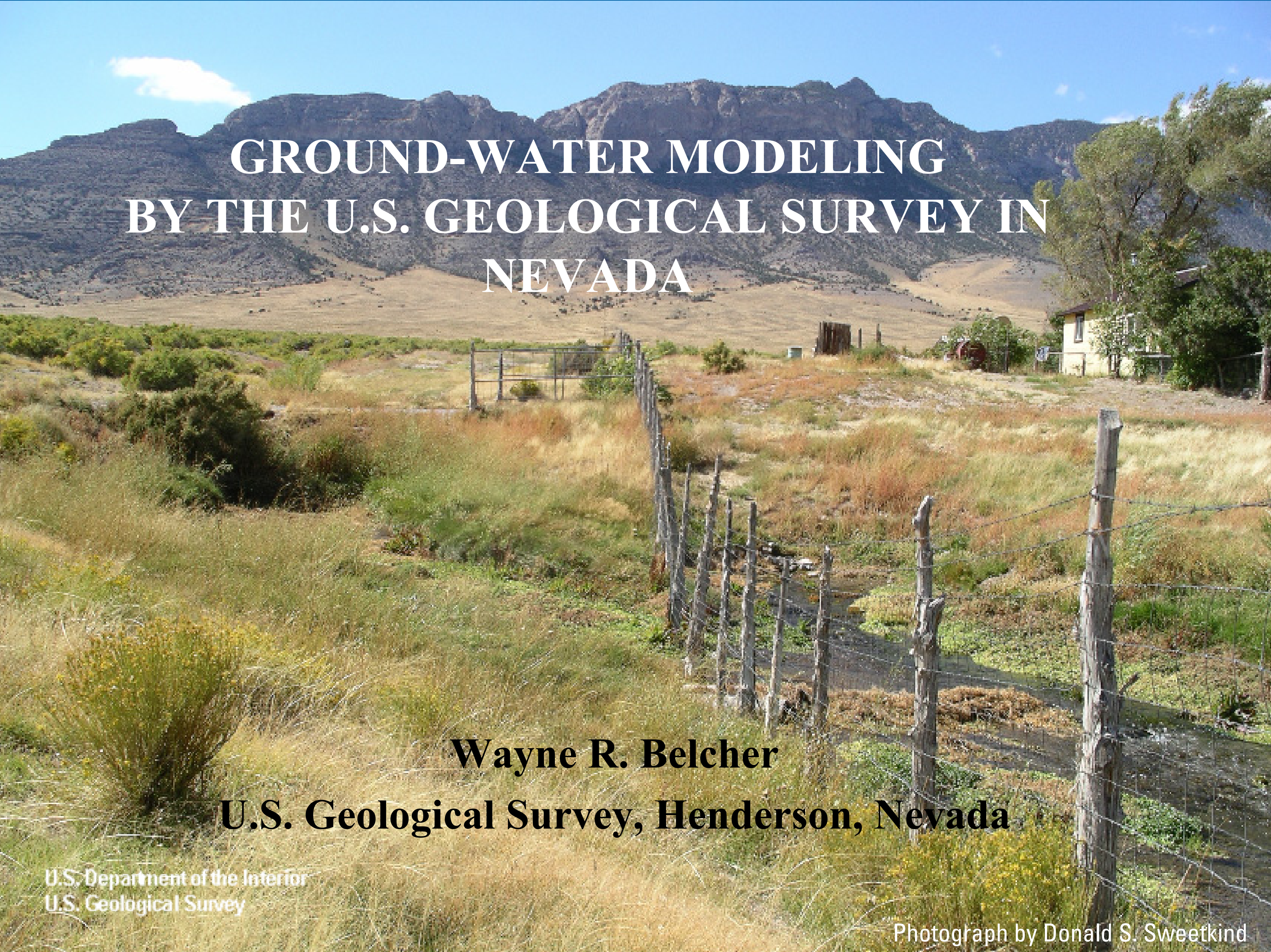


GROUND-WATER MODELING BY THE U.S. GEOLOGICAL SURVEY IN NEVADA

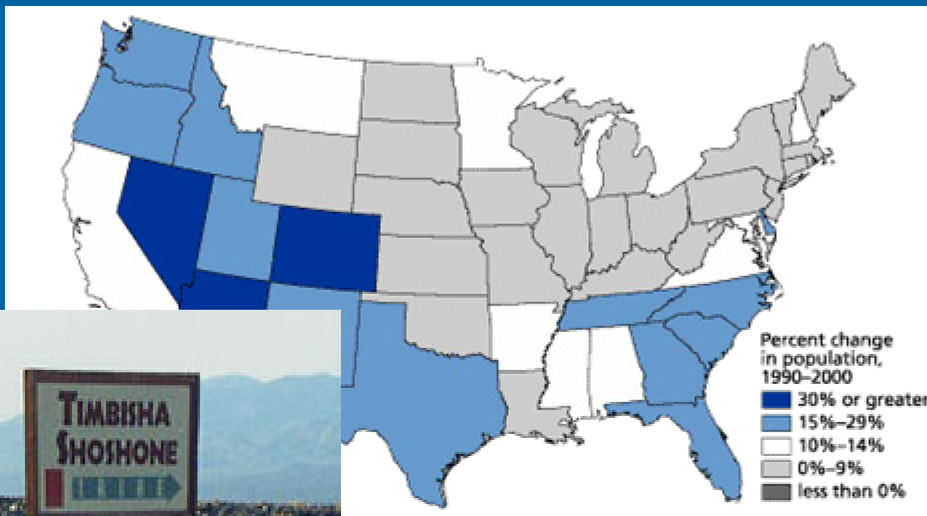
Wayne R. Belcher

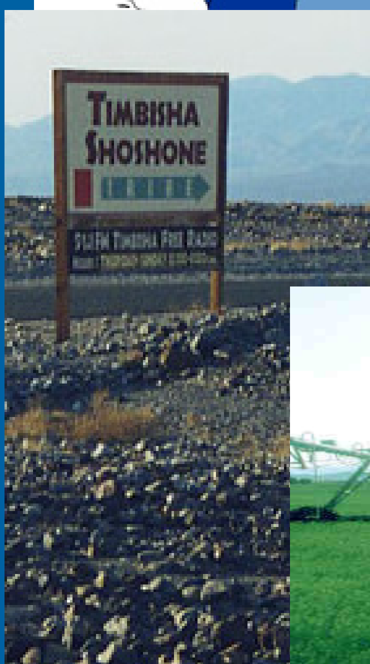
U.S. Geological Survey, Henderson, Nevada

U.S. Department of the Interior
U.S. Geological Survey

Photograph by Donald S. Sweetkind

Water Use – Driving the need for hydrogeologic understanding





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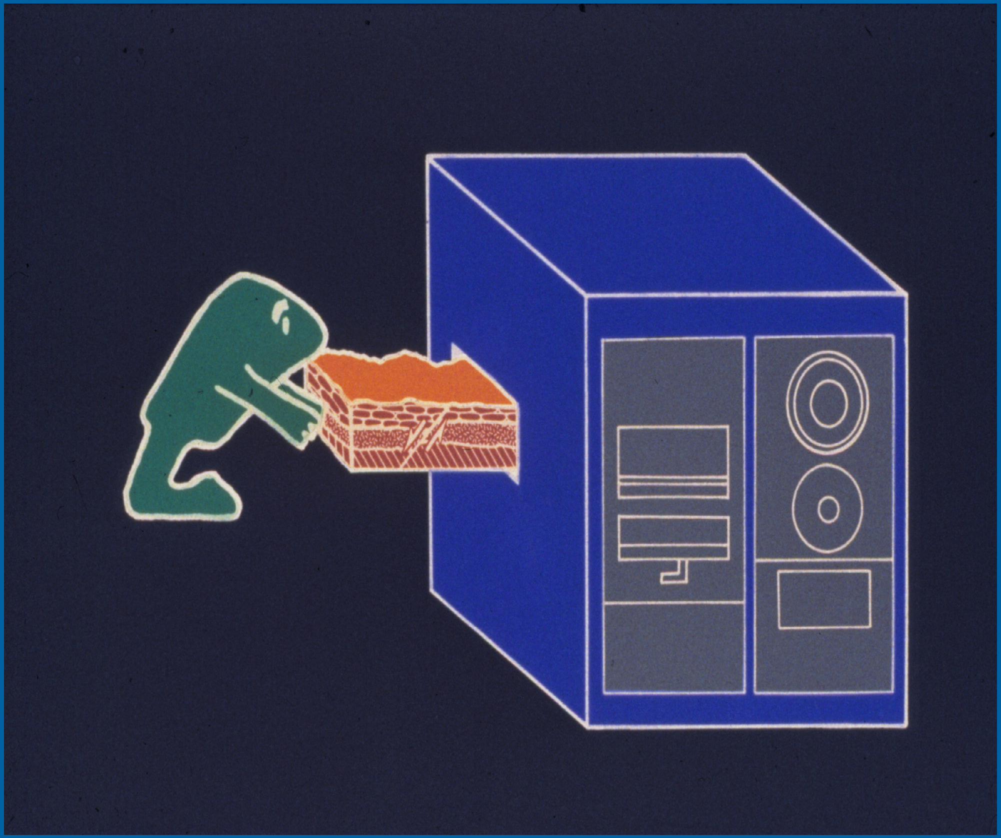
Model

Any device representing an approximation of a field situation



"Cartoon of reality"

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Types of Ground-water Models

- Conceptual
- Analytical
- Numerical

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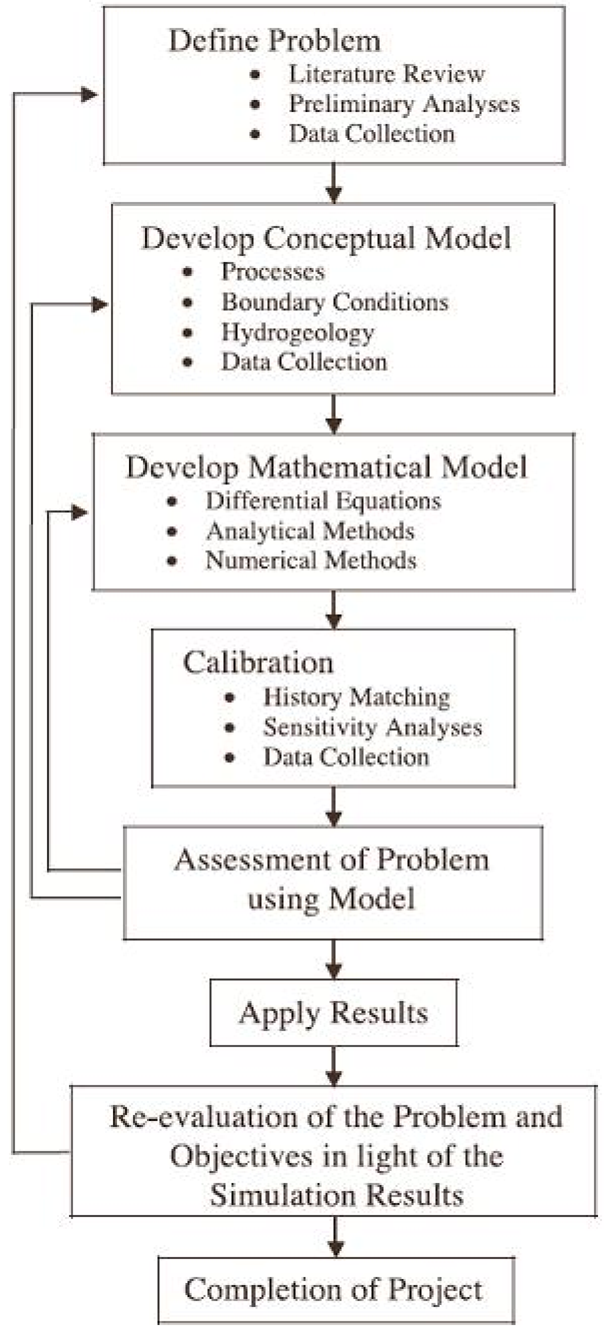
THE MODELING PROCESS



Conceptual Models

Pictoral representation of the ground-water flow system

- Block diagrams
- Profiles
- Cross sections

Define how the water flows through the system

- What the water flows through (hydrogeologic/hydrostratigraphic units)
- Where and how much water enters and leaves the system (budget)
- Boundaries

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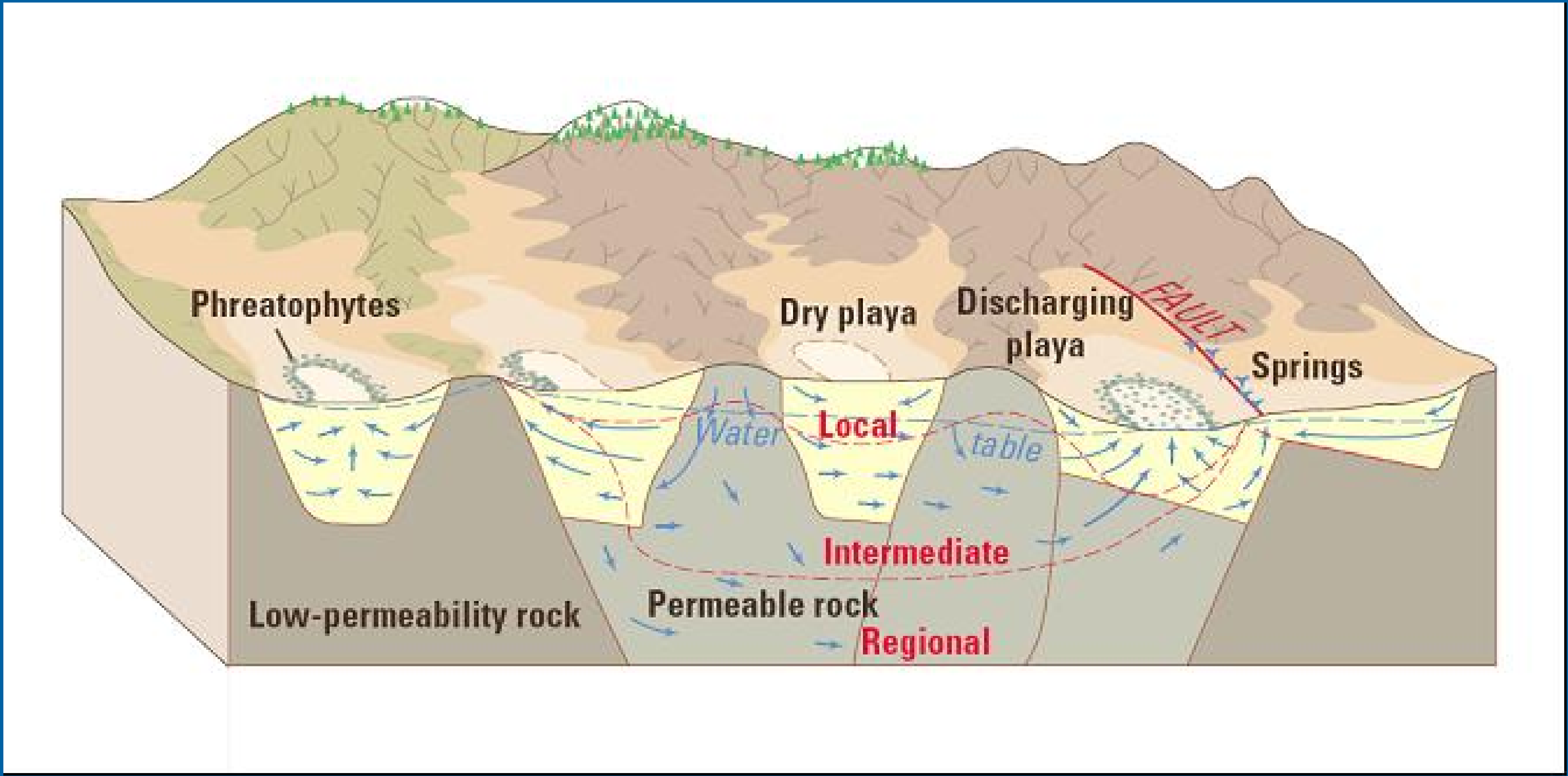
Conceptual Models



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Analytical Models

Natural processes described using mathematical equations

Ground-water flow equation:

(time, 3D, properties vary in space and direction)

Solve equation for specific conditions

$$\frac{\partial}{\partial x}\left(Kx\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(Ky\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial z}\left(Kz\frac{\partial h}{\partial z}\right)=Ss\frac{\partial h}{\partial t}$$

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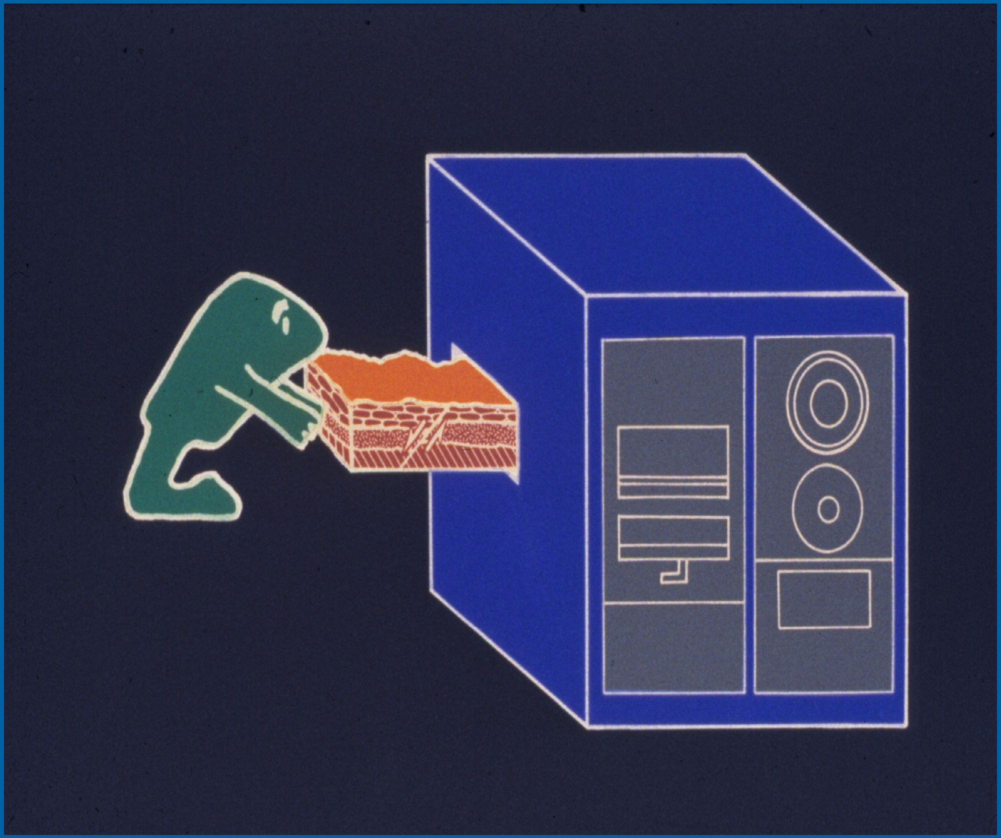
Numerical Modeling

Solve ground-water equations (time, space)

Computer-based



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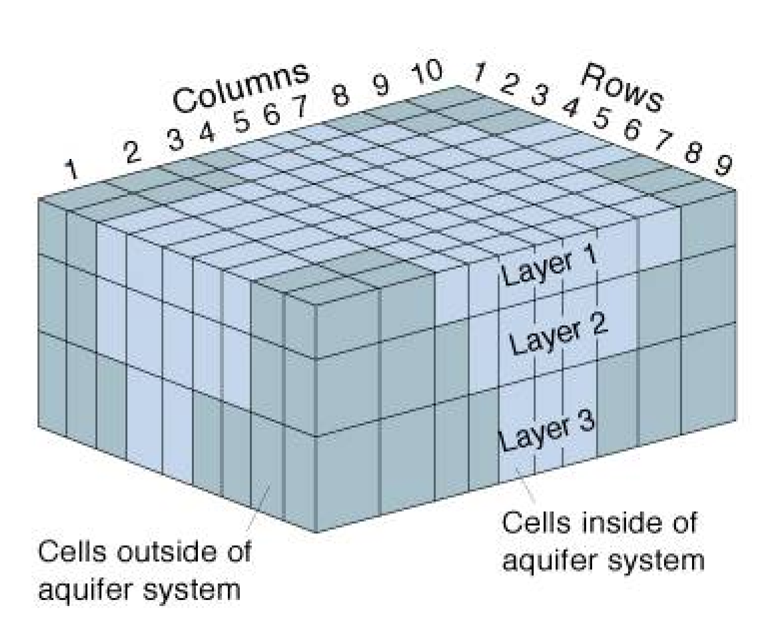
Numerical Modeling (cont.)

"Slice" up volume into blocks

Solve for water entering and exiting each block

Boundary conditions

$$\frac{\partial}{\partial x}\left(Kx\frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(Ky\frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial z}\left(Kz\frac{\partial h}{\partial z}\right) = Ss\frac{\partial h}{\partial t}$$



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Forward and Inverse Modeling

- Forward (deterministic)

  Parameters ⟶ water levels

- Inverse (stochastic)

  Water levels ⟶ parameters

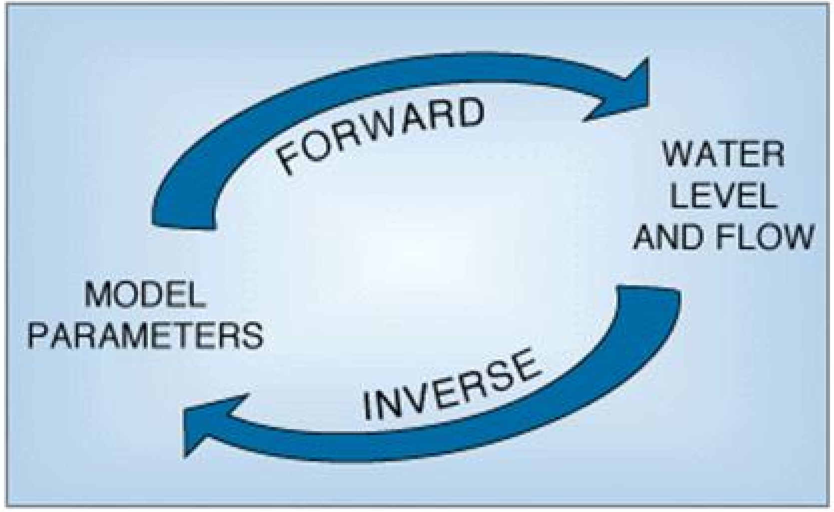

Figure 4. Forward and inverse approaches to modeling.

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Numerical Modeling with MODFLOW

Finite-difference method

Since 1980s

Many different processes

Widely used

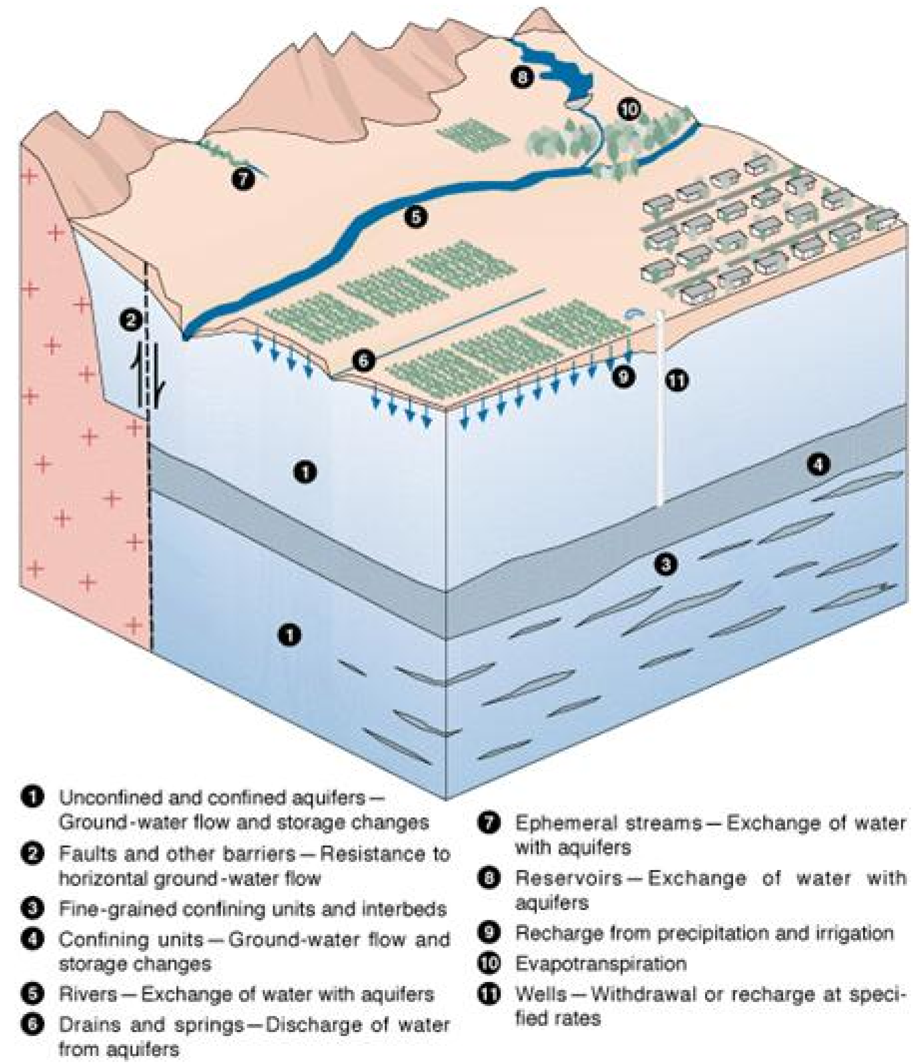

Figure 1. Features of an aquifer system that can be simulated by MODFLOW.

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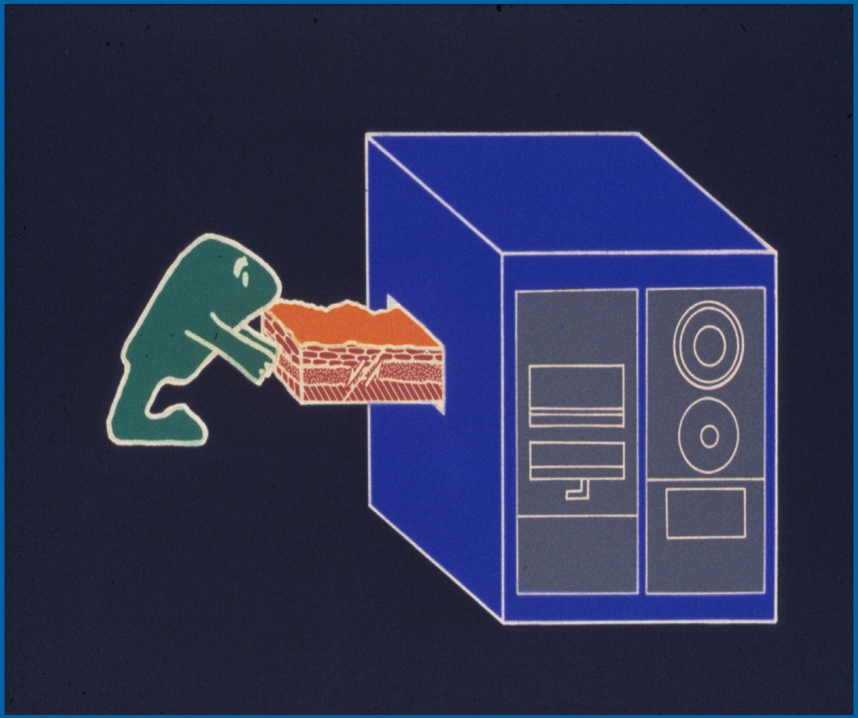
Modeling Components

Defines input and output of water; aquifer properties



- Hydrogeology
- Hydraulic properties
- Spring flow
- Evapotranspiration
- Pumping
- Recharge
- Water levels
- Boundary conditions

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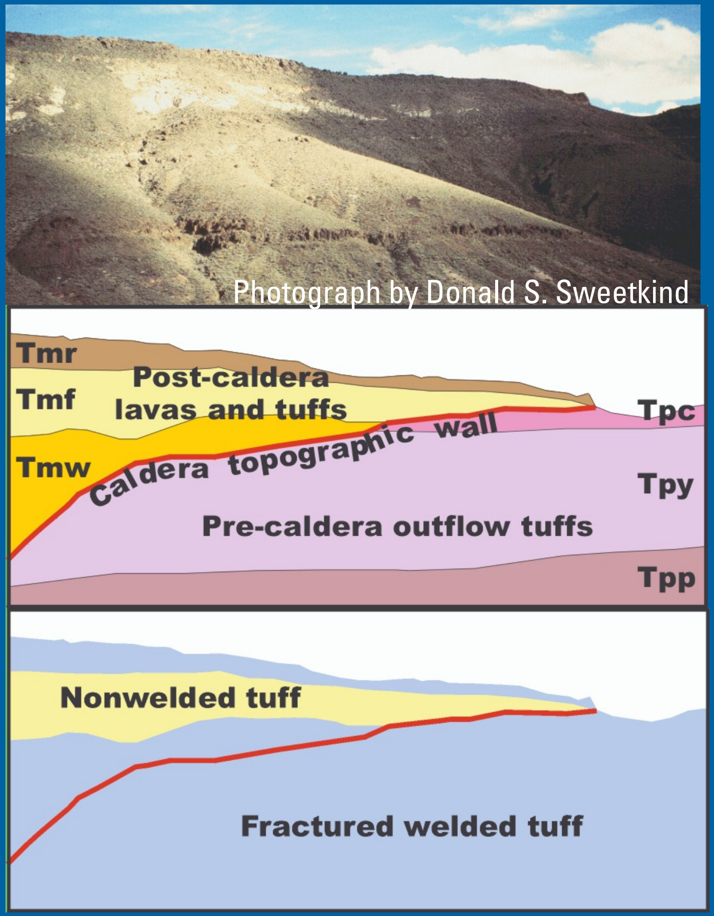
Hydrogeology

- **Geometry of hydrogeologic units**
  - Extent and thickness of units
  - Juxtaposition of units
  - Framework model

- **Properties vary spatially**
  - Alteration and welding
  - Deformation

- **Structures**
  - Conduits (zones)
  - Flow barriers



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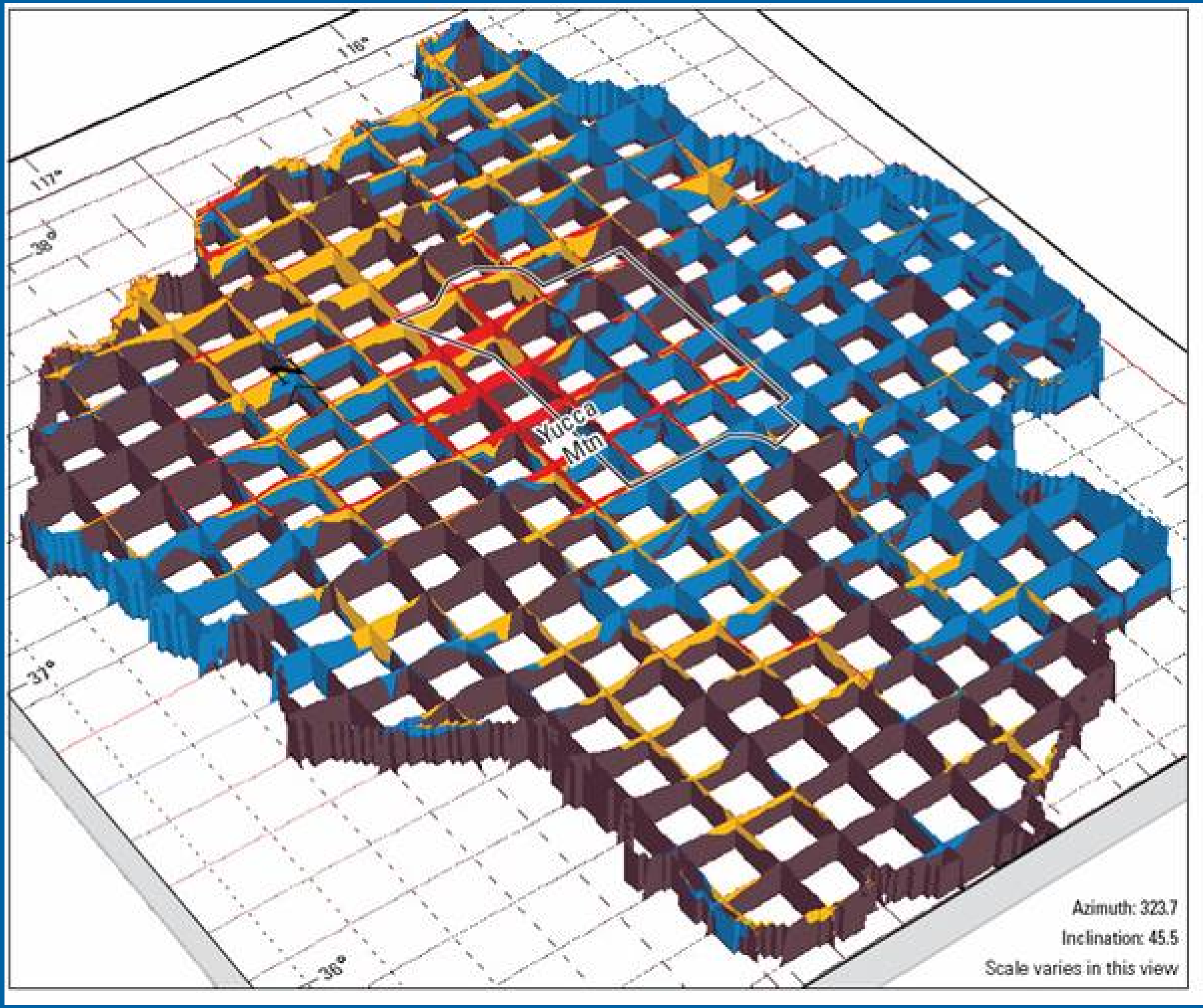
Hydrogeologic Framework Model

(HUF Package)



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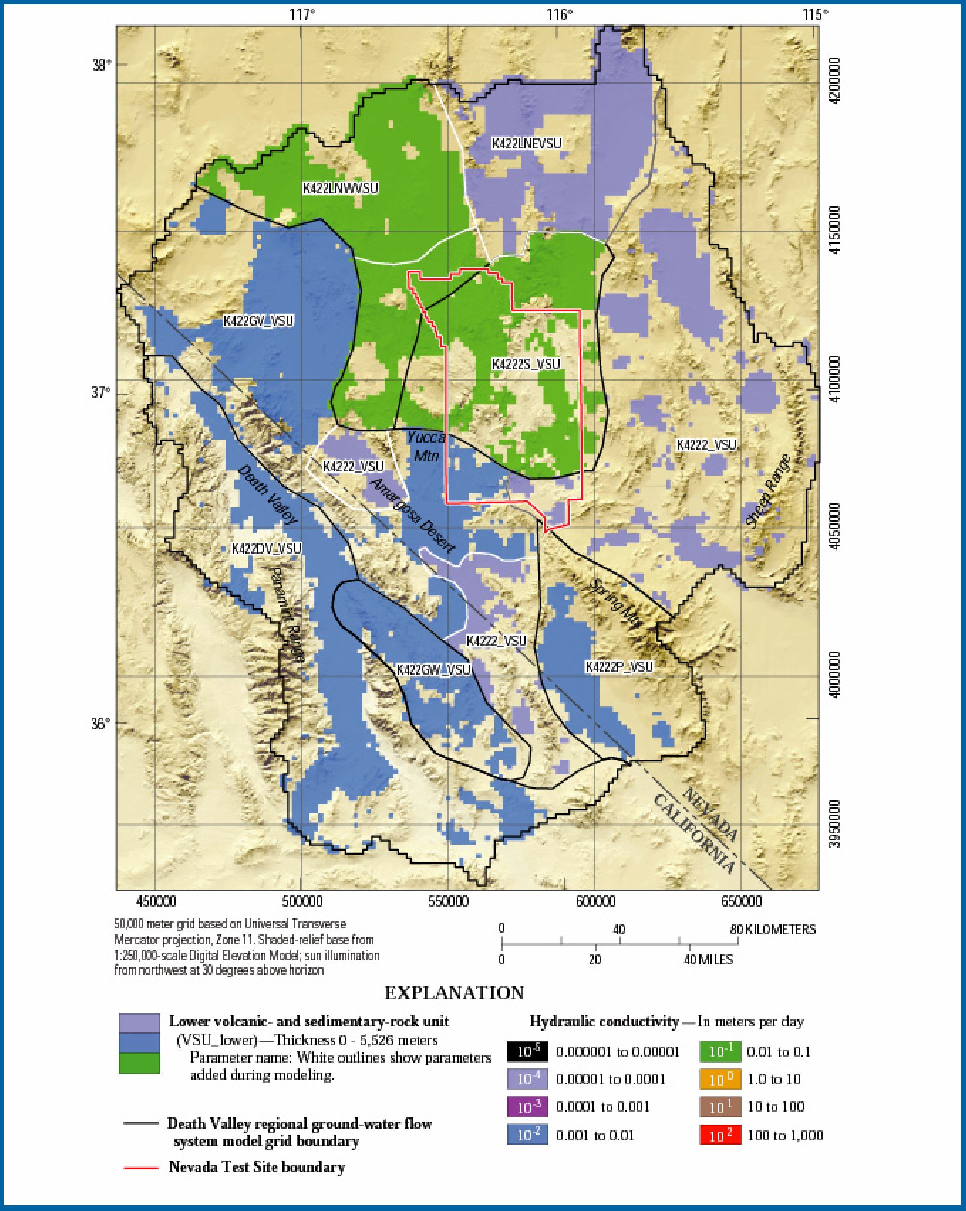
Death Valley (example)

Property Zones

Zonation for changes in hydraulic properties based on:

- Alteration and welding
- Facies changes
- Structural deformation
- Depth decay

(HUF Package)



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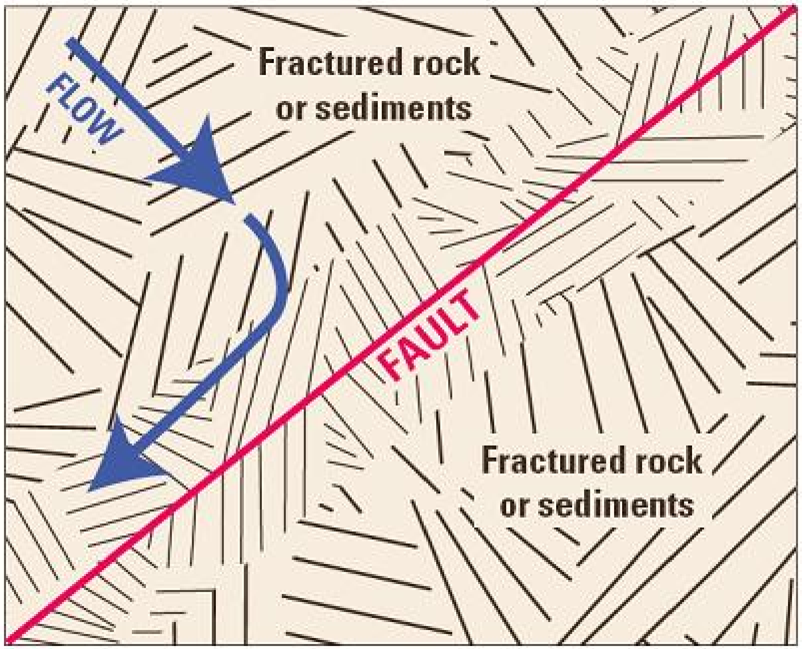
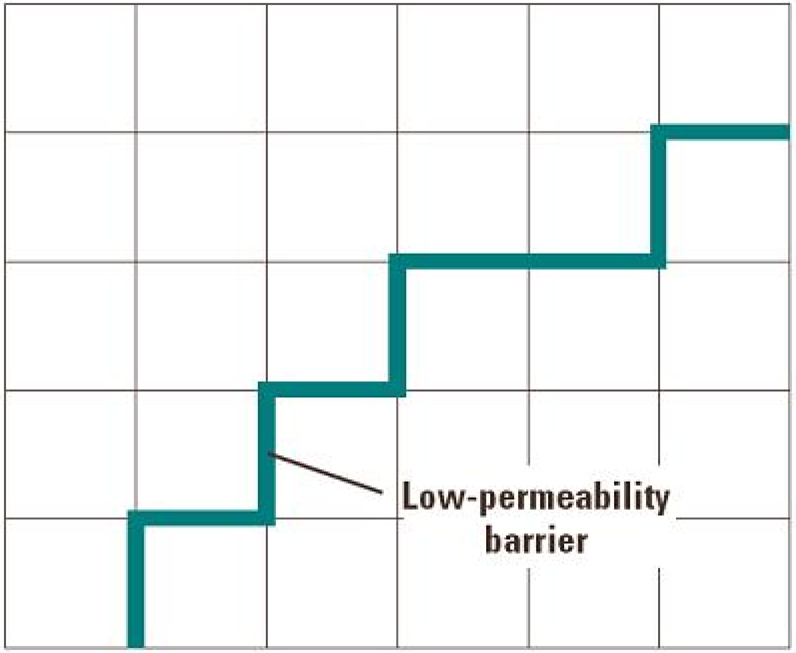
Flow Barriers (faults)



Natural conditions



Flow Model
(Horizontal flow barriers)

(HFB Package)

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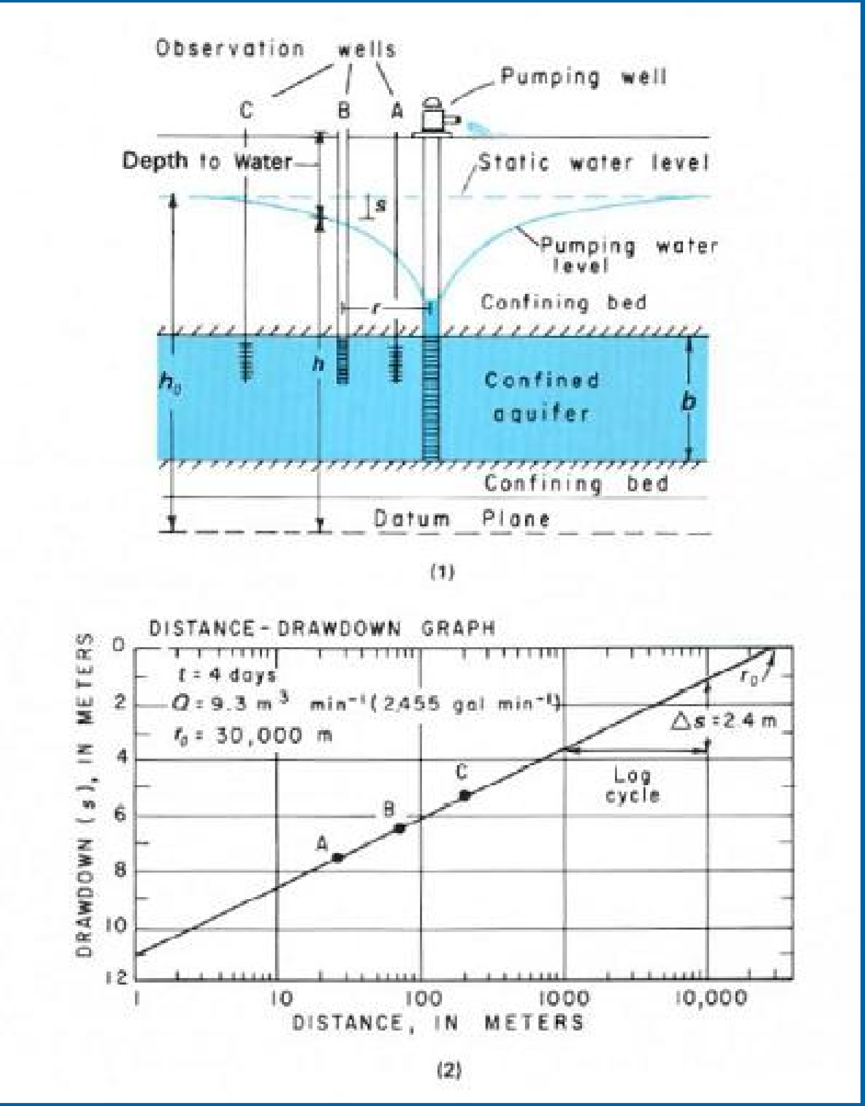
Hydraulic Properties

How water flows through material

Aquifer tests

- Hydraulic conductivity
- Storage



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Natural Discharge - Springs

Regional vs. local

Measured
Estimated

(DRN Package)

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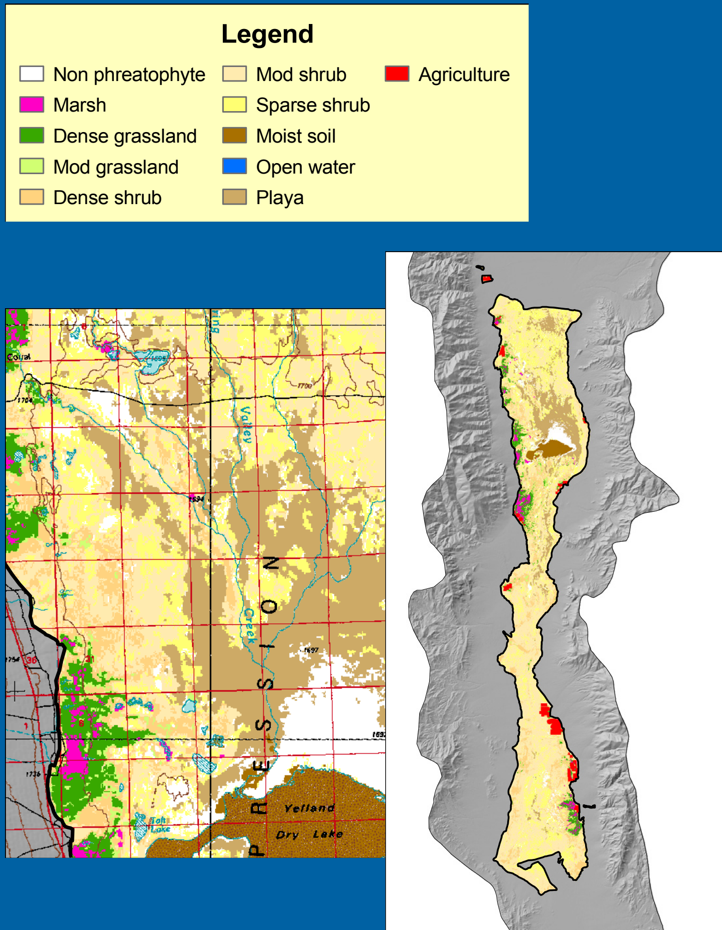
Natural Discharge Evapotranspiration

Microclimatological studies

– ET rates



Remote sensing

– Acreages of ET areas

GW Discharge = (Area * ET Rate) – Precipitation

(DRN Package)

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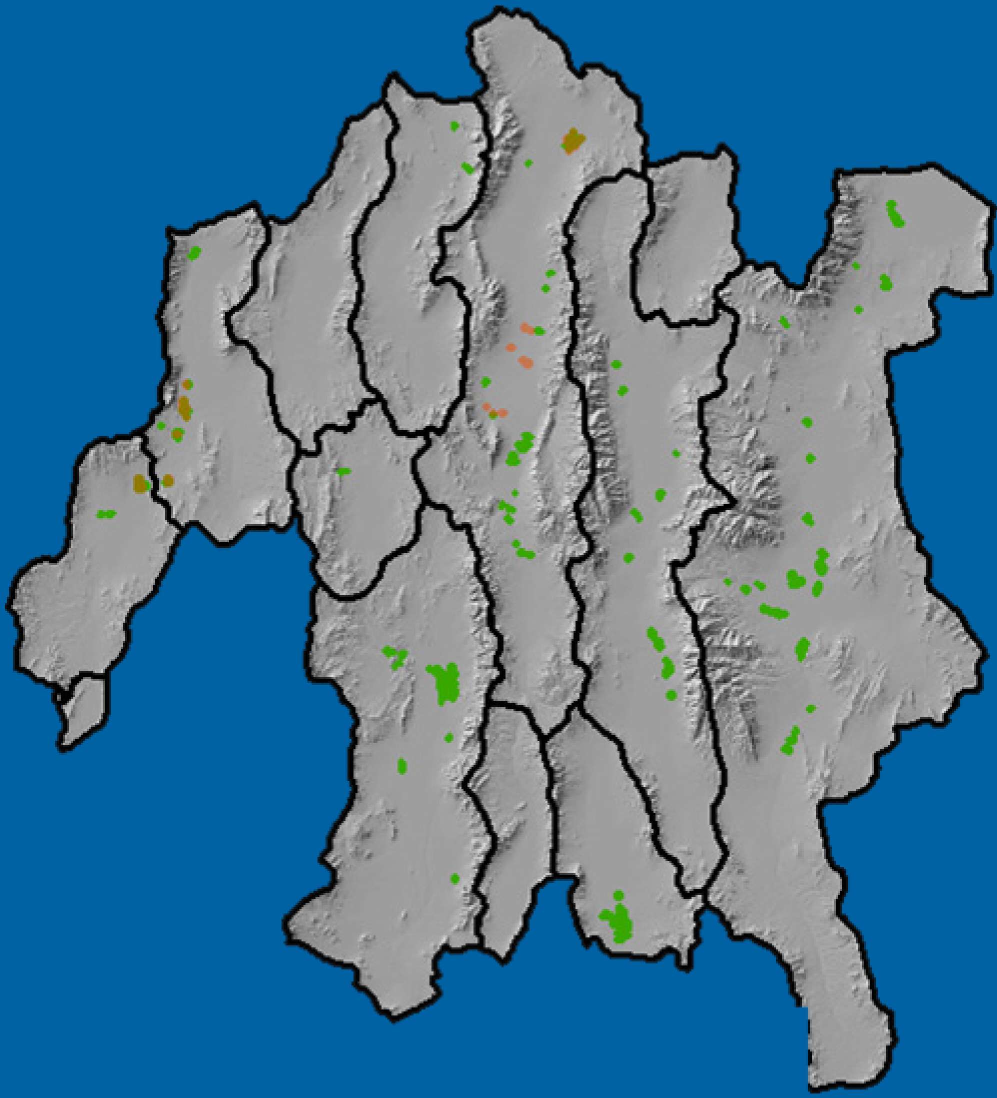
Anthropogenic Discharge - Pumping

Historical records

- Irrigation/Stock
- Domestic
- Water systems
- Mining

Remote sensing

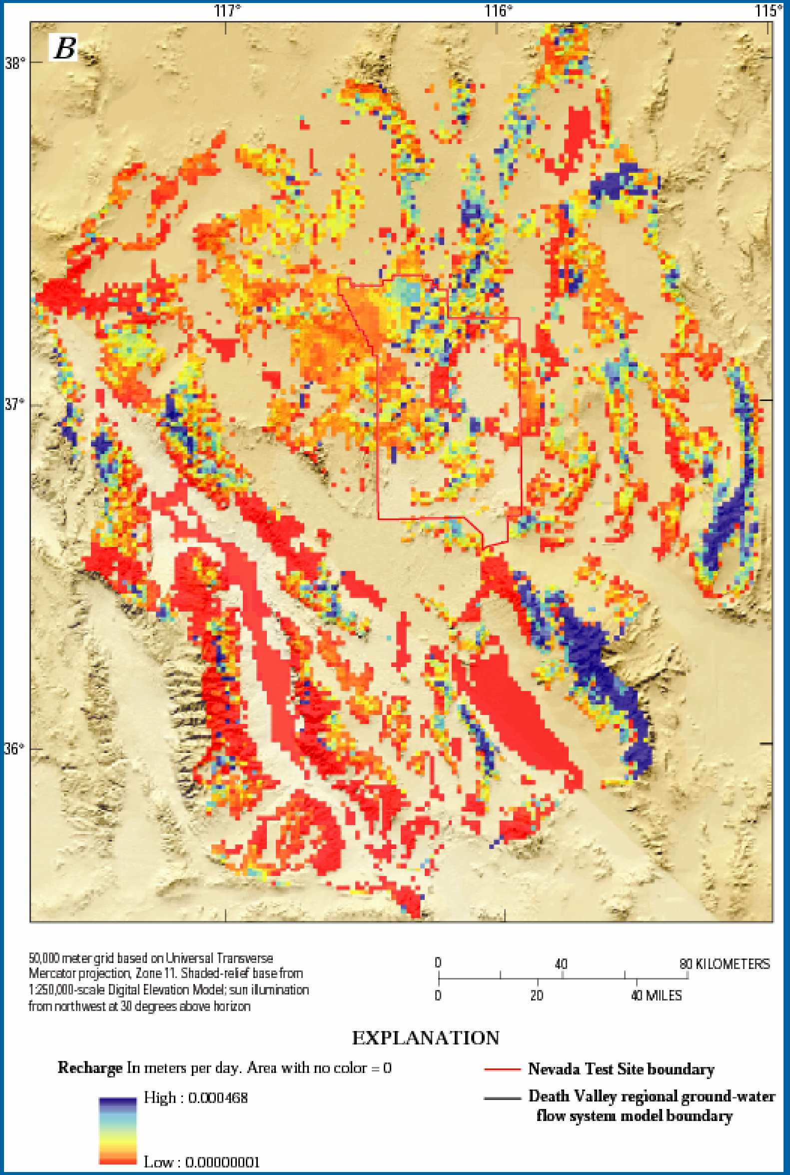
(MNW Package)



Recharge

- Process-based
- Altitude, geology, vegetation
- Net infiltration

(RCH Package)



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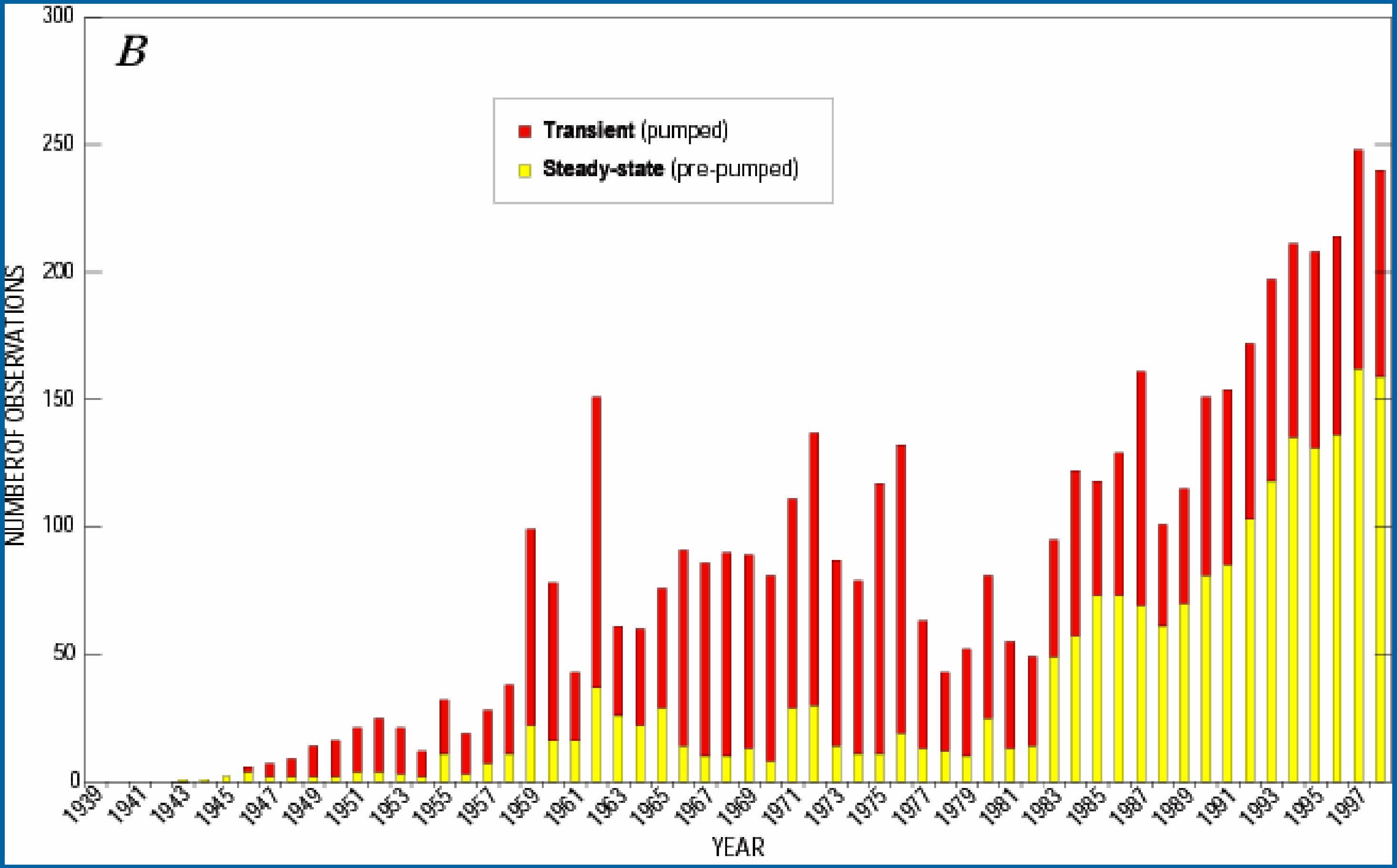
Hydraulic-Head (Water level) Observations



Steady-State ("predevelopment")
Transient (pumping)

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Boundary Conditions

How and where water enters or leaves system

Physical

ex., lakes, streams, wetlands, springs, recharge, ET

Artificial (non-physical)

ex., no-flow or flow line

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Calibration

Compare calculated vs. measured
- Water levels
- Flows
- Discharges

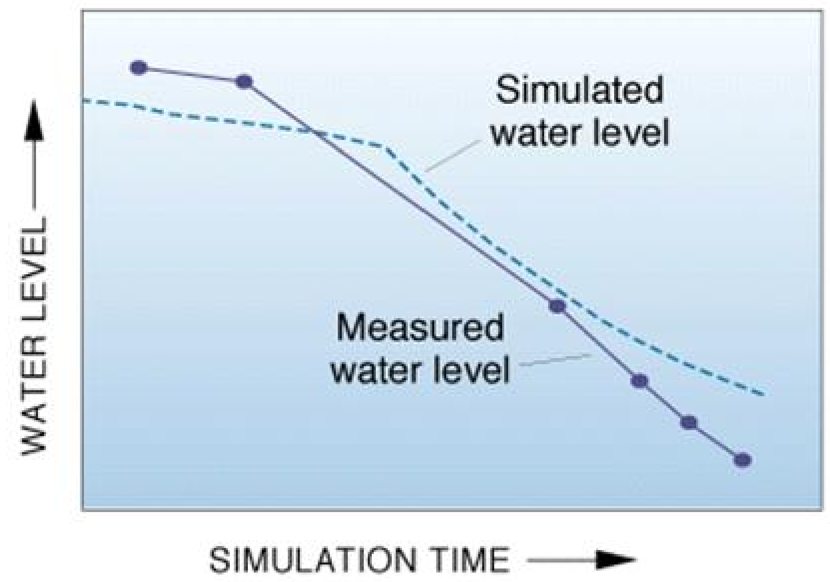

Figure 3. Example comparison of com-puted and measured water levels.

Adjust parameters
- Manually (trial and error)
- Automatically (parameter estimation)

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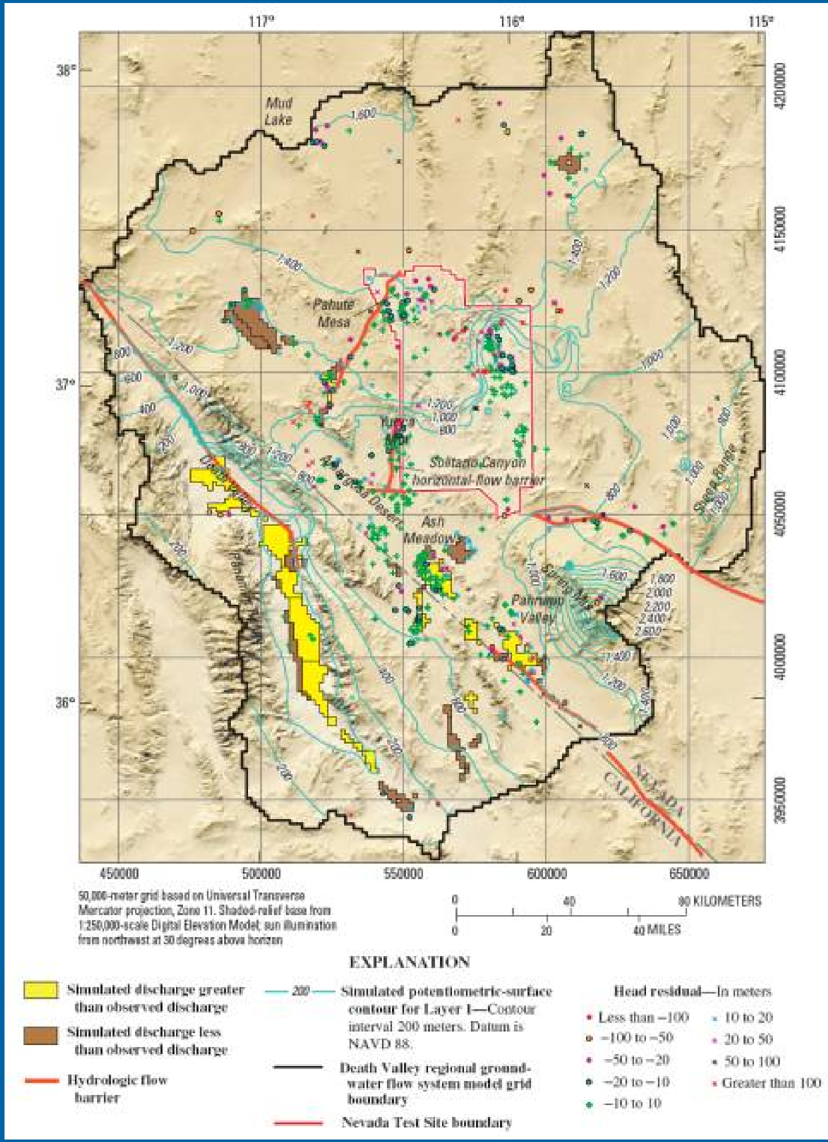
Calibration: Matching Observations

Matching the observations to reality

- Flows
- Spring discharge
- Hydraulic heads (water levels)



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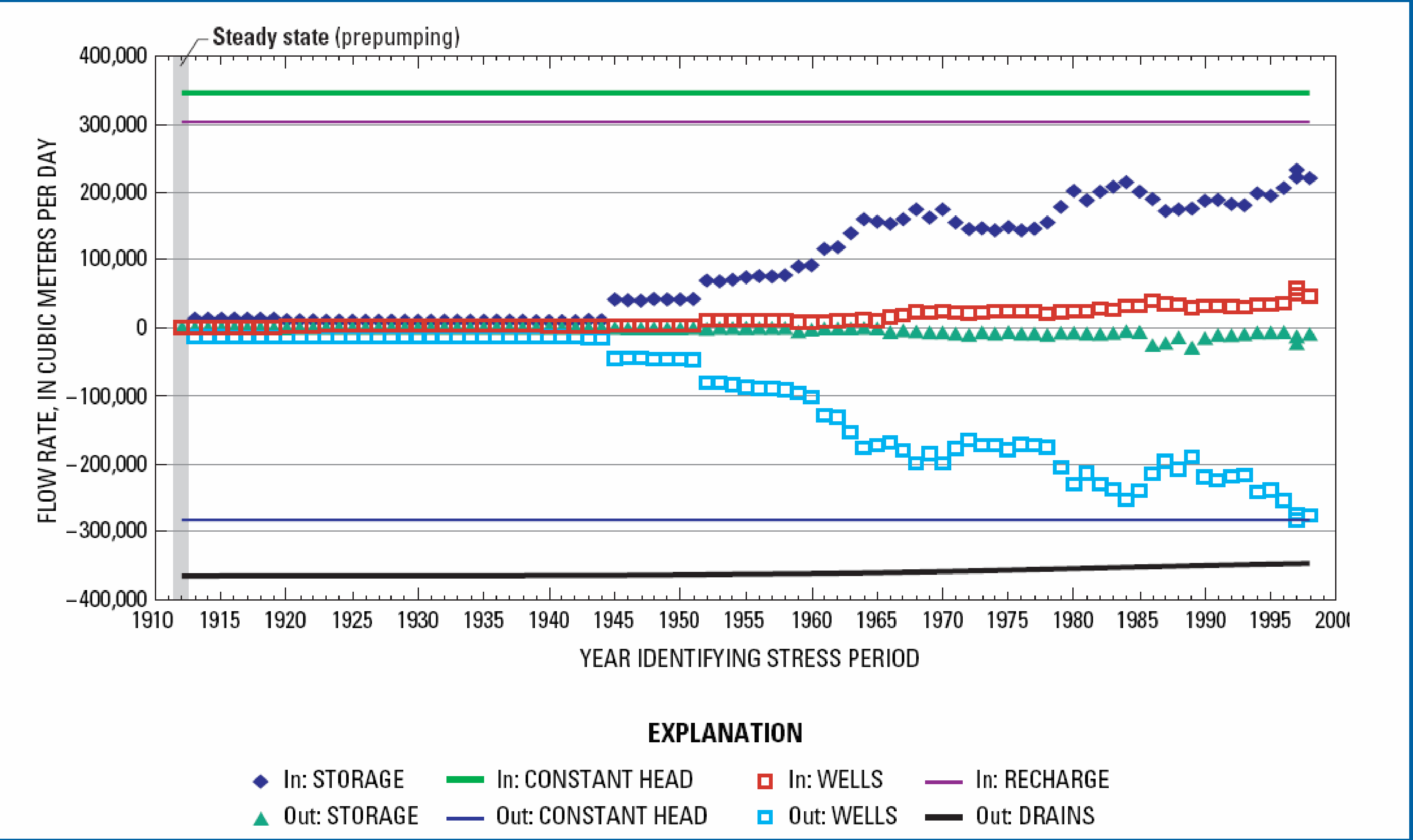
Mass Balance



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Regional vs. Local

REGIONAL MODELS

Good for answering regional questions

- Boundary conditions for local-scale models
- Decrease in spring discharge based on pumping in region
- Change in water levels based on pumping over time

LOCAL MODELS

Site-specific scale models to address more detailed concerns

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Regional Models in Nevada

Regional Aquifer-system Analysis (RASA):

- Carbonate-rock province of Nevada, Utah, and adjacent states

Death Valley Regional Ground-water Flow System (DVRFS):

- Several versions
- Most recent is 3D transient (1913-98)
- Updating

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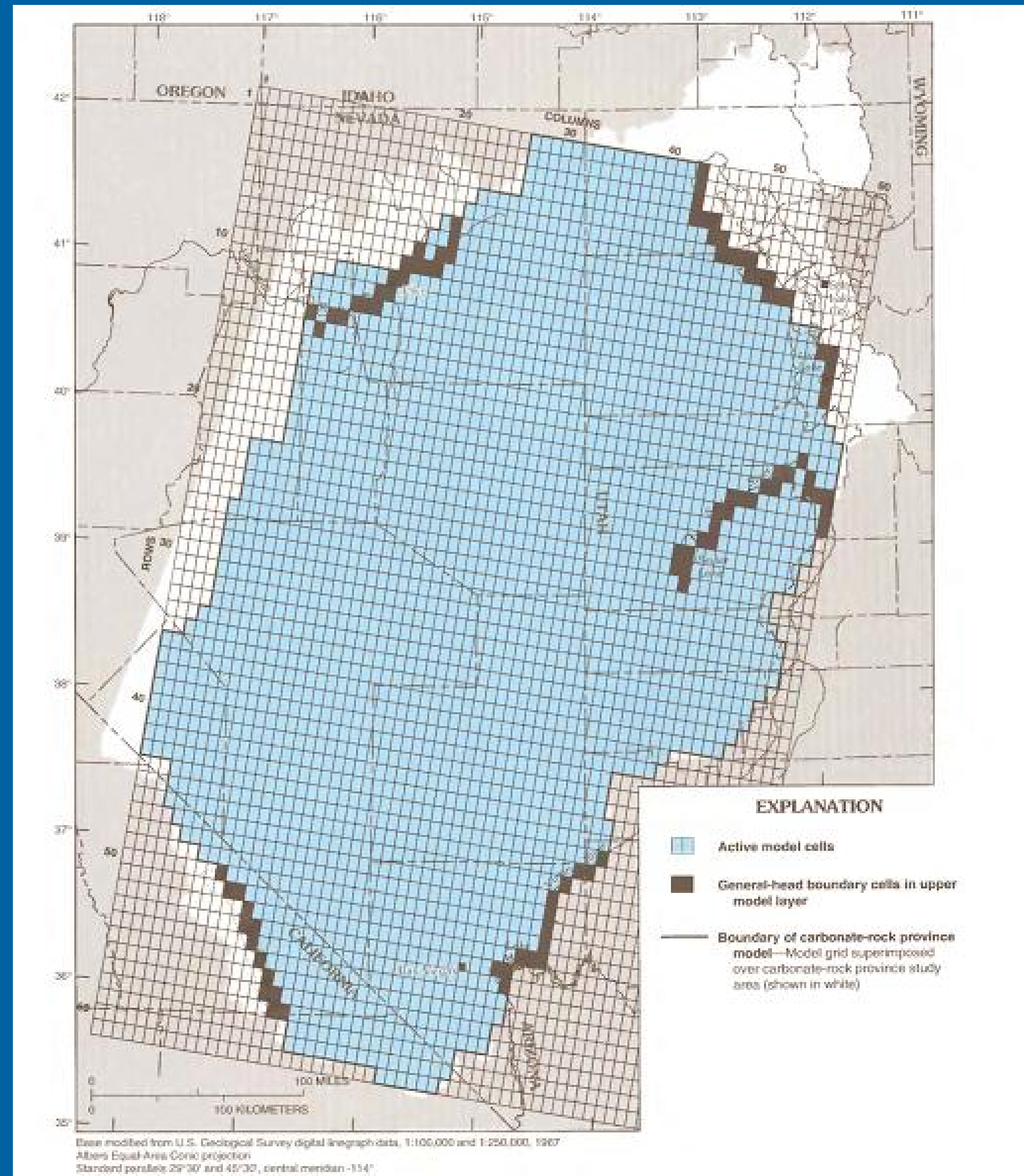
RASA – Carbonate-Rock Province

Test conceptual model

Interbasin flow

Alluvium/carbonate



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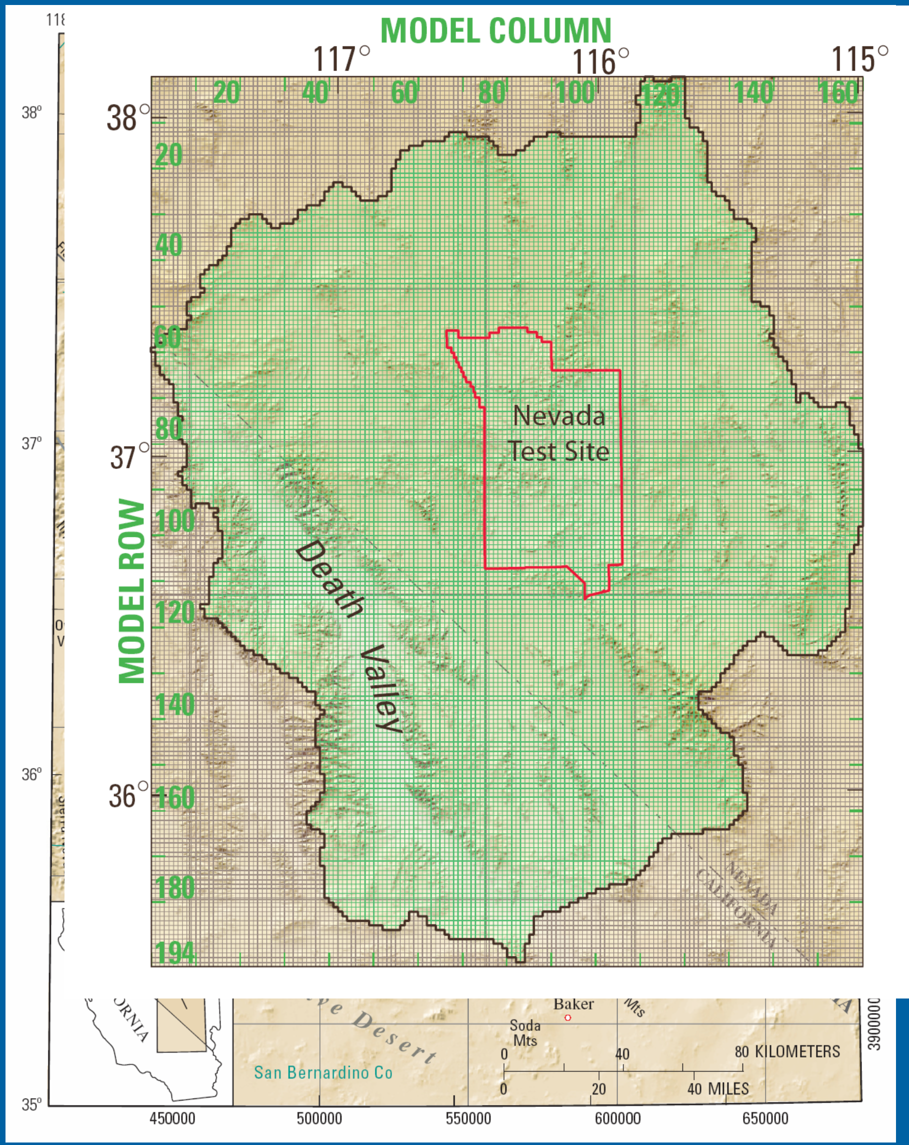
Death Valley Regional Ground-Water Flow System

Large area

Complex geology

Arid climate



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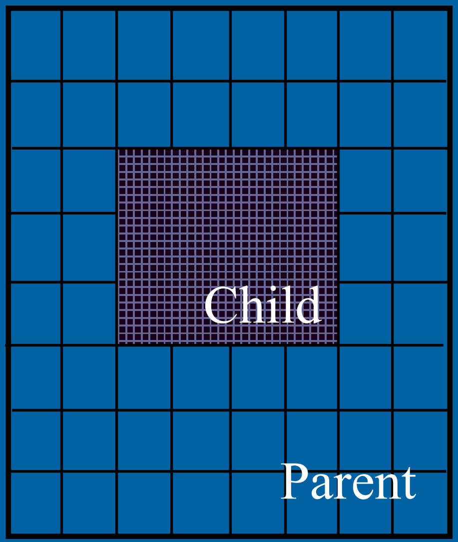
Linking Regional and Local Models

Telescoping Mesh

- model-within-a-model
- two separate models.
    - BCs for the child grid (hydraulic head or flow)
    - No feedback from child grid
    - Very flexible – can combine different types of models

Directly embedded

- Modify regional grid for local grid
    - Solve as a single grid
    - Integrated “co-calibration”
    - Local grid refinement



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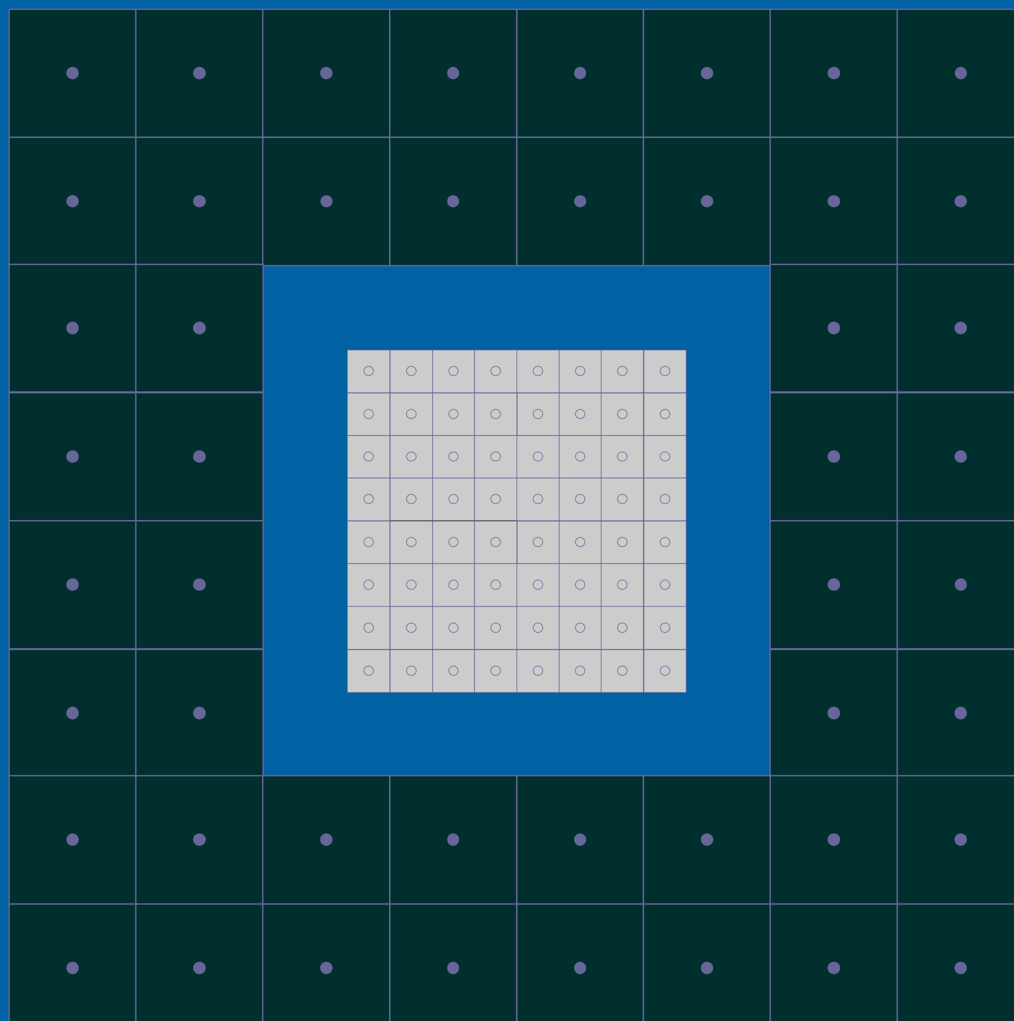
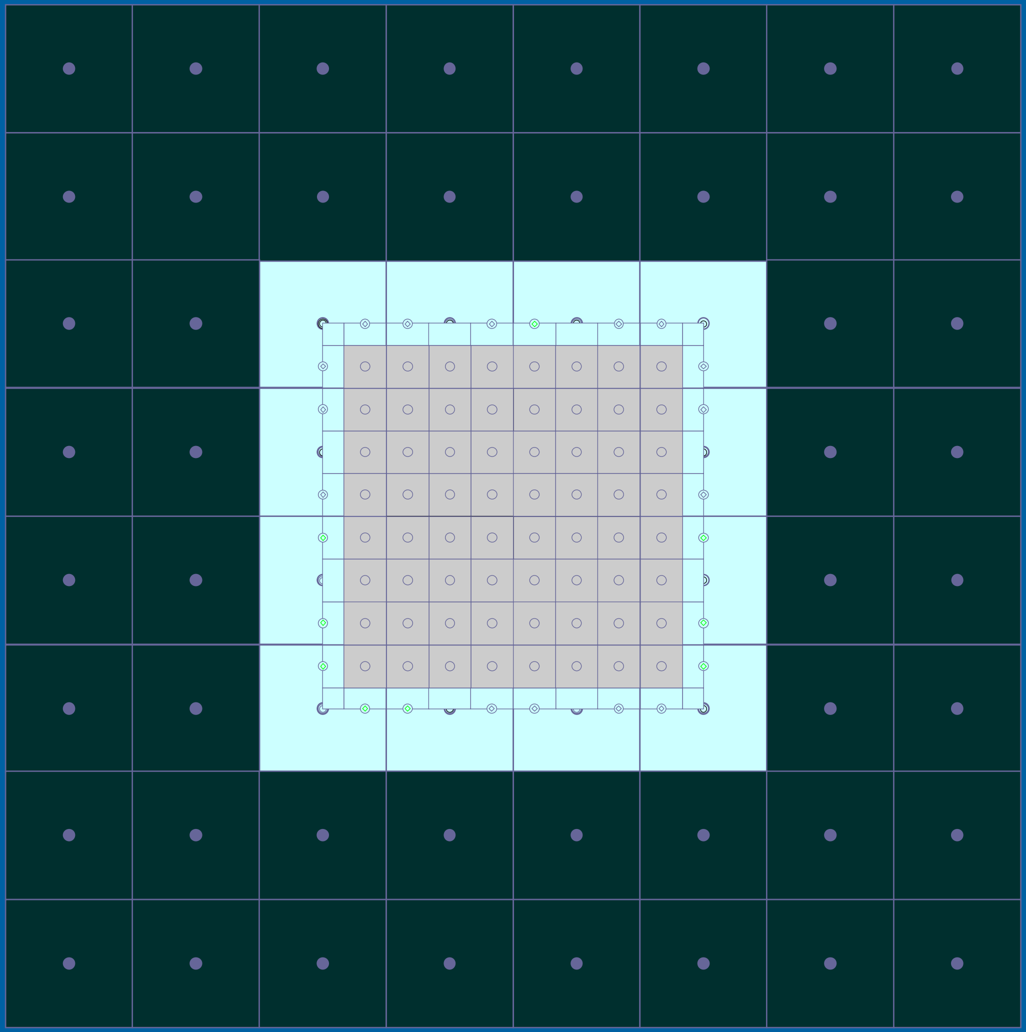
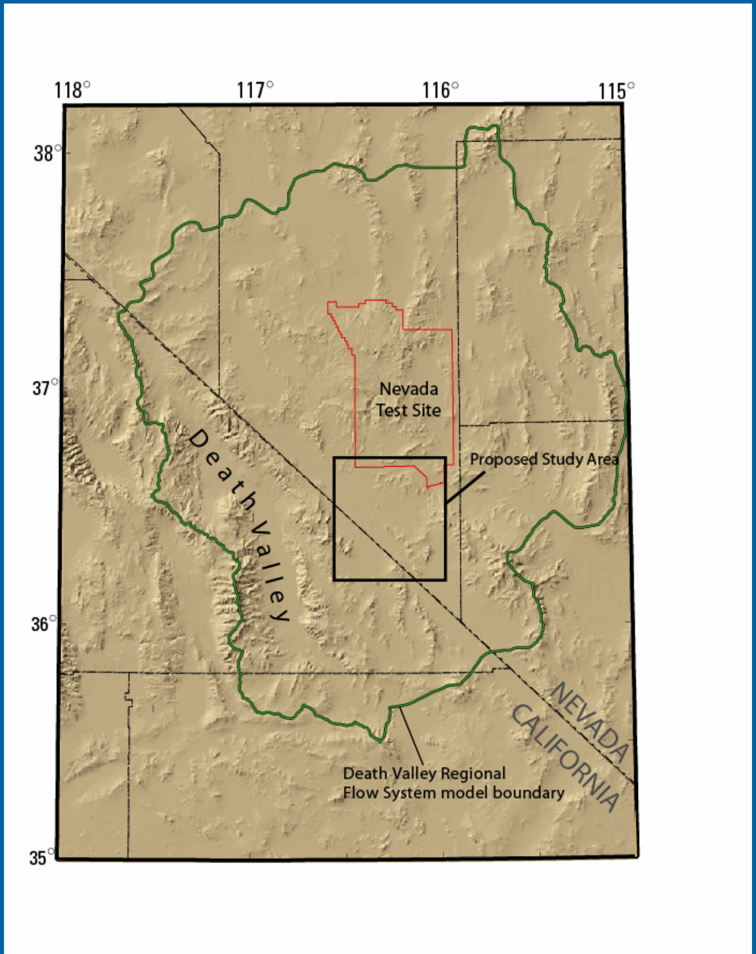
LGR Package Grid Structure

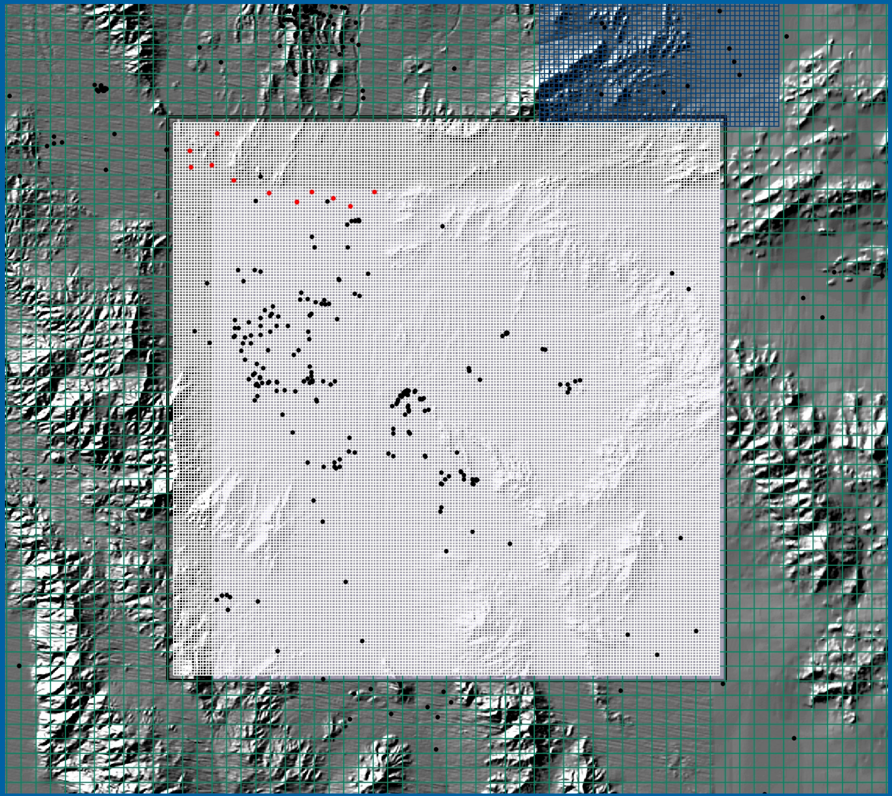


LGR Package Grid Structure



Southern Amargosa Desert – Embedded Model





5:1 refinement ratio
Embedded model grid is 5 X finer than regional model
Grid size of 300 m vs 1,500 m

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Southern Amargosa Desert Water-Resource Issues

Potential pumping effects on:

- Ash Meadows Devils Hole, and selected reaches of the Amargosa River
- Amargosa Desert from Pahrump Valley
- Mesquite-woodland habitat from Pahrump or Amargosa Valleys
- Federal water-rights allocations

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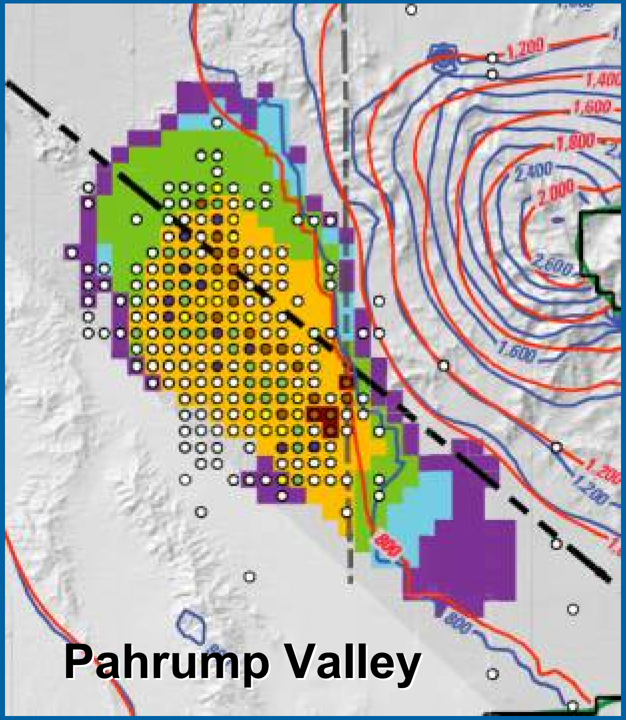
Utility of Numerical Models

- Data integration
- Resource management tool
- Predictive tool
  - Impacts from pumping
  - Impacts from climate change

Water levels
Spring flows
Flow paths



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Photograph by Donald S. Sweetkind