Impacts of Utility-Scale Solar Development on Water Resources

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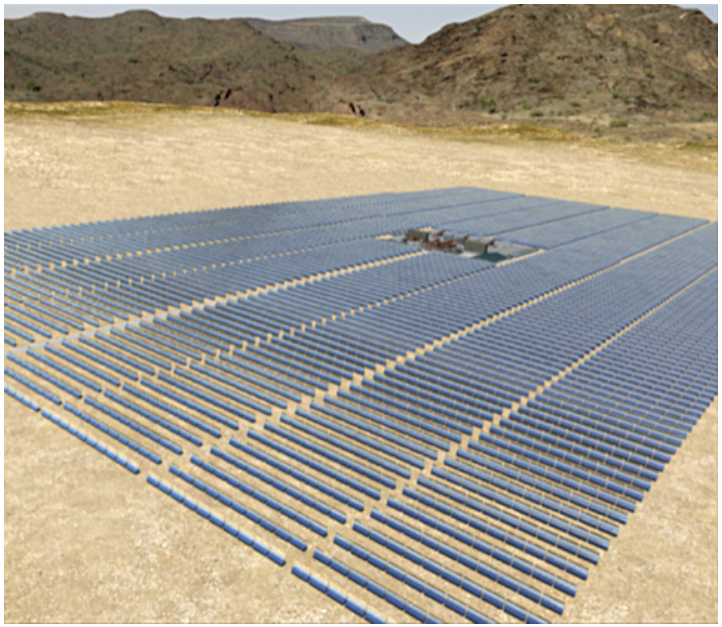
Land Requirements for Utility-Scale Solar Facilities

- Land use requirements for a 400-MW facility:
  - Parabolic trough requires about 2,000 acres (~3 mi^2)
  - Power tower, dish engine, and PV facilities require about 3,600 acres (~5.6 mi^2)

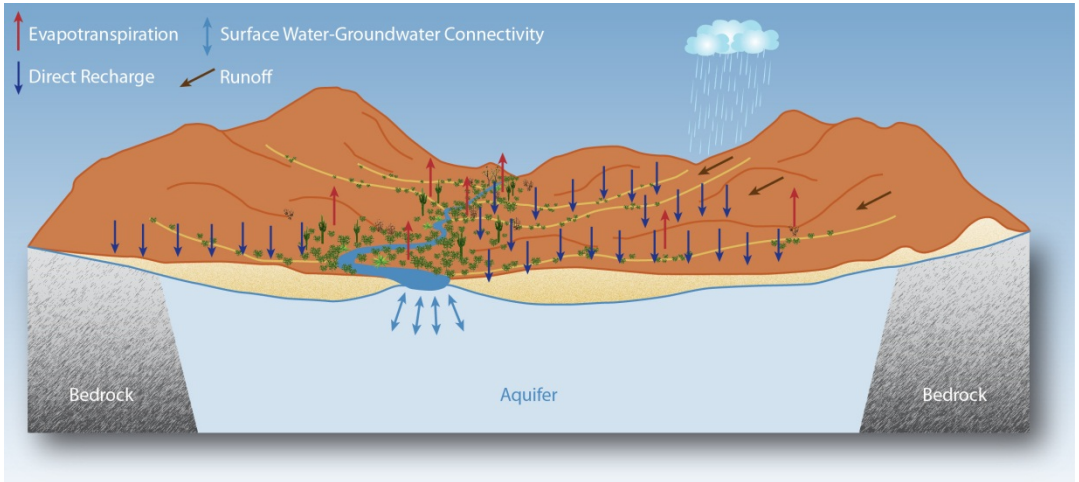


Abengoa Solana, AZ
(280-MW Parabolic Trough, 1,920 acres)

Ivanpah, CA
(370-MW Power Tower, 3,471 acres)

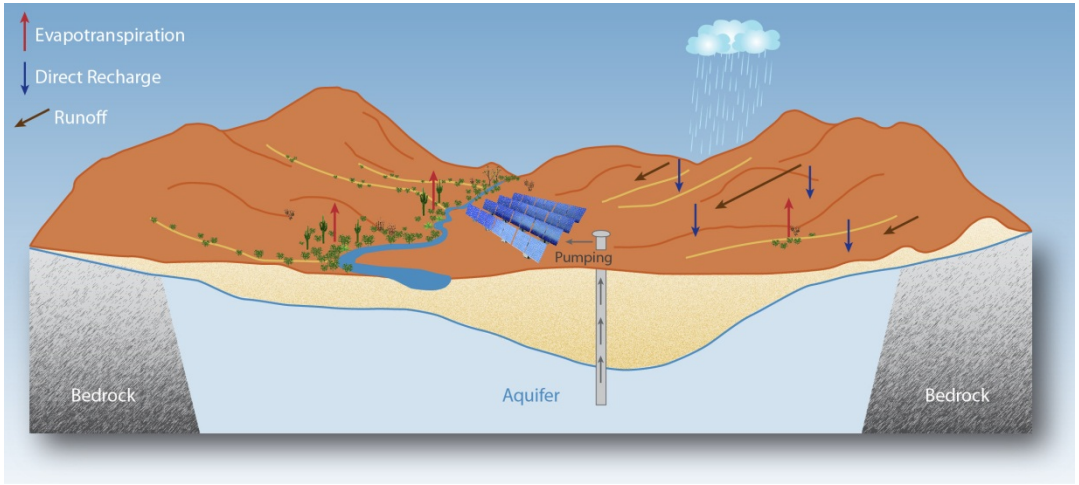
Water Resources: Overview of Potential Impacts

Before

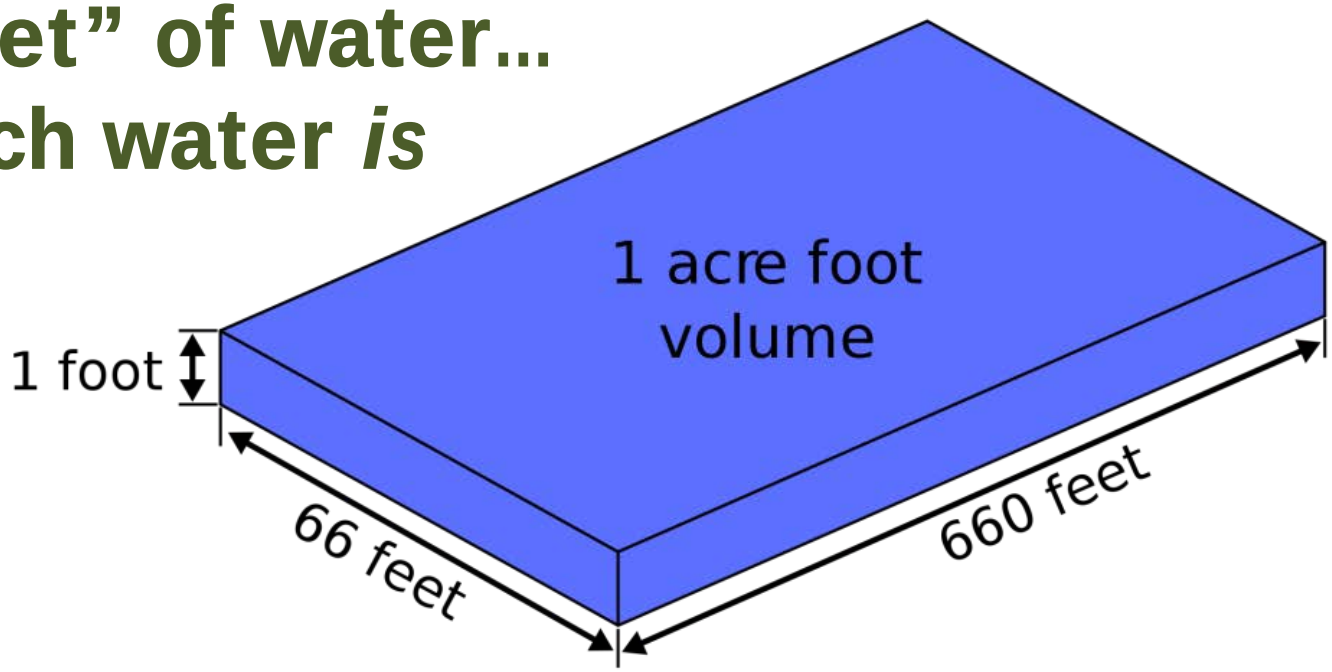


- Water use
  - Groundwater table drawdown
  - Alteration/reduction in surface water flows
- Alteration of surface water-groundwater connectivity
- Modification of natural surface water and groundwater systems
- Water quality degradation
  - Erosion-sedimentation
  - Excessive withdrawals
  - Leaks and spills of chemicals

After



Water Use is discussed in "acre-feet" of water… How much water *is* that?



- 1 acre foot of water = 43,560 cubic feet of water
  = 325,853 gallons of water
- In the U.S., household water usage ~ 1 acre-foot per year
- In the Southwest, household water use ~ 0.25 ac-ft/yr (AFY)

Water Requirements for Utility-Scale Solar Facilities

Water use estimates include:

- Mirror/panel washing
- Dust control
- Workforce water supply
- Power plant cooling (trough and tower only)

Technology-Specific Water Use Estimates (AFY/MW)

Technology	Major Water Uses	Construction	Operation
CSP: Concentrating Solar Power (Parabolic trough & Power tower)	Wet cooling and washing	1.23 to 2.79	5.01 to 6.84
	Dry cooling and washing	0.27 to 3.25	0.21 to 0.81
Photovoltaic	Dust control & panel washing	0.22 to 2.92	0.001 to 0.07

- AFY/MW data from Table 1 of The Development of Environmental Monitoring Programs for Utility-Scale Solar Installations, *Initial Focus: Water Resources* (O'Connor et al. 2013)
- Ranges of water use for CSP assume 30% to 60% operating times
- Workforce water supply would range between 0.2 and 6 ac-ft/yr

Water Resources: Impacts by Development Phase

- Site Characterization
  - Water use - minor impacts - use is limited in extent and duration
    - Water use for dust suppression
  - Land disturbance - minor impacts to soil/vegetation
    - Transport of well-drilling equipment
    - Access road modification

Water Resources: Impacts by Development Phase

- Construction
  - Water use
    - Largest water use is for dust suppression (up to 6 AFY/MW)
    - Water also needed for workers and concrete preparation
    - Water rights/permits needed
    - Groundwater most likely source
    - For PV and dish engine, water use is greater during construction than operations
    - Water use can lead to loss of connectivity between surface water and groundwater
  - Sanitary wastewater to be trucked off-site

Water Resources: Impacts by Development Phase

- Construction (continued)
  - Land disturbance
    - Streams, floodplains, wetlands, playas, and riparian areas
      - Altered drainage patterns
      - Timing of runoff, peak flows, and annual flow rates
      - Loss of sand supply to dunes
      - Decreased recharge
  - Water quality degradation
    - Land disturbance-related erosion and sedimentation
      - Transport by wind or water
    - Leaks and spills of fuels and other chemicals
    - Storage and/or treatment of wastewater
    - Application/storage of pesticides, herbicides, or dust suppressants.

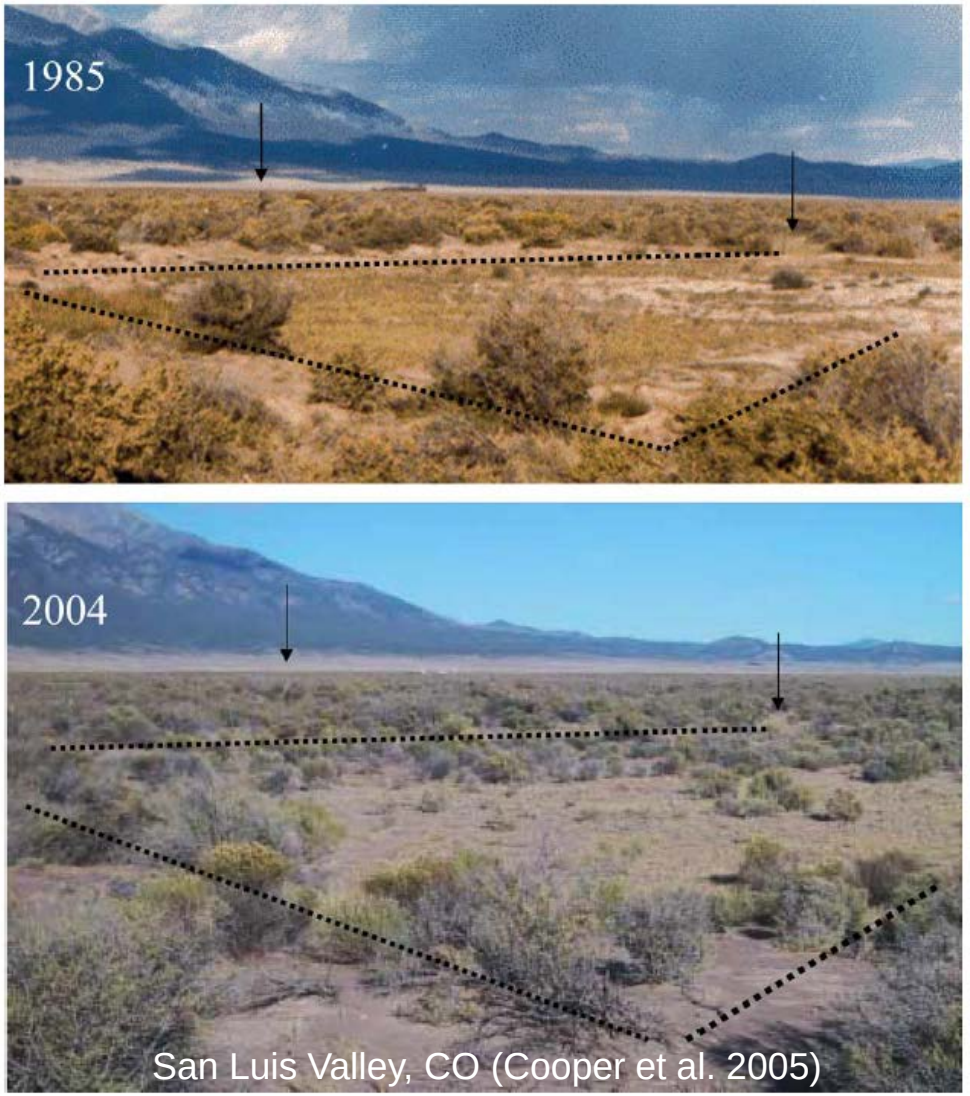

Genesis solar project, CA

Water Resources: Impacts by Development Phase

- Operations
  - Water use impacts depend on solar technology
    - Groundwater is the most likely source
    - Groundwater withdrawals could lead to:
      - Loss of connectivity with surface water features
      - Subsidence of the land surface
      - Impacts to other water users
      - Impacts could extend well beyond life of solar facility
  - Surface water quality could be adversely affected through increased runoff, erosion, sedimentation, and spills
    - Truck traffic and maintenance activities
  - Wastewater
    - Sanitary
    - Blowdown (wet and hybrid cooling)

Operations Impacts: Surface Water and Other Users

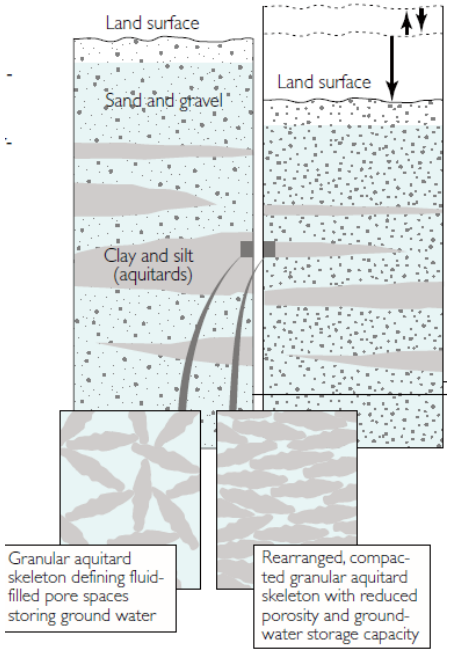
- Water table declines over the long term can:
  - Shift the balance in perennial streams from gaining to losing conditions
    - Can reduce the ecological habitat within the riparian zone
  - Create dry wells in neighboring pumping centers
  - Change wetlands to playa



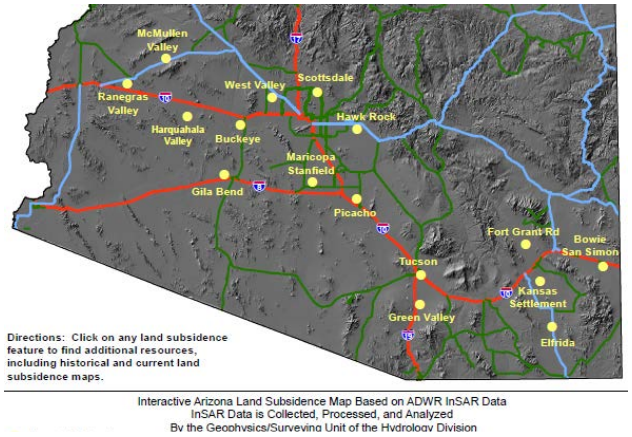
San Luis Valley, CO (Cooper et al. 2005)

Operations Impacts: Subsidence

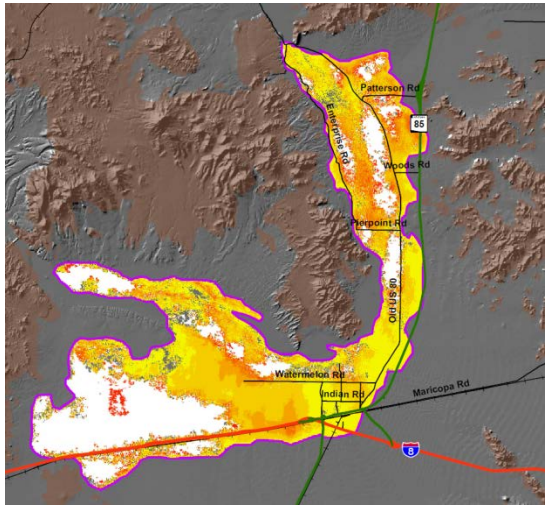
- Removal of groundwater from:
  - Sand and gravel aquifers
    - Provide an immediate supply
  - Clay and silt aquitards
    - Become "depressurized" after long periods of pumping



Active Land Subsidence Areas in Arizona Based on ADWR InSAR Data



http://www.azwater.gov/azdwr/hydrology/geophysics/documents/ArizonaLandSubsidenceInteractiveMap.pdf

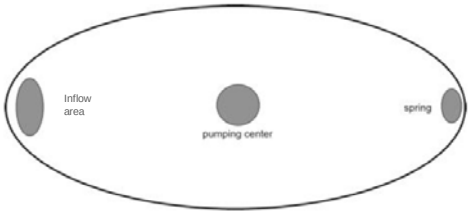


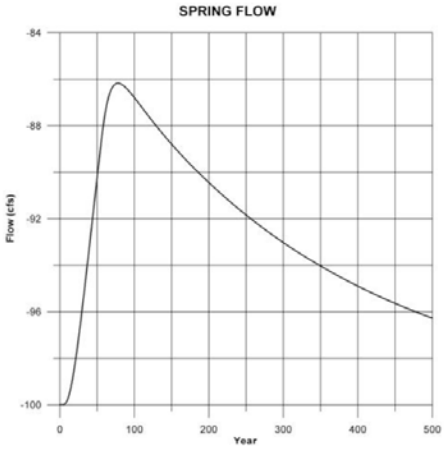
- Gila Bend, AZ
  - Satellites measure the change in the elevation of the ground surface over time
  - Red = subsidence of 3-4 cm between 2006 and 2008

Operations Impacts: Beyond the Facility Lifespan

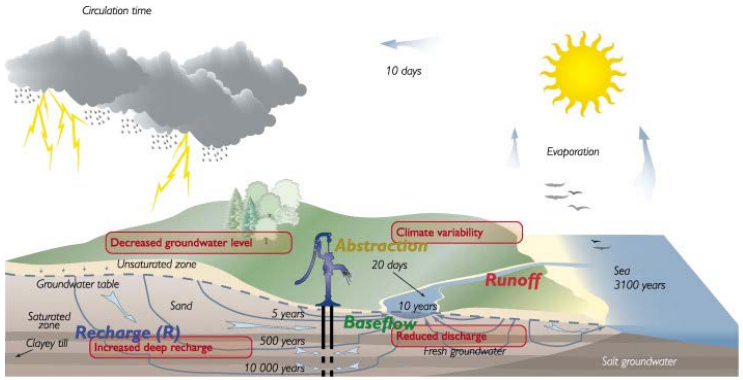
- *Sustainable* Pumping is not simply equal to Recharge
- Other water budget indicators must be considered and can take decades (or longer) to equilibrate with pumping

  (Bredehoeft 2012, Balleau 2013):
  - Groundwater Storage
  - Baseflow/Discharge
    - or Surface Water Influx in losing conditions (loss of connectivity)
  - Evapotranspiration
  - Reduction of Rejected recharge (Runoff)
  - Ecological reserves
  - Etc…





Figures from Bredehoeft's (2012) simple "pumped-spring" MODFLOW model.



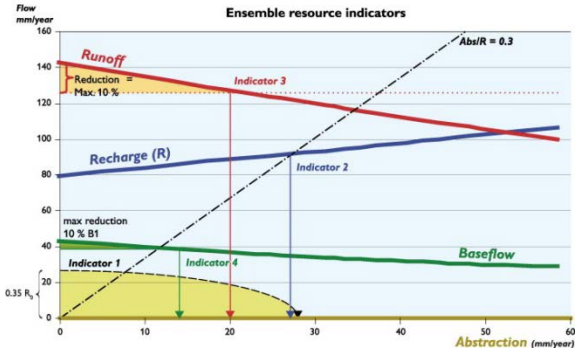


Figure 4 from Henriksen et al.'s (2013) Denmark MIKE SHE model.

Water Resources: Impacts by Development Phase

- Decommissioning/Reclamation
  - Similar to impacts during construction
    - Water needed for dust control (demolition, traffic, etc.)
    - Land disturbance
  - Additional water use for vegetation restoration

Water: Mitigation Requirements by Development Phase

- Siting and Design
  - Maximize water conservation through technology selection and/or water source selection
    - Use recycled or reclaimed water, if available
  - Siting and design should avoid impacts to surface water features
  - Conduct hydrologic studies
  - Obtain water rights

Water: Mitigation Requirements by Development Phase

- Site Characterization and Construction
  - Use best management practices (BMPs) to
    - Avoid/minimize alteration of existing drainage systems
    - Control erosion and sedimentation
    - Maintain water quality
    - Protect habitats
    - Comply with NPDES Construction General Permit
    - Avoid/minimize spills and leaks
  - Construct groundwater wells using state/local standards

Water: Mitigation Requirements by Development Phase

- Operations
  - Water use
    - Should not cause overdraft of aquifers (e.g., groundwater table drops, land subsidence, decreased flows to surface water bodies, discharge/recharge processes)
    - Should not cause significant decline in surface water flows
    - Should be minimized through conservation practices
  - Sanitary and/or industrial wastewater should be stored and treated to comply with federal/state/local regulations
  - Downstream water quality should be monitored to ensure it is protected
    - Potential for increased sediment, temperature, peak flows, chemical contamination
  - Use BMPs such as pollution prevention and physical barriers (e.g., berms) to prevent contamination from:
    - Heat transfer fluids or thermal energy storage fluids at CSP facilities
    - Fuels, pesticides, herbicides and any other chemicals stored on site
- Groundwater/surface water monitoring may be needed/required

Water: Mitigation Requirements by Development Phase

- Decommissioning/Reclamation
  - Apply management plans and mitigation measures developed for the construction phase
  - Use best management practices (BMPs) to
    - Avoid/minimize alteration of existing drainage systems
    - Control erosion and sedimentation
    - Maintain water quality
    - Protect habitats
    - Avoid/minimize spills and leaks

Individual Project Analysis
- Water Use Impacts to Water Resources

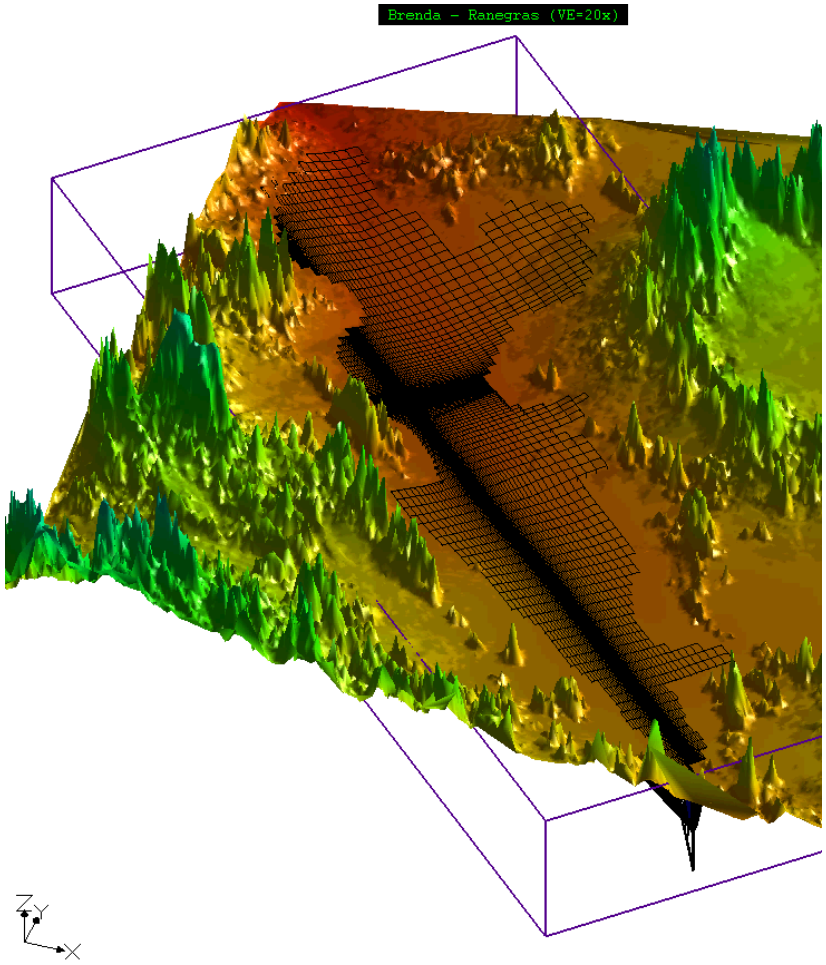
Qualitative: Compare water use requirements assuming full build-out of site to estimates of the aquifer water balance

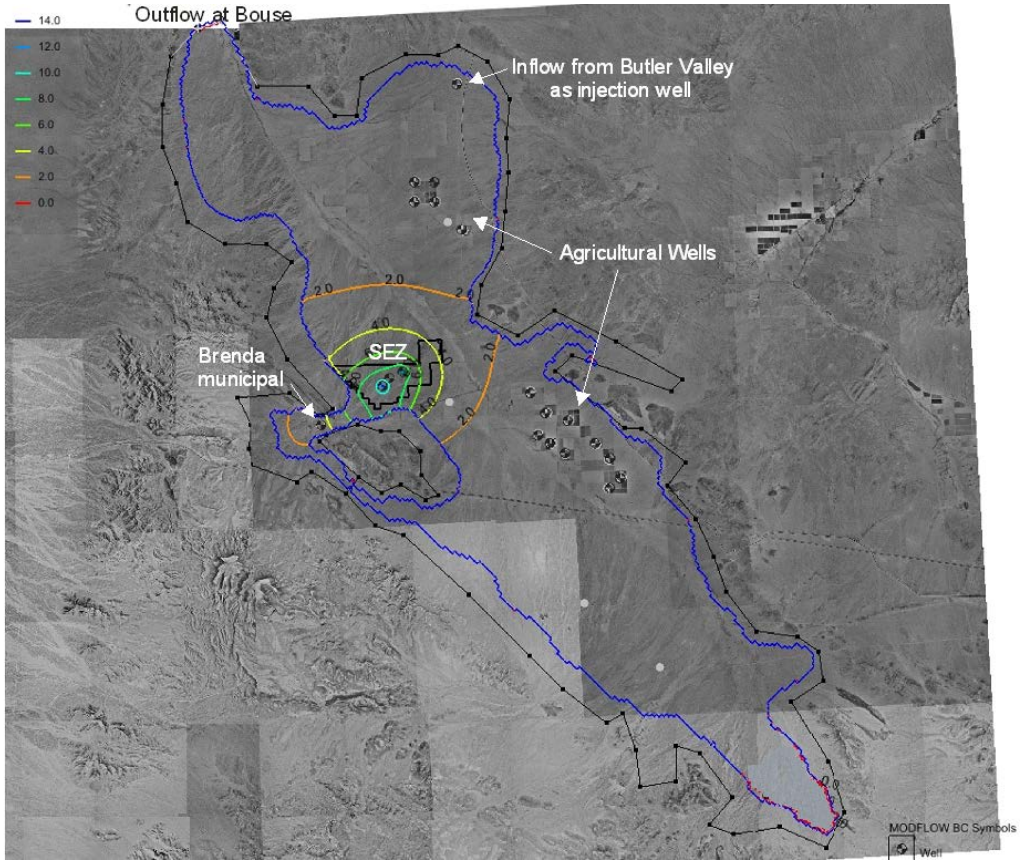
Quantitative: Incorporate results from existing groundwater models (regional, USGS, etc.) when applicable or do your own groundwater modeling

Issues:

- Very little data in many desert valleys
- What level of model complexity is needed?
- How to address cumulative impacts of multiple facilities, technologies, etc.

Groundwater Model
- Ranegras Plain Basin: Brenda, AZ



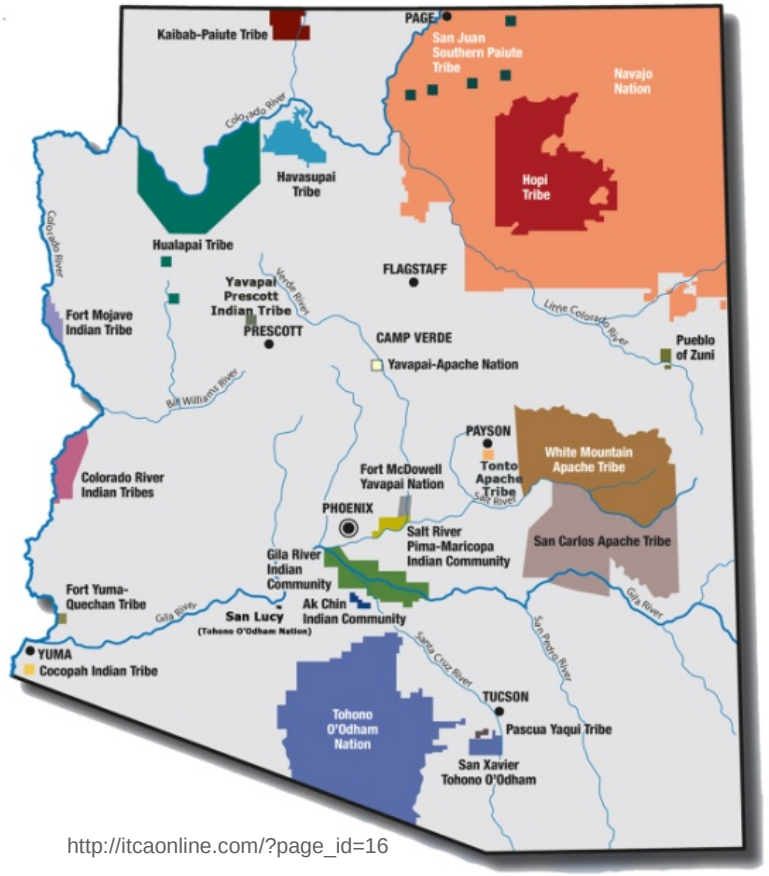


(images: John Quinn/ANL)

Two wells simulating the effect of 20 years of an estimated 2,680 AFY withdrawal for the full build-out of one 400 MW hybrid-cooled CSP facility (approx. 6.7 AFY/MW)

Water Management and Regulations to Protect Water Resources

- Water use requires available water rights
  - Existing tribal settlements (as of August 2011)
    - Ak-Chin, Fort McDowell, Salt River Pima-Maricopa, San Carlos Apache, San Xavier and Schuk Toak Districts (Tohono O'Odham), Yavapai-Prescott, Zuni, Gila River Indian Community, White Mountain Apache
  - Unallocated rights *or* conversion of existing rights (including Colorado R.)
  - Surface water, groundwater, or recycled water
  - Other uses in the area will be considered, including ecological uses



http://itcaonline.com/?page_id=16

Water Management and Regulations to Protect Water Resources

- Federal laws
  - Clean Water Act and Safe Drinking Water Act
    - Discharges from operations and construction
    - Impacts to streams, wetlands and wells
  - Executive Order 11988: Floodplain Management
  - Executive Order 11990: Protection of Wetlands
  - National Environmental Policy Act (NEPA) → Environmental Impact Analysis/Statement
- Tribal Energy Resource Agreement (TERA)
  - If established, NEPA does not apply (no Federal approval required)
  - But TERA includes an Environmental Impact Analysis that is substantively equivalent to a NEPA analysis (identify impacts, mitigations, etc.)
- Many state laws and regulations may not apply (www.teeic.anl.gov)