SEGMENTNUMBER₁]

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[SEGMENTNUMBER_{MAXNUMSEGS}]

Item 14: [END]

SEGMENT LIST Character variable specified to indicate irrigation diversion segments will be included in simulation. All irrigation segments used in a simulation must be listed.

SEGMENTNUMBER₁ Integer value equal to the first irrigation segment used in a simulation.

SEGMENTNUMBER_{MAXNUMSEGS} Integer value equal to the last irrigation segment used in a simulation.

END Character variable specified to indicate the end segment list data block.

Wells used for irrigation, including those used to supplement surface water diversions, are defined within the WELL LIST. Well numbering is implicitly defined according to the order of wells in the WELL LIST, the first entry is well 1, numbered consecutively to the total number of wells used during a simulation. There are 2 options for specifying information in the WELL LIST. The first option uses TABFILES to vary the maximum pumping rate during a simulation, and the second option uses a single specified value for the maximum pumping rate that does not vary during the simulation.

Input instructions for AG Package TABFILES are included at the end of this document.

Item 15: [WELL LIST]

If character variable TABFILES is specified in the OPTIONS block, then item 16a is read as a space delimited list in free format. Otherwise, item 16b is read.

Item 16a: [TABUNIT₁ TABVAL₁ WELLLAY₁ WELLROW₁ WELLCOL₁]

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.
[TABUNIT_{Numtab} TABVAL_{Numtab} WELLLAY_{Numtab} WELLROW_{Numtab} WELLCOL_{Numtab}]

If character variable TABFILES is not specified in the OPTIONS block then item 16b is read as a space delimited list in free format.

Item 16b: [WELLLAY₁ WELLROW₁ WELLCOL₁ Q₁]

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[WELLLAY_{Maxwell} WELLROW_{Maxwell} WELLCOL_{Maxwell} Q_{Maxwell}]

Item 17: [END]

WELL LIST Character variable specified to indicate that AG wells will be included in a simulation.

TABUNIT Integer variable equal to the unit number for the TABFILE used to specify pumping rates for a well.

TABVAL	Integer variable equal to the maximum number of rows to be read from a TABFILE.
WELLLAY	Integer variable equal to the layer number of the cell containing a well.
WELLROW	Integer variable equal to the row number of the cell containing a well.
WELLCOL	Integer variable equal to the column number of the cell containing a well.
Q	Real variable equal to the maximum pumping rate or applied pumping rate.
END	Character variable specified to indicate the end of the well list data block.

Block 4: Stress period information

Character variables “STRESS PERIOD” and “END” are required for each stress period. There are 3 options for specifying stress period information: 1) use stress period data for irrigation segments, irrigation wells, or supplemental wells from previous stress period; 2) specify data for all active irrigation segments, irrigation wells, or supplemental wells for stress period; or 3) set all irrigation segments, irrigation wells, or supplemental wells to inactive for a stress period. Combinations of these 3 options can be used for any stress period.

Items 21a and 25a are specified for MODFLOW simulations; items 21b and 25b are specified for GSFLOW simulations. Some values are not used for a simulation due to specifications in the OPTIONS block; dummy values must be specified for unused input variables.

STRESS PERIOD

Item 18: [IRRDIVERSION]

Item 19: [NUMIRRSEGSP]

Item 20: [SEGID NUMCELLSEG IRRPERIODSEG TRIGGERFACTSEG]

Item 21a: [IRRROW_DIVERSION₁ IRRCOL_DIVERSION₁ EFF_FACT_DIVERSION₁
FIELD_FACT_DIVERSION₁]

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[IRRROW_DIVERSION_{numcellseg} IRRCOL_DIVERSION_{numcellseg} EFF_FACT_DIVERSION_{numcellseg}
FIELD_FACT_DIVERSION_{numcellseg}]

Item 21b: [HRU_ID_DIVERSION₁ DUM_DIVERSION₁ EFF_FACT_DIVERSION₁
FIELD_FACT_DIVERSION₁]

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[HRU_ID_DIVERSION_{numhruseg} DUM_DIVERSION_{numhruseg} EFF_FACT_DIVERSION_{numhruseg}
FIELD_FACT_DIVERSION_{numhruseg}]

Item 22: [IRRWELL]

Item 23: [NUMIRRWELLSP]

Item 24: [IRRWELLID NUMCELLWELL IRRPERIODWELL TRIGGERFACTWELL]

Item 25a [IRRROW_WELL₁ IRRCOL_WELL₁ EFF_FACT_WELL₁
FIELD_FACT_WELL₁]

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[IRRROW_WELL_{numcellwell} IRRCOL_WELL_{numcellwell} EFF_FACT_WELL_{numcellwell}
FIELD_FACT_WELL_{numcellwell} KCROP_{numcellwell}]

Item 25b [HRU_ID_WELL₁ DUM_WELL₁ EFF_FACT_WELL₁
FIELD_FACT_WELL₁]

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[HRU_ID_WELL_{numhruwell} DUM_WELL_{numhruwell} EFF_FACT_WELL_{numhruwell}
FIELD_FACT_WELL_{numhruwell}]

Item 26: [SUPWELL]

Item 27: [NUMSUPWELLSP]

Item 28: [SUPWELLNUM NUMSEGWELL]

Item 29: [SEGWELLID₁ FRACSUP₁ FRACSUPMAX₁]

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.
.

[SEGWELLID_{numsegwell} FRACSUP_{numsegwell} FRACSUPMAX_{numsegwell}]

[END]

IRRDIVERSION An optional character variable. IRRDIVERSION can be specified if character variable IRRIGATION_DIVERSION is specified in the OPTIONS block.

NUMIRRSEGSP An integer variable equal to the number of SFR2 segments active during a stress period that will divert water to cells. If NUMIRRSEGSP < 0, irrigation segment data from the previous stress period will be used. If NUMIRRSEGSP = 0, all irrigation segments will be set to inactive.

SEGID An integer variable equal to the SFR2 segment number for the diversion used for irrigation.

NUMCELLSEG An integer variable equal to the total number of MODFLOW cells or PRMS HRUs that will be irrigated by SFR2 diversion segment SEGID.

IRRPERIODSEG A real variable equal to the length of time water will be diverted for a single irrigation event. Although this variable is specified for each SEGID, it only is used if the character variable TRIGGER is specified in the options block. Units for this variable are determined from the DIS file input variable ITMUNI. Values should be greater than or equal to the length of the largest model time step during irrigation periods.

TRIGGERFACTSEG A real variable between 0 and 1 that triggers an irrigation event. If TRIGGERFACTSEG is set to 0.5 then an irrigation event will start when ETo/ETa = 0.5. Although this variable is specified for each SEGID, it only is used if the character variable TRIGGER is specified in the options block.

IRRROW_DIVERSION An integer variable equal to the cell row number that will be irrigated by segment SEGID. This variable only is specified for MODFLOW-only simulations.

IRRCOL_DIVERSION An integer variable equal to the cell column number that will be irrigated by segment SEGID. This variable only is specified for MODFLOW-only simulations.

HRU_ID_DIVERSION An integer variable equal to the HRU ID number that will be irrigated by segment SEGID. This variable only is specified for PRMS-only and GSFLOW simulations.

DUM_DIVERSION An integer variable that must be specified but is not used and can be set to zero. This variable only is specified for PRMS-only and GSFLOW simulations.

EFF_FACT_DIVERSION A real variable equal to the fraction of surface water applied to a cell that can be used to represent crop evapotranspiration and other field losses. If evapotranspiration is being simulated explicitly then set EFF_FACT_DIVERSION to zero.

FIELD_FACT_DIVERSION A real variable equal to the fraction of the diverted water applied to a cell that is used to distribute a diversion among multiple cells. The sum of all FIELD_FACT_DIVERSION values for a diversion should sum to 1.

IRRWELL An optional character variable. IRRWELL can be specified if character variable IRRIGATION_WELL is specified in the OPTIONS block.

NUMIRRWELLSP An integer variable equal to the number of AG wells active during a stress period that will pump water for irrigation on MODFLOW cells or PRMS HRUs. If NUMIRRWELLSP < 0, irrigation well data from the previous stress period will be used. If NUMIRRWELLSP = 0, all irrigation wells will be set to inactive.

IRRWELLID An integer variable equal to the well identification number used to pump groundwater for irrigation.

NUMCELLWELL An integer variable equal to the total number of MODFLOW cells or PRMS HRUs that receive water from a well.

IRRPERIODWELL A real variable equal to the length of time water will be pumped for a single irrigation event. Although this variable is specified for each WELL, it only is used if the character variable TRIGGER is specified in the options block and for wells that are not SUP wells. Units for this variable are determined from the DIS file input variable ITMUNI. Values should be greater than or equal to the length of the largest model time step during irrigation periods.

TRIGGERFACTORWELL A real variable between 0 and 1.0 that triggers an irrigation event. If TRIGGERFACTORWELL is set to 0.5 then an irrigation event will start when $ET_o/ET_a = 0.5$. Although this variable is specified for each SEGID, it only is used if the character variable TRIGGER is specified in the options block.

IRRROW_WELL An integer variable equal to the cell row number to which pumped water will be applied as irrigation. This variable only is specified for MODFLOW-only simulations.

IRRCOL_WELL An integer variable equal to the cell column number to which pumped water will be applied as irrigation. This variable only is specified for MODFLOW-only simulations.

HRU_ID_WELL An integer variable equal to the HRU ID to which pumped water will be applied as irrigation. An integer variable that must be specified but is not used and can be set to zero. This variable only is specified for PRMS-only and GSFLOW simulations.

DUM_DIVERSION An integer variable that must be specified but is not used and can be set to zero. This variable only is specified for PRMS-only and GSFLOW simulations.

EFF_FACT_WELL A real variable equal to the fraction of groundwater applied to a cell that can be used to represent crop evapotranspiration and other field losses. If evapotranspiration is being simulated explicitly then set EFF_FACT_WELL to zero.

FIELD_FACT_WELL A real variable equal to the fraction of the groundwater applied to a cell that is used to distribute water pumped from a well among multiple cells. The sum of all FIELD_FACT_WELL values for a well should sum to 1.

SUPWELL An optional character variable indicating that supplemental well stress period data will be specified.

NUMSUPWELLSP An integer variable equal to the number of active supplementary wells during a stress period that will pump groundwater to meet the surface water shortfall for irrigation. If NUMSUPWELLSP < 0, supplementary well data from the previous stress period will be used. If NUMSUPWELLSP = 0, all supplementary wells will be set to inactive.

SUPWELLNUM An integer variable equal to the AG well number that supplements one or more surface water diversions.

NUMSEGWELL An integer variable equal to the number of SFR2 segments that will be supplemented by a well.

SEGWELLID An integer variable equal to the SFR2 segment number that will be supplemented by a well.

FRACSUP A real variable between 0 and 1 that is equal to the fraction of the surface water shortfall for segment SEGWELLID that will be supplemented by a well.

FRACSUPMAX A real variable between 0 and 1 that is equal to the fraction of the surface water demand that is used to calculate the net irrigation water requirement with supplemental groundwater pumping. Supplemental groundwater pumping (Q_{sup}) will be calculated as $Q_{sup} = FRACSUP * [FRACSUPMAX * Q_{demand} - Q_{div}]$, where Q_{demand} is the specified surface water diversion rate for irrigation.

END Character variable specified to indicate the end of each stress period data block.

Input data for TABFILES

Item 1: [TIME_i Q_i]
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 .
 .
 [TIME_{TABVAL} Q_{TABVAL}]

TIME A real variable equal to the simulation time that the pumping rate Q will be used to interpolate the maximum or applied pumping rate for a time step. The pumping rate for a time step is calculated using linear interpolation. The units for TIME must be consistent with the DIS Package input variable ITMUNI.

Q A real variable equal to the maximum pumping rate for supplementary wells or for simulations that include the character variable ETDEMAND, otherwise Q is the applied pumping rate that can be used for setting the irrigation demand for wells used for irrigation (IRRWELL). Pumping rates are set equal to the pumping rate at the end of the time interval

Water budget table

Table 1: Water budget for agricultural water use package, where inflows (“IN”) are sources of groundwater from wells (“AG WELLS”) and surface water diversions (“DIVERSION SEGMENTS”) used for irrigation, and outflows (“OUT”) are consumptive use of groundwater (“GW IRRIGATION”) and surface water (“SW IRRIGATION”), groundwater return flows (“SYSTEM LOSSES GW”) and surface water return flows (“SYSTEM LOSSES SW”).

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 15, STRESS PERIOD 8				

	CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
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IN:			IN:	
---			---	
AG WELLS =	11775075.0000		AG WELLS =	8.9560
DIVERSION SEGMENTS =	153412592.0000		DIVERSION SEGMENTS =	50.8780
GW IRRIGATION =	0.0000		GW IRRIGATION =	0.0000
SW IRRIGATION =	0.0000		SW IRRIGATION =	0.0000
SYSTEM LOSSES GW =	0.0000		SYSTEM LOSSES GW =	0.0000
SYSTEM LOSSES SW =	0.0000		SYSTEM LOSSES SW =	0.0000
TOTAL IN =	165187664.0000		TOTAL IN =	59.8340
OUT:			OUT:	
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AG WELLS =	0.0000		AG WELLS =	0.0000
DIVERSION SEGMENTS =	0.0000		DIVERSION SEGMENTS =	0.0000
GW IRRIGATION =	11775075.0000		GW IRRIGATION =	8.9560
SW IRRIGATION =	153415664.0000		SW IRRIGATION =	50.8790
SYSTEM LOSSES GW =	0.0000		SYSTEM LOSSES GW =	0.0000
SYSTEM LOSSES SW =	0.0000		SYSTEM LOSSES SW =	0.0000
TOTAL OUT =	165190736.0000		TOTAL OUT =	59.8350
IN - OUT =	-3072.0000		IN - OUT =	-1.0185E-03
PERCENT DISCREPANCY =	-0.00		PERCENT DISCREPANCY =	-0.00