CWEMF
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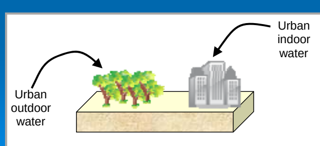
Session 5:
Simulation of Agricultural and Urban Water Demands

Urban Water Demand

- Urban Water Demand = Population x Per Capita Water Usage
- Computed for each cell
- Divided between indoor demand (residential indoor and industrial) and outdoor demand (irrigation of parks, residential yards, etc.) based on user-specified fractions



Preparing Input Files: Urban Water Demand Parameters

- A city can be divided into multiple grid cells
- Water demand parameters (population, per capita water use and indoor water use fraction) are intended to be specified for each city, not for each cell (assuming availability of data, they can be specified for each cell as well)
- Distribution of city-wide water demand to individual cells is controlled by user-specified fractions

Non-Ponded Crop Water Demand

- Can be computed dynamically or specified by the user as time-series data
- Computed using an irrigation-scheduling-type approach
- Computed only during irrigation period specified by the user as time-series irrigation period flags (0 or 1) for each crop
- Computation can be based on the soil moisture at the beginning or at the end of a time step
  - Suggestion:
    - use soil moisture at the beginning of the time step when time step length is short (e.g. 1 day)
    - use moisture at the end of the time step when time step length is long (e.g. 1 month)
- Optionally, a minimum deep percolation requirement (subject to maximum permeability of the soil) can be specified as part of water demand

Non-Ponded Crop Water Demand: Using Moisture at the Beginning of Time Step

- If irrigation period, and if moisture content is less than the minimum soil moisture, θ_{min}, compute irrigation amount to raise the moisture to irrigation target moisture (generally field capacity) , θ_{trg}, and that will cover losses due to ET, deep percolation and return flow

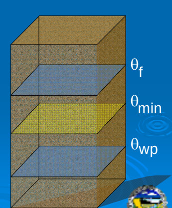
where θ_{min} = $\theta_{wp} + f_{\theta min} TAW$

TAW = $\theta_f - \theta_{wp}$ (Total Available Water)

θ_{wp} = wilting point

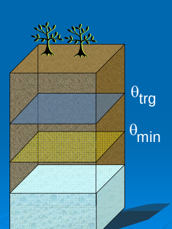
θ_f = field capacity

$f_{\theta min}$ = user-specified fraction



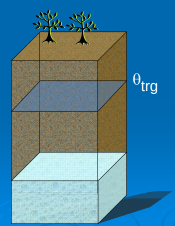
Non-Ponded Crop Water Demand: Using Moisture at the Beginning of Time Step

At the beginning of time step …



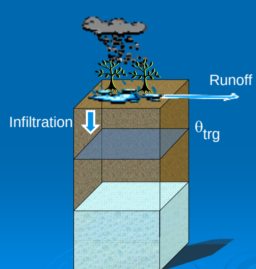
Non-Ponded Crop Water Demand: Using Moisture at the Beginning of Time Step

At the beginning of time step …



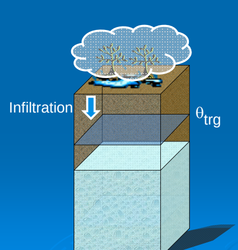
Non-Ponded Crop Water Demand: Using Moisture at the Beginning of Time Step

Consider infiltration of precipitation …



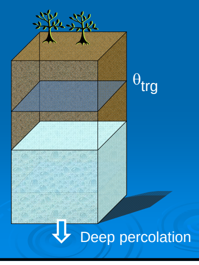
Non-Ponded Crop Water Demand: Using Moisture at the Beginning of Time Step

Consider generic sources of moisture …



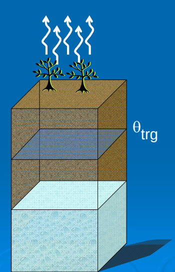
Non-Ponded Crop Water Demand: Using Moisture at the Beginning of Time Step

Consider deep percolation …



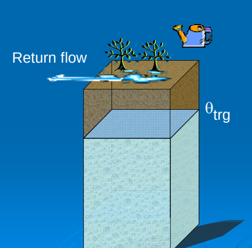
Non-Ponded Crop Water Demand: Using Moisture at the Beginning of Time Step

Consider evapotranspiration…



Non-Ponded Crop Water Demand: Using Moisture at the Beginning of Time Step

Consider net return flow and compute demand!



Non-Ponded Crop Water Demand: Using Moisture at the Beginning of Time Step

- Conservation equation is solved for A_W to compute water demand:

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

- D_{trg} and ET_{trg} are the deep percolation and ET at irrigation target soil moisture, θ_{trg}, respectively
- θ_{trg} can be less then field capacity (e.g. deficit irrigation) or greater than field capacity (e.g. leaching practices)

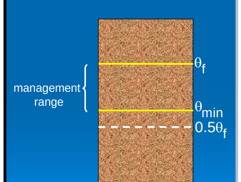
Non-Ponded Crop Water Demand: Using Moisture at the End of Time Step

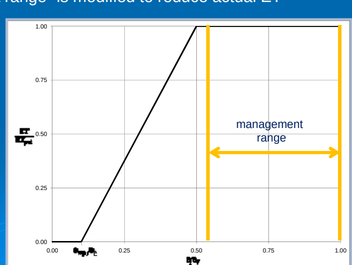
- First, assume zero irrigation and compute soil moisture at the end of time step
- If moisture at the end of time step is less than target soil moisture, θ_{trg}, solve conservation equation for applied water

$$A_W = \frac{\dfrac{(\theta_{trg} Z)^{t+1} - (\theta Z)^t - \Delta\theta_a}{\Delta t} - P + R_p - GZ + D_{trg} + ET_{trg}}{1 - \left(f_{R_{f,ini}} - f_U\right)}$$

Non-Ponded Crop Water Demand: Representation of Regulated Deficit Irrigation

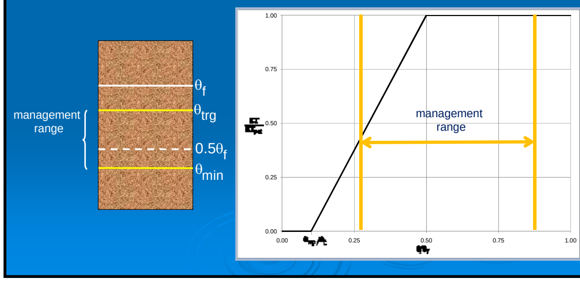
- Available only for non-ponded crops
- "Moisture management range" is modified to reduce actual ET





Non-Ponded Crop Water Demand: Representation of Regulated Deficit Irrigation

- Lower minimum soil moisture below half of field capacity and lower irrigation target moisture



Ponded Crops

- Ponded crops are rice and refuges (not a crop but managed very similar to rice ponds)
- 5 types of ponded crops can be simulated:
  - Rice with flooded decomposition
  - Rice with non-flooded decomposition
  - Rice with no decomposition
  - Seasonal refuges
  - Permanent refuges

Management of Ponded Crops

- Management of all three rice types during irrigation period is the same
- Rice fields with flooded decomposition have established ponds during the decomposition period
- Rice fields with non-flooded decomposition get a certain amount of water during the decomposition period but there are no ponds
- Rice fields with no decomposition get no water after the irrigation period; e.g. burning of rice fields before mid-1990s in California
- “Seasonal” and “permanent” refuges in IDC are different only in notation to help users for identification; they require the same type of data for simulation
- Multi-purpose use of seasonal refuge lands can be simulated by specifying land-use acreages with time intervals less than a year

Ponded Crop Water Demand

- Can be computed dynamically or specified by the user as time-series data
- Computed using an irrigation-scheduling-type approach
- Computed only during irrigation period specified by the user as time-series irrigation period flags
- Computed to achieve a user-specified pond depth while covering losses due to ET, deep percolation and return flow

Ponded Crop Water Demand

- If irrigation period, and if pond depth is less than the user-specified ponding depth, compute irrigation amount to raise the pond depth to the specified level while covering losses due to ET, deep percolation and return flow
- Conservation equation is solved for AW to compute water demand:

$$A_W = \frac{\theta_T Z + P_D - \theta^t Z - \Delta\theta_a}{\Delta t} - P + R_p - GZ + K_S + ET_{pot} + D_r + R_{f,ini} - U$$

where P_D = ponding depth, [L];
D_r = pond drainage if pond depth is decreasing, [L/T];
U = reuse, [L/T].

- During ponding
  - Deep percolation, D, equals saturated hydraulic conductivity, K_s
  - ET equals user-specified potential ET, ET_{pot}
  - Soil moisture at the end of time step, θ^{t+1}, equals total porosity, θ_T

Tracking the Source of Moisture

- Fraction for applied water

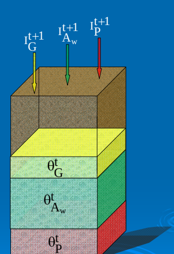
$$\alpha_{A_W} = \frac{\theta^t_{A_W} + I^{t+1}_{A_W}}{\theta^t_P + \theta^t_{A_W} + \theta^t_G + I^{t+1}_P + I^{t+1}_{A_W} + I^{t+1}_G}$$

- Fraction for precipitation

$$\alpha_P = \frac{\theta^t_P + I^{t+1}_P}{\theta^t_P + \theta^t_{A_W} + \theta^t_G + I^{t+1}_P + I^{t+1}_{A_W} + I^{t+1}_G}$$

- Fraction for generic moisture

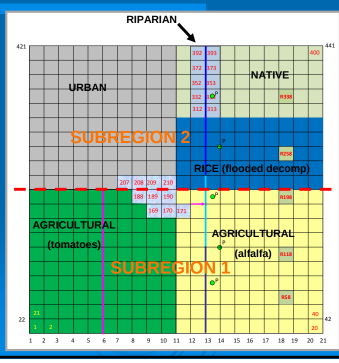
$$\alpha_G = \frac{\theta^t_G + I^{t+1}_G}{\theta^t_P + \theta^t_{A_W} + \theta^t_G + I^{t+1}_P + I^{t+1}_{A_W} + I^{t+1}_G}$$



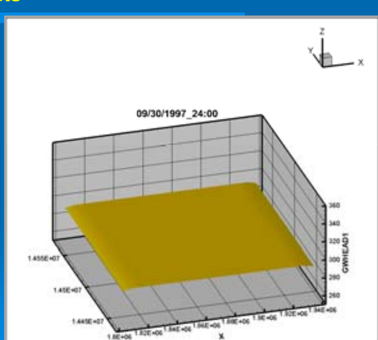
Tracking the Source of Moisture

- ET and deep percolation are partitioned using the source fraction; e.g. ET_{AW}, ET_P and ET_G
- All 3 "colors" of moisture are tracked using the partitioned flow terms (infiltration, ET and deep percolation)
- Partitioning of the initial soil moisture is based on user specified fraction for precipitation
- Initially, moisture due to generic source is assumed to be zero
- For native and riparian vegetation, all of the initial soil moisture is assumed to be from precipitation
- Since sources of moisture are tracked, irrigation / precipitation in a given time step may affect ET_{AW} / ET_P in future time steps

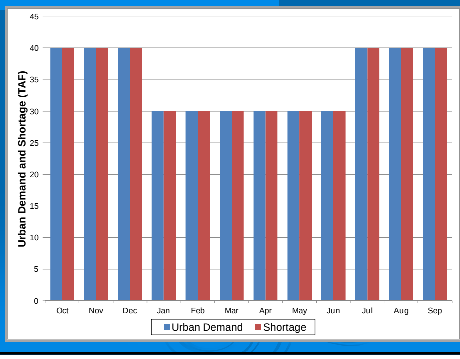
Example 5



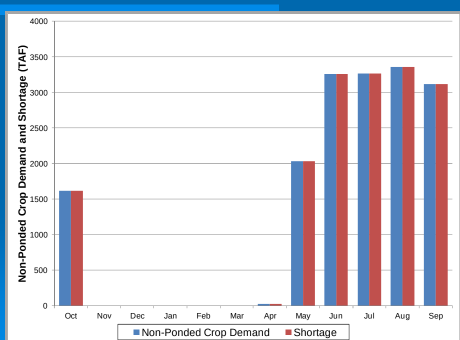
Example 5: Results



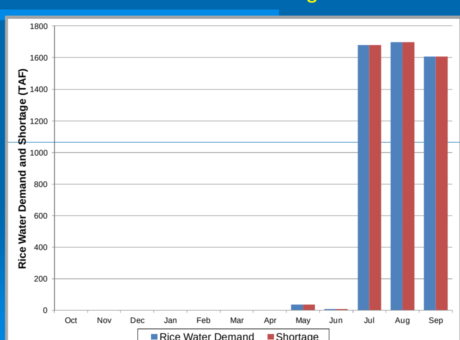
Example 5:
Urban Water Demand and Shortage



Example 5:
Non-Ponded Crop Water Demand and Shortage

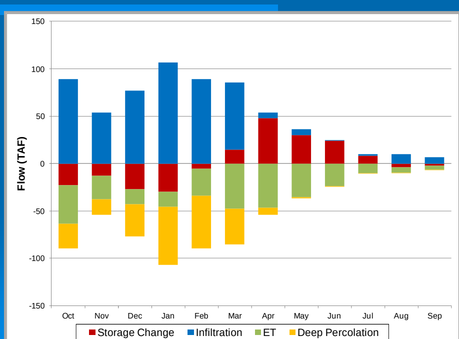


Example 5:
Rice Water Demand and Shortage

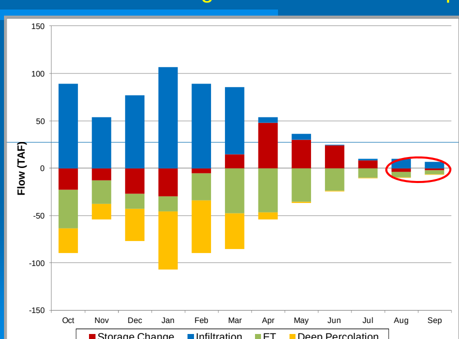


Example 5:
Agricultural Evapotranspiration

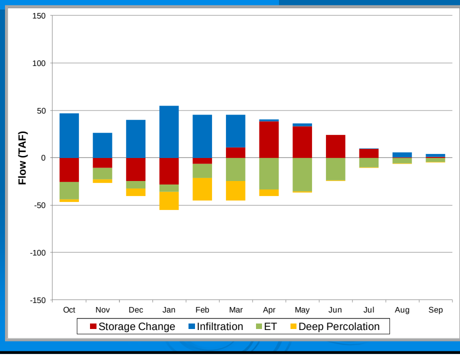
Example 5:
Root Zone Water Budget for Non-Ponded Crops



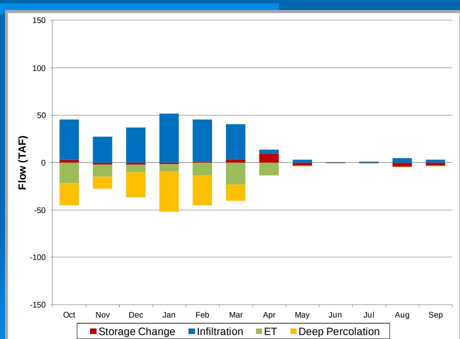
Example 5:
Root Zone Water Budget for Non-Ponded Crops



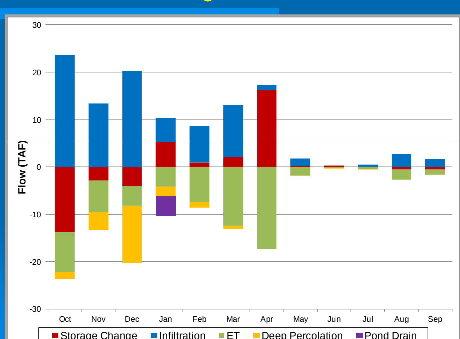
Example 5:
Root Zone Water Budget for Alfalfa



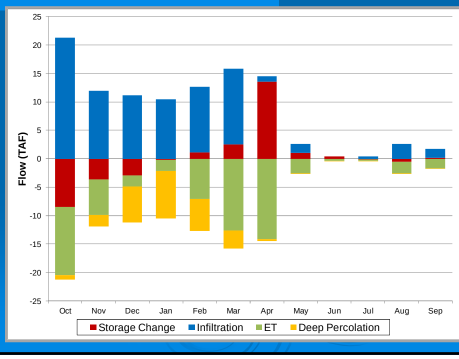
Example 5:
Root Zone Water Budget for Tomatoes



Example 5:
Root Zone Water Budget for Rice



Example 5:
Root Zone Water Budget for Urban Area



Example 5:
Fate of Precipitation on Non-Urban Areas