Use of the Hydro-Salinity, Crop Production Optimization Model APSIDE to Validate Results from an Updated Regional Flow Model of the San Joaquin River Basin

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Unresolved modeling issues

- Original data behind legacy simulation models used for basin planning are rarely questioned or reviewed
- Past research upon which many parameters are based are difficult to repeat – leaving legacy data and analysis unchanged
    - crop ET data, irrigation diversions (magnitude and scheduling)
- Political implications – collusion between water agencies and stakeholders – "use it or lose it" doctrine, use set to "water right"
- Problem gets worse over time as new basin planning models are developed – re-calibration of these tools is time consuming and expensive (despite past issues with calibration – especially sub-regional scale models)

LESSON 1

- Minor methodological algorithmic differences can have significant impacts on model simulation results even when models use the same input data.
- The sequence in which certain hydrologic parameters are accounted for in the model can also impact model simulation results.
- These impacts become more pronounced during unusual water year types – floods, extended droughts which impose more stress on the hydrologic system
- Models are rarely compared “head-to-head”, often because of scaling differences, model area aggregation/disaggregation issues and differences in data and data reduction methodologies.

STUDY OBJECTIVES

- Compare underlying conceptual models for two major Basin-scale groundwater/surface water simulation models in California – CVHM2 (MODFLOW-FMP) and C2VSIM (IWFM)
- Run simulations of the two models comparing pumpage estimates (equated to residual water requirements)
- Assess relative model accuracy and reliability

How do you estimate pumpage, recharge, and changes in storage with few or no data?

Groundwater & Agriculture

Irrigation from groundwater resources often dominates the water budget …

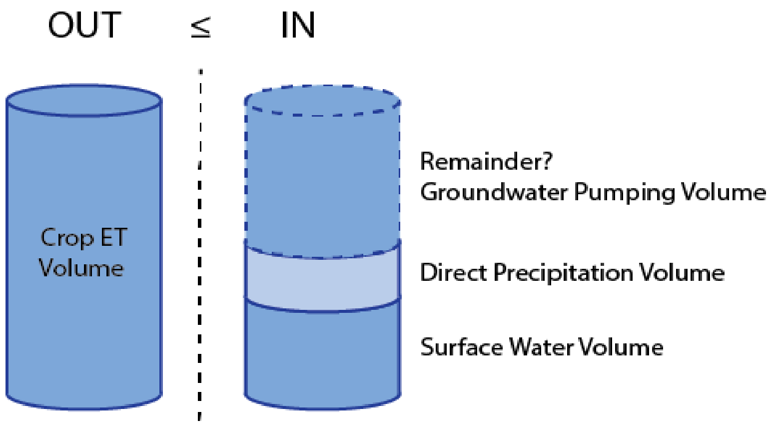
… but pumpage is often unmeasured

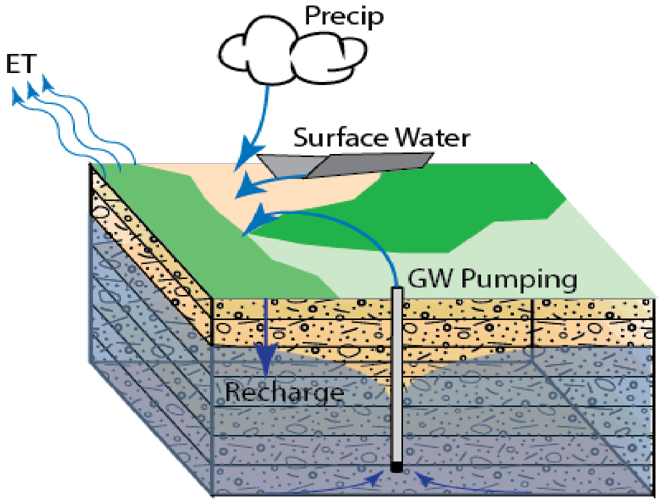
Method:

- groundwater pumpage as land-surface water budget "closure term"

Data requirements:

- crops
- weather/climate
- surface water diversions
- irrigation efficiency





Credit: Maples, 2017, UC Davis

How to estimate pumpage and recharge with few or no data?

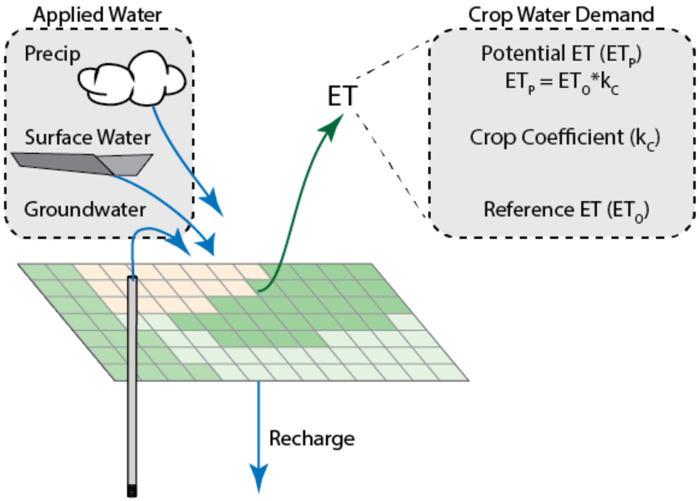
Answer: Pumpage is the “closure term” for the land-surface water budget

uncoupled approaches

(e.g. Belitz & Phillips, 1992; Fogg et al., 2002)

Demand calculated *a priori*:

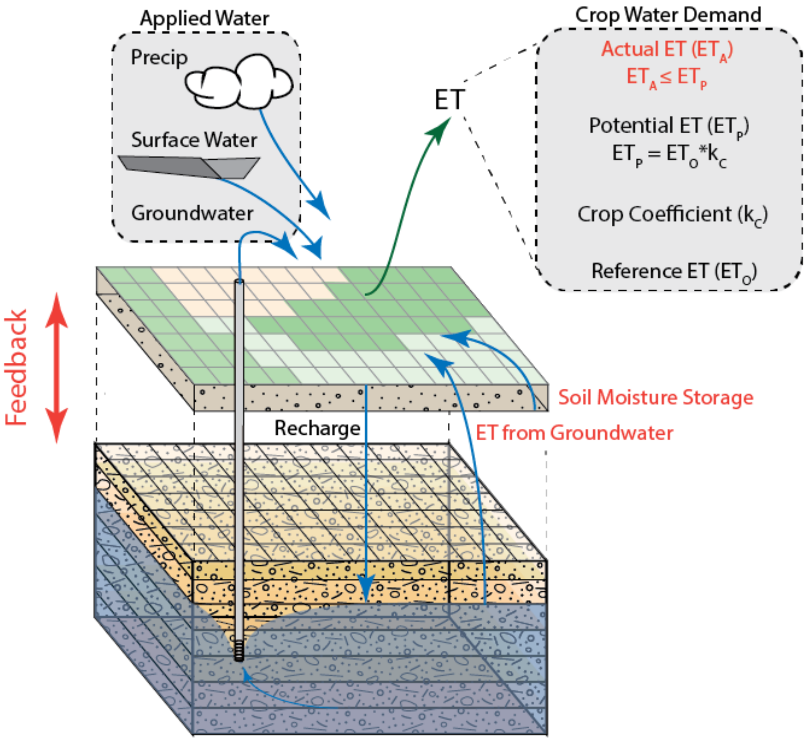
Applied Water = Crop Water Demand / Irrigation Efficiency
Crop Water Demand = $ET_P = ET_O * k_C$
GW Pumping = Applied Water - (Surface Water + Direct Precipitation)
Recharge = Applied Water - Crop Water Demand



coupled approaches

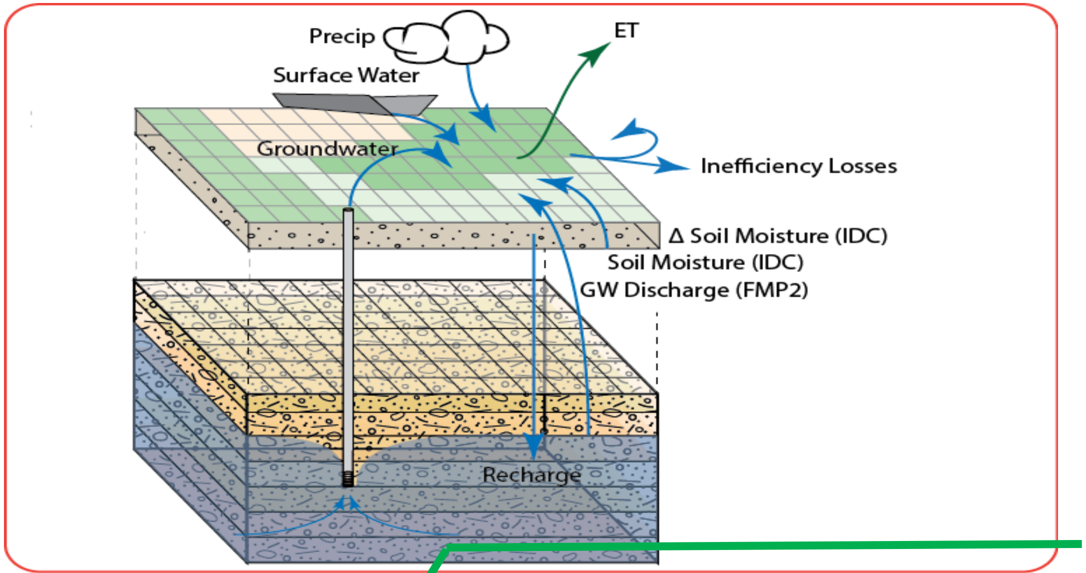
(e.g., MODFLOW-FMP2 and IWFM)

Demand calculated iteratively:



Credit: Maples, 2017, UC Davis

Coupled approaches - methodological differences



IDC	FMP2
IDC ET single ET_A term wilting reductions in ET_A soil moisture contribution	FMP2 ET 6 land-use dependent E_A & T_A terms wilting and anoxia reductions in ET_A groundwater contribution
IDC Inefficiency Losses calculated before ET	FMP2 Inefficiency Losses calculated after ET satisified
IDC Deep Percolation function of soil moisture storage	FMP2 Deep Percolation inefficiency losses minus surface runoff
IDC Allocation Prioritization (1) Precipitation (2) Surface Water (3) Soil Moisture (4) GW Pumping	FMP2 Allocation Prioritization (1) ET from GW (2) Precipitation (3) Surface Water (4) GW Pumping

FACTORS

1. evapotranspiration
2. soil moisture
3. routing
4. prioritization

IDC – Irrigation Demand Calculator
IWFM model pre-processor
California Dept. of Water Resources

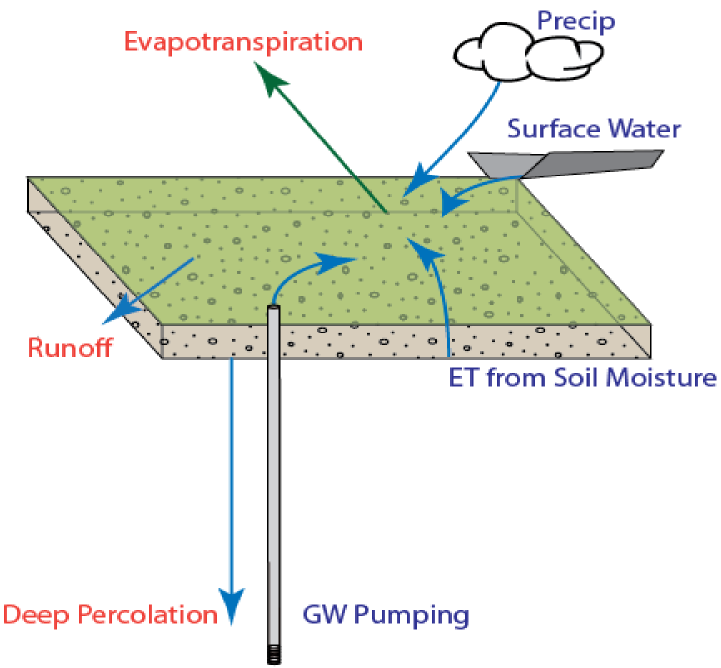
FMP – Farm Management Process
OWHM agricultural hydrology pre-processor
US Geological Survey

Credit: Maples, 2017, UC Davis

Model conceptual root zone control volume

IDC Methodology

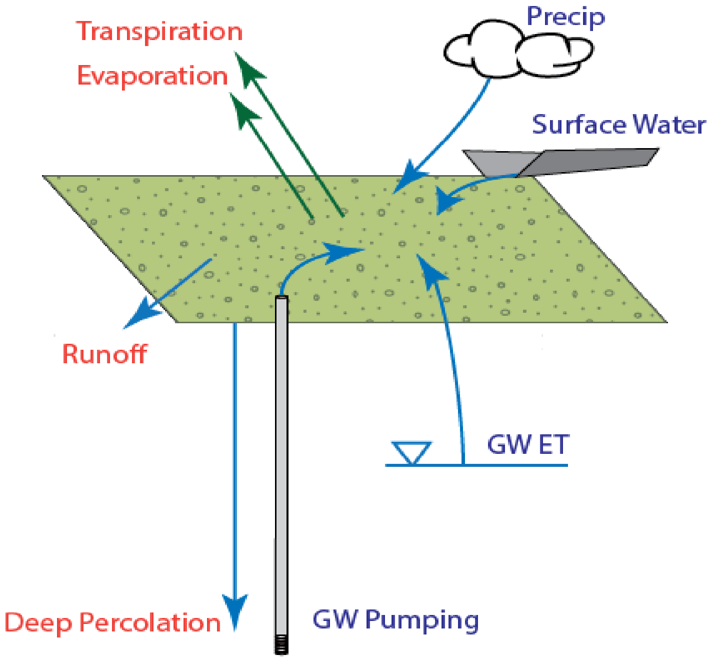
True root-zone “Control Volume”



FMP2 Methodology

Root-zone “Control Interface”

(no soil-zone storage)



IN OUT

Credit: Maples, 2017, UC Davis

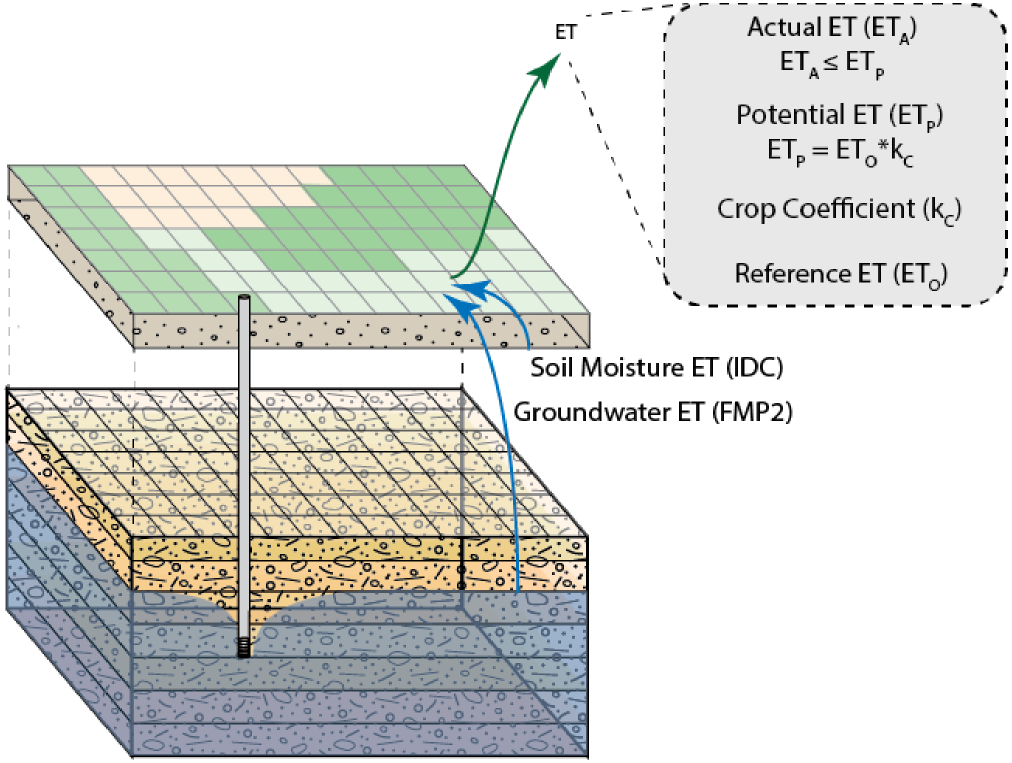
Evapotranspiration and soil moisture

IDC – Irrigation Demand Calculator

IDC ET
single ET_A term
wilting reductions in ET_A
soil moisture contribution

FMP2 – Farm Management Process

FMP2 ET
6 land-use dependent E_A & T_A terms
wilting and anoxia reductions in ET_A
groundwater contribution



Actual ET (ET_A)
$ET_A \leq ET_P$

Potential ET (ET_P)
$ET_P = ET_O{*}k_C$

Crop Coefficient (k_C)

Reference ET (ET_O)

Soil Moisture ET (IDC)
Groundwater ET (FMP2)

Coupled approach methodological differences

1. evapotranspiration
2. soil moisture
3. routing
4. prioritization

Credit: Maples, 2017, UC Davis

Soil moisture and water accounting (routing)

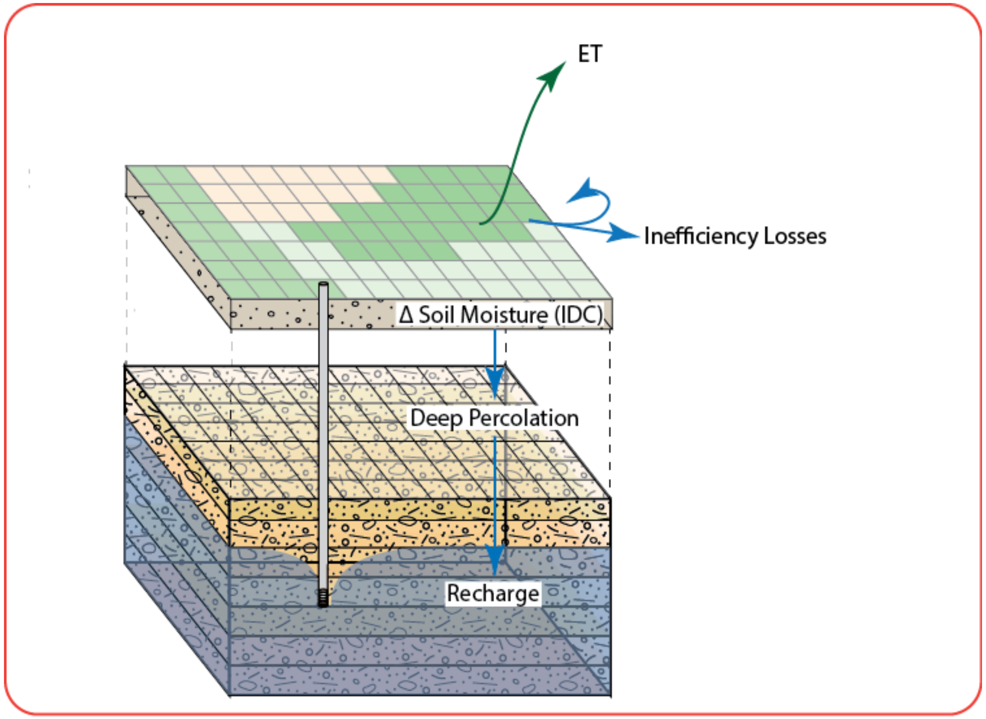
IDC – Irrigation Demand Calculator **FMP2 – Farm Management Process**

IDC
Inefficiency Losses
calculated before ET

FMP2
Inefficiency Losses
calculated after ET satisified

IDC
Deep Percolation
function of soil moisture storage

FMP2
Deep Percolation
inefficiency losses minus surface runoff



Coupled approach methodological differences

1. evapotranspiration
2. **soil moisture**
3. **routing**
4. prioritization

Credit: Maples, 2017, UC Davis

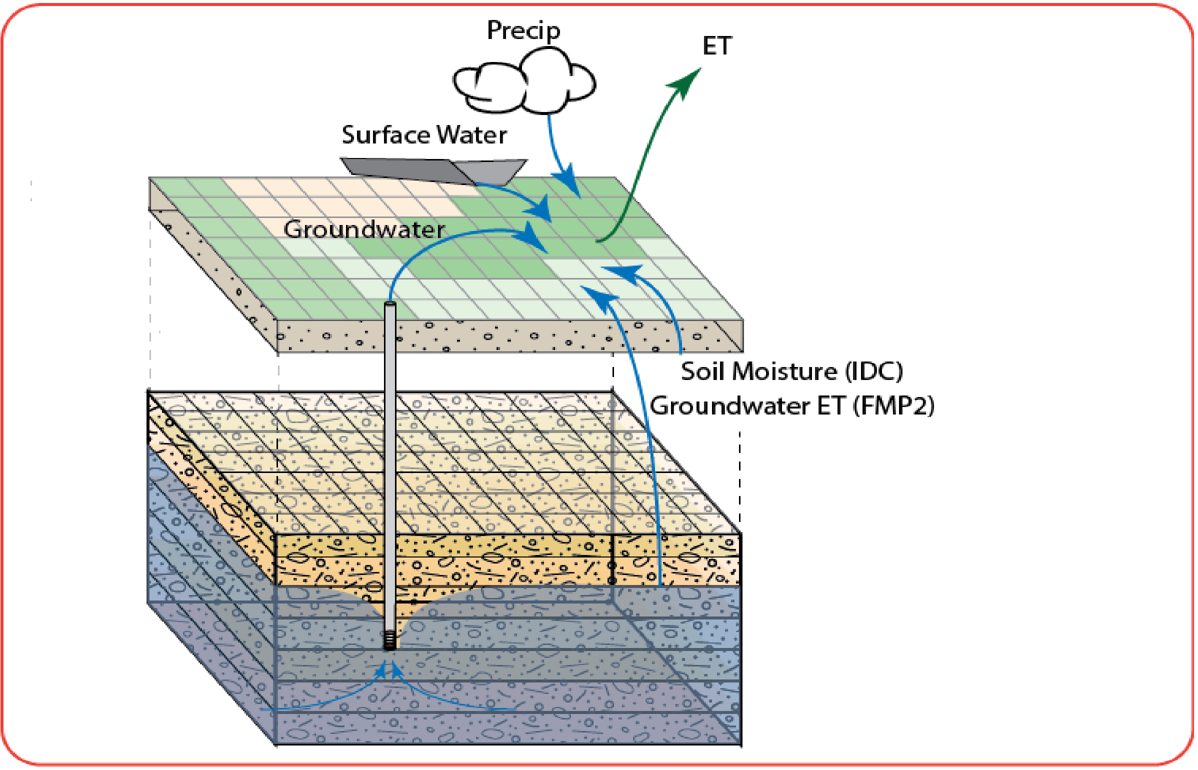
Hydrological process allocation prioritization

IDC – Irrigation Demand Calculator

IDC
Allocation Prioritization
(1) Precipitation
(2) Surface Water
(3) Soil Moisture
(4) GW Pumping

FMP2 – Farm Management Process

FMP2
Allocation Prioritization
(1) ET from GW
(2) Precipitation
(3) Surface Water
(4) GW Pumping

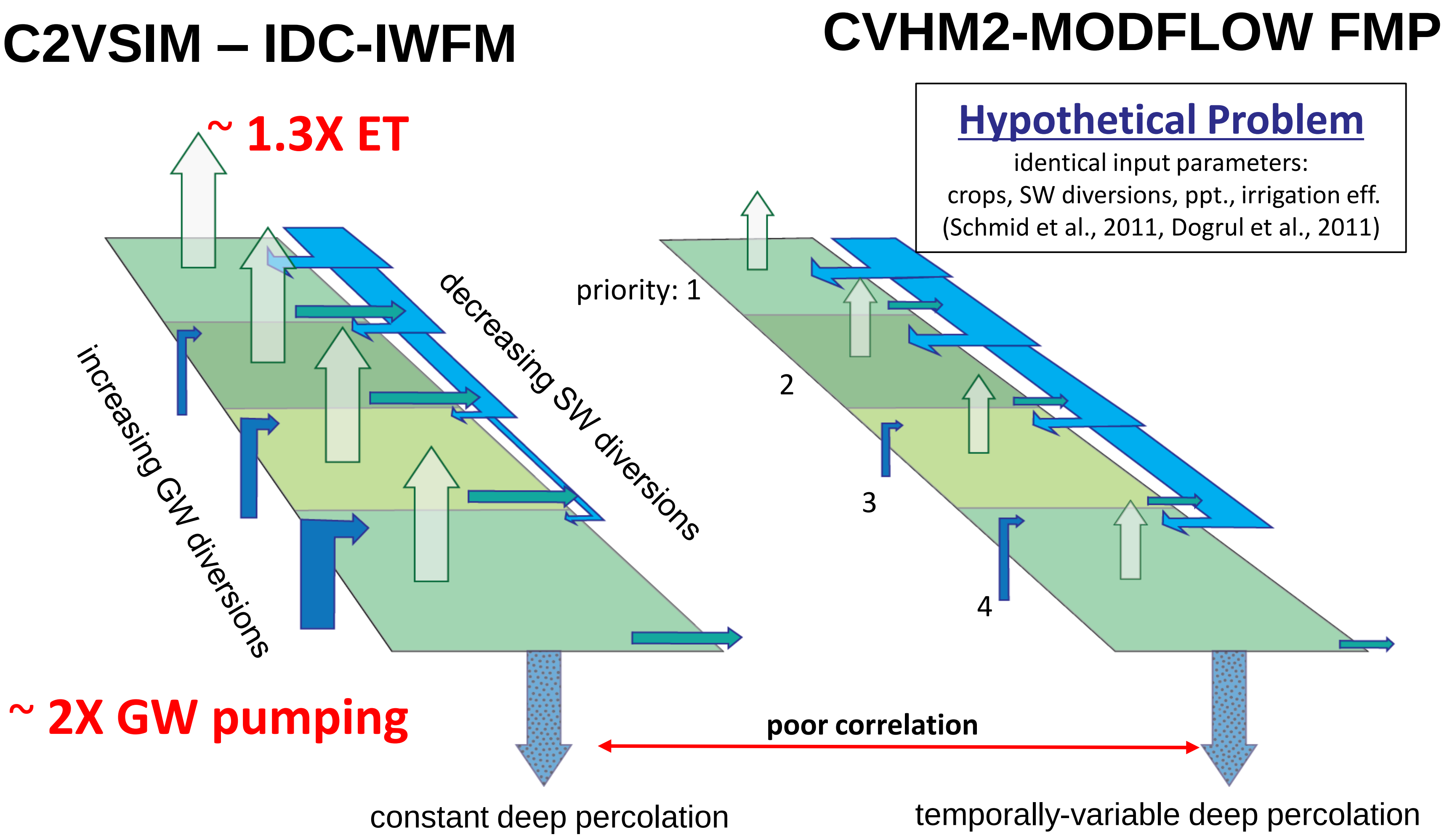


Coupled approaches methodological differences

1. evapotranspiration
2. soil moisture
3. routing
4. prioritization

Credit: Maples, 2017, UC Davis

Annual agricultural pumping quantities



Hypothetical Problem

identical input parameters:
crops, SW diversions, ppt., irrigation eff.
(Schmid et al., 2011, Dogrul et al., 2011)

Credit: Maples, 2017, UC Davis

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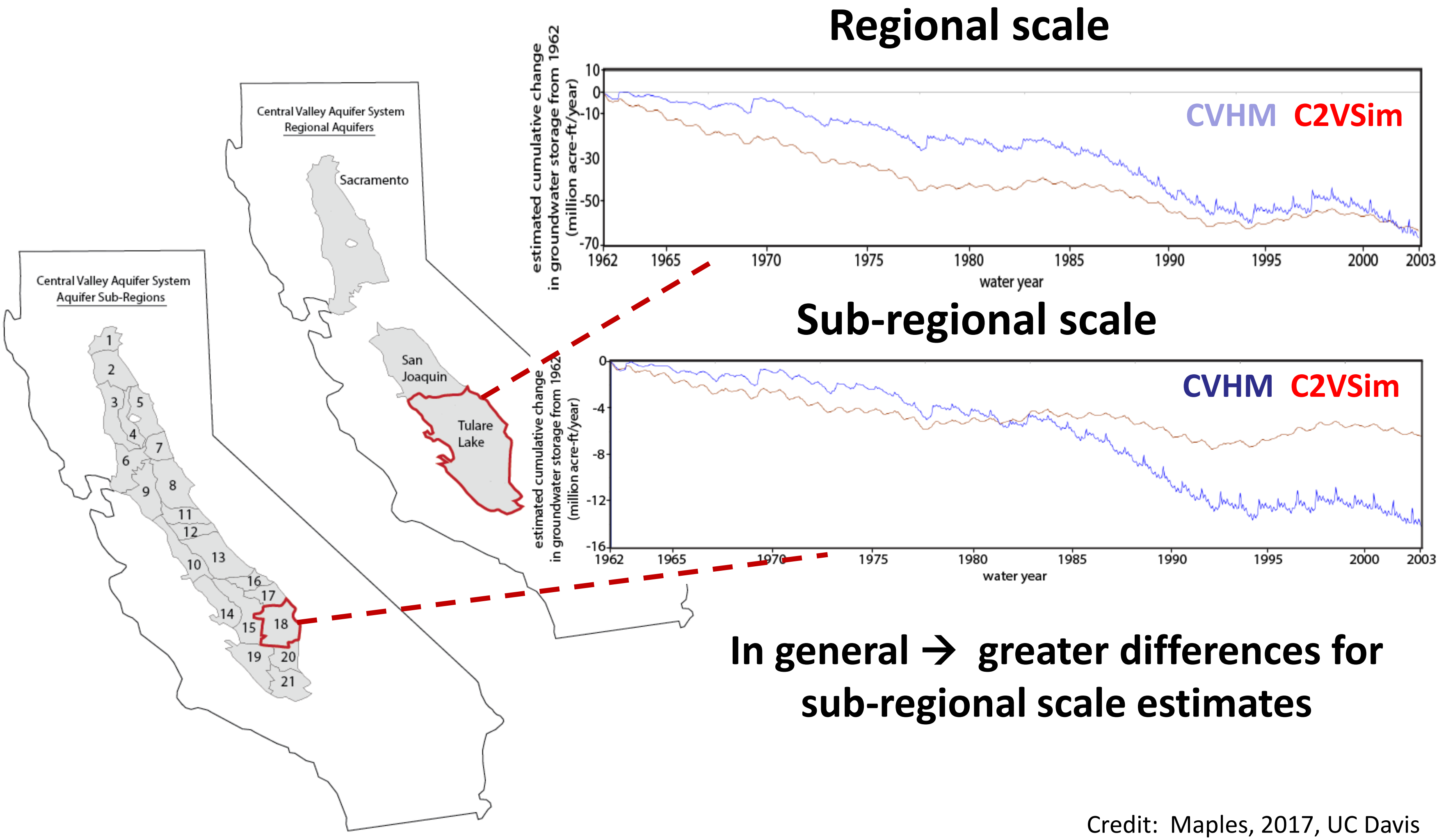
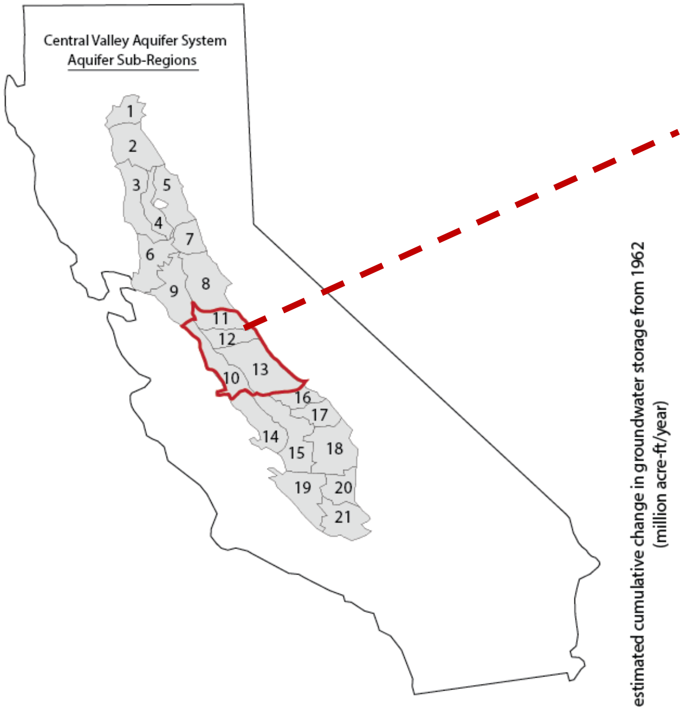
Cumulative Δ Groundwater Storage

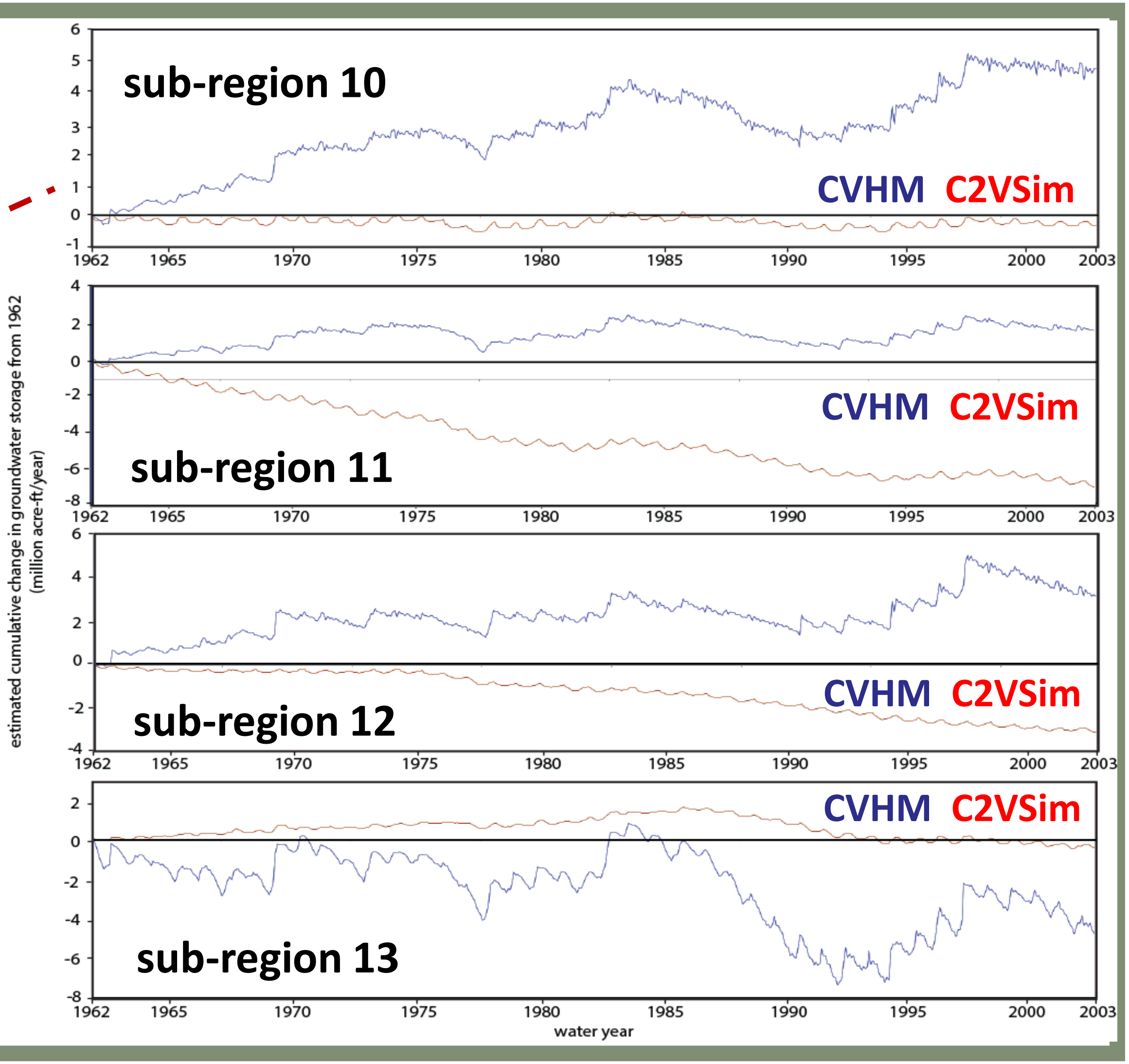


In general → greater differences for sub-regional scale estimates

Credit: Maples, 2017, UC Davis

Cumulative Δ Groundwater Storage





Sub-regional scale

Credit: Maples, 2017, UC Davis

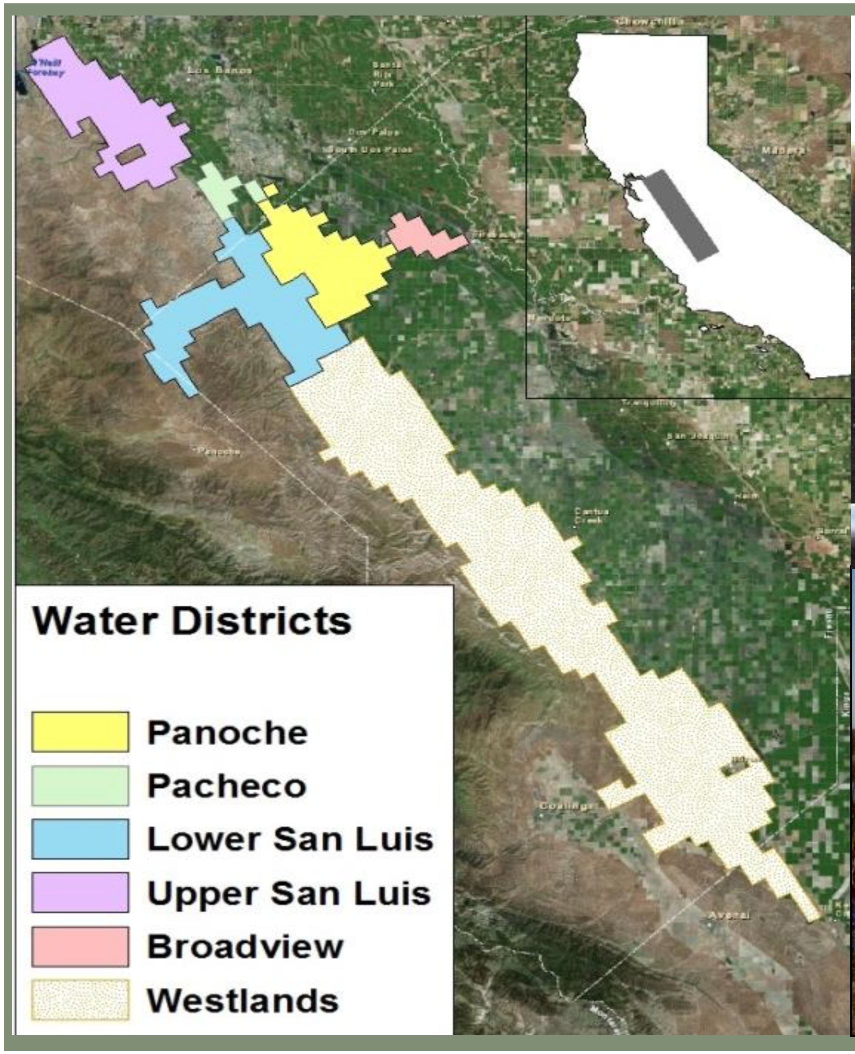
LESSON 2

- Modelers don’t question basic modeling assumptions that are disconnected from their mainstream expertise i.e irrigation efficiency, irrigation diversions – relying instead on past published data and agency data reports and bulletins
- Model sensitivity to these potentially important factors is rarely analyzed and updated in the model
- There are analytical techniques and complementary models that could be used to validate model input, parameter values and modeling results
- Modelers rarely have the time or scope in budgets to perform these analyses – perception that resources are better spent on model calibration

STUDY OBJECTIVES

- Investigate known anomalies in CVHM2 Basin groundwater model using the APSIDE model
- Develop APSIDE model for five highly relevant agricultural water districts where there is high quality available field data (Grassland Bypass Project monitoring for selenium management).
- Address model discrepancies (if real) through plan to collect CVHM model inputs using more direct approach if feasible

Four water districts selected for APSIDE model study



Salinity management options simulated by APSIDE

- Increase irrigation efficiency by re-using drain water to blend with good irrigation water
- Improve on-farm drainage management, recycle surface and subsurface drainage water
- Grow more salt-tolerant crops, allowing use of recycled water after plant germination
- Fallow or retire agricultural land
- Utilize the assimilative capacity of the San Joaquin River in a coordinated fashion to discharge limited amounts of salt load without exceeding salinity objectives
- APSIDE considers the salinity consequences and economic costs of salinity management options

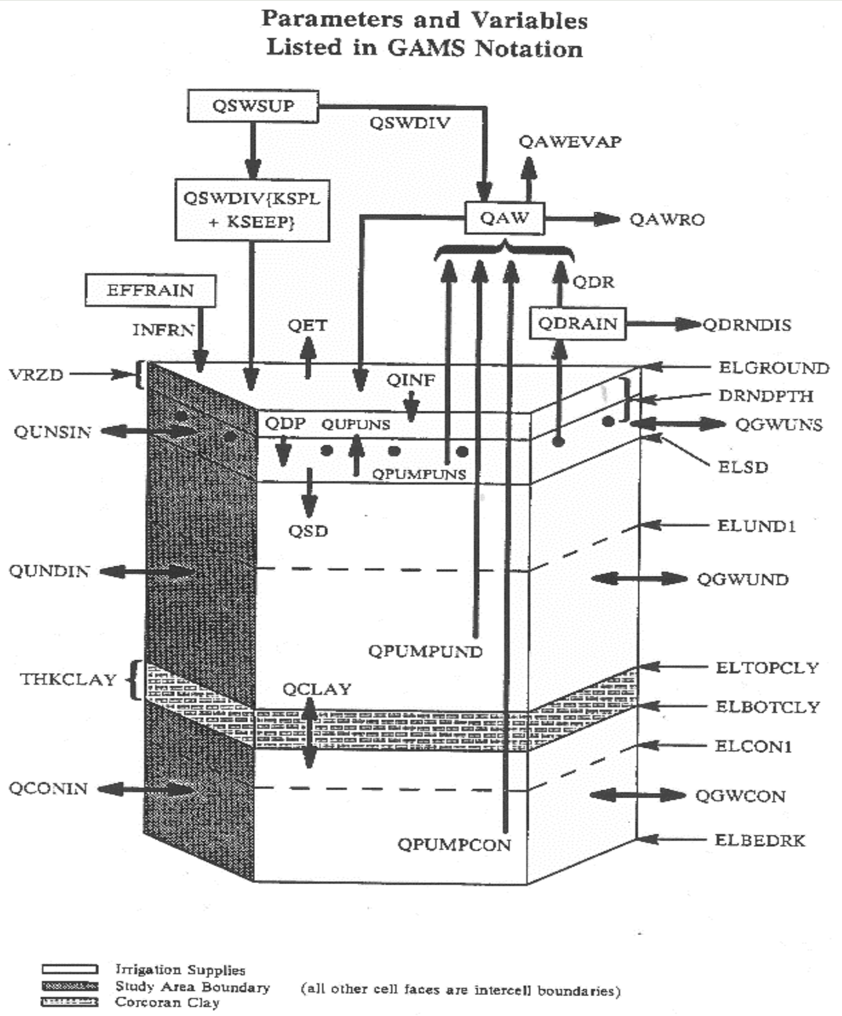
Positive mathematical programming

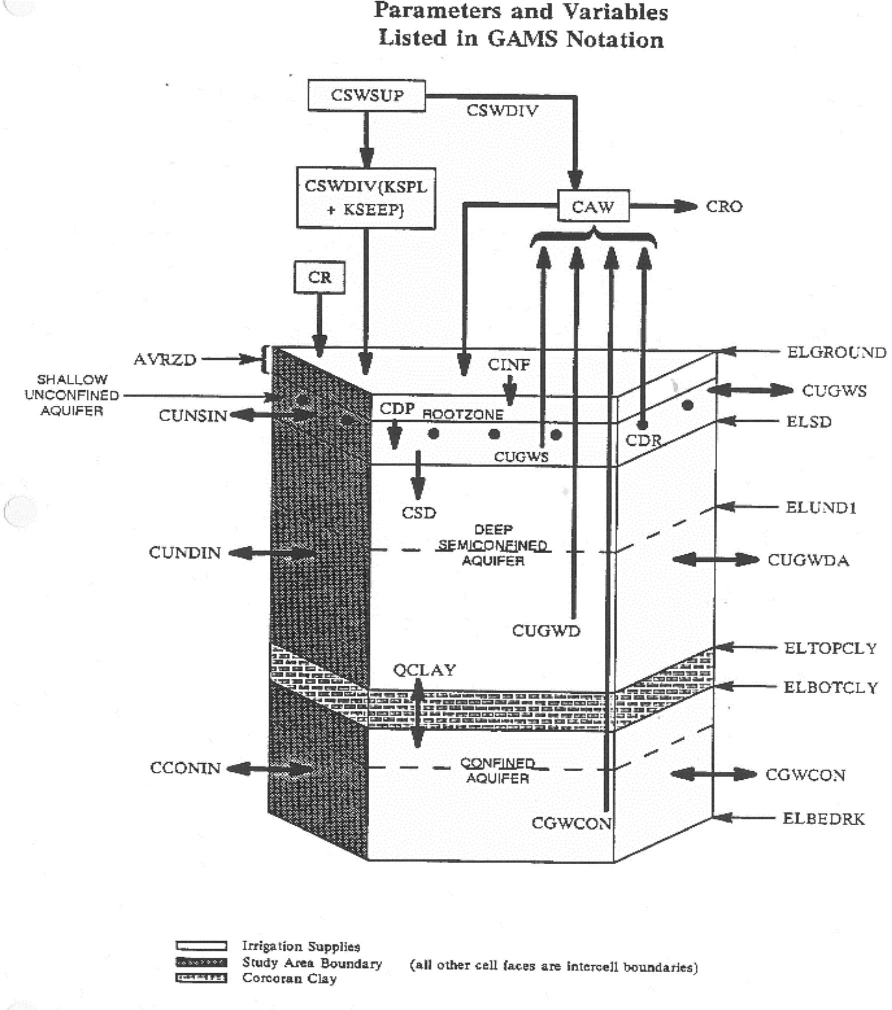
- Relies on concept of dual variables “shadow prices” to infer unobserved cost differences among activities
- Two stage procedure – (a) calibration using traditional programming model (b) computation of marginal cost function after crop acreage constraints removed
- Linear marginal cost function for each crop activity – quadratic form appended to objective function
- Used to estimate proxy crop activity levels at beginning of each year simulated by the model
- The PMP algorithm duplicates the crop mix from the restricted calibration model and allows smooth changes in crop levels as conditions or policies change

APSIDE data inputs and model features

- Five proxy crops were considered in the APM ;
    - alfalfa (hay and seed crops, rice, irrigated pasture)
    - trees (almonds, apples, apricots, olives, peaches, walnuts, pistachios, grapes, nectarines, oranges)
    - row crops (cotton, sugar-beets, tomatoes, corn, sorghum)
    - grain crops (wheat, barley, oats)
    - vegetable crops (beans, melons, lettuce, spinach, onions, garlic, broccoli, peas)
- Proxy crops assigned average hydraulic properties of district
- Equations of motion represent lateral flows between districts
- Costs and hydrologic response of irrigation and drainage technology substitution built into model

Conceptual model stratigraphy in APSIDE model

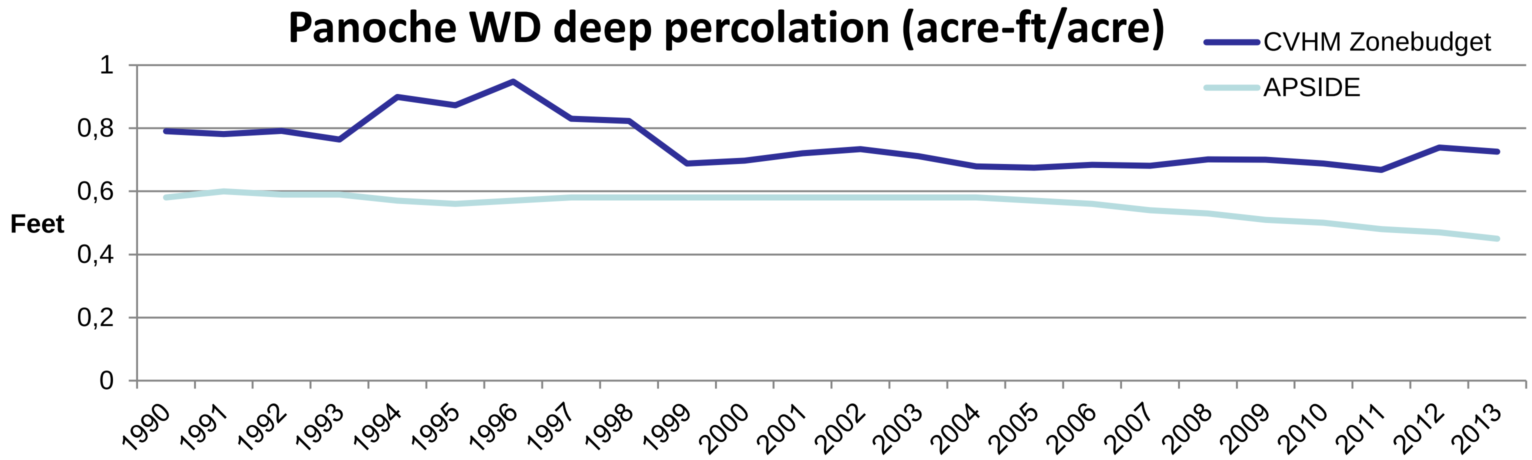




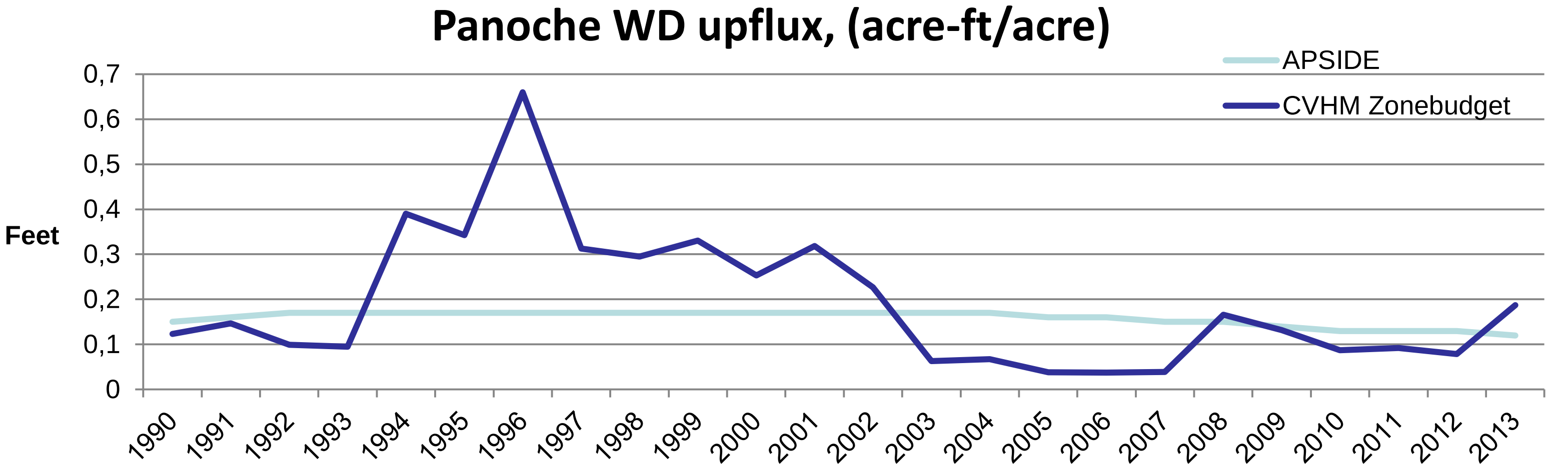
APSIDE model results compared to CVHM

- Cost of drainage disposal have increased over time
- Overall trend of increased almond production driven by commodity prices and marketing
- APSIDE model substitutes more water conserving irrigation technologies (sprinkler and drip irrigation) for furrow and basin flooding techniques
- APSIDE model improves on-farm drainage management by recycling irrigation tailwater and subsurface drainage water
- APSIDE model achieved optimal yields and farm income largely by reducing irrigation application resulting in deep percolation rates that were approximately 50% lower than those produced by CVHM2

Comparison of CVHM2/APSIDE deep percolation/upflux

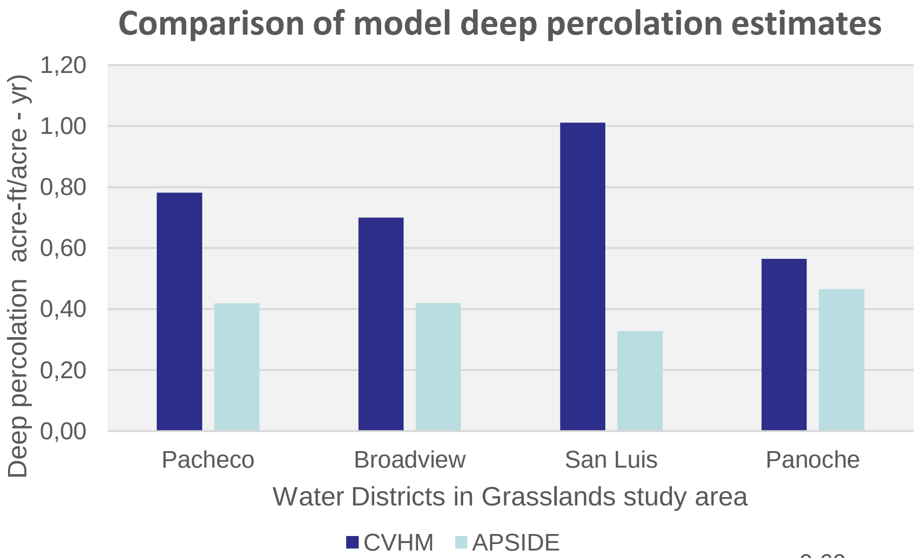


Panoche WD deep percolation (acre-ft/acre)



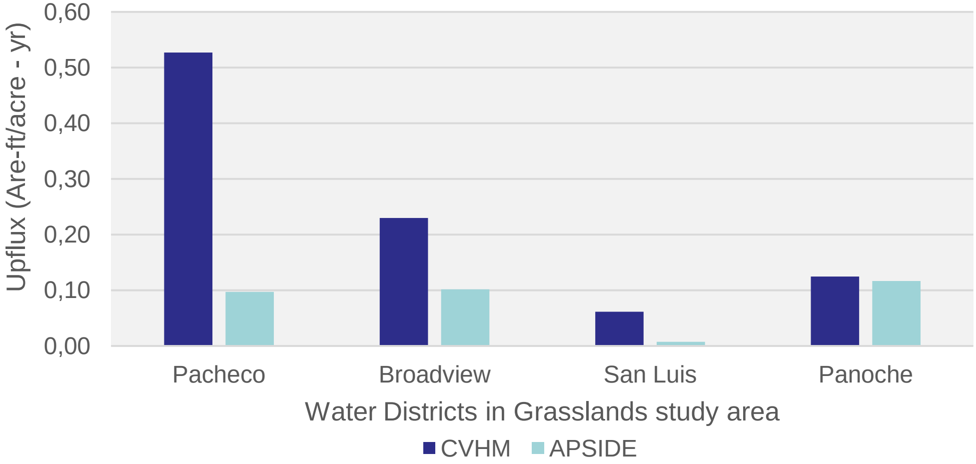
Panoche WD upflux, (acre-ft/acre)

CVHM2/APSIDE - comparison of deep percolation, upflux



Comparison of model deep percolation estimates

Comparison of model upflux estimates



Summary and Conclusions

- Legacy models sometimes retain assumptions and input data that can produce misleading results if not updated and verified. Need to overcome modeler complacency.
- Modelers often ignore factors impacted by human behavior and economics. Simple economics-driven models such as APSIDE can provide more realistic future trajectories.
- In this study – deep percolation estimates made with APSIDE were about 50% of previous model values. This result has been confirmed by data derived directly from canal turnout measurements.