IWFM Demand Calculator (IDC) Version 4.0

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California Department of Water Resources

Background

- IWFM Demand Calculator (IDC) is a stand-alone program that simulates land surface and root zone flow processes as well as agricultural and urban water demands under user-specified land-use, soil, climate and farm management conditions
- IDC version 4.0 includes features developed based on CA DWR Bay-Delta Office's experience gained from its own water resources related applications as well as from other groups' applications using previous versions IDC and IWFM
- Although there are previous versions of IDC, IDC v4.0 is the first version that is officially made available to public

Background

- IDC v4.0 is being integrated into IWFM that will be released to the public as IWFM v4.0 in 2010
- The root zone module in IWFM v3.1 which was used in comparison to Modflow Farm Process, is not IDC v4.0 although the concepts and simulation methods are similar

New Features of IDC v4.0

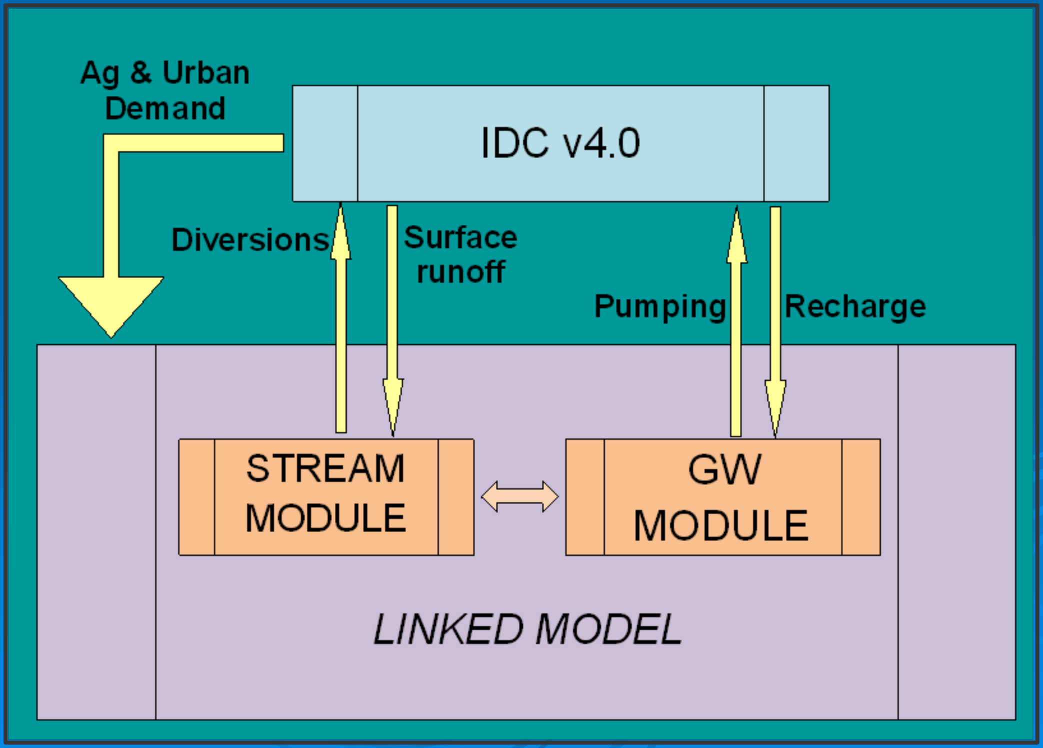
- Use of a computational grid, *finite-element or finite-difference*, to represent spatial distribution of land-use, climatic, soil and farm management properties; each cell can have multiple land-use types specified as time-series data
- Simulation of land surface and root zone flow processes as well as water demand computations are done at each grid cell for each land-use type
- Irrigation-scheduling-type approach at each grid cell for each agricultural crop
- Direct representation of rice fields and refuges
- Ability to simulate regulated deficit irrigation

New Features of IDC v4.0

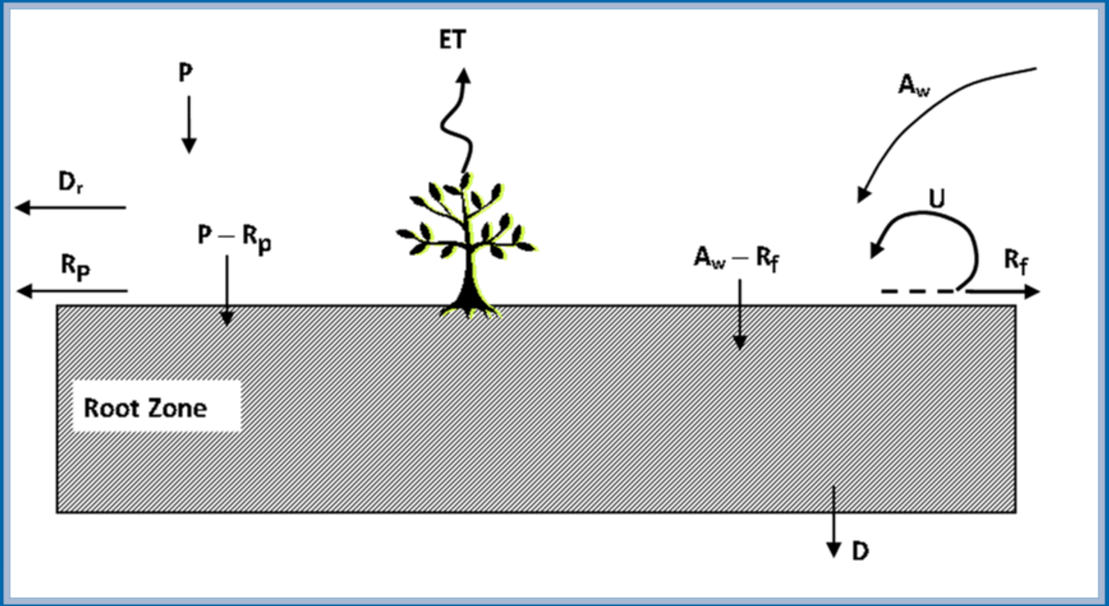
- Urban water demand computation based on population and per capita water usage
- Water supply delivered to a subregion (collection of grid cells) or to an individual grid cell
- Simulation of ETAW and effective precipitation
- Simulation of re-use of irrigation return flow that takes place at a grid cell, between grid cells or between subregions
- Water demand can be either computed dynamically or can be specified (e.g. contractual water demands) by the user; both options can be used in a single simulation
- Budget output includes soil moisture, and land and water use budgets for individual crops at each subregion

New Features of IDC v4.0

- Available as a stand-alone executable or as a dynamic link library (dll)
- It can easily be linked to finite-element or finite-difference hydrologic models



Schematic Representation of Flow Terms



P = precipitation

A_w = applied water

R_P = direct runoff

U = re-use

R_f = net return flow

ET = evapotranspiration

D_r = drain from ponds

D = deep percolation

Soil Moisture Routing in IDC v4.0

- Governing conservation equation (implicit scheme; all flow terms are computed at time step t+1):

$$\theta^{t+1} = \theta^{t} + \Delta t\left(P - R_P + A_w - R_f - D_r - D - ET\right) + \Delta\theta_a$$

where
θ = soil moisture, [L];
P = precipitation, [L/T];
R_P = surface runoff from precipitation, [L/T];
A_W = applied water, [L/T];
R_f = net return flow of applied water, [L/T];
D_r = pond drainage, [L/T];
D = deep percolation, [L/T];
ET = actual evapotranspiration, [L/T];
$\Delta\theta_a$ = soil moisture change due to changing land use area, [L];
Δt = time step length, [T];
t = time step counter (dimensionless).

Infiltration and Direct Runoff due to Precipitation

$$\theta^{t+1} = \theta^{t} + \Delta t\left(P - R_P + A_w - R_f - D_r - D - ET\right) + \Delta\theta_a$$

- Modified version of the SCS method (USDA, 1985) based on HELP model (Schoeder et al. 1994) to convert event-based approach to time-continious approach

Infiltration and Net Return Flow due to Applied Water

$$\theta^{t+1} = \theta^{t} + \Delta t\left(P - R_P + A_w - R_f - D_r - D - ET\right) + \Delta\theta_a$$

- Applied water is either computed dynamically or user-specified
- Return flow and re-use are computed as user-specified fractions of applied water

Drainage of Rice and Refuge Ponds

$$\theta^{t+1} = \theta^{t} + \Delta t \left(P - R_P + A_W - R_f - D_r - D - ET \right) + \Delta\theta_a$$

- Computed based on user-specified ponding depths:

$$D_r = \frac{P_D^{t} - P_D^{t+1}}{\Delta t} \geq 0$$

where P_D = ponding depth, [L]

Deep Percolation

$$\theta^{t+1} = \theta^{t} + \Delta t \left(P - R_P + A_w - R_f - D_r - D - ET \right) + \Delta\theta_a$$

- Conservation of momentum using van Genuchten-Mualem equation:

$$D = K_u \frac{dh(\theta)}{dz} \cong K_s \left(\frac{\theta^{t+1}}{\theta_T} \right)^{1/2} \left\{ 1 - \left[1 - \left(\frac{\theta^{t+1}}{\theta_T} \right)^{1/m} \right]^m \right\}^2 \quad ; \quad m = \frac{\lambda}{\lambda + 1}$$

where K_s = saturated hydraulic conductivity, [L/T];

λ = pore size distribution index, [dimensionless]

Evapotranspiration (Allen et al., 1998)

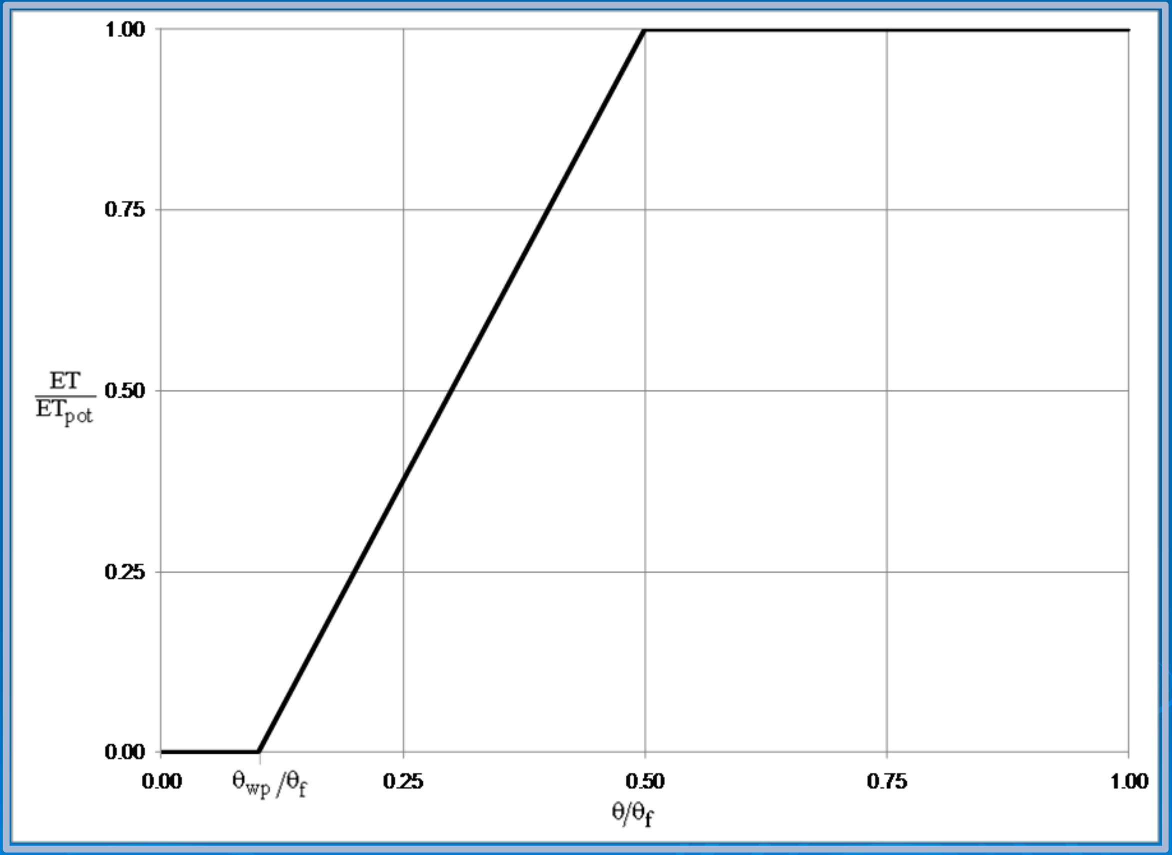
$$\theta^{t+1} = \theta^{t} + \Delta t\left(P - R_P + A_w - R_f - D_r - D - ET\right) + \Delta\theta_a$$

$$ET = \begin{cases} ET_{pot}^{t+1} & \text{if} \quad \dfrac{\theta^{t+1} - \theta_{wp}}{\frac{\theta_f}{2} - \theta_{wp}} > 1 \\ \dfrac{\theta^{t+1} - \theta_{wp}}{\frac{\theta_f}{2} - \theta_{wp}} ET_{pot}^{t+1} & \text{if} \quad 0 \le \dfrac{\theta^{t+1} - \theta_{wp}}{\frac{\theta_f}{2} - \theta_{wp}} \le 1 \\ 0 & \text{if} \quad \dfrac{\theta^{t+1} - \theta_{wp}}{\frac{\theta_f}{2} - \theta_{wp}} < 0 \end{cases}$$

Evapotranspiration *(continued)*

Assumptions:

- p is taken as 0.5
- ET_{pot} can be taken as ET_c, ET_{cadj} or whatever is specified by the user



Change in Moisture Due to Area Change

$$\theta^{t+1} = \theta^{t} + \Delta t \left(P - R_P + A_W - R_f - D_r - D - ET \right) + \Delta\theta_a$$

- Introduced to maintain the mass balance when land-use acreages change through simulation period
- When area of a land-use type decreases it is zero
- When area of a land-use type increases, moisture from other land-uses are assimilated and it is non-zero

Agricultural Demand Computation in IDC

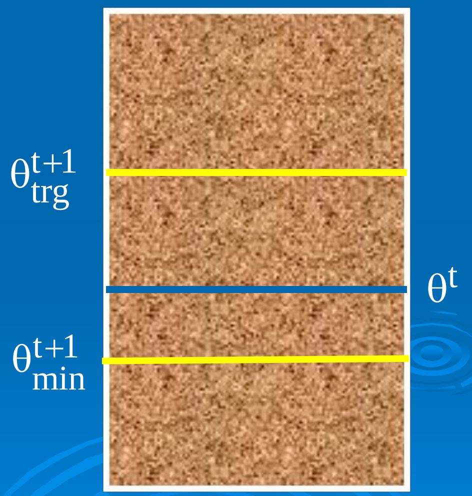
- Physical agricultural demand (computed by IDC)
  - *Non-ponded crops*: required amount of applied water in order to increase the soil moisture to an irrigation target moisture when the moisture falls below a threshold
  - *Ponded crops*: amount of applied water to achieve the required ponding depth or for the decomposition of rice residues
- Contractual agricultural demand (specified by the user) that may or may not be equal to the physical demand

Agricultural Demand Computation in IDC *(continued)*

- Non-ponded crops:

  During an irrigation or pre-irrigation period, IDC checks if moisture content is below a user-specified threshold. If it is, it uses the governing conservation equation to compute A_w that will raise the moisture to a target moisture content:

$$A_w = \begin{cases} \dfrac{\dfrac{\theta_{trg}^{t+1} - \theta^t - \Delta\theta_a^{t+1}}{\Delta t} - P^{t+1} + R_p^{t+1} + D_{trg}^{t+1} + ET_{trg}^{t+1}}{1 - \left(f_{R_{f,ini}}^{t+1} - f_U^{t+1} \right)} & \text{if} \quad \theta^t < \theta_{min}^{t+1} \\ 0 & \text{if} \quad \theta^t \geq \theta_{min}^{t+1} \end{cases}$$



Agricultural Demand Computation in IDC *(continued)*

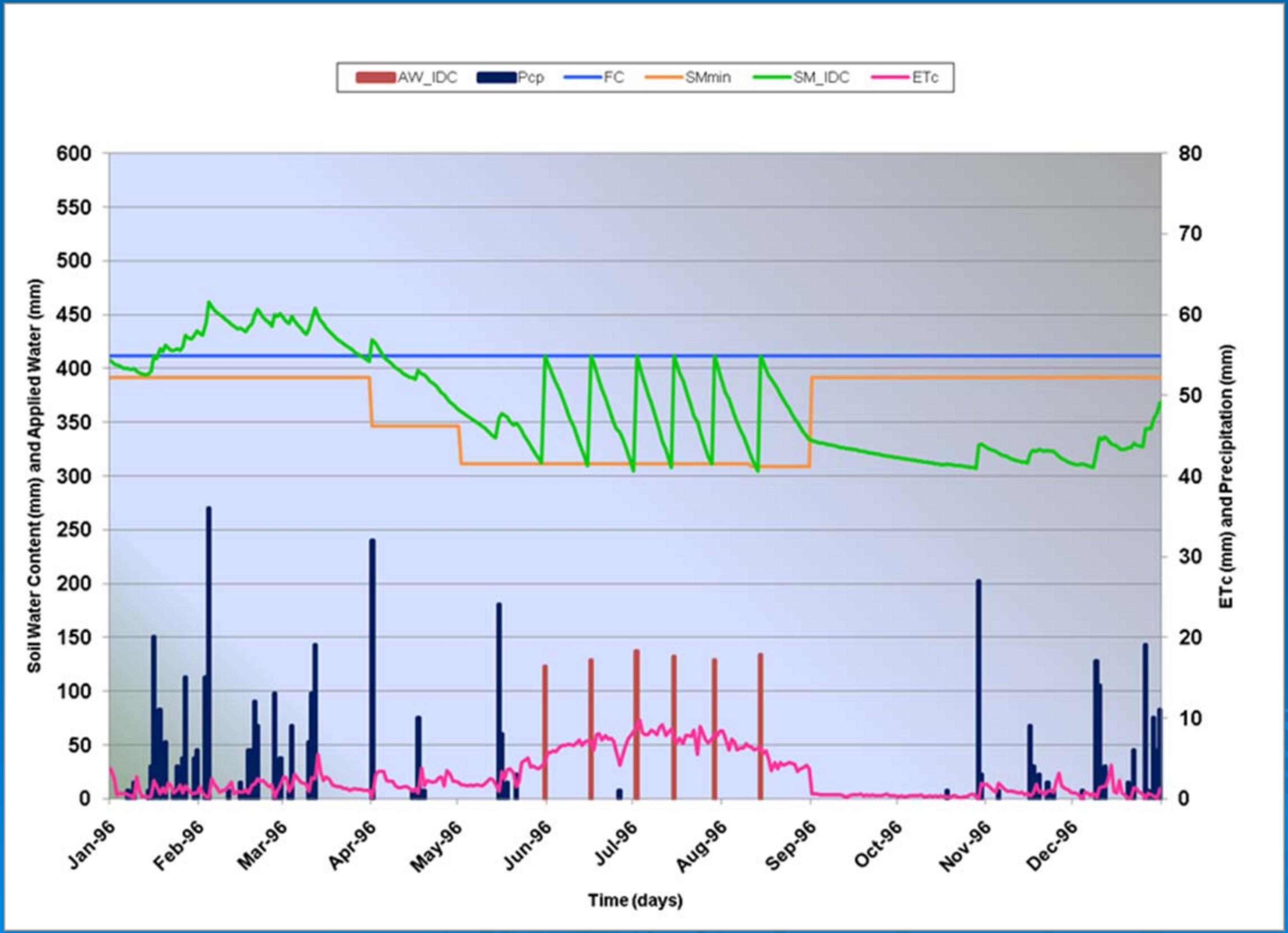
- Ponded crops:

  During an irrigation or flooded decomposition period, IDC computes A_w to maintain the pond depth at user-specified values:

$$A_w^{t+1} = \frac{\theta_T + P_D^{t+1} - \theta^t - \Delta\theta_a^{t+1}}{\Delta t} - P^{t+1} + R_p^{t+1} + K_s + ET_{pot}^{t+1} + R_f^{t+1} - D_r^{t+1} > 0$$

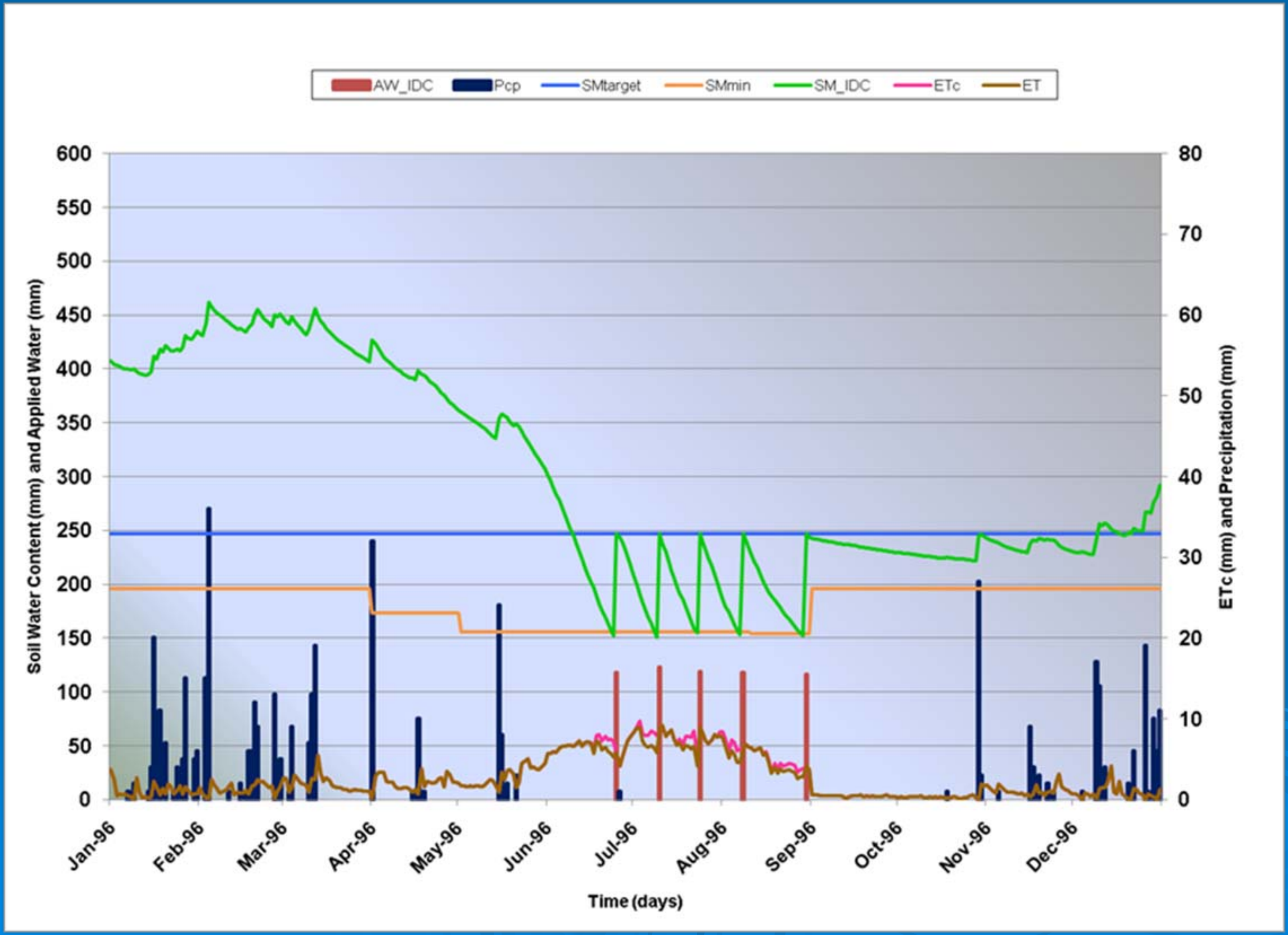
Example 1 – Tomatoes

Normal Irrigation Scheme (A_w = 783 mm , ET = 764 mm)



Example 1 – Tomatoes

Regulated Deficit Irrigation (A_w = 594 mm , ET = 718 mm)

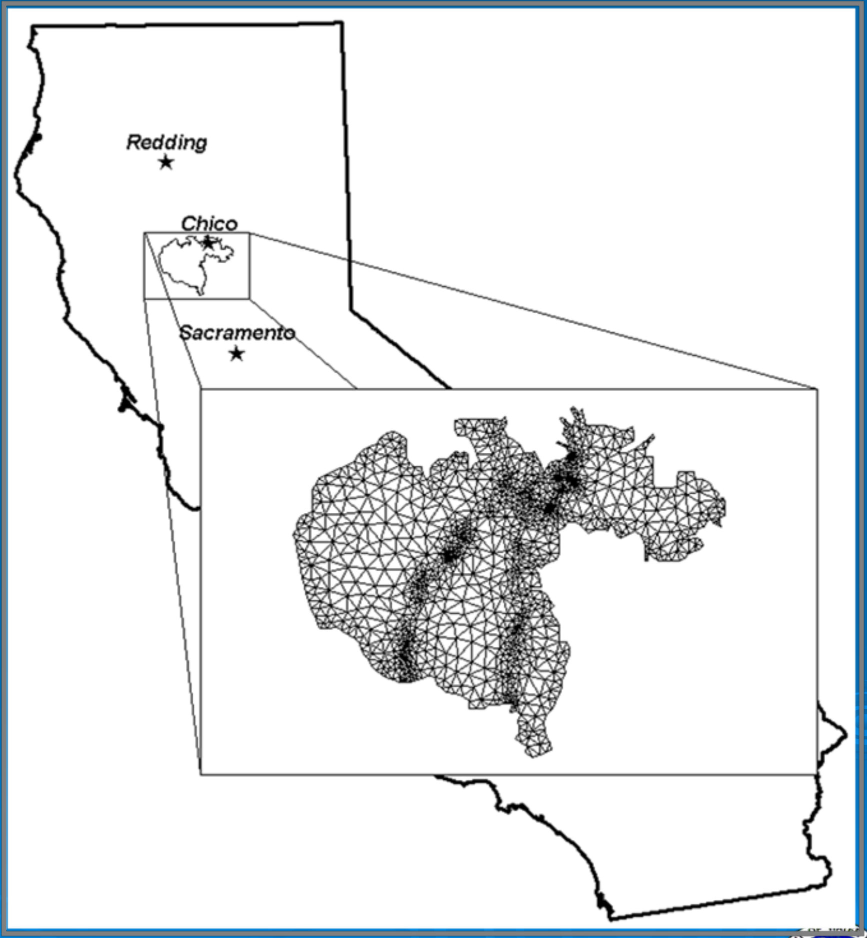


Example 2 – A Real-World Application

- Four WBAs (7N, 8N, 9 and 10) from CalSim 3.0 are modeled
- Simulation period: WY 1991 through WY 2001
- 20 non-ponded crops (including fallow and idle lands), rice, refuges, urban lands and native vegetation
- Simulation results for WY 1998 through WY 2001 are compared to available values from DPLA (effort concentrated on non-ponded crops and rice separately)
- Most of the input data was adopted from CalSim 3.0 hydrology development project

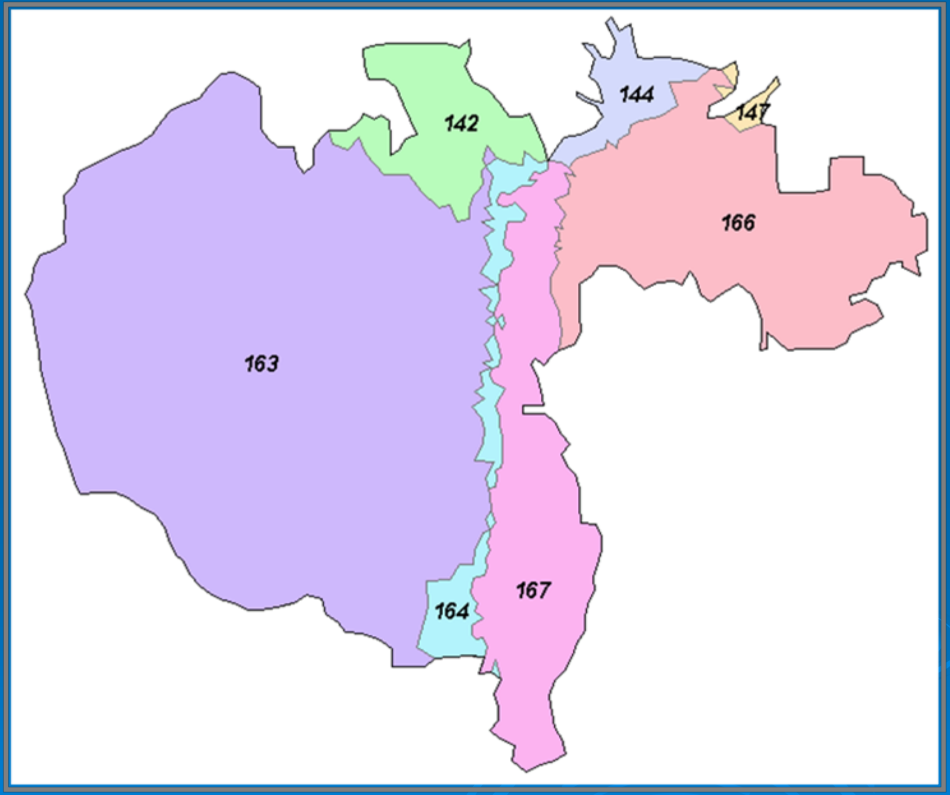
Example 2 – Computational Grid

- 2622 grid cells
- Model area is 1083 mi^2
- Average cell area is 0.4 mi^2



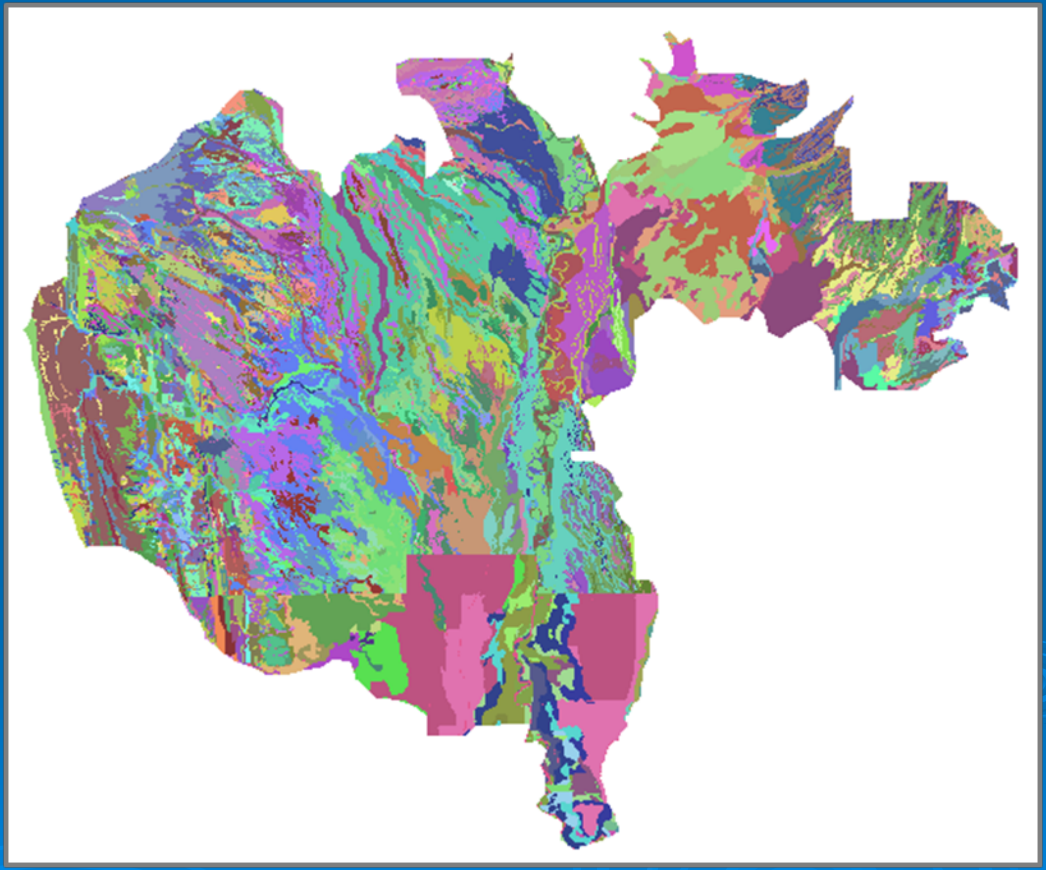
Example 2 – Subregions

- DAU boundaries are used as subregion boundaries



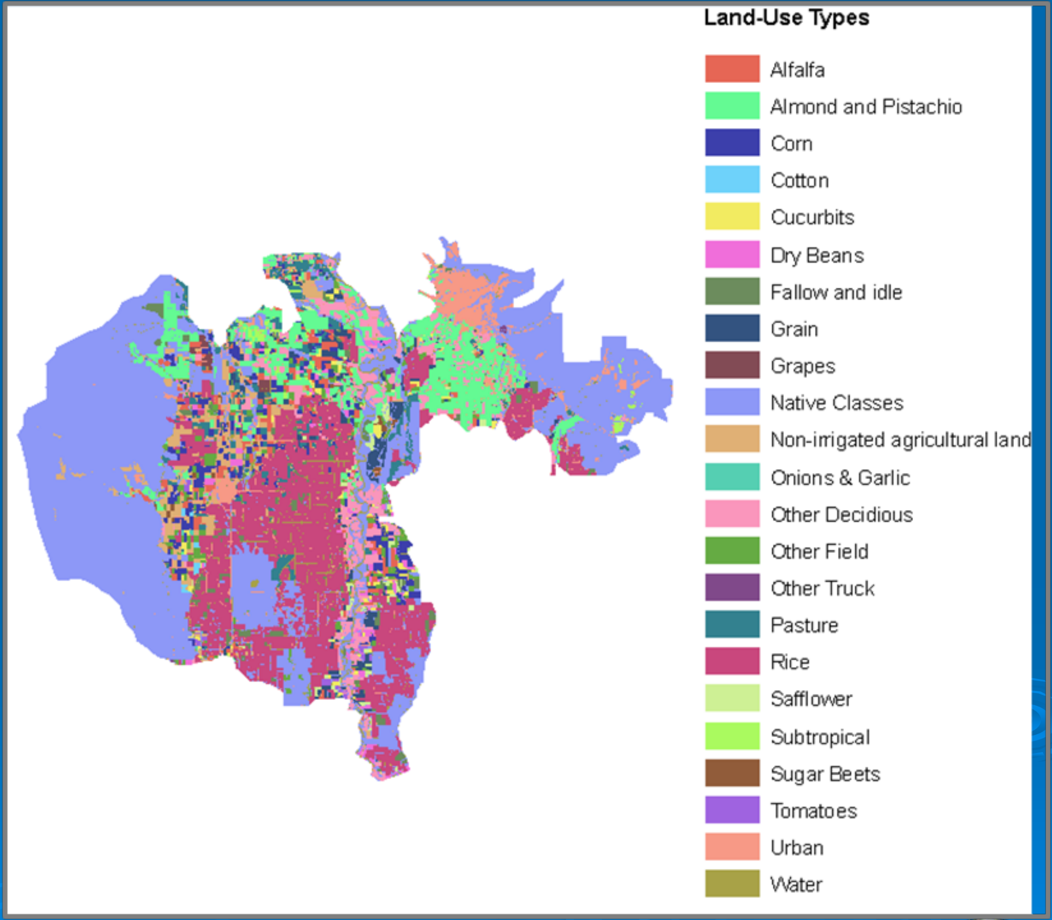
Example 2 – Soils

- NRCS SSURGO soils database is used to calculate soil physical properties for each grid cell



Example 2 – Land-Use Types

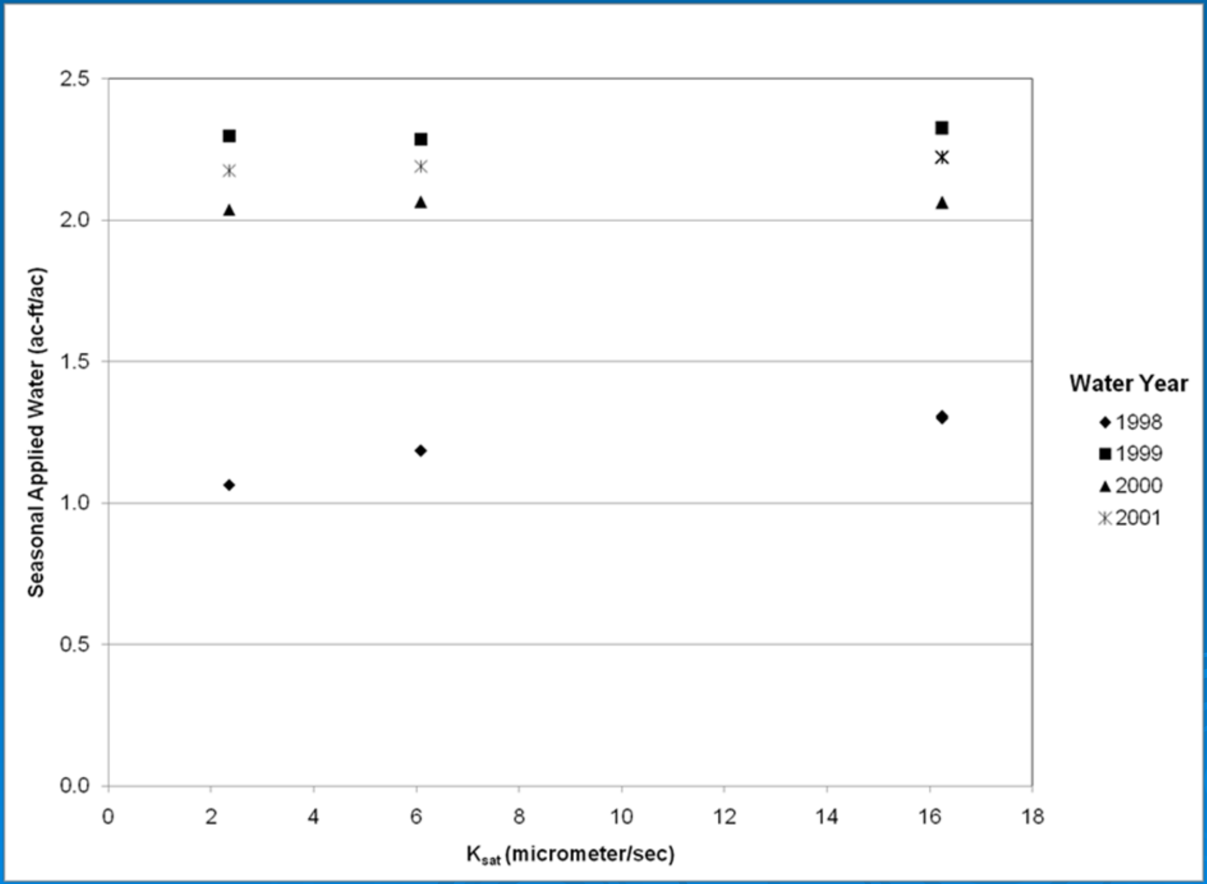
- DPLA land-use map for year 2003 was used
- Water (2% of total model area) and non-irrigated agricultural lands (4% of the total model area) were combined into native vegetation lands



Example 2 – Sensitivity to K_{sat}

Non-ponded Crops at DAU142

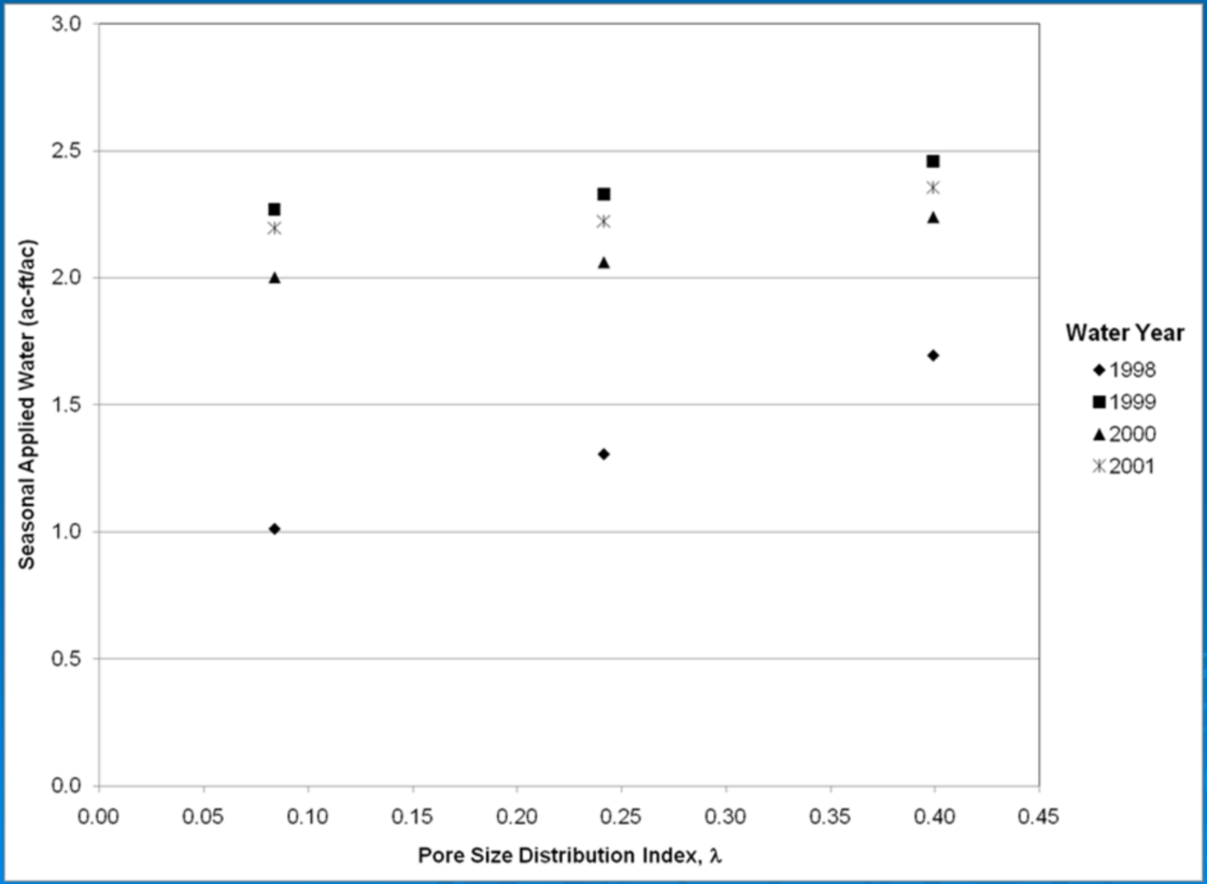
- A_w for non-ponded crops is not very sensitive to K_{sat}



Example 2 – Sensitivity to λ

Non-Ponded Crops at DAU142

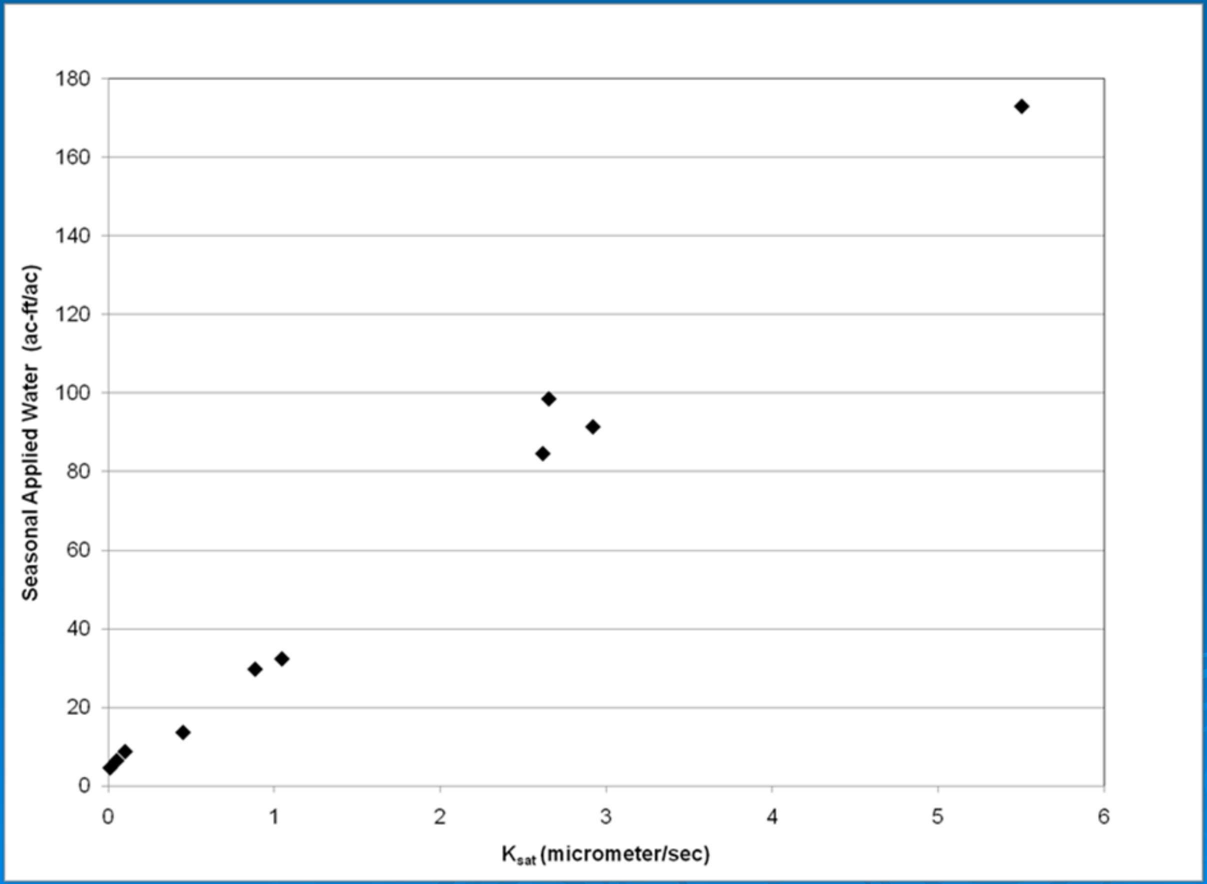
- A_w for non-ponded crops is more sensitive to λ



Example 2 – Sensitivity to K_{sat}

Rice fields at DAU163 for WY 2000

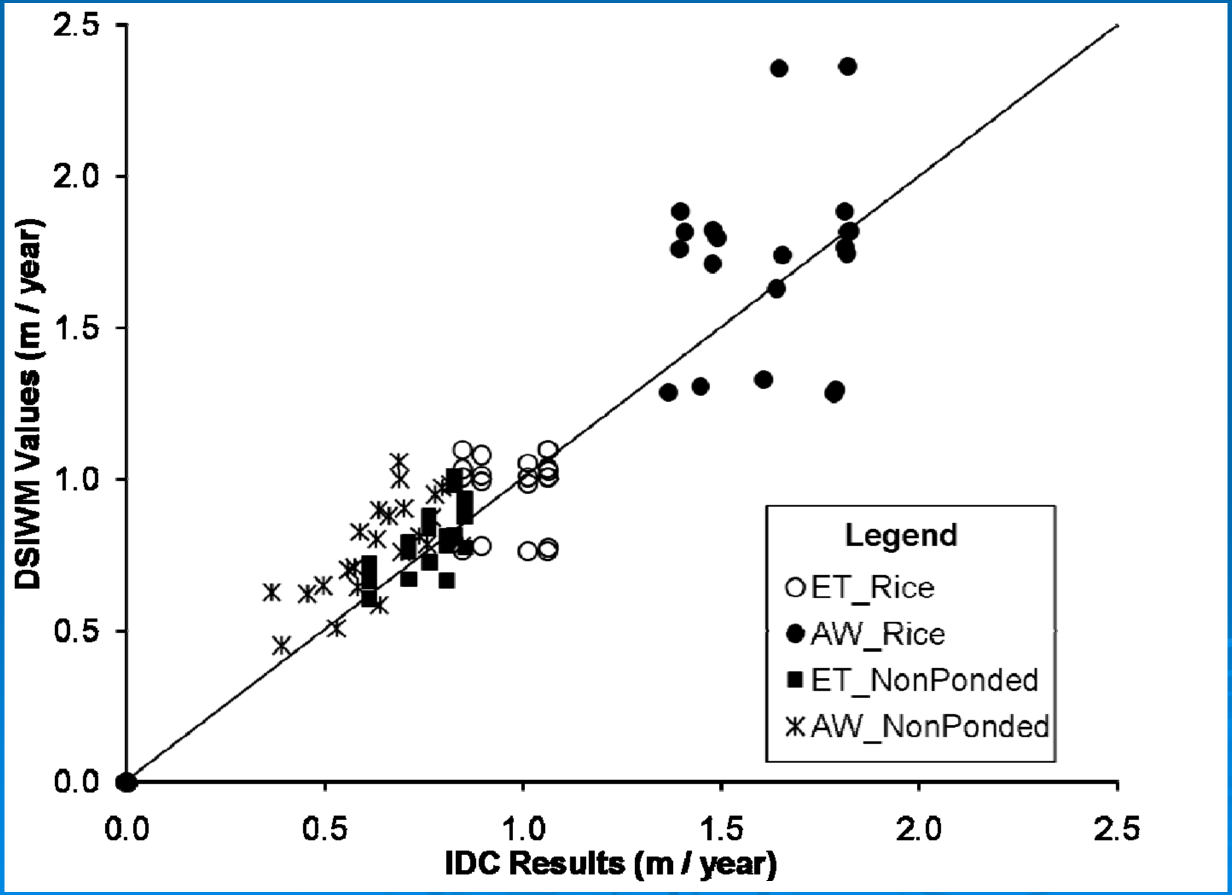
- A_w for rice is very sensitive to K_{sat}



Example 2 – Comparison to DSIWM Values

(with K_{sat} = 0.01 μm/sec at cells with rice)

- With minimal effort and no calibration, IDC values are reasonably close to DSIWM values



Example 2 - Conclusions

- A_w for rice is very sensitive to K_{sat} and has zero sensitivity to λ
- A_w for non-ponded crops is not very sensitive to K_{sat} but sensitive to λ
- For proper simulation of A_w and deep percolation, calibrate K_{sat} for rice and λ for non-ponded crops
- Compared to DSIWM values, IDC seems to generate reasonable results given that precipitation, crop acreages and input ET values are different between IDC and DSIWM

Final Remarks

- IDC v4.0 executables, source code and documentation are available for download at the DWR's IWFM web site
- IDC v4.0 is being integrated into IWFM which will be released as IWFM v4.0 in 2010

Questions?