Limitations of perennial yield concept and principles of groundwater sustainability in Nevada

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Central Nevada Water Authority
March 18 2016, Eureka, NV

Outline of presentation

- Groundwater and Surface water – A single resource
- What is perennial yield?
- What are limitations of perennial yield concept?
- What is groundwater sustainability?
- What information is needed for sustainable decisions?
- Comparison of perennial yield and sustainable concepts.
- Sustainable strategies and examples.

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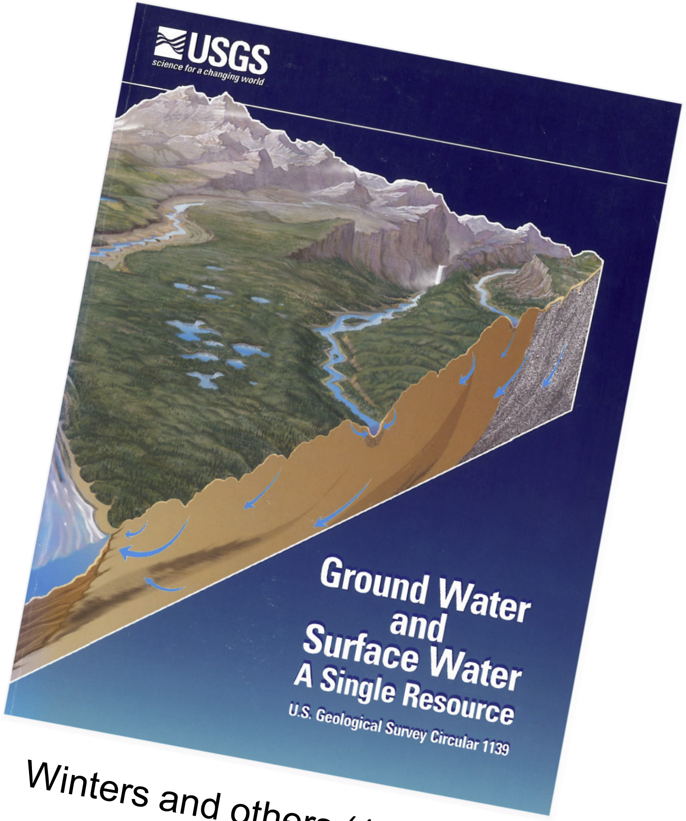
Groundwater and Surface Water are a single resource

Important concept for understanding how groundwater works.

And how Nevada's water resources should be conceptualized.



Winters and others (1998)

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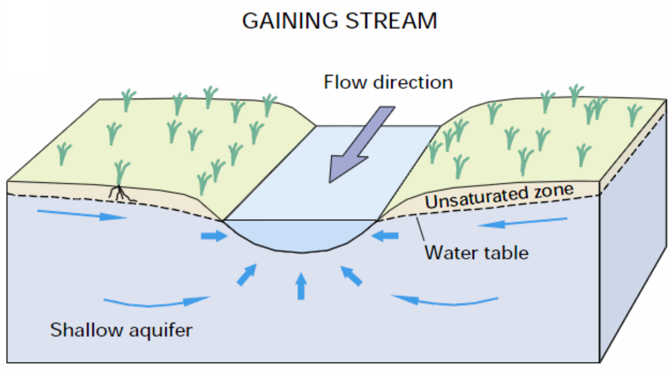
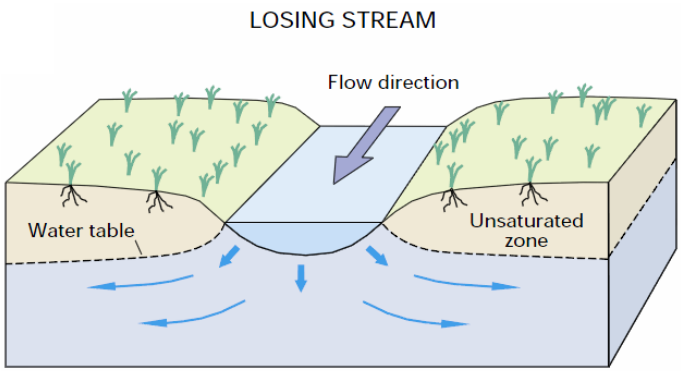
Groundwater and Surface water are a single resource

- **Streams flowing year-round are connected with groundwater.**
- **Groundwater can:**
  - **Discharge to a stream (gaining stream).**
  - **Receive water from a stream (losing stream).**
- **Streams can:**
  - **Lose water to groundwater (losing).**
  - **Gain water from groundwater (gaining).**





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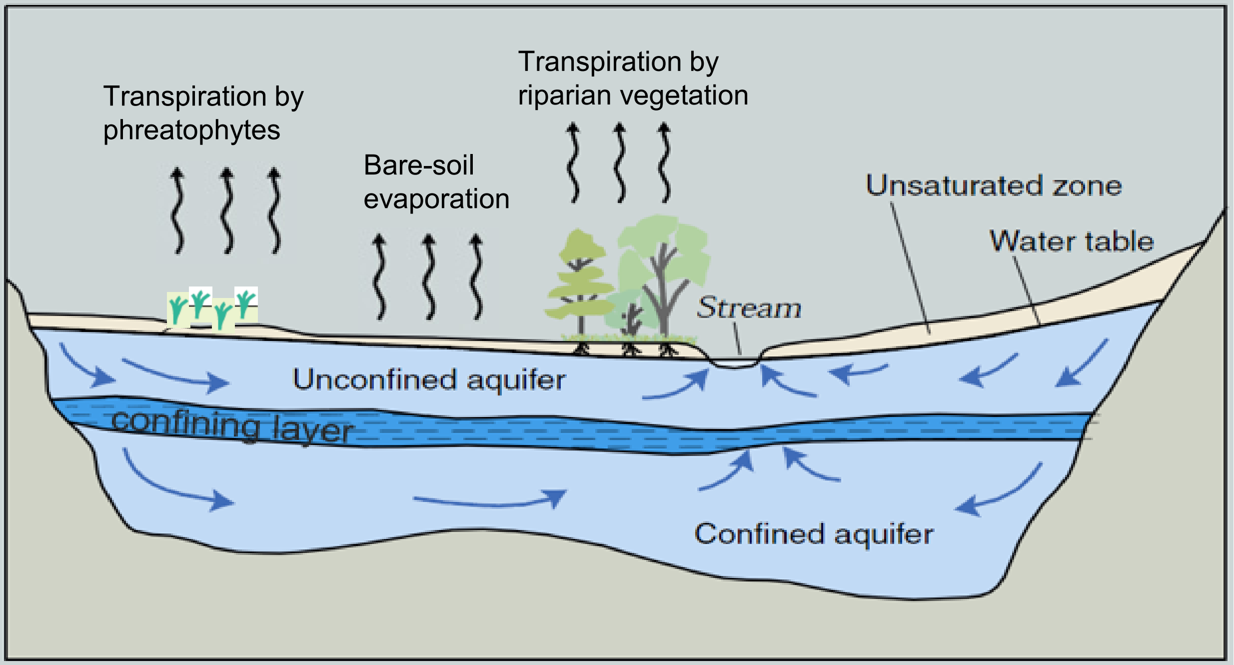
$$ET = Evapotranspiration = Evaporation + Plant\ Transpiration$$

- **Phreatophytes – desert shrubs that use shallow groundwater.**
- **Riparian vegetation – trees and shrubs that grow along water features using shallow gw.**
- **Evaporation**
  – shallow gw through soil.
  – open water.



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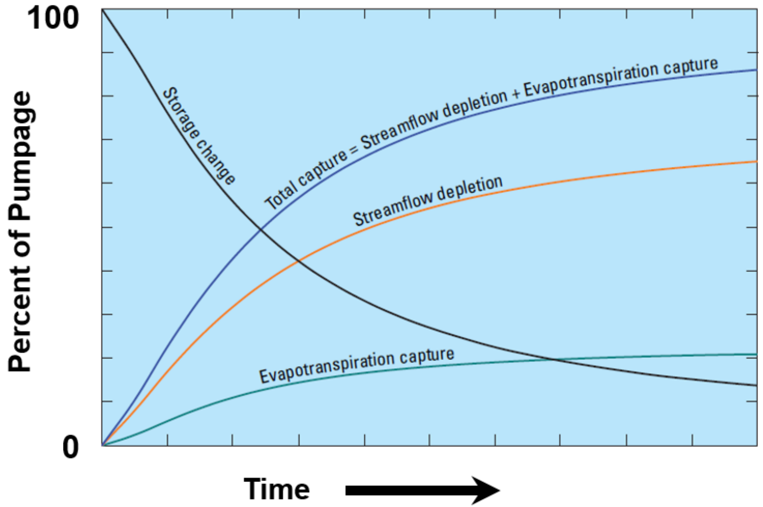
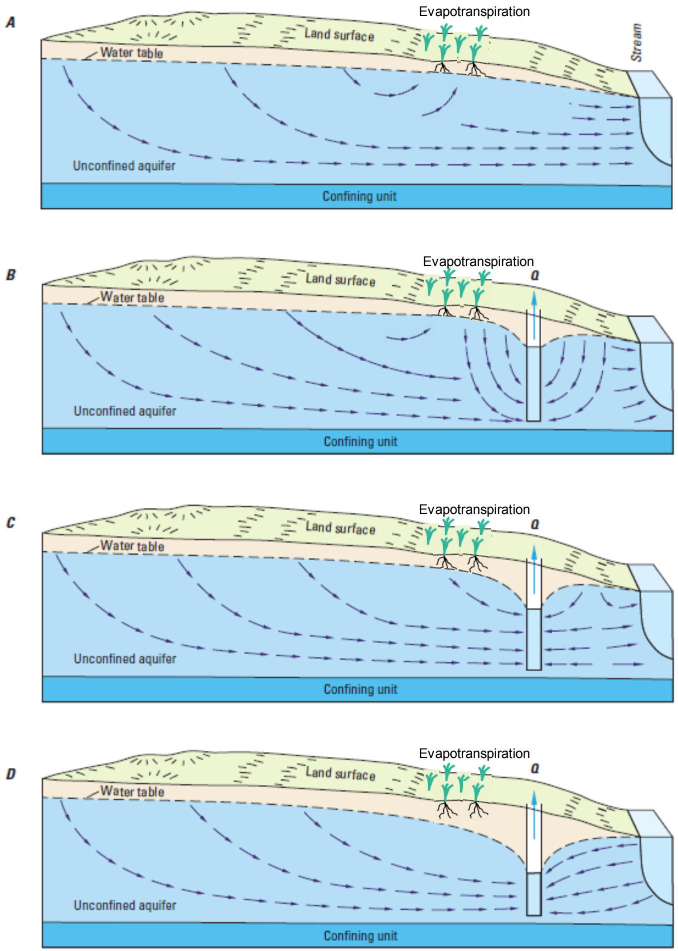
Source of water to wells

- **Storage change – water from aquifer near well.**
- **Streamflow depletion – diversion from stream.**
- **Evapotranspiration capture – water intercepted from plant use and evaporation.**





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Perennial Yield

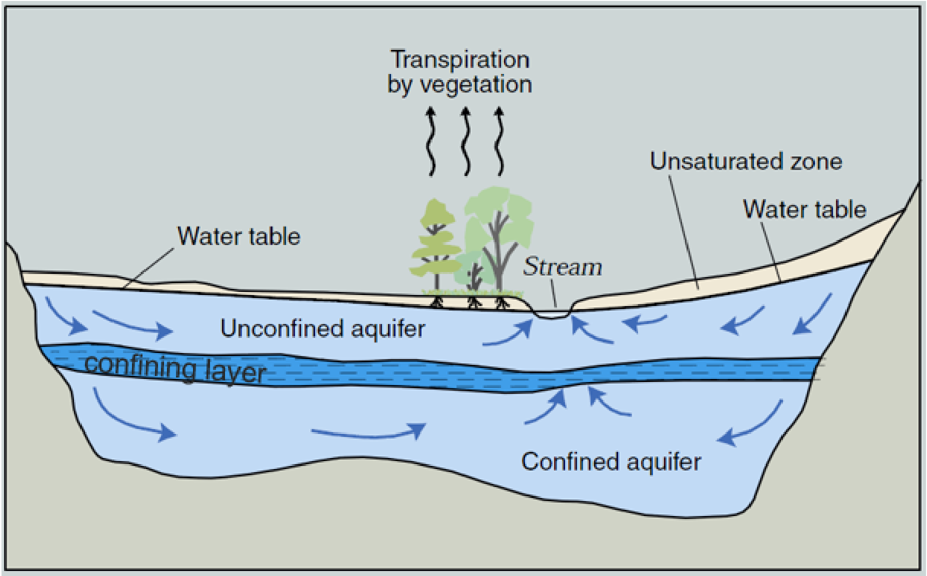
"Perennial yield is the maximum amount of groundwater that can be salvaged each year over the long term without depleting the groundwater reservoir."

source: Nevada Water Law 101
http://dcnr.nv.gov/documents/documents/nevada-water-law-101/

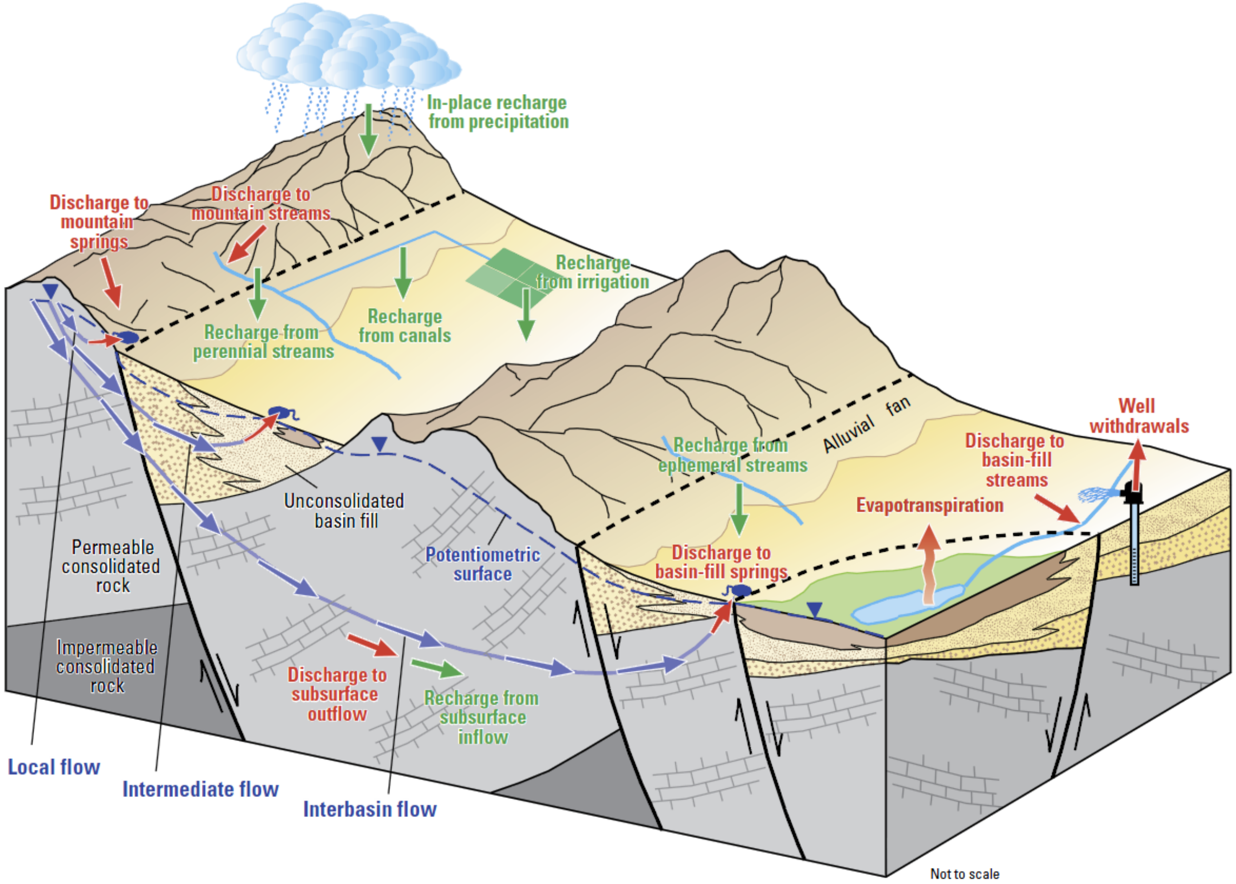
- Amount of groundwater in a given hydrographic area available for appropriation.
- Perennial yield is determined from estimated groundwater budgets for each of the hydrographic areas.

Groundwater Budgets

- **Summarize hydrologic inflows and outflows from a groundwater basin.**
- **Prior to groundwater development; water entering a groundwater system is equivalent to water leaving the system.**
- **Once groundwater development begins; pumping and storage change become part of the budget.**



Groundwater Budget Components



Recharge is water inflow to groundwater system:

From precipitation, streams, irrigation, and subsurface inflows.

Storage change:

Change in amount of water in aquifer; change in water level.

Discharge is water outflow from groundwater system:

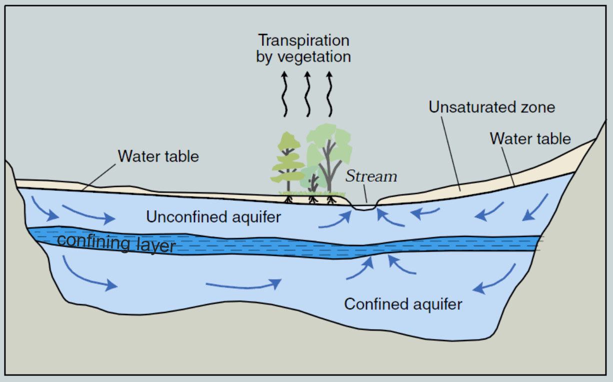
Streams and Springs.

Pumping and subsurface outflow.

Evapotranspiration includes evaporation from soil and transpiration from groundwater dependent vegetation.

Limitations of Perennial Yield concept

- Under ideal conditions, perennial yield is effective concept.
- Has constrained over-development of groundwater resources Nevada.
- In many basins, groundwater discharges to streams, springs, and wetlands.
- Estimates of perennial yield usually include this discharge.
- But streams and springs are often already appropriated for beneficial use or provide critical habitat.



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"Perennial yield is the maximum amount of groundwater that can be salvaged each year over the long term without depleting the groundwater reservoir."

Limitations of Perennial Yield concept

- **Ideal results from groundwater development using perennial yield concept.**
  - **All groundwater discharge is intercepted.**
  - **No phreatophytic vegetation remains.**
  - **Springs dry up.**
  - **No riparian areas around springs.**
  - **Stream baseflows disappear.**
  - **Groundwater level declines stabilize at some reasonable level.**

(Dorothea Lange/Farm Security Administration/Office of War Information Photo Collection/Library of Congress)

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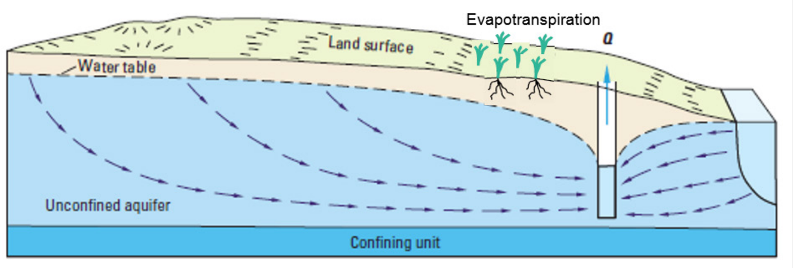
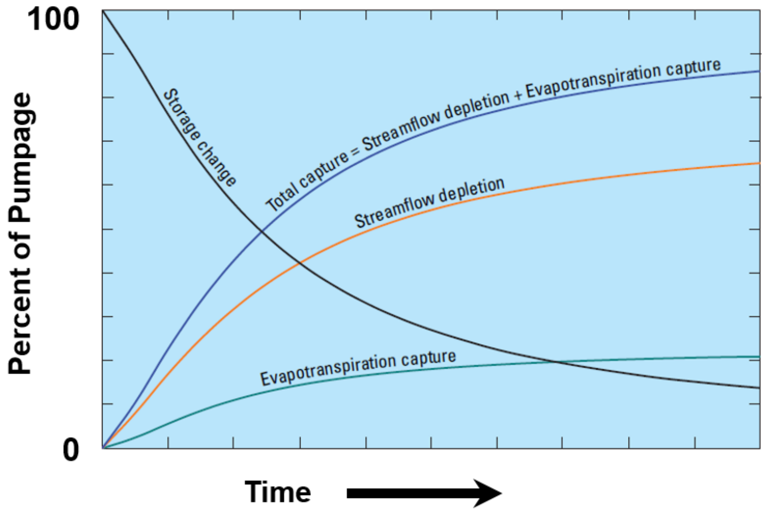
Limitations of Perennial Yield concept

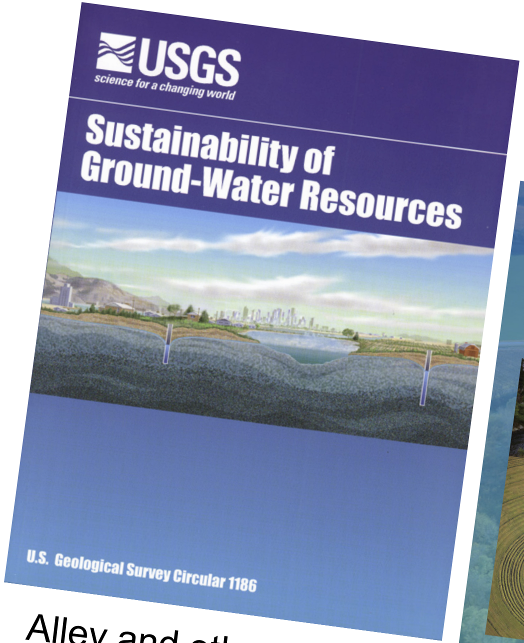
- Groundwater and surface water are a single resource
- Cannot capture evapotranspiration without also depleting springs and streams.
- A new perspective for groundwater management needed.



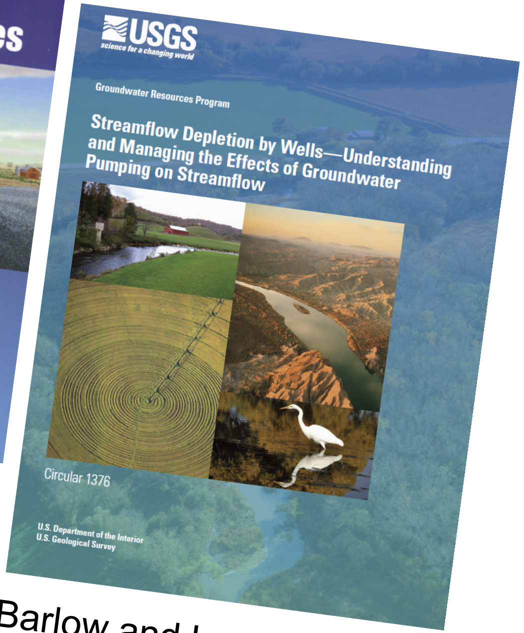


What is Sustainability of Groundwater Resources?

- A different perspective for thinking about groundwater.
- Perspective changes from ‘How much flow is entering system’ to ‘What are acceptable changes to the system’?
- Recognizes interrelation of groundwater and surface water.
- About understanding effect of pumping on *timing, rates,* and *locations* of depletions (diversions).



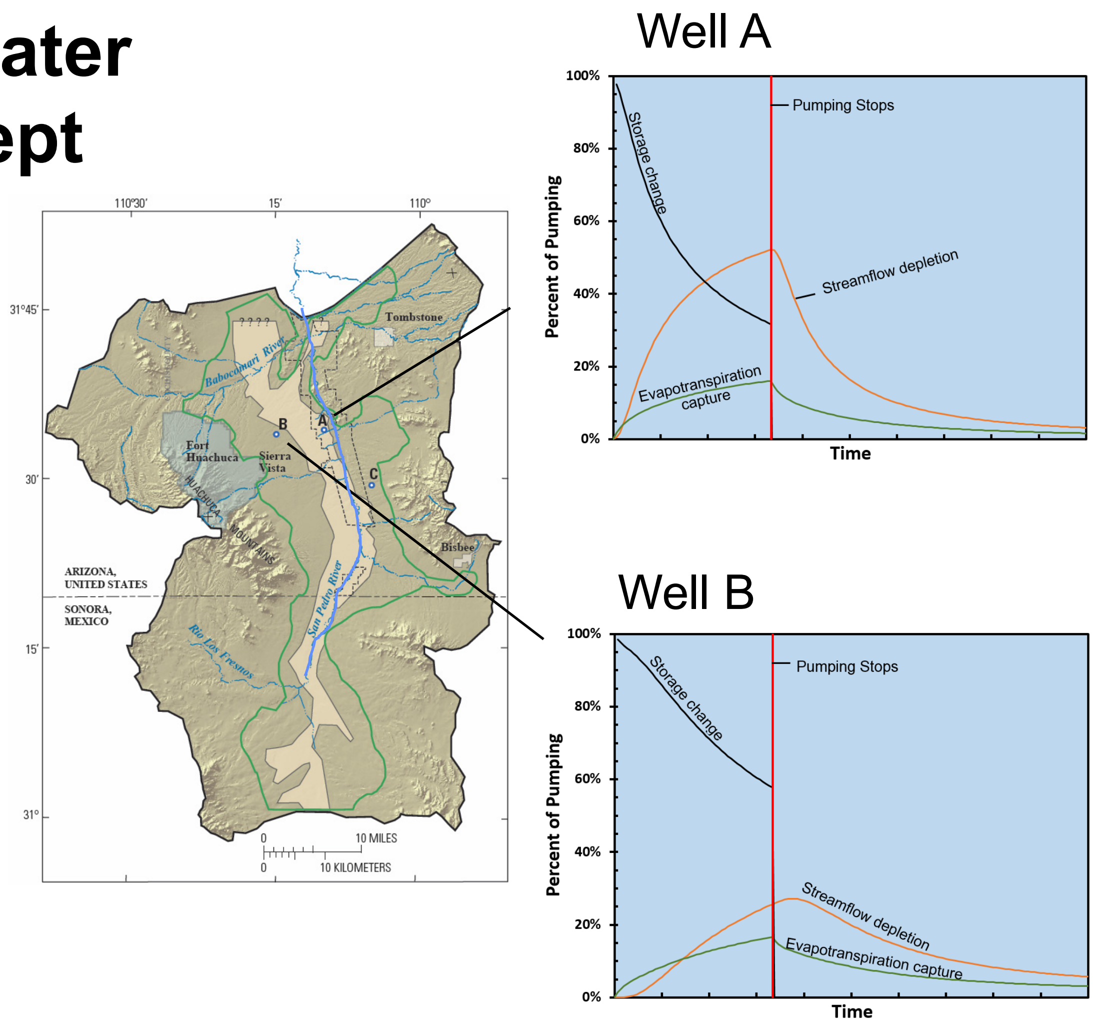
Alley and others (1999)



Barlow and Leake (2012)

Sustainable groundwater – Illustration of concept

- **Understanding that wells at different distances from river will:**
  - **Get their water at varying proportions from storage, streamflow depletion, and captured evapotranspiration.**
  - **The closer well (Well A), takes a greater proportion of water from the stream sooner.**
  - **The further well (Well B), takes a smaller proportion from stream, but for a longer duration after pumping stops.**



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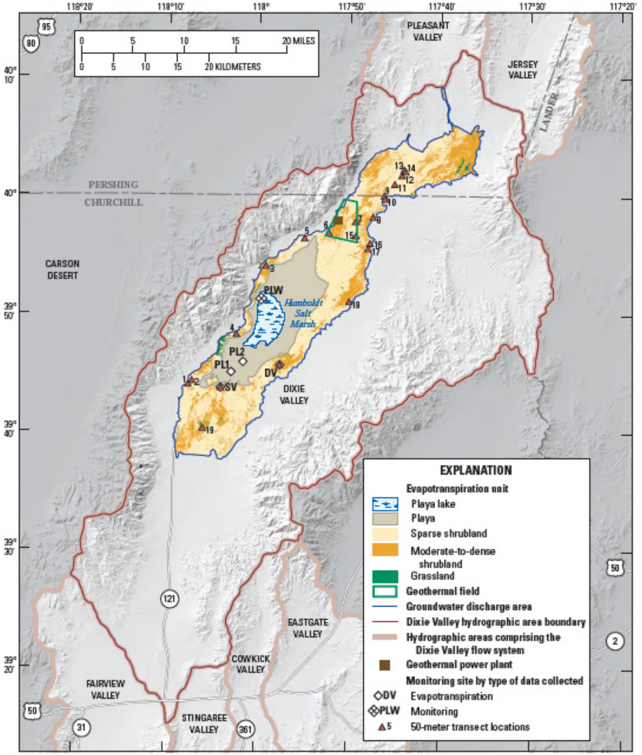
Information needed for sustainable decisions

- **Water budgets.**
  - **How much groundwater is supporting streams, springs, wetlands, and natural vegetation/habitat.**
- **Decisions on acceptable changes.**
  - **How much stream/spring depletion.**
  - **How much reduction in natural vegetation and habitat.**
  - **What is acceptable water level change.**
  - **Mitigation to offset impacts.**
  - **Based on stakeholder values.**

Dixie Valley Discharge map



Base modified from 1:24,000-scale U.S. Geological Survey digital data, 2010. Shaded-relief base from 10-meter National Elevation Data, 2011. Universal Transverse Mercator, Zone 11, North American Datum of 1983

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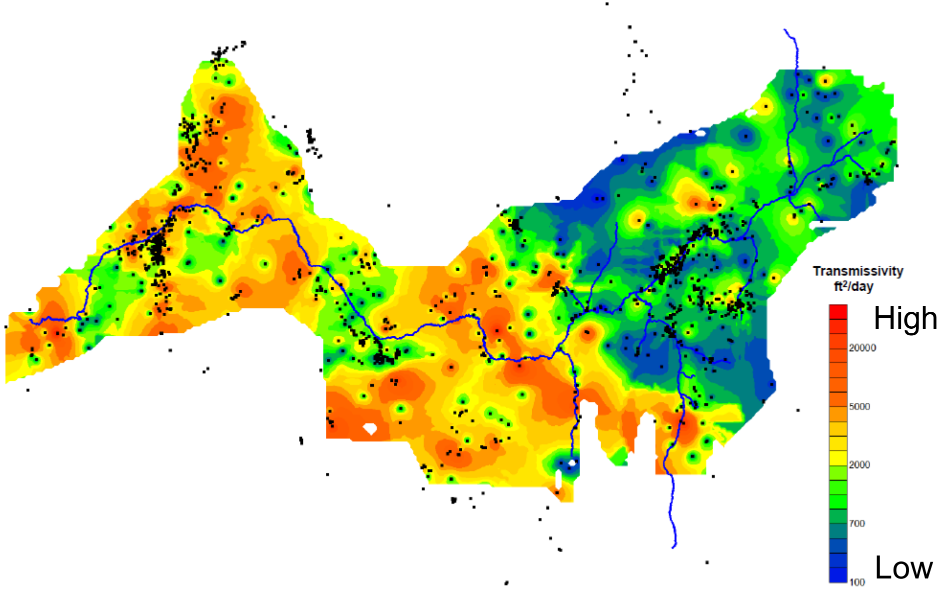
Information needed for sustainable decisions (continued)

- **Properties affecting relations.**
  - **Transmissivity (permeability) and aquifer storage properties.**
  - **Aquifer tests, specific capacity tests, groundwater flow models.**
- **Estimate impacts of groundwater pumping on identified resources.**
  - **Using analytical solutions (Glover analysis, Theis solution, Butler method).**
  - **Using numerical solutions (Groundwater models).**
  - **Response functions and Capture Maps.**

Humboldt River Basin Transmissivity map determined from specific capacity tests. Glover analysis by NSE.



http://water.nv.gov/HumboldtRiver/HumboldtRiverMeetings1-14and15.pdf

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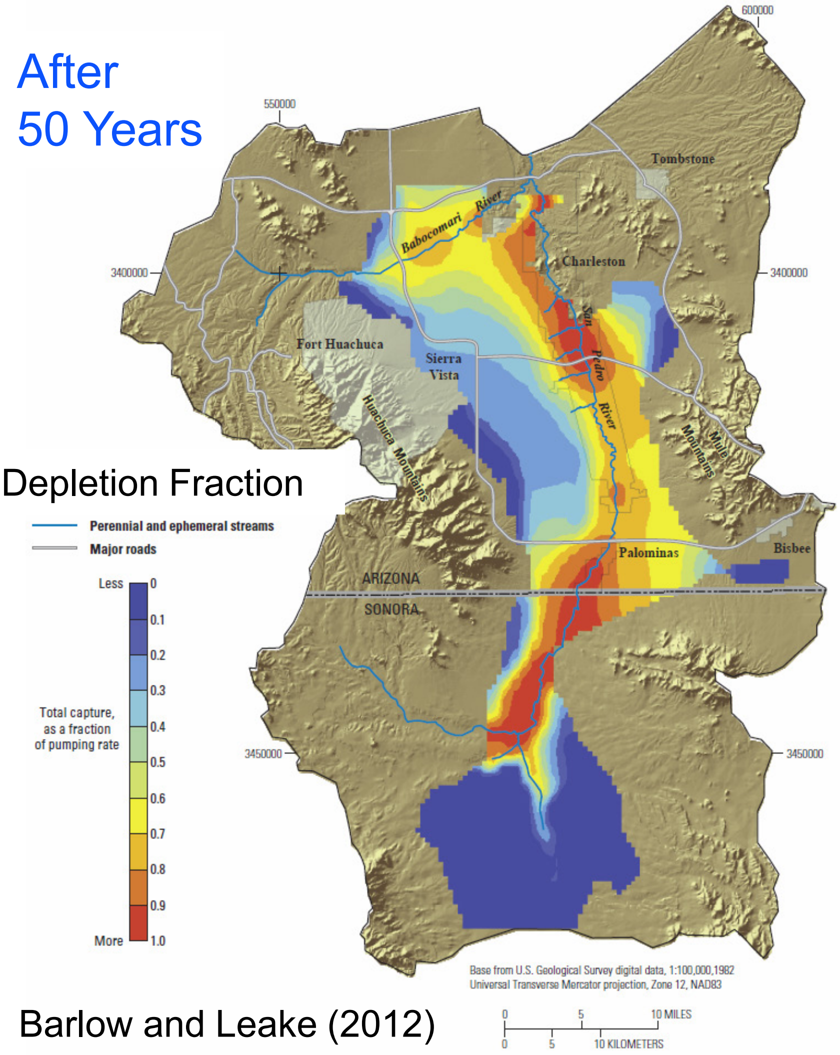
Sustainable groundwater – Capture maps

- **Provide estimates of pumping impacts on other resources based on location and properties of system.**
- **Are for select durations of pumping.**
- **Developed using ‘calibrated’ groundwater flow models.**



Barlow and Leake (2012)

Perennial yield vs Sustainable groundwater use

Component or Action	Perennial Yield	Sustainable groundwater
Water budgets needed	Yes	Yes
Fixed quantity of water	Yes	No
Decisions on acceptable changes	Not needed	Yes
Knowledge of properties	Not needed	Yes
Location of pumping	Anywhere in HA	Relative to features (boundary conditions)
Allows for infringement on existing water rights	Yes	Maybe, but known and mitigated
Overdraft of aquifers	Yes	No
Adaptive management	No	Yes
Sustainable	No	Yes

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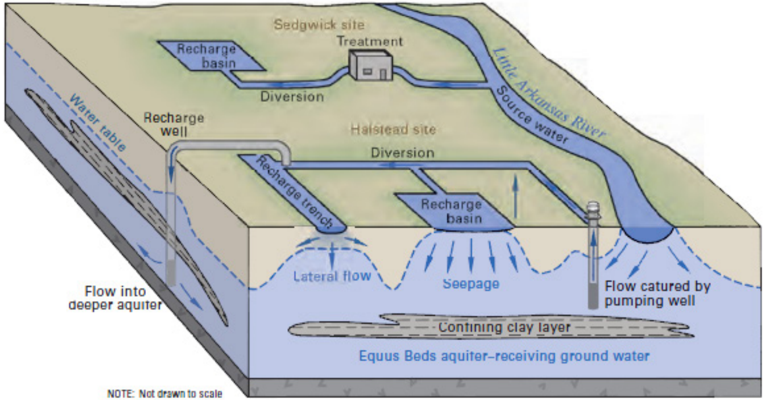
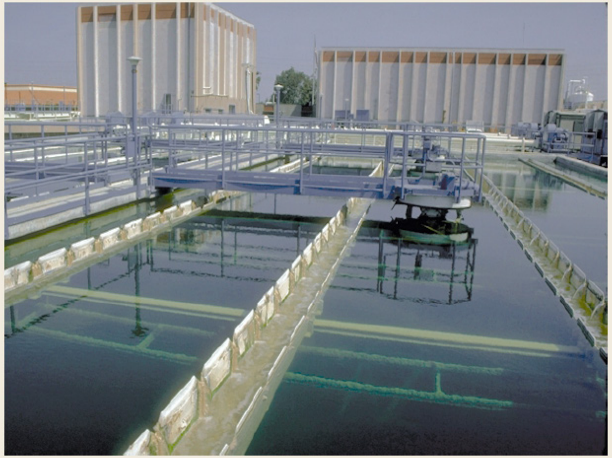
Sustainable strategies

- Use sources other than local groundwater. Artificial recharge.
- Limit withdrawal rates, conservation.
- Locate pumping in optimal locations.
- Optimized pumping schedules and/or rotation.
- Monitoring.
- Adaptive Management.
- Mitigation.





Water Factory 21 treatment facility. (Photograph courtesy of Orange County Water District.)

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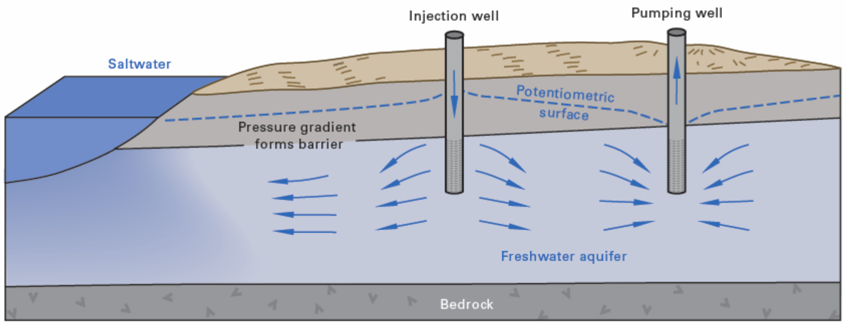
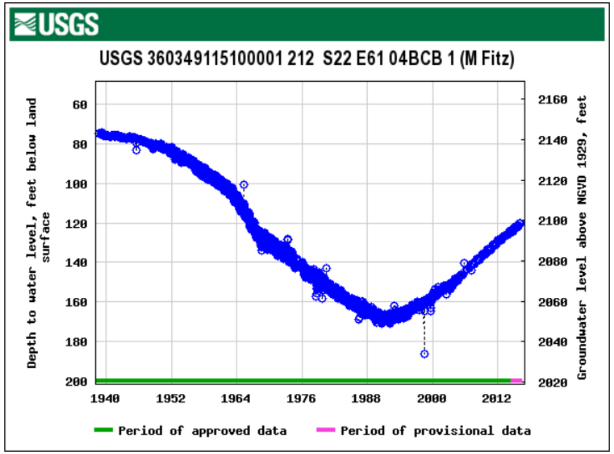
Examples of sustainable groundwater decisions

- **National.**
  - **Orange County, CA – Strategic injection of reclaimed water to prevent saltwater intrusion.**
  - **Long Island, NY – Recharge of storm-water runoff through infiltration basins.**



- **Nevada.**
  - **ASR projects in Truckee Meadows and Las Vegas Valley. Carson City.**
  - **Newmont mine water plan in Goshute Valley.**

Las Vegas Well Hydrograph



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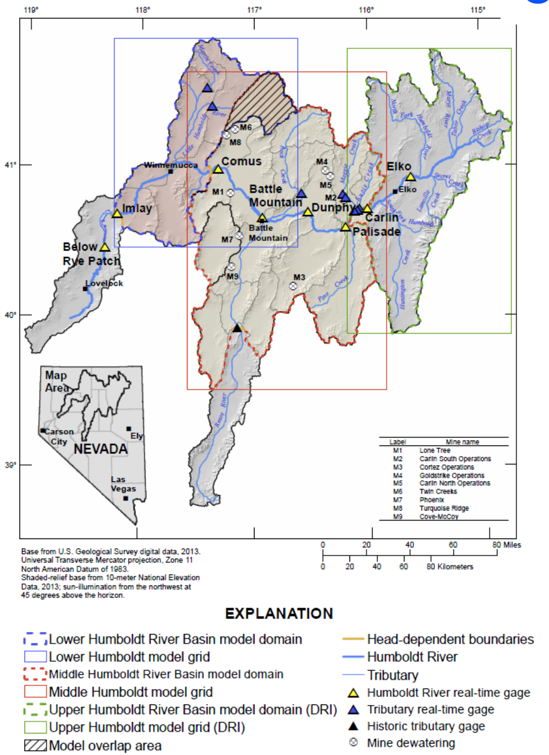
Examples of sustainable groundwater decisions

Collaborative effort

- **Humboldt River Basin example.**
  - **Understanding the effect of pumping on *timing, rates,* and *locations* of depletions (diversions).**
  - **Information needed for transition of management.**
  - **Conjunctive management of groundwater and surface water.**

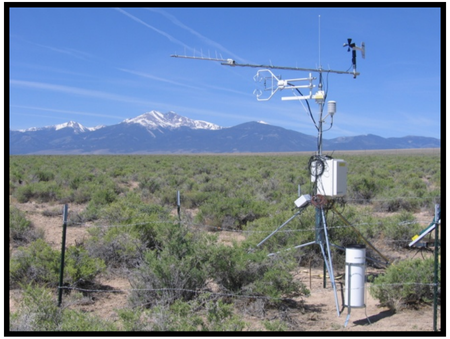


http://water.nv.gov/HumboldtRiver/Humboldt_Modeling_Workshop_Nov2-3_2015.pdf

Importance of monitoring data

- Critical for successful management of water resources.
- Data provide the information we need to determine properties of the system.
- The properties of the system govern the processes and interactions.
- Our ability to understand, model, and predict system processes and interactions is greatly improved with long-term data.

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