# Agricultural Water Use Package for MODFLOW-NWT

The Agricultural Water-Use Package (AGO) was developed for MODFLOW-NWT in order to simulate water use for irrigation. The AGO Package works with the Streamflow-Routing (SFR2) and the Unsaturated Flow (UZF1) Packages, and includes capabilities for simulating pumping wells, similar to the WELL Package. The AGO has 4 major capabilities, including 1) apply water flowing in SFR2 diversion segments as infiltration to UZF1 cells; 2) apply water pumped by wells in the AGO Package as infiltration to UZF1 cells; 3) automatically pump water in wells to supplement SFR2 diversions when the available flow in a diversion segment is less than demand; and 4) calculate irrigation demand using the UZF1 ET deficit (ETo-ETa). Option 4 includes sub-irrigation where the ET demand is supplemented by groundwater.

Input required for simulating agricultural diversions, supplementary pumping, irrigation, and demand calculations are all specified within the AGO Package input file. All exchanges between different packages (SFR2, UZF1, and AGO) are calculated within the AGO Package; however, the SFR2 and UZF1 Packages must be active in order to use their capabilities in conjunction with the AGO Package. Diversion segments must be specified within the SFR2 Package in order to apply diverted water as irrigation. All data for supplementary and irrigation wells is specified within the AGO Package input file; the AGO Package calculates and applies its own boundary conditions to the groundwater flow equation for representing irrigation and/or supplementary wells.

AgOptions can be used to simulate agricultural water use with three different configurations: 1) surface water diversions and supplemental groundwater pumping are assumed to be fully consumed by ET, and ET by crops is not explicitly simulated; 2) net surface water and groundwater are applied to UZF1 cells to simulate surface water and groundwater return flows, again without explicitly simulating ET by crops; 3) surface water and groundwater are applied to UZF1 cells while the unsaturated and saturated zone ET option is active in order to explicitly simulate ET by crops and corresponding surface water and groundwater return flows. For this last configuration, the surface water and supplemental groundwater demand for irrigation can be calculated internally by the AGO Package, and surface water diversions and pumping rates are set internally.

Agricultural water demands can be specified using several options. 1) values specified for the SFR2 input variable “FLOW” is the surface water demand, and values specified for the AGO well variable “Qcapacity” is the groundwater demand for irrigation wells that are not supplemental wells.

The specified flow for the diversion (SFR2 variable “FLOW”) can serve as the demand, or if the ET-based demand calculator is active, the maximum flow delivered to an agricultural region.

The AGO Package is activated by specifying a file type of “AGO” within the MODFLOW-NWT Name file. The AGO input file contains 3 types of data, including 1) Options, 2) Well List, and 3) Stress Period data for specifying connectivity between segments and irrigation cells, supplemental wells and diversion segments, and irrigation wells and irrigation cells.

# Input data for the AGO Package input file

**FOR EACH SIMULATION**

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

OPTIONS

[IRRIGATIONSEGMENT Numirrsegment Maxcellssegment]

[IRRIGATIONWELL Numirrwell Maxcellswell]

[SUPPLEMENTALWELL Numsupwell Maxsegment]

[MAXWELL Nummaxwell]

[TABFILES Numtab Maxval]

[PHIRAMP]

[ETDEMAND]

END

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

IRRIGATIONSEGMENT An optional character variable. When IRRIGATESEGMENT is specified, the option to add water flowing in SFR2 diversion segments to UZF1 cells is activated.

Numirrsegment An optional integer variable. When IRRIGATESEGMENT is specified, the integer variable Numirrsegment also is specified. Numirrsegment is the maximum number of diversion segments in any stress period that will apply water to UZF1 cells.

Maxcellssegment An optional integer variable. When IRRIGATESEGMENT is specified, the integer variable Maxcellssegment also is specified. Maxcellssegment is the maximum amount of UZF1 cells associated with any single SFR2 diversion segment.

IRRIGATIONWELL An optional character variable. When IRRIGATEWELL is specified, the option to add groundwater pumped by a well to UZF1 cells is activated.

Numirrwell An optional integer variable. When IRRIGATEWELL is specified, the integer variable Numirrwell also is specified. Numirrwell is the maximum number of wells in any stress period that will apply water to UZF1 cells.

Maxcellwell An optional integer variable. When IRRIGATEWELL is specified, the integer variable Maxellwell also is specified. Maxell is the maximum number of UZF1 cells associated with any single supplemental well.

SUPPLEMENTALWELL An optional character variable. When SUPPLEMENTALWELL is specified, the option to automatically pump water to supplement the difference between a specified SFR2 diversion and the actual diversion when there is a surface water shortfall.

Numsupwell An optional integer variable. When SUPPLEMENTALWELL is specified, the integer variable Numsupwell also is specified. Numsupwell is the maximum number of wells in any stress period that will pump supplementary groundwater to meet a surface water diversion shortfall.

Maxsegment An optional integer variable. When SUPPLEMENTALWELL is specified, the integer variable Maxsegment also is specified. Maxsegment is the maximum number of SFR2 segments that are supplemented by a supplemental well.

MAXWELL An optional character variable. MAXWELL is the maximum number of unique supplemental and irrigation wells used during a simulation. If there are no supplemental or irrigation wells in a simulation then MAXWELL does not need to be specified.

Nummaxwell The total number of unique supplemental and/or irrigation wells used in the AGO Package. Well numbers and associated model cell information is input in the WELL LIST data block.

TABFILES An optional character variable. TABFILES is included in order set supplemental and irrigation well pumping capacities using time series input files. This option is the same as used within the standard MODFLOW-NWT Well Package.

Numtab

Maxval

PHIRAMP An optional character variable. PHIRAMP is included in order to specify the smoothing interval used to chnage negative pumping rates to zero when the groundwater cell dewaters. 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 water demand for irrigation segments and irrigation wells. Demand is calculated as the difference between PET and actual ET calculated by the UZF1 Package.

END Character variable specified to indicate the end of the key word options.

**FOR EACH SIMULATION**

Wells used for irrigation, either as a supplement to a surface water diversion or to fully satisfy an irrigation demand are defined within the WELL LIST data block. Well numbering is implicitly defines 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. Wells can be made inactive during a stress period by setting the capacity to zero, either through a tabular input file or through the variable Q that is set in the STRESS PERIOD information.

Item 1: [WELL LIST]

If character variable TABFILES is specified in the OPTIONS block then item 2 is read as a space delimited list in free format.

Item 2: [TABUNIT1 TABVAL1 TABLAY1 TABROW1 TABCOL1]

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[TABUNITNumtab TABVALNumtab TABLAYNumtab TABROWNumtab TABCOLNumtab]

If character variable TABFILES is not specified in the OPTIONS block then item 3 is read as a space delimited list in free format.

Item 3: [WELLLAY1 WELLROW1 WELLCOL1 Qcapacity1]

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[LAY Maxwell ROW Maxwell COLMaxwell QcapacityMaxwell]

**FOR EACH STRESS PERIOD**

Stress period data must be proceeded and followed by the character variables “STRESS PERIOD” and “END,” respectively. 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 during a stress period.

STRESS PERIOD

Item 1: [IRRSFR]

Item 2: [NUMIRRSEGSP]

Item 3: [SEGID NUMCELLSEG EFF\_FACT1 FIELD\_FACT1 IRRROW1 IRRCOL1…. EFF\_FACTnumcellseg FIELD\_FACTnumcellseg IRRROWnumcellseg IRRCOLnumcellseg]

Item 4: [IRRWELL]

Item 5: [NUMIRRWELLSP]

Item 6: [IRRWELLID NUMCELLWELL EFF\_FACT1 FIELD\_FACT1  IRRROW1 IRRCOL1…. EFF\_FACTnumcellwell FIELD\_FACTnumcellwell IRRROWnumcellwell IRRCOLnumcellwell]

Item 7: [SUPWELL]

Item 8: [NUMSUPWELLSP]

Item 9: [SUPWELLNUM NUMSEGWELL PCTSUP­1 SEGWELLID1…. PCTSUP­numsegwell SEGWELLIDnumsegwell

IRRSFR An integer variable. IRRSFR is required if character variable IRRGATIONSEGMENT is specified in the OPTIONS block. If IRRSFR < 0, irrigation segment data from the previous stress period will be used. If IRRSFR=0, all irrigation segments will be set to inactive. If IRRSFR>0 then IRRSFR is equal to the number of irrigation segments specified during the stress period.

NUMIRRSEGSP An integer variable equal to the number of diversion segments that will supply water to UZF cells.

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

NUMCELLSEG An integer variable equal to the total number of UZF1 cells that water diverted from SEGID will be applied for irrigation.

EFF\_FACT A real variable equal to the fraction of the water applied to a cell, defined by IRROW and IRRCOL that is removed from the model before being applied to cell due to crop evapotranspiration and other field evaporation losses. If evapotranspiration is being simulated explicitly by UZF1 then set EFF\_FACT to zero.

FIELD\_FACT A real variable equal to the fraction of the diverted water applied to a cell, for example, FIELD\_FACT1 is the fraction of the diversion amount multiplied by EFF\_FACT that is applied to cell IRROW1 and IRRCOL1. The sum of all FIELD\_FACT values specified in each item should sum to 1.

KCROP A real variable equal to the crop coefficient (Kc) that is the ratio of the crop ET to potential ET.

IRRROW An integer variable equal to the UZF1 cell row number to which diverted water will be applied as irrigation.

IRRCOL An integer variable equal to the UZF1 cell column number to which diverted water will be applied as irrigation.

IRRWELLID An integer variable equal to the well identification number used to pump groundwater for irrigation. IRRWELLID is set according to the order that

NUMCELLWELL An integer variable equal to the total number of UZF1 cells that water pumped by IRRWELLID will be applied for irrigation.

EFF\_FACT A real variable equal to the fraction of the water applied to a cell, defined by IRROW and IRRCOL that is removed from the model before being applied to cell due to crop evapotranspiration and other field evaporation losses. If evapotranspiration is being simulated explicitly by UZF1 then set EFF\_FACT to zero.

FIELD\_FACT A real variable equal to the fraction of the diverted water applied to a cell, for example, FIELD\_FACT1 is the fraction of the diversion amount multiplied by EFF\_FACT1 that is applied to cell IRROW1 and IRRCOL1. The sum of all FIELD\_FACT values specified in each item should sum to one.

IRRROW An integer variable equal to the UZF1 cell row number to which pumped water will be applied as irrigation.

IRRCOL An integer variable equal to the UZF1 cell column number to which pumped water will be applied as irrigation.

SUPWELL An optional character variable indicating that supplemental well stress period data will be specified. If NUMIRRSEGSP is less than or equal to zero then no supplemental well data will be read during the stress period.

Note 1: Item 3 only is specified if NUMIRRSEGSP is greater than zero.

Note 2: Item 3 is repeated NUMIRRSEGSP times, resulting in NUMIRRSEGSP records for each stress period.

Note 3: Variables EFF\_FACT, FIELD\_FACT, IRRROW, and IRRCOL are repeated NUMCELLSSEG times for each record.

Note 4: Item 6 only is specified if NUMIRRWELLSP is greater than zero.

Note 5: Item 6 is repeated NUMIRRWELLSP times, resulting in NUMIRRWELLSP records for each stress period.

Note 6: Variables EFF\_FACT, FIELD\_FACT, IRRROW, IRRCOLare repeated NUMCELLWELL times.