# 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, and these segments must not have an outflow connection to another segment (SFR2 input variable OUTSEG=0). Additionally, all UZF1 cells used for agricultural fields by the AGO Package must be active (IUZFBND>0). All data for supplementary and irrigation wells is specified within the AGO Package input file; the standard MODFLOW Well Package is not used by the AGO Package.

AgOptions can be used to simulate agricultural water use with three different configurations: 1) surface water and supplemental groundwater used for irrigation can be removed from the model, assuming all water is consumed by plants; 2) surface water and groundwater can be applied to UZF1 cells to simulate groundwater return flows using user-specified irrigation efficiency factors, and surface water return flow using the UZF1 IRUNBND option to route water to receiving SFR2 reaches or LAK surface reservoirs; and, 3) surface water and groundwater can be applied to UZF1 cells while the unsaturated and saturated zone ET option is active in order to simulate plant water consumption 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 accordingly.

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

An 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

[IRRIGATIONSTREAM Numirrseg Unitirs Maxells]

[IRRIGATIONWELL Numirrwells Maxcells]

[SUPPLEMENTALWELL Numsupwells Unitsupwells Maxsegs]

[MAXWELLS]

[PHIRAMP]

[TABFILES]

[ETDEMAND]

END

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

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

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

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

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

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

Maxells An optional integer variable. When IRRIGATE is specified, the integer variable Maxells also is specified. Maxells is the maximum number of UZF1 cells associated with any single supplemental well.

SUPPLEMENTALWELL An optional character variable. When SUPPLEMENTAL 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.

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

Unitsup An optional integer variable. When SUPPLEMENTAL is specified, the integer variable Unitsup also is specified. Unitsup is the file unit number for the Supplemental Pumping (SUP) input file.

Maxsegs An optional integer variable. When SUPPLEMENTAL is specified, the integer variable Maxsegs also is specified. Maxsegs is the maximum number of SFR2 segments that are supplemented by a SUP well.

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

PHIRAMP An optional character variable. PHIRAMP is included in order to specify the smoothing interval used to reduce pumping rates to zero when the groundwater cell dewaters. This variable only is used when the Newton solver is active.

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.

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 STRESS PERIOD**

Stress period data must be proceeded and followed by the character variables “STRESSPERIOD” and “END,” respectively. Character variables “STRESSPERIOD” and “END” are required for each stress period; however, segment irrigation, and supplemental and irrigation well stress data does not need to be specified if these data do not change between stress periods.

STRESSPERIOD

Item 1: [NUMIRRSEGSP]

Item 2: [SEGNUM NUMCELLSSEG EFF\_FACT1 FIELD\_FACT1  KCROP1 IRRROW1 IRRCOL1…. EFF\_FACTnumcells FIELD\_FACTnumcells KCROPnumcells IRRROWnumcells IRRCOLnumcells]

Item 3: [NUMIRRWELLSSP]

Item 4: [WELLNUM NUMCELLSWELL EFF\_FACT1 FIELD\_FACT1  IRRROW1 IRRCOL1…. EFF\_FACTnumcells FIELD\_FACTnumcells IRRROWnumcells IRRCOLnumcells]

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

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

NUMCELLSSEG An integer variable equal to the total number of UZF1 cells that water diverted from SEGNUM 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.

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

NUMCELLSWELL An integer variable equal to the total number of UZF1 cells that water pumped by WELLNUM 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.

Note 1: Item 2 only is specified if NUMIRRSEGSP is greater than zero.

Note 2: Item 2 is repeated NUMIRRSEGSP times, resulting in NUMIRRWELLSSP 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 4 only is specified if NUMIRRWELLSSP is greater than zero.

Note 5: Item 4 is repeated NUMIRRWELLSSP times, resulting in NUMIRRWELLSSP records for each stress period.

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