Analysis and Simulation of Conjunctive Water Use for Agricultural Settings with the Farm Process for MODFLOW

Randy Hanson¹, and Wolfgang Schmid²
¹ U.S. Geological Survey
² University of Arizona

Toward Sustainable Groundwater in Agriculture – An International Conference Linking Science and Policy
15-17 June 2010
San Francisco, California

Sustainability of Resources is subject to changing Demands and Supplies that are integrated through Conjunctive Use ➔ FLOWS PAY THE BILLS!

TODAY’S TALK

• Conjunctive-Use Features of MODFLOW-Farm Process (MF-FMP)
• Macro-Agriculture Example
• Micro-Agriculture Example

Current Features of FMP

Supply-Constrained—Demand–Driven Mass Balances

Why do we need and how can we use a “Farm Process” in Water Management?

Estimation of Historic Well Pumpage if not metered
• Historical model calibration
• Historical use assessments such as stream adjudications

Climate Model Predictions jointly with Farm Process
• Forecast of Future Supply & Demand (e.g., ahead of Droughts)
• Projections for Policy/Projects

Surface-Water Rights Appropriations
• Individual Farms
• Irrigation Districts
• Transboundary Settings

Conjunctive Management by Drought Response Policies:
• Acreage Optimization
• Deficit Irrigation
• Water Stacking on Priority Crops

Operational

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Operational
(1) Precipitation input (FMP)
(2) Irrigation demand supplied in order of decreasing priority by
   (a) Non-routed deliveries (FMP),
   (b) Semi- or fully routed surface-water deliveries streamflow or
       surface-water rights constrained stream diversions (FMP and SFR),
   (c) Groundwater pumpage from capacity- or head-constrained single-
       or multi-node wells (FMP and MNW),
   (d) Potential other external water supplies (FMP).
(3) Uptake from groundwater (FMP) with groundwater flow simulated by
(4) Transpiration through vegetation of water derived from precipitation,
    irrigation, and groundwater sources separately (FMP).
(5) Evaporation from bare soil of water derived from precipitation,
    irrigation, and groundwater sources separately (FMP).
(6) Surface returnflows from precipitation and irrigation in excess
    of consumptive use as overland runoff to stream network (FMP and SFR).
(7) Sub-surface returnflows as instant deep percolation or delayed
    recharge (FMP and UZF) and optionally also as well injections (FMP and MNW).

Simulation of Conjunctive Use Components
Two types of interdependency: head-dependent flows and flow-dependent flows

Conjunctive Use in Central Valley
Virtual Farms, “Plumbing”, & Land Use
- 21 Virtual Farms
- 43 Rivers/66 Diversions
- 22 Crop Groups
  - Including
    - urban
    - Native/Riparian
  - 5 Land-use windows
  - Climate periods
  - Crop coefficients

Macro-Agriculture Example
Climate Change Analysis ➔ Central Valley, California

Micro-Agriculture Example

Central Valley Conjointive Use ➔ Stream Network
- Inflows (43)
- Diversions (66) – Deliveries
  - 64 to Virtual Farms
  - 2 diverted outside of model

Faunt et al., 2009 (USGS – PP 1766)

Paleo-Extreme Climate Events Central Valley, California

Historical Change in Groundwater Storage (Water Years 1961 – 2003)

DSS & LINKAGE BETWEEN GCM and BCM & CVHM

Supply-Constrained/Demand-Based Hydrologic Model System

CLIMATE VARIABILITY within CHANGE: Precipitation Stationarity & Weak-Stationarity?
**Agricultural Water Supply and Demand for DGQ-A2 Scenario, Central Valley, California**

- **Historical**
  - Water Year

- **Predicted**
  - Surface-water Deliveries
  - Groundwater Deliveries

**Sustained Drought**

**Intermittent Droughts**

- Historical:
  - Irrigation Supply/Demand

**Predominantly Surface-water Deliveries**

**Predominantly Groundwater Deliveries**

**2053**

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**TODAY’S TALK**

- Conjunctive-Use Features of MODFLOW-Farm Process (MF-FMP)
- Macro-Agriculture Example
- Micro-Agriculture Example
  - Aquifer-Storage & Recovery with Coastal Delivery System
  - Pajaro Valley, California

**Aquifer Storage & Recovery System Coupled To:**

- Supply
- Capture Local Runoff
- Demand
- Coastal Distribution System (CDS)

- Harkins Slough Deliveries: 4.3 Million m$^3$ (3,470 ac-ft)
- CDS Deliveries: 2.6 Million m$^3$ (2,100 ac-ft) – 61% of Recharged Water
- ASR Deliveries: 21% of Recharged water & 35% of CDS Delivery
- Local Recharge occurring as well as ASR operation
- Recycled Water Contribution up to 16% of 2004-2008 Total Agricultural Water Demand

**Priority of Water Supply for Farm – Balance of Flows per Stress Period (each Month):**

1) Recovery wells
2) Recycled Water Facility (2008)
3) City Connection
4) Blend Wells
5) On farm wells will make up remainder of demand

**Simulation of ASR and CDS Related Projects**

- Sun water demand from all injected WRS
- Deliver water demand from 7th priority source (ASR/Recovery Wells)
- Parcels on coastal WRS wells in safely remaining water demand 7th priority source
- All total water demand is satisfied prior to delivery from all sources, including step 7. Total supply is 157,000 ac-ft per year, coastal WRS below wells any pumping of supply additional water demand

**Preliminary Results Subject to USGS approval and modification**
**Misnomers & Differences**
- FMP has many options but is easy to use (especially in data deficient settings).
- Not all FMP options have to be used. Start simple!
- FMP options can be implemented incrementally and easily changed.
- FMP makes you think about hydrology plus all of the flows, climate, soils, & vegetation.
- FMP requires more analysis (flows and heads).
- FMP requires more associations (wells, diversions, rivers, etc).
- FMP is easy to build.
- FMP can be estimated from simple and primary data.

**FMP SUMMARY OF FEATURES AND ADVANTAGES**

**MODEL FEATURES MADE EASY**
- Estimates Irrigation Demand
- Estimates Surface-Water Deliveries
- Estimates Ground-water Pumpage
- Estimates Net Recharge
- Estimates all Components for ET, Runoff, and Deep Percolation
- Complete Linkage to Ground-water and Surface-water Flow

**ADVANTAGES FOR MODELERS**
- No need for indirect estimates of Pumpage, Recharge, ET, Runoff, or Surface-water deliveries.
- Uses Natural Data → Easy to Update Model.
- Saves time and money for constructing, operating, and updating models.
- Facilitates Operational and Forecasting Simulations.

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**MODFLOW → Interdependency of Flows and Heads**
- Recent MODFLOW Developments → More Linked & Complete Hydrologic Models
- More Realistic Simulations → Better Analysis of Linked Flows (Conjunctive Use)
- within the entire Hydrologic Cycle of Regional Hydrologic Systems
- Linked Model Architecture → Decision Support Tools & Self-Updating Models

**Ground-Water Flow Features ("Packages")**
- Ground-Water Processes (Transport: GWT, MODPATH, Management: GWM FMP, Parameter Estimation: UCODE/Pest, Landscape: FMP)

**Integration with Other Models in Hydrologic Cycle**
- Atmospheric: GCMs, Runoff: PRMS(GSFLOW)/BCM/VIC,
- Water-Allocation Models (ex. CALVIN), Reservoir Operation Models

**Integration with Other Processes**
- Ecological & Biogeochemical Models & Agro-Economic Models

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**CONJUNCTIVE USE:GROUND-WATER SUSTAINABILITY = STRAWBERRY FIELDS FOREVER?**

rthanson@usgs.gov
(619)225-6139

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**THE END**

→ FINAL COMMENTS & DISCUSSION ?

THANKS!