

**RSWB Model Construction**

# Appendix 5-A. RSWB Model Construction

Section 5 of the report described the role of the watershed model in COHYST 2010. An overview of the modeling processes, inputs, and results was provided. This appendix provides additional details related to the construction of a specific portion of the watershed model referred to as the RSWB model.

## 5-A.1. RSWB Model Construction

The RSWB consists of 9 programs (listed below) which incorporate distributed CropSim results, develop irrigation estimates, make adjustments to the water balance parameters, organize the results into properly formatted groundwater model input files, and generate water balance summary reports.

Within the COHYST 2010 model, the RSWB can make two types of runs as part of the integrated model: demand run and supply run. The 9 programs comprising the RSWB model are:

1. Irrigation Application and Demand (IAD)
2. District Demand
3. Irrigation Application and Supply (IAS)
4. Water Supply Partitioning Program (WSPP)
5. Make Well
6. Make Recharge
7. Compile Well
8. Compile Recharge
9. Summary Reports

The following sections provide a general description of each program. Generalized schematics showing major conceptual components of the major programs are provided to assist a user interested in reviewing source code. The descriptions discuss in general terms the inputs required for each program. Refer to Appendix 5-B: Guide to the Watershed Model Programs and Files for a more complete discussion of the input parameters and their development. Refer to Appendix 5-C: Making a Watershed Model Run for a description of independently executing the model.

### 5-A.1.1. Demand Run

Demand Runs (Figure 5A.1) develop estimates of the surface water irrigation demand for each district and provide the results to the surface water operations model. The demand runs assume that supplies are sufficient to meet demands. These assumed supply volumes are input into the RSWB to develop an initial estimate of the pumping, recharge, and runoff contributions to streamflow for the groundwater model and surface water operations model. A demand run is typically the first step to creating an integrated model run.

## RSWB Program Flow Chart: Demand Run

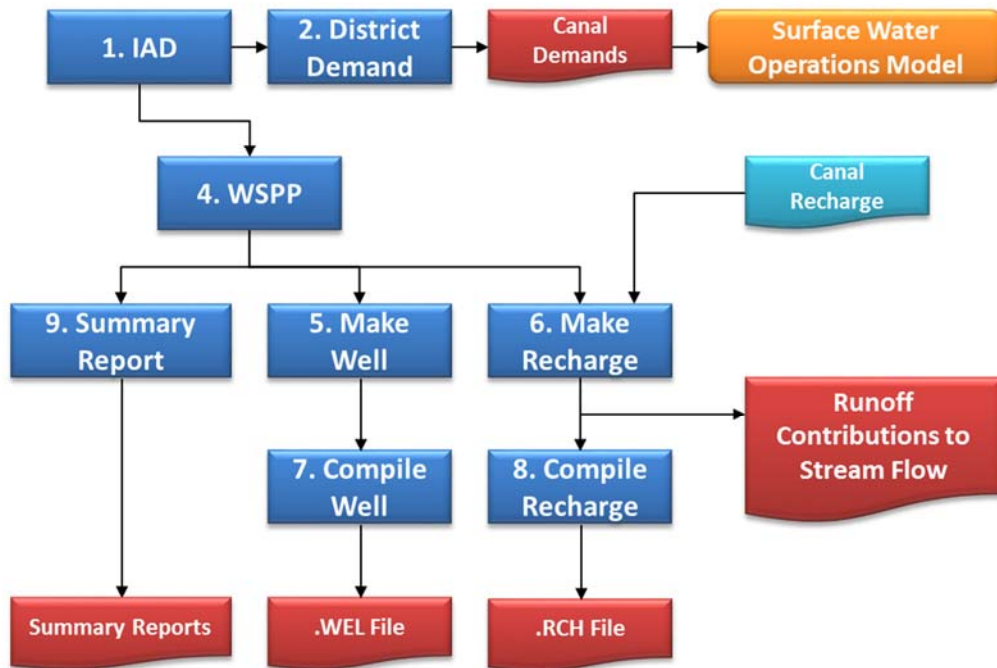


Figure 5A.1. Process flow diagram for Demand Runs.

### 5-A.1.2. Supply Run

Supply Runs (Figure 5A.2) integrate the surface water deliveries to the irrigation district and canal seepage estimates from the surface water operations model. The Supply Runs input these surface water delivery volumes into the RSWB to develop a new estimate of pumping, recharge and runoff contributions to streamflow for the groundwater model and surface water operations model. All subsequent runs after the demand run are supply runs. The supply run can be repeated multiple times until it is deemed that the integrated model has reached closure. A more detailed account of the model integration and interaction is available in Chapter 8.

## RSWB Program Flow Chart: Supply Run

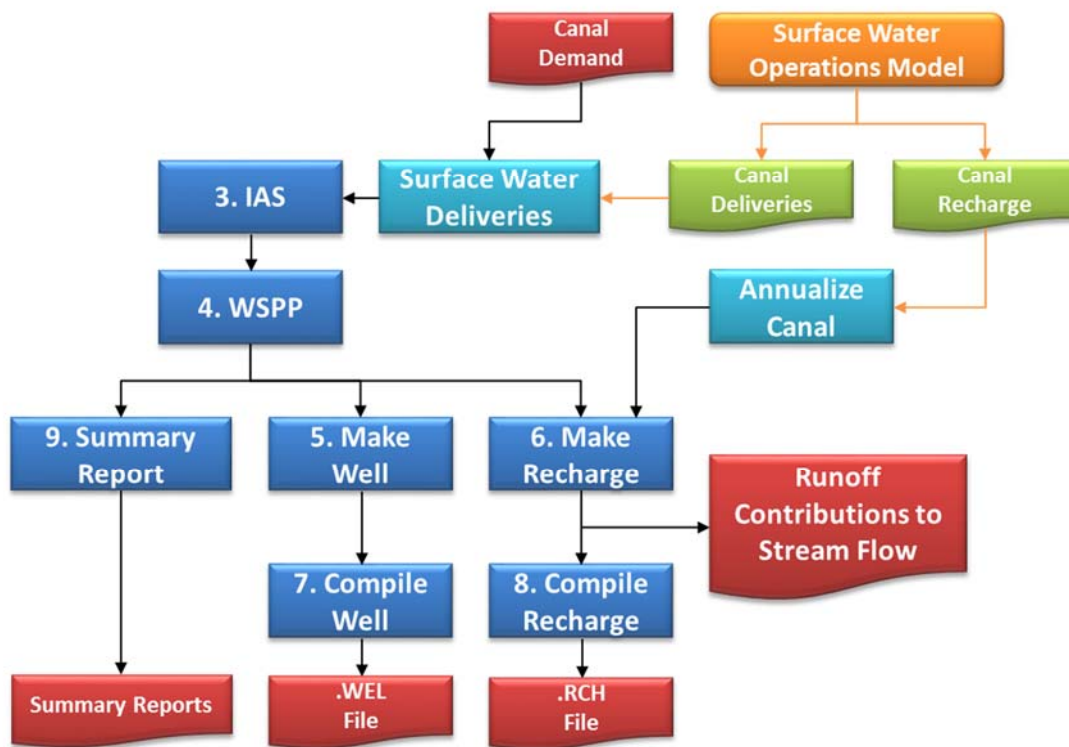


Figure 5A.2. Program Flow Diagram for Supply Runs.

### 5-A.1.3. Irrigation Application and Demand (IAD)

The Irrigation Application and Demand program (Figure 5A.3) develops estimates of demanded irrigation volumes based upon land use classifications and irrigation source. The IAD uses the distributed Net Irrigation Requirement (NIR) and application efficiency (AE) to estimate the gross volume of irrigation water demanded within each cell, as well as the depth of irrigation water that was applied to each crop. The volume and depths of water demands are passed to the District Demand program and implemented directly into the Water Supply Partitioning Program for demand runs.

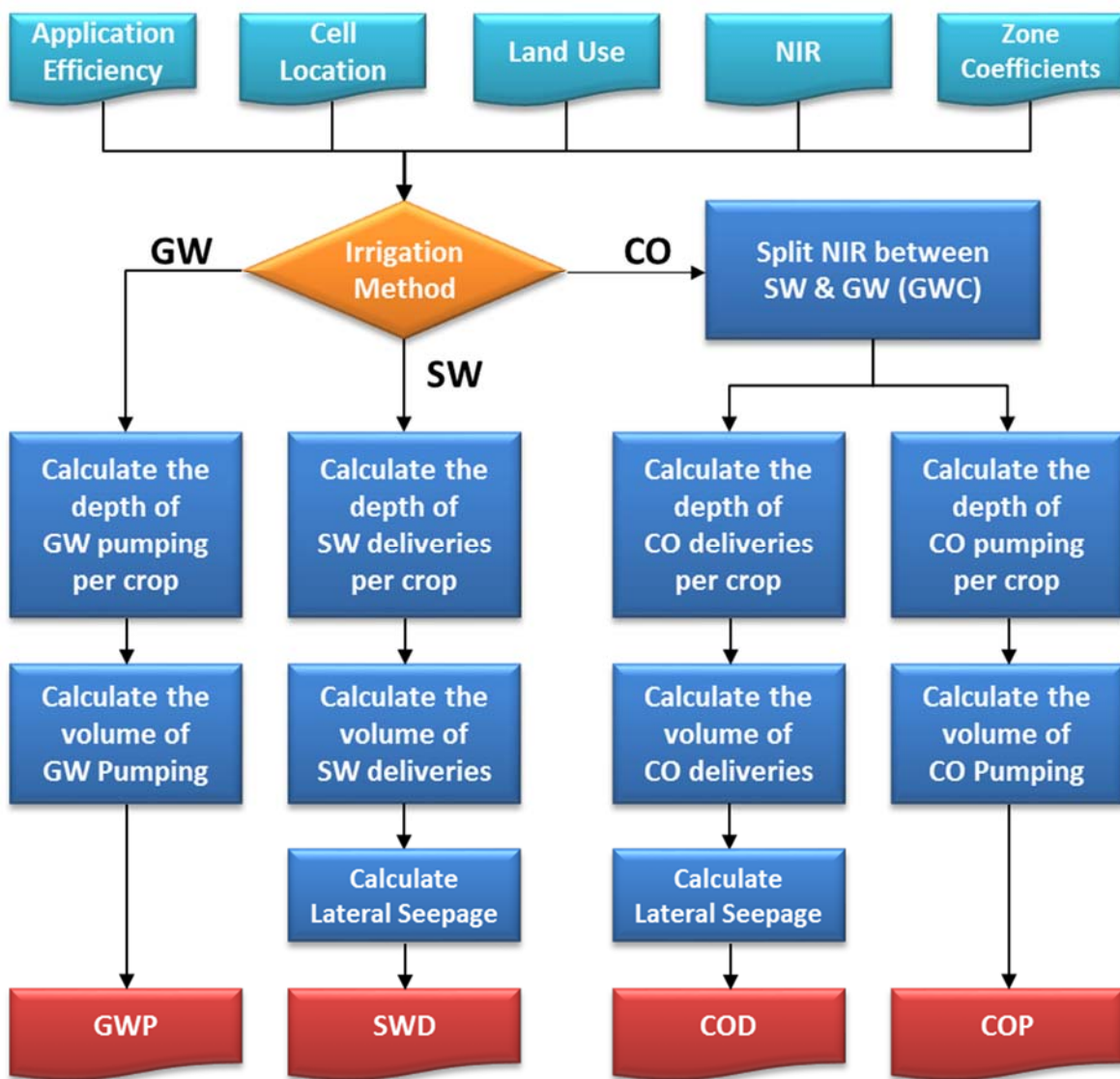


Figure 5A.3. Flow Chart depicting the inputs, outputs, and major functions of the IAD program.

## Appendix 5-A. RSWB Model Construction

The volume of irrigation demand is estimated using the distributed NIR, adjusting it with an NIR target parameter, and then determining the gross irrigation volume needed using the application efficiency (Equation 1).

$$IrrD_{crop, irr\ source} = NIR_{crop} * \frac{Target_{NIR}}{AE_{irr\ source}} \quad (1)$$

$IrrD_{crop, irr\ source}$	Depth of irrigation water demand by the crop from irrigation source (in)
$NIR_{crop}$	Net Irrigation Requirement for a given crop (in)
$Target_{NIR}$	Representative target indicating the portion of the full demand expected to be applied by rational producers
$AE_{irr\ source}$	Application efficiency of the irrigation source
crop	Land use classification of the type of vegetation being produced
irr source	Source of water applied as irrigation: groundwater only, surface water only, or comingled

The volume of water applied within a cell is computed by multiplying the per acre value by the number of acres covered by the crop. The calculation is repeated for each crop being grown in the cell (Equation 2).

$$IrrD_{cell, irr\ source} = \sum \left( \frac{IrrD_{crop, irr\ source}}{12} * ACS_{crop, irr\ source} \right) \quad (2)$$

$IrrD_{cell, irr\ source}$	Volume of irrigation water demanded by the cell from irrigation source (AF)
$IrrD_{crop, irr\ source}$	Depth of irrigation water demand by the crop from irrigation source (in)
$ACS_{crop, irr\ source}$	Number of acres of the specified crop type and irrigated from the irrigation source (acres)
cell	Relevant model grid unit
crop	Land use classification of the type of vegetation being produced
irr source	Source of water applied as irrigation: groundwater only, surface water only, or comingled

For comingled lands, irrigation demand was split between surface water and groundwater using the groundwater concentration (GWC) factor. The GWC is used to represent the understanding of producers that the volume of available surface water is limited and may be insufficient to meet the full demand of their crop. The producer enters the irrigation season expecting to meet a portion of their irrigation needs on comingled lands with groundwater; thereby allowing a larger proportion of the available surface water to be applied to surface water only land. Figure 5A.4 illustrates this concept graphically.

Appendix 5-A. RSWB Model Construction

The NIR value from Equation 1 was weighted by the GWC to determine the portion of demand met by either groundwater pumping or surface water deliveries (Equations 3-4).

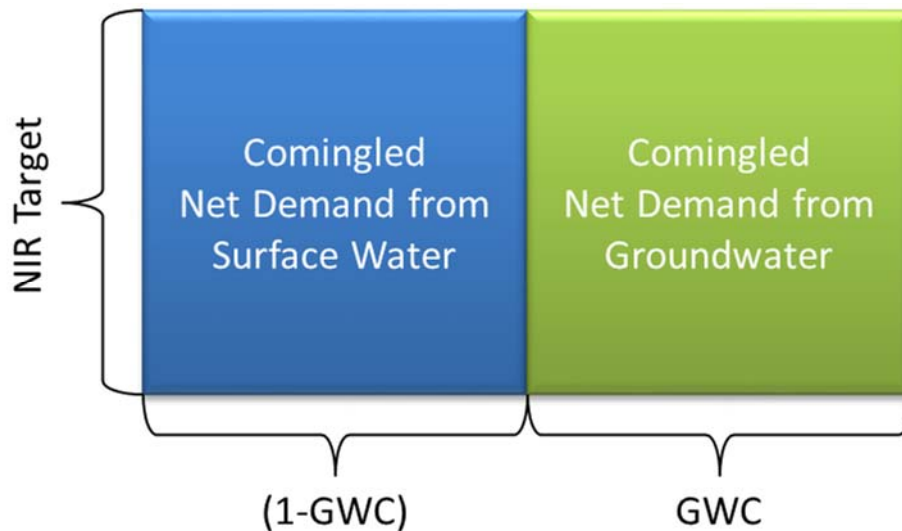


Figure 5A.4. Division of demand for irrigation on comingled lands.

$$NIR_{GW} = NIR * GWC \quad (3)$$

$$NIR_{SW} = NIR * (1 - GWC) \quad (4)$$

NIR	Net irrigation requirement (in)
$NIR_{GW}$	Portion of the net irrigation requirement expected to be met by groundwater pumping (in)
$NIR_{SW}$	Portion of the net irrigation requirement expected to be met by surface water deliveries (in)
GWC	Groundwater concentration factor
GW	Groundwater irrigated
SW	Surface water irrigated

The NIR parameter from Equation 1 was then replaced with  $NIR_{GW}$  and  $NIR_{SW}$  for calculation of pumped groundwater or applied surface water, respectively.

Finally, the demand for surface water is adjusted upwards to account for transportation inefficiencies in the laterals between the main canal and fields. The lateral seepage is a proportional amount related to the field demand (Equation 5).

$$SeepD_{Lat} = IrrD_{cell,SW} * LatLoss \quad (5)$$

$SeepD_{Lat}$	Seepage in the canal laterals from irrigation demands (AF)
$IrrD_{cell,SW}$	Volume of surface water irrigation water demanded by the cell (AF)

LatLoss            Transportation inefficiency of the canal’s delivery system between the main canal and the field

**5-A.1.4. District Demand**

The District Demand program (Figure 5A.5) combines each of the individual field demands for surface water within an irrigation district (Equation 6). These district demands are written to a single district demand file. The demands are then provided to the surface water operations model.

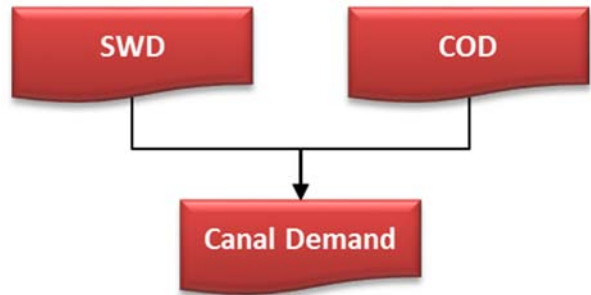


Figure 5A.5. Flow Chart depicting the inputs, outputs, and major functions of the District Demand program.

$$IrrD_{district} = \sum(IrrD_{cell,SW} + SeepD_{Lat}) \tag{6}$$

$IrrD_{district}$             Irrigation District demands for surface water (AF)  
 $IrrD_{cell, SW}$             Volume of surface water irrigation water demanded by the cell (AF)  
 $SeepD_{Lat}$             Seepage in the canal laterals from irrigation demands (AF)

**5-A.1.5. Irrigation Application and Supply**

The Irrigation Application and Supply program (Figure 5A.6) incorporates the irrigation district deliveries from the surface water operations model, the estimated deliveries to irrigation districts not included in the surface water operation model, and estimates groundwater pumping volumes to determine the applied irrigation water to each crop within each cell.



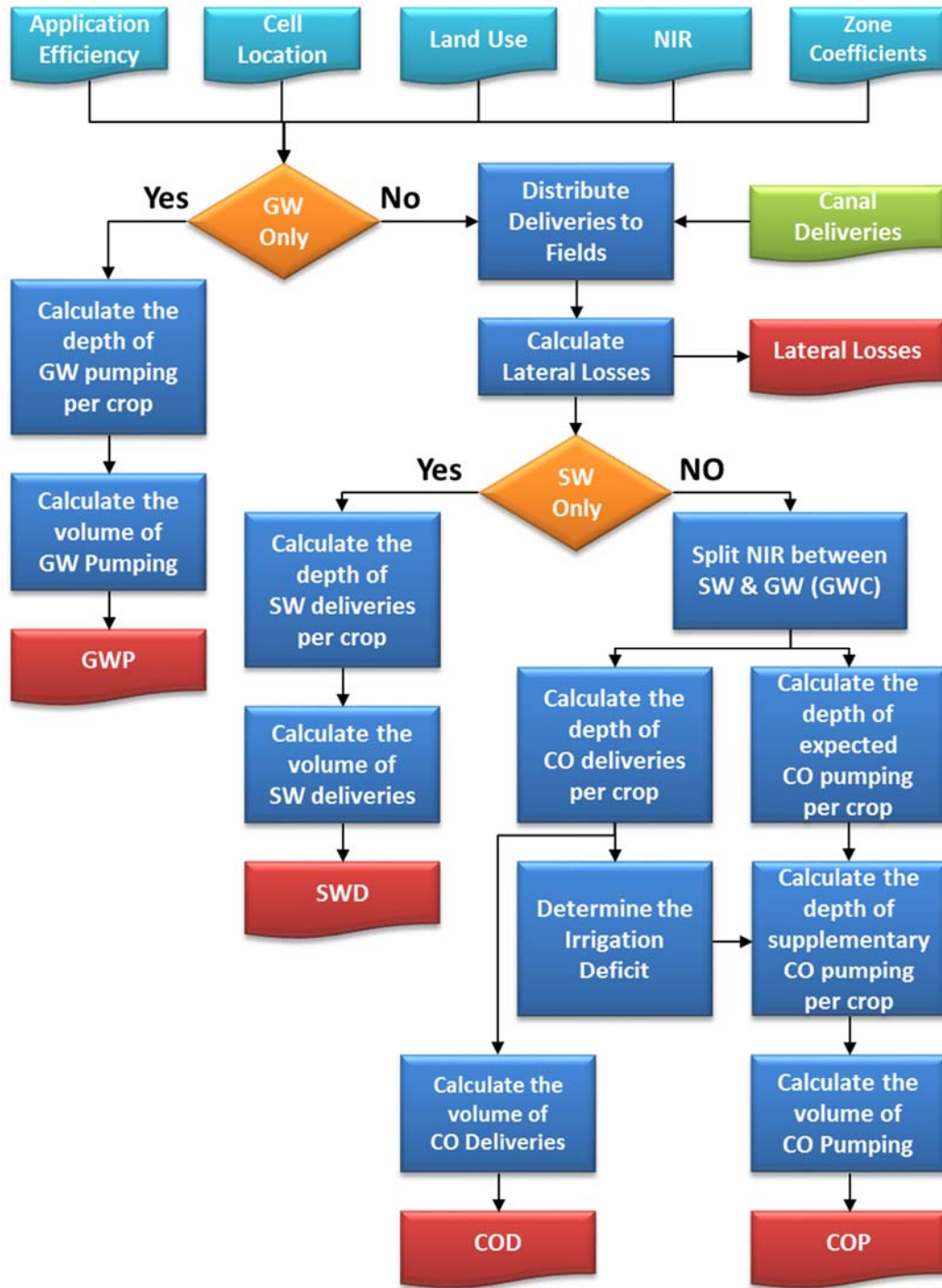


Figure 5A.6. Flow Chart depicting the inputs, outputs, and major functions of the IAS program.

Surface water deliveries to either surface water only lands or comingled lands within each irrigation district are split between the individual crops and fields weighted by NIR and acres (Equations 7-8).

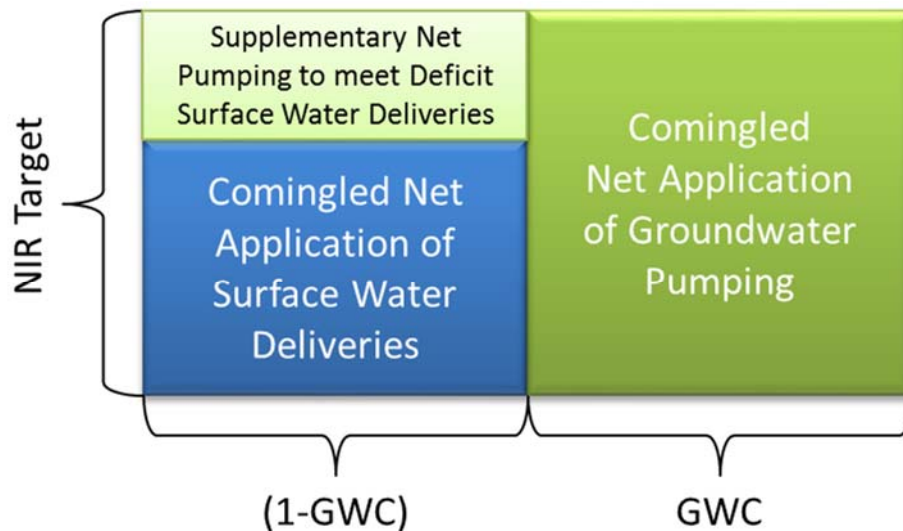
Appendix 5-A. RSWB Model Construction

$$IrrA_{crop,SW} = Delivery_{district} * \frac{\frac{IrrD_{crop,SW} * ACS_{crop,SW} * (1+LatLoss)}{12}}{IrrD_{district}} \quad (7)$$

$$IrrA_{crop,CO} = Delivery_{district} * \frac{\frac{IrrD_{crop,CO} * ACS_{crop,CO} * (1-GWC) * (1+LatLoss)}{12}}{IrrD_{district}} \quad (8)$$

$IrrA_{crop,SW}$	Volume of surface water delivered to a crop in the surface water only field (AF)
$IrrA_{crop,CO}$	Volume of surface water delivered to a crop in the comingled field (AF)
$Delivery_{district}$	Volume of field deliveries for the irrigation district (AF)
$IrrD_{district}$	Irrigation district demands for surface water (AF)
$IrrD_{crop,XX}$	Depth of irrigation water demand by the crop from irrigation source (in)
$ACS_{crop,XX}$	Number of acres of the specified crop type and irrigated from the irrigation source (acres)
GWC	Groundwater concentration factor
LatLoss	Transportation inefficiency of the canal's delivery system between the main canal and the field
SW	Surface water
CO	Comingled

Groundwater pumping on groundwater irrigated only lands is estimated using Equations 1 and 2 from Section 5-A.1.3.



**Figure 5A.7.** Depiction of the application of comingled irrigation when there are insufficient surface water deliveries to meet the demand for surface water.

For comingled land, pumping is calculated in two parts. First, the producer pumps the demanded irrigation expected from applying the GWC. Next, in the event that there were insufficient surface water

## Appendix 5-A. RSWB Model Construction

deliveries to meet the irrigation demands on the rest of the comingled field, groundwater is pumped to meet the difference (Equations 9-10). Figure 5A.7 represents this concept graphically.

$$IrrA_{crop,COP1} = \frac{NIR_{crop} * Target_{NIR}}{12 * AE_{GW}} * AC_{crop,CO} * (GWC) \quad (9)$$

$$IrrA_{crop,COP2} = \frac{NIR_{crop} * Target_{NIR} - IrrA_{crop,CODnet}}{12 * AE_{GW}} * AC_{crop,CO} * (1 - GWC) \quad (10)$$

$IrrA_{crop,COP1}$	Volume of comingled pumping on the portion of the comingled field expecting to apply groundwater first (AF)
$IrrA_{crop,COP2}$	Volume of comingled pumping necessary to account for deficit surface water deliveries (AF)
$NIR_{crop}$	Net Irrigation Requirement for a given crop (in)
$Target_{NIR}$	Representative target indicating the portion of the full demand expected to be applied by rational producers
$IrrA_{crop,CODnet}$	The net irrigation portion of the surface water deliveries to the field; deliveries minus lateral seepage minus application inefficiencies (in) (Equation 11)

$$IrrA_{crop,CODnet} = \frac{IrrA_{crop,COD}}{(1 + LatLoss) * AC_{crop,CO} * (1 - GWC)} * 12 * AE_{SW} \quad (11)$$

$IrrA_{crop,COD}$	Volume of surface water delivered to a crop in the comingled field (AF)
$AE_{GW}$	Application efficiency for groundwater pumping
$AC_{crop,CO}$	Crop acres for the comingled field (acres)
$GWC$	Groundwater concentration factor
$LatLoss$	Transportation efficiency of the canal's delivery system between the main canal and the field

The applied irrigation volumes are passed to the Water Supply Partitioning Program.

### 5-A.1.6. Water Supply Partitioning Program (WSPP)

The purpose of the WSPP is to partition precipitation and applied irrigation between evapotranspiration, recharge, runoff, and changes in soil water content. Additionally, the program is used to adjust the parameters of the water balance from the idealized conditions in CropSim, through calibration, to more accurately reflect the conditions experienced in the field. Calibration is accomplished using the distributed water balance parameters, land use classifications, and applied irrigation volumes (Figure 5A.8). WSPP can incorporate either estimated irrigation amounts (demand runs) or applied irrigation data sets developed outside the RSWB model (ex. defined district deliveries or metered pumping records).

Within WSPP, all adjustments made to any water balance parameter must maintain the water balance shown in Equation 12.

$$P + NIR - ET - RO - DP = \Delta SWC \quad (12)$$

P	Precipitation (in)
NIR	Net Irrigation Requirement (in)
ET	Evapotranspiration (in)
RO	Runoff (in)
DP	Deep Percolation (in)
$\Delta SWC$	Change in soil water content (in)

Each combination of irrigation source and crop is evaluated separately. Calculations are first made for dryland conditions. An adjustment is made to the dryland ET to reflect the difference between the idealized conditions from CropSim and those observed in the field (Equation 13).

$$ET_{dry,adj} = ET_{dry} * ADJ_{ET,dry} \quad (13)$$

$ET_{dry,adj}$	Adjusted dryland evapotranspiration (in)
$ET_{dry}$	Distributed evapotranspiration (in)
$ADJ_{ET,dry}$	Dryland evapotranspiration adjustment factor

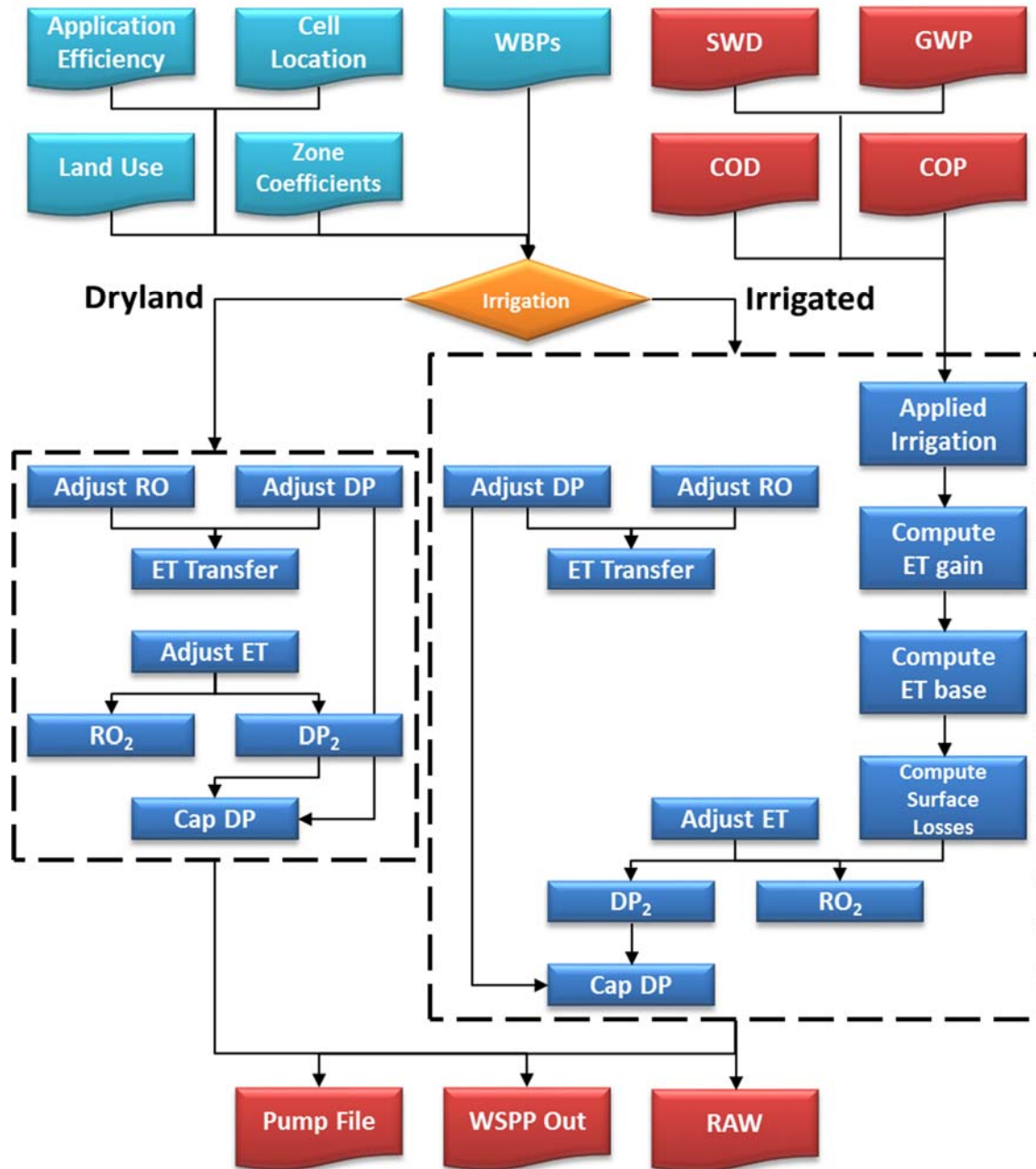


Figure 5A.8. Flow Chart depicting the inputs, outputs, and major functions of the WSPP program.

The change in ET is then converted to runoff and deep percolation (Equations 14-16).

$$\Delta ET_{dry} = ET_{dry} - ET_{dry,adj} \quad (14)$$

$$RO_2 = \Delta ET_{dry} * DryET_2RO \quad (15)$$

$$DP_2 = \Delta ET_{dry} - RO_2 \quad (16)$$

## Appendix 5-A. RSWB Model Construction

$\Delta ET_{dry}$	Change in dryland evapotranspiration (in)
$ET_{dry, adj}$	Adjusted dryland evapotranspiration (in)
$ET_{dry}$	Distributed evapotranspiration (in)
$RO_2$	Additional runoff from evapotranspiration adjustment (in)
$DP_2$	Additional deep percolation from evapotranspiration adjustment (in)
$DryET_2RO$	Partitioning factor used to divide unassigned water between runoff and deep percolation

Similarly, runoff and deep percolation adjustment factors are available to make adjustment to the volume of either respective parameter resulting from CropSim<sup>1</sup>. Changes caused by these parameters are converted to non-beneficial consumptive use (ET) (Equations 17-19).

$$RO_1 = RO_{dry} * ADJ_{RO} \quad (17)$$

$$DP_1 = DP_{dry} * ADJ_{DP} \quad (18)$$

$$ET_{trans} = (DP_{dry} - DP_1) + (RO_{dry} - RO_1) \quad (19)$$

$RO_{dry}$	Distributed runoff (in)
$DP_{dry}$	Distributed deep percolation (in)
$RO_1$	Adjusted dryland runoff (in)
$DP_1$	Adjusted dryland deep percolation (in)
$ADJ_{RO}$	Runoff adjustment factor
$ADJ_{DP}$	Deep percolation adjustment factor
$ET_{trans}$	Conversion of runoff and deep percolation from CropSim converted into non-beneficial evapotranspiration (in)

Finally, the WSPP program allows for upper limits to be applied to recharge rates. A diminishing returns function is employed such that after the annual rate of deep percolation exceeds a lower threshold; as the depth of deep percolation goes to infinity, the depth realized by the model approaches the deep percolation cap (Equations 20-23). The routine was implemented to account for the fact that soils may be limited on their ability to drain water which has seeped below the modeled root zone, causing an over estimation of recharge rates.

$$\lim_{DP_1+DP_2 \rightarrow \infty} DP_{dry,tot} = DP_{cap} \quad (20)$$

$$DP_{dry,tot} = DP_{ll} + (DP_{cap} - DP_{ll}) * \left( 1 - \left( 1 - \frac{DP_1+DP_2-DP_{ll}}{DP_{ul}-DP_{ll}} \right)^{\frac{1}{\alpha}} \right) \quad (21)$$

<sup>1</sup> These two parameters are not used in the current COHYST model.

## Appendix 5-A. RSWB Model Construction

Where

$$\alpha = \frac{DP_{cap} - DP_{ll}}{DP_{ul} - DP_{ll}} \quad (22)$$

$$DP_2RO = DP_1 + DP_2 - DP_{dry,tot} \quad (23)$$

$DP_{dry,tot}$	Model realized rate of deep percolation (in)
$DP_1$	Adjusted dryland deep percolation (in)
$DP_2$	Additional deep percolation from evapotranspiration adjustment (in)
$DP_{cap}$	Maximum rate or realized deep percolation (in)
$DP_{ll}$	Rate of deep percolation at which the model begins to taper off the realized rate of deep percolation (in)
$DP_{ul}$	Rate of deep percolation at which the realized rate of deep percolation has reached its maximum (in)
$DP_2RO$	Deep percolation converted to runoff due to the recharge cap limit (in)
$\alpha$	Weighting factor used to create the shape of the diminishing returns function

The recharge realized by the model and the additional runoff is distributed to monthly values proportional to the initial recharge rates  $DP_1$  and  $DP_2$ .

Working forward from Equation 12, the water balance can be rewritten for dryland crops as shown in Equation 24 below<sup>2</sup>.

$$P - ET_{dry,adj} - DP_{dry,tot} - DP_2RO - RO_1 - RO_2 - ET_{trans} = \Delta SWC \quad (24)$$

$P$	Precipitation (in)
$ET_{dry,adj}$	Adjusted dryland evapotranspiration (in)
$DP_{dry,tot}$	Model realized rate of deep percolation (in)
$DP_2RO$	Recharge converted to runoff due to the recharge cap limit (in)
$RO_1$	Adjusted dryland runoff (in)
$RO_2$	Additional runoff from evapotranspiration adjustment (in)
$ET_{trans}$	Conversion of runoff and deep percolation from CropSim converted into non-beneficial evapotranspiration (in)
$\Delta SWC$	Change in soil water content (in)

To calculate the water balance for irrigated crops, WSPP uses the distributed CropSim output for the irrigated crops, the dryland crop ET, and the volume of irrigation water applied to the crop<sup>3</sup>. The first step is to convert the volume of irrigation water to a depth of applied water (Equation 25) after removing any lateral seepage (Equation 5).

<sup>2</sup> Note that for dryland crop NIR is equal to zero.

<sup>3</sup> For the COHYST model, the irrigation volumes were a combination of deliveries from the surface water operations model and estimates for pumping and deliveries from the Irrigation Application and Supply program.

Appendix 5-A. RSWB Model Construction

$$IrrA = \frac{IrrA_{crop,irr\ source} - SeepS_{Lat}}{AC_{crop,irrsources}} * 12 \quad (25)$$

$IrrA$	Depth of applied irrigation water (in)
$IrrA_{crop, irr\ source}$	Volume of applied irrigation water (AF)
$AC_{crop, irr\ source}$	Acres over which the irrigation water is to be applied (acres)
$SeepS_{Lat}$	Seepage in the canal laterals from the supplied irrigation (AF)

Then, similar to the dryland calculations, the water balance coming out of the soil water balance model (Equation 12) is maintained, keeping precipitation and change in soil water content constant.

Furthermore, as described in Equations 17-19, a potential adjustment can be made to runoff and deep percolation.

The next major objective of an irrigated calculation is to estimate ET gain. ET gain is the increase in beneficial consumptive use from the application of irrigation water. ET gain is a cumulative endeavor over the entire irrigation season. However, the marginal gains in ET from the application of additional irrigation is subject to diminishing returns. This process is defined by Equation 26.

$$ET_{gain} = \begin{cases} CIR * \left(1 - \left(1 - \frac{IrrA_{sea}}{GIR}\right)^{\frac{1}{\beta}}\right) & IrrA_{sea} < GIR \\ ET_{irr,max,sea} - ET_{dry,max,sea} & IrrA_{sea} \geq GIR \end{cases} \quad (26)$$

$ET_{gain}$	Increase in evapotranspiration from the application of irrigation water (in)
$CIR$	Consumptive irrigation requirement – the additional amount of evapotranspiration that a plant must use to maximize its yield potential over a rainfed crop; defined by Equation 27 (in)

$$CIR = ET_{irr,max,sea} - ET_{dry,max,sea} \quad (27)$$

$GIR$	Gross irrigation requirement – the amount of irrigation that needs to be applied in order to meet the net irrigation requirement (in)
$\beta$	Water use efficiency term; defined by Equation 28

$$\beta = \frac{CIR}{GIR} \quad (28)$$

$IrrA_{sea}$	Depth of irrigation water applied during the irrigation season (in)
$ET_{irr, max, sea}$	Evapotranspiration needed to meet the max yield potential for an irrigated crop during the growing season (in)
$ET_{dry, max, sea}$	Rainfed evapotranspiration utilized during the irrigation season (in)



## Appendix 5-A. RSWB Model Construction

The resultant ET gain was then distributed back to the months based upon: 1) Applied Water > 0 and  $ET_{irr} > ET_{dry}$ , 2) Applied Water > 0 and  $ET_{irr} < ET_{dry}$ , and any remaining ET gain by 3) Applied Water = 0 and  $ET_{irr} > ET_{dry}$ . The ET gain is added to the non-irrigated ET to determine the total ET. Finally, an adjustment of the irrigated ET was made to account for differences between the idealized conditions in the soil water balance model and those observed in the field (Equation 29).

$$ET_{irr,adj} = ET_{irr} * ADJ_{ET,irr} \quad (29)$$

$ET_{irr, adj}$	Adjusted irrigated evapotranspiration (in)
$ET_{irr}$	Irrigated evapotranspiration <sup>4</sup> (in)
$ADJ_{ET, irr}$	Irrigated evapotranspiration adjustment factor (in)

After determining the effect of irrigation on ET, the remainder of the total applied water needs to be partitioned. Surface losses are calculated to determine the portion of the applied water lost directly to non-beneficial consumptive use. These losses are assumed to be a fixed percentage of the total applied volume. Finally, the remaining applied water in excess of the surface losses and ET, while maintaining the change in soil water content from the soil water balance model output, was divided between runoff ( $RO_2$ ) and deep percolation ( $DP_2$ ), defined by Equation 30. This water includes both the irrigation inefficiencies and the shift from idealized CropSim conditions.

$$RODP_{wt} = MIN \left( MAX \left( \frac{RO_f DP * RO_1}{RO_f DP * RO_1 + DP_1}, RO_{min} \right), RO_{max} \right) \quad (30)$$

$RODP_{wt}$	Irrigated partitioning factor used to divide water between runoff and deep percolation
$RO_f DP$	Weighting factor to control the influence of runoff on the partitioning factor
$RO_1$	Adjusted irrigated runoff (in)
$DP_1$	Adjusted irrigated deep percolation (in)
$RO_{min}$	Minimum partitioning factor value
$RO_{max}$	Maximum partitioning factor value

Finally, the WSPP program allows for upper limits to be applied to irrigated recharge rates in the same way they are applied to dryland crops (Equations 20-23). The results from the irrigated calculations are summarized in Equation 31. The partitioning of the applied irrigation is further illustrated in Figure 5A.9.

---

<sup>4</sup> The irrigated ET is function of applied water

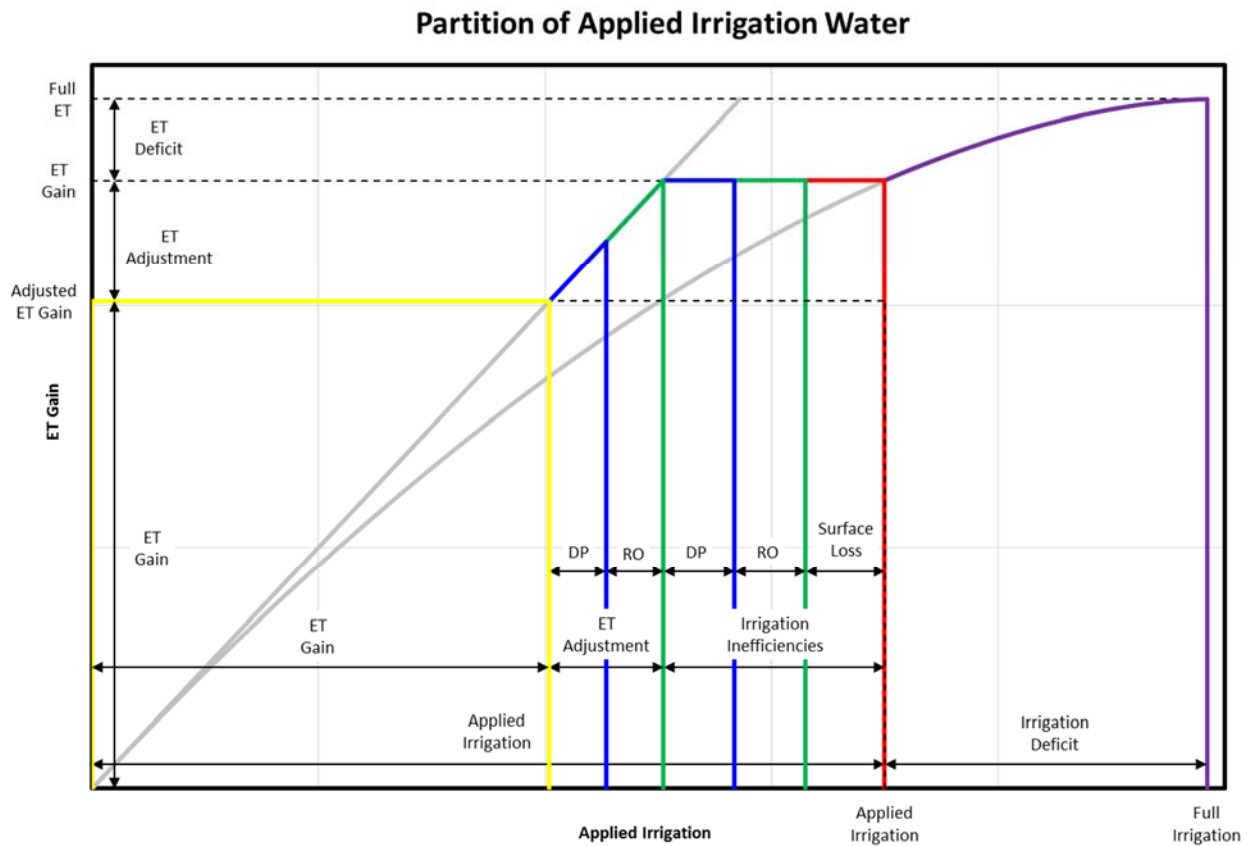


Figure 5A.9. Partitioning of applied irrigation water.<sup>5</sup>

$$P + IrrA - SL - ET_{irr,adj} - DP_{irr,tot} - DP_2RO - RO_1 - RO_2 - ET_{trans} = \Delta SWC \quad (31)$$

P	Precipitation (in)
IrrA	Depth of applied irrigation water (in)
SL	Surface Losses <sup>6</sup> (in)
$ET_{irr,adj}$	Adjusted irrigated evapotranspiration (in)
$DP_{irr,tot}$	Model realized rate of deep percolation (in)
$DP_2RO$	Recharge converted to runoff due to the recharge cap limit (in)
$RO_1$	Adjusted irrigated runoff (in)
$RO_2$	Additional runoff from evapotranspiration adjustment and irrigation inefficiencies (in)
$ET_{trans}$	Conversion of runoff and deep percolation from CropSim converted into non-beneficial evapotranspiration (in)
$\Delta SWC$	Change in soil water content (in)

<sup>5</sup> Terms are exaggerated to assist in visualizing the process.

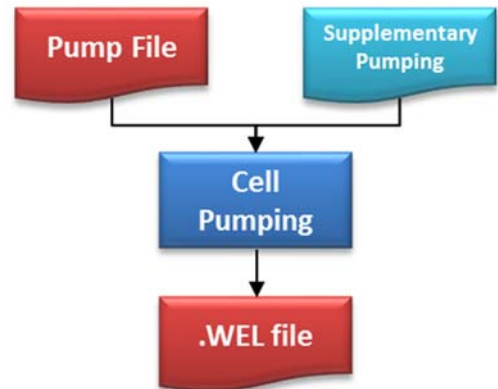
<sup>6</sup> Surface losses in this context refer to irrigation water lost during application: drift, evaporation, interception, etc.

These results are then scaled to the cell level by multiplying the water balance results by the number of crop acres serviced by the irrigation source within the cell. Finally, the cell totals were calculated by summing all the crop-irrigation source combination present within the cell.

### 5-A.1.7. Make Well

The primary purpose of the Make Well program is to combine the various sources of pumping data into a set of annual files in the groundwater model's '.WEL' format. The COHYST model does not specify the relationship between fields and irrigation wells. Rather, the COHYST model incorporates a virtual well technique in which the location of the well is assumed to be in the cell where the water is applied.

The only required source is the groundwater pumping from the WSPP program. However, the program is able to accommodate other sources such as municipal & industrial pumping, or supplementary pumping<sup>7</sup> (Figure 5A.10).



**Figure 5A.10.** Flow Chart depicting the inputs, outputs, and major functions of the Make Well program.

---

<sup>7</sup> Supplementary pumping refers to estimates of pumping created outside of the RSWB model and not applied as irrigation, but are merged into the pumping file for the groundwater model. Example: Augmentation Pumping.

### 5-A.1.8. Make Recharge

The Make Recharge program combined the various forms of recharge data into a set of annual files in the groundwater model's '.RCH' format. These sources include but are not limited to direct agricultural recharge, indirect agricultural recharge, canal recharge, lateral seepage and supplementary recharge<sup>8</sup> (Figure 5A.11).

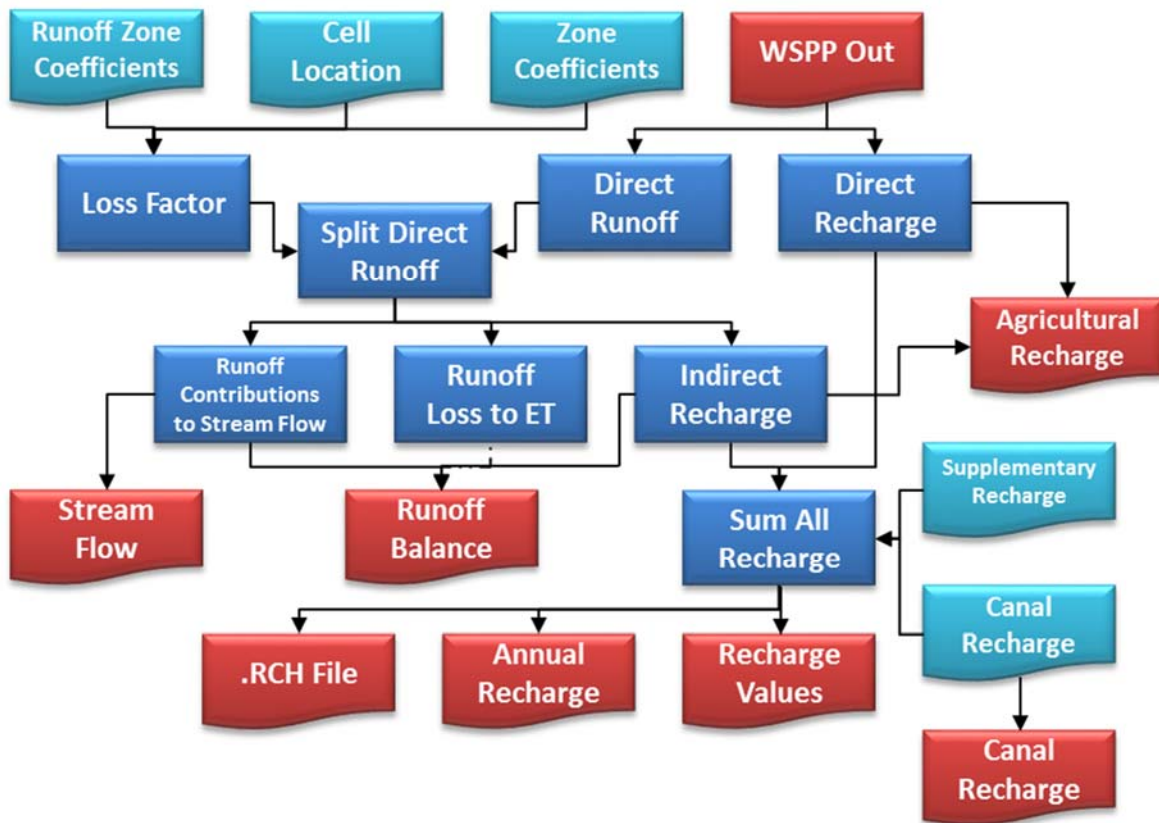


Figure 5A.11. Flow Chart depicting the inputs, outputs, and major functions of the Make Recharge program.

The make recharge program is responsible for estimating the indirect recharge from field runoff. Indirect recharge is the additional recharge resulting from transit losses between the field and the stream gauge. It is a function of direct agricultural runoff from a cell, a loss per mile variable and the distance from the cell to the stream gauge at the end of the runoff zone. The runoff loss is divided into non-beneficial ET and recharge (Equation 32-35).

<sup>8</sup> Supplementary recharge refers to estimates of recharge that were created outside the RSWB model, but were merged into the recharge dataset provided to the groundwater model. Example: recharge from an augmentation recharge pond.

## Appendix 5-A. RSWB Model Construction

$$RO = SF + RO_2DP + RO_2ET \quad (32)$$

$$SF = RO * (1 - LossFactor) \quad (33)$$

$$RO_2DP = RO * LossFactor * \%2Rch \quad (34)$$

$$RO_2ET = RO * LossFactor * (1 - \%2Rch) \quad (35)$$

RO	Runoff (AF)
SF	Runoff contribution to stream flow (AF)
RO <sub>2</sub> DP	Runoff transmission losses to recharge (AF)
RO <sub>2</sub> ET	Runoff transmission losses to non-beneficial evapotranspiration (AF)
%2Rch	Runoff partitioning factor
LossFactor	Portion of the field runoff lost to recharge or evapotranspiration during transit from the field to the stream gauge; calculated using Equation 36

$$LossFactor = Min(1 - e^{-lpm * Mi2Gauge}, 1.0) \quad (36)$$

lpm	Loss per mile factor (mi <sup>-1</sup> )
Mi2Gauge	Distance between the cell centroid and the stream gauge identifying the accumulation point of the basin (mi)

### 5-A.1.9. Compile Well

The Compile Well program is a simple program developed to combine the annual '.WEL' format files into a single .WEL file with the appropriate headers ready for use in the groundwater model. A program schematic would not materially assist in reviewing the Compile Well's source code.

### 5-A.1.10. Compile Recharge

The Compile Recharge program is a simple program developed to combine the annual '.RCH' format files into a single .RCH file with the appropriate headers ready for use in the groundwater model. A program schematic would not materially assist in reviewing the Compile Recharge's source code.

### 5-A.1.11. WSPP Report

The WSPP Report program is also a simple program developed to compile the water balance parameters into several annual and monthly summary files. Summaries are created on each the regional, county, coefficient zone, runoff zone, surface water irrigation districts, CNPPID sub-districts, and U-areas. Within each of these areas, summaries are created for combinations of soils, crops, and irrigation sources.

### **5-A.1.12. Master Input File**

The master input file represents the control file for a simulation. Each of the programs listed above use the Master Input File to define the model scenario. The Master input file contains naming conventions, input file names and locations, output locations, and control parameters to define the size of the model and the length of the simulation. The Master Input File contains a header followed by 56 items plus the number of crops included in the simulation

1. Header
2. Run Designation
3. Model Name
4. Input Directory
5. Output Directory
6. Water Balance Parameter Directory
7. Land Use Directory
8. Canal Recharge Directory
9. Miscellaneous Directory
10. Municipal and Industrial Directory
11. Groundwater Only Land Use Folder
12. Surface Water Only Land Use Folder
13. Comingled Land Use Folder
14. Dryland Land Use Folder
15. Groundwater Only Land Use File Prefix
16. Surface Water Only Land Use File Prefix
17. Comingled Land Use File Prefix
18. Dryland Land Use File Prefix
19. Groundwater Concentration Folder
20. Groundwater Concentration File Prefix
21. Cell Location File
22. Coefficient Zone Coefficient File
23. Application Efficiency File
24. Runoff Zone Coefficient File
25. Percent to Recharge File
26. Surface Water Irrigation District Index File
27. County Identification File
28. County-Cell Relationship File
29. Canal Master File
30. Miscellaneous Master Recharge File
31. Miscellaneous Master Pumping File
32. Municipal and Industrial Master Recharge File
33. Municipal and Industrial Master Pumping File
34. Active Cells File
35. Call Year File
36. Number of Grid Cells

## Appendix 5-A. RSWB Model Construction

37. Simulation Starting Month
38. Simulation Starting Year
39. Simulation Ending Month
40. Simulation Ending Year
41. Flag indicating a non-active cell within the Watershed Model – was used for Lake McConaughy
42. Flag to restrict the application of irrigation water
43. Flag to restrict the application of groundwater irrigation
44. Flag to indicate the existence of canal recharge
45. Flag to indicate the existence of miscellaneous recharge
46. Flag to indicate the existence of miscellaneous pumping
47. Flag to indicate the existence of municipal and industrial recharge
48. Flag to indicate the existence of municipal and industrial pumping
49. Number of control years in the Call Year File
50. Number of coefficient zones
51. Number of runoff zones
52. Number of soils
53. Number of irrigation districts
54. Size of the model cell in acres
55. Number of columns in the entire model grid
56. Number of rows in the entire model grid
57. Number of crop included in the simulations
58. List of crops

Greater Detail on the Master Input File can be found in Appendix 5-B.

### **5-A.1.13. Miscellaneous Master Files**

The miscellaneous master files are used to control the addition of externally developed pumping and recharge into the '.WEL' and '.RCH' files. Rather than requiring a new set of inputs be created for the entire model area when additions, removals, or changes are made these data sets; the data sets can be kept separate. Then the Miscellaneous Master Files control which data sets are included in the final '.RCH' and '.WEL' files.

*Example: The Integrated model uses canal recharge from the Republican River Canals and seepage developed for the Platte River Canals from the surface water operations model. The current version of the Integrated Model tasks the groundwater model with incorporating the Platte River Canals; while the previous version relegated this task through the RSWB. Rather than having to create a new canal recharge file sans the Platte River Canal Seepage, the Master Canal File allows each data set to be maintained separately and included in the .RCH file only when the data set is included in the Master Canal file.*

## Appendix 5-A. RSWB Model Construction

Greater Detail on the Master Input File can be found in Appendix 5-B.

### **5-A.1.14. Call Year File**

The call year file is a temporal guide for the program. For a given year in a simulation, the call year file controls the input data for the land use, water balance parameters, the ground water concentration, canal seepage, miscellaneous pumping and recharge, and municipal pumping and recharge. While the base model uses the annual data from the relevant year, the call year file allows the user to analyze certain scenarios or project the model into the future while limiting the development of additional input files.

Greater Detail on the Call Year File can be found in Appendix 5-B.