Salt Water Intrusion and Delineation of Brackish Water Resources:

The US Perspective

September 26, 2002

US-Mexico Workshop
Application of Innovative Technologies to Water Issues on the Border
Radisson Hotel, La Jolla, California

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Sandia National Laboratories

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

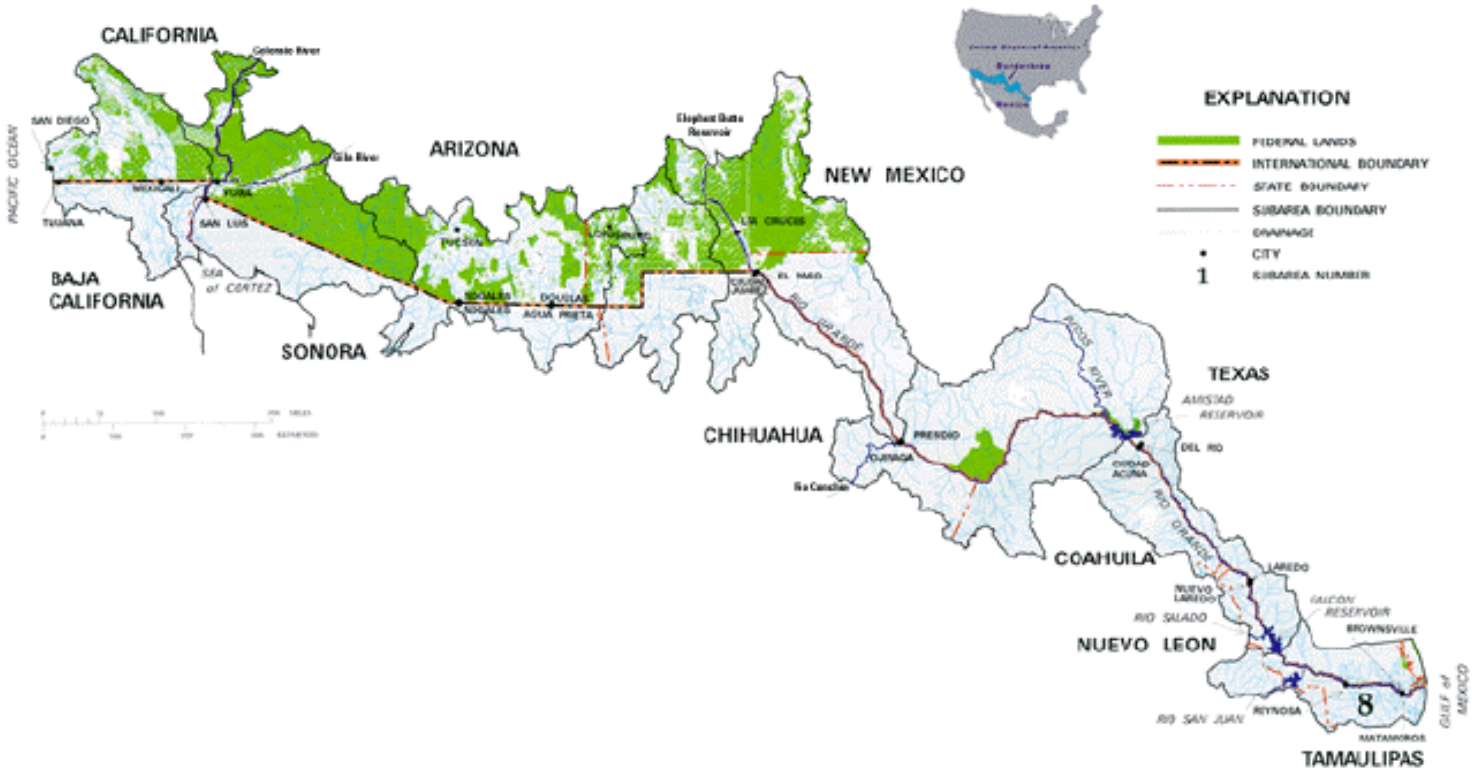
Outline

- **Define Problem – Sea Water Intrusion, Deeper Saline water intrusion, Brackish water characterization (Why matters, water supply, water storage, GW-SW interactions)**
- **Principles: Holistic View of Water Management**
- **US Approaches – Data acquisition, data management, detailed characterization, complex modeling, optimization of water, development of new models, Conferences, Papers**
- **Outstanding Issues / Research Questions**
- **Expanding Technology – System Dynamics, advanced sensors and monitoring**
- **Suggestions – Exchange of Data, Exchange of Models, Collaborative Projects (one in US, one in Mexico, one on Border).**

Water: A Shared Resource

Freshwater Resources in the Arid Regions along the US-Mexico Border include:

- Annually replenished surface water and
- Slowly replenished groundwater (aquifers)



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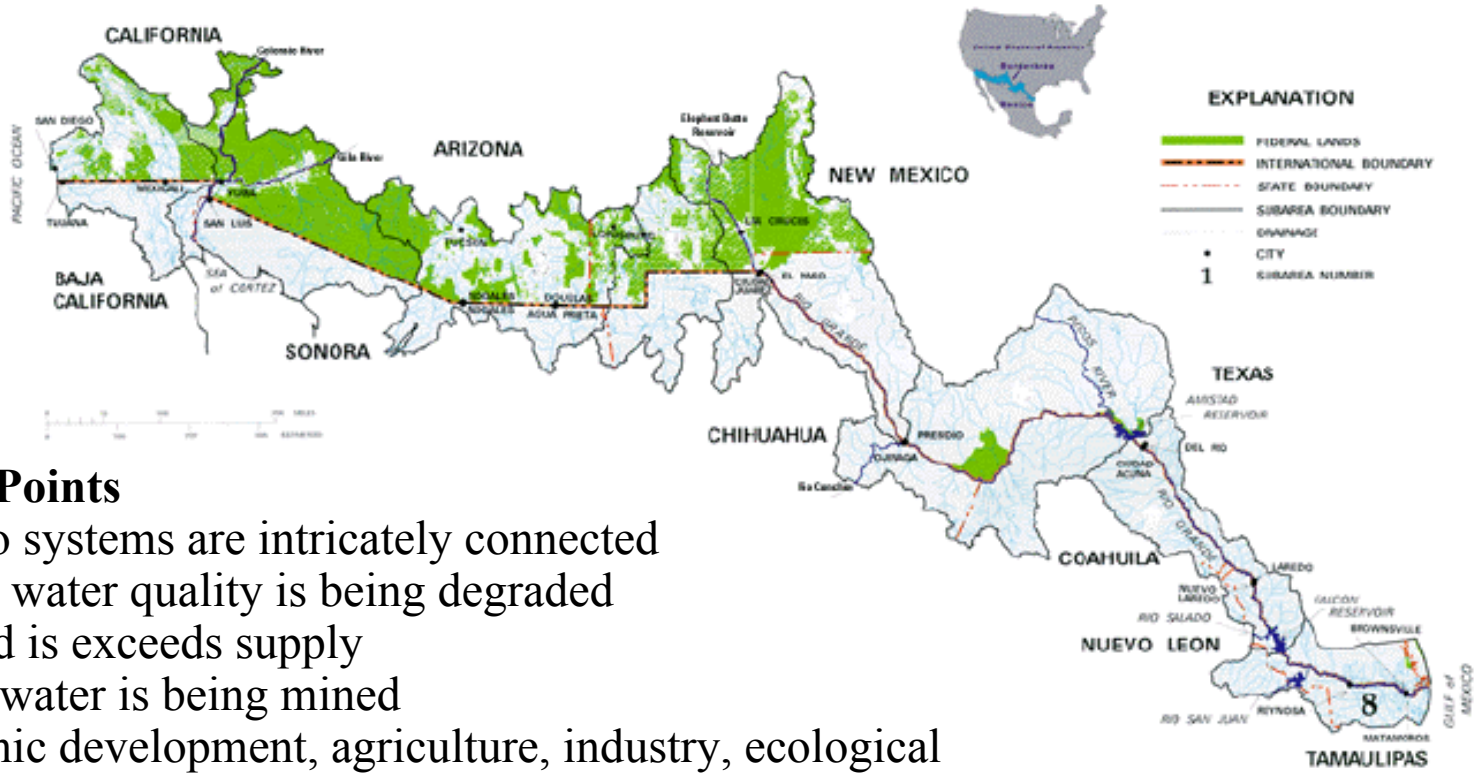

Critical Points

- The two systems are intricately connected
- Surface water quality is being degraded
- Demand is exceeds supply
- Groundwater is being mined
- Economic development, agriculture, industry, ecological systems and communities depend on this resource

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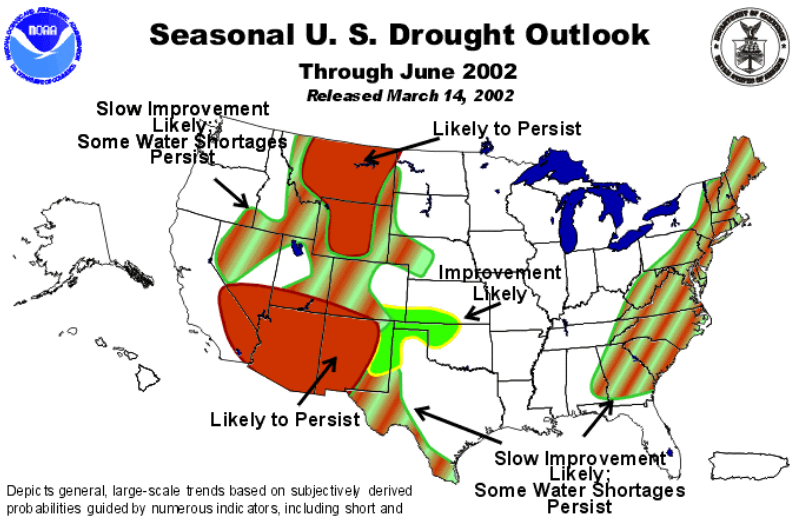
Water Stresses

- **Drought**



Depicts general, large-scale trends based on subjectively derived probabilities guided by numerous indicators, including short and long-range statistical and dynamical forecasts. Short-term events--such as individual storms--cannot be accurately forecast more than a few days in advance, so use caution if using this outlook for applications–such as crops–that can be affected by such events. Initial drought areas--shown schematically–are approximated from the Drought Monitor. For weekly updates on drought, see the latest Drought Monitor map and text.

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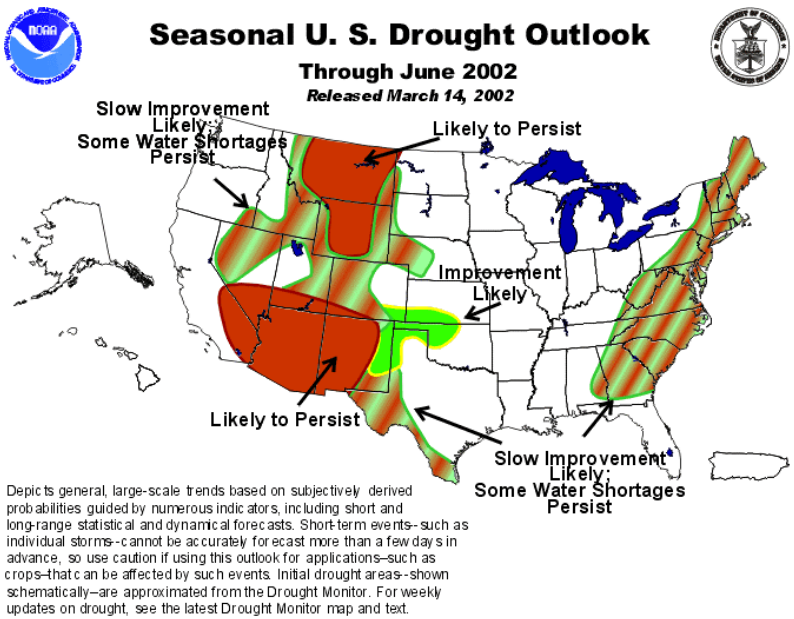
Water Stresses

- Drought
- **Climate Change**

"*adaptation for water, health, food, energy And cities are likely to require substantial Institutional and infrastructure changes … It may not be possible to continue current high levels of reliability of water supply*." (World Meteorological Organization Intergovernmental Panel on Climate Change Speaking of North America).



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Water Stresses

- Drought
- Climate Change
- **Population Growth**

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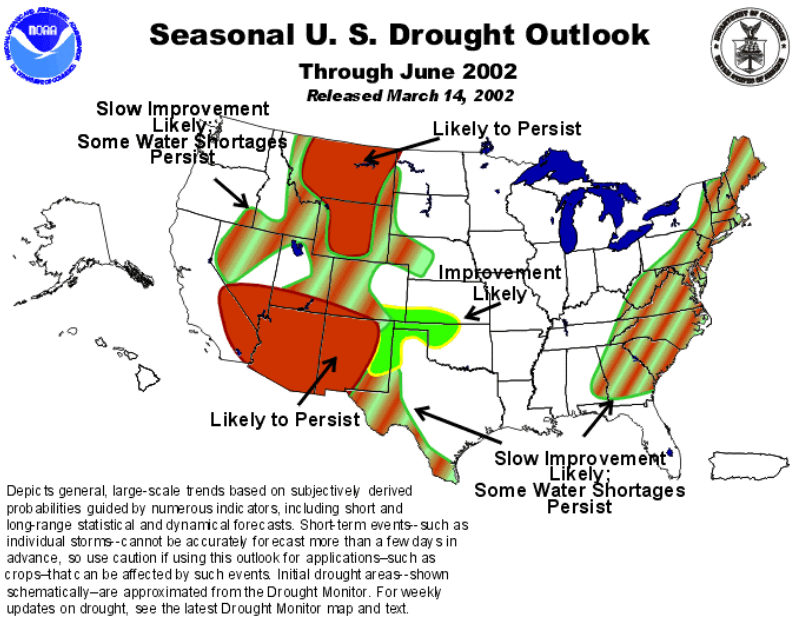

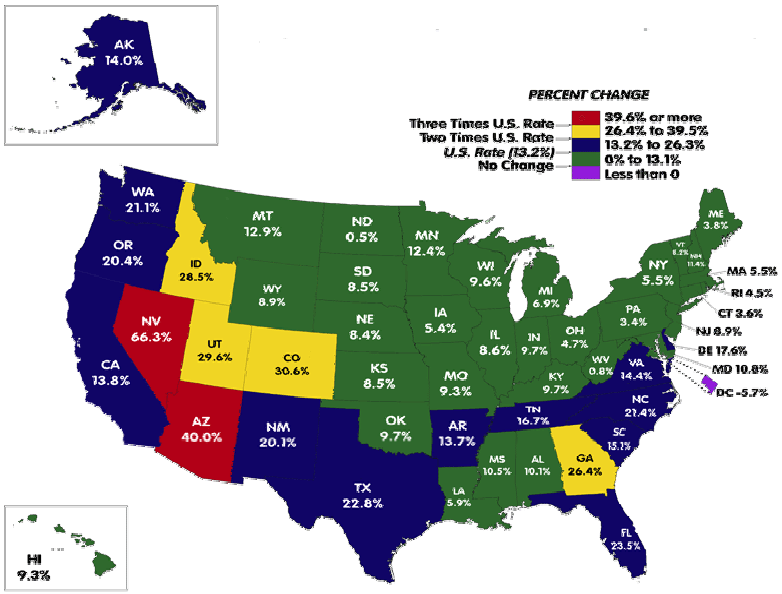

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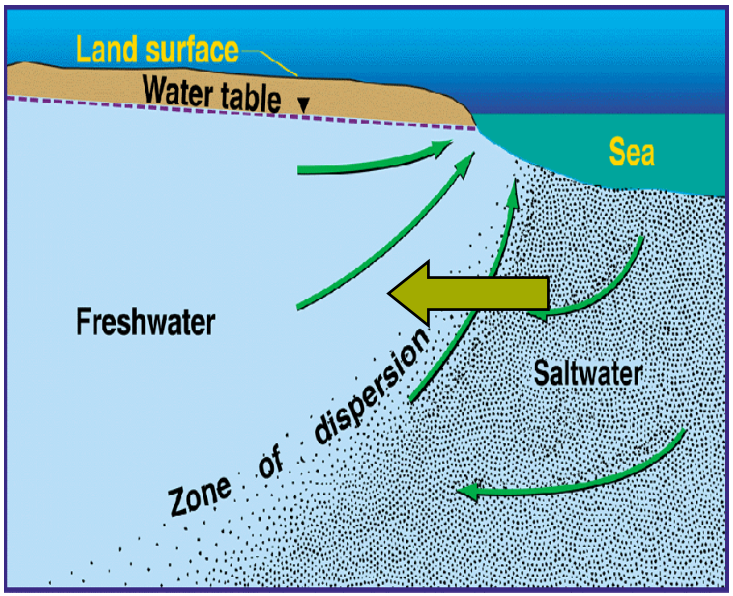
Critical Issue: Saline Water

- **Sea water intrusion** is usually caused by depletion of freshwater by pumping, which alters the hydraulic head and allows the boundary between Freshwater and Sea Water to move in-land



Critical Issue: Saline Water

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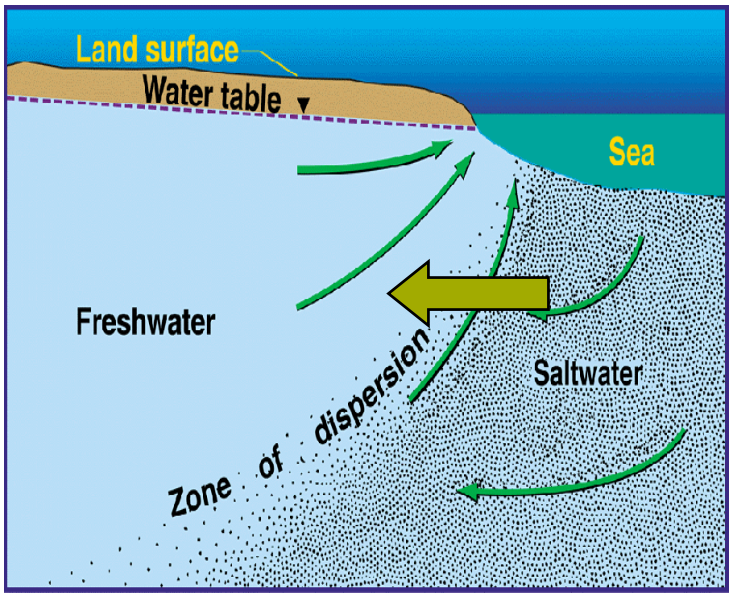
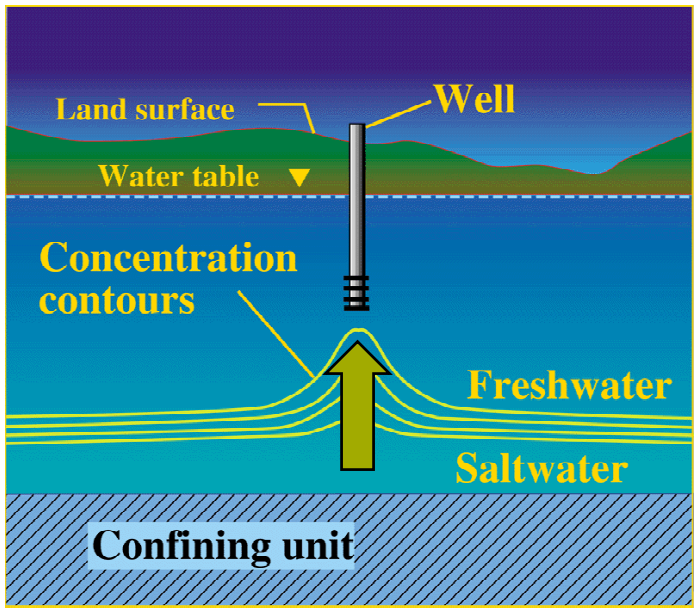
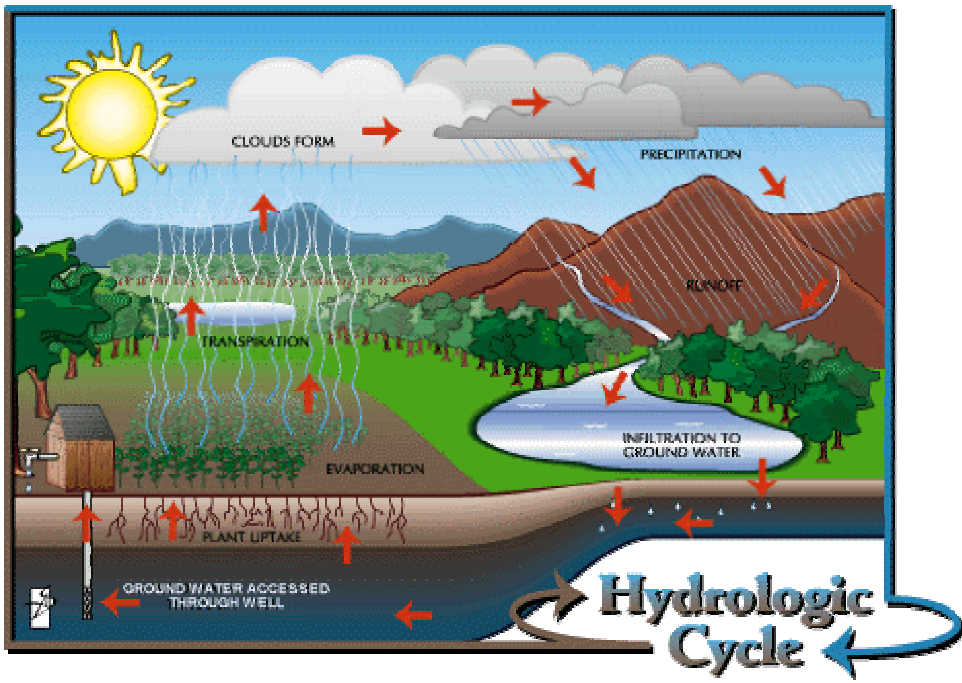
- **Saline water** that exists lower in an aquifer may move upward when pressures change due to pumping of overlying fresh water.





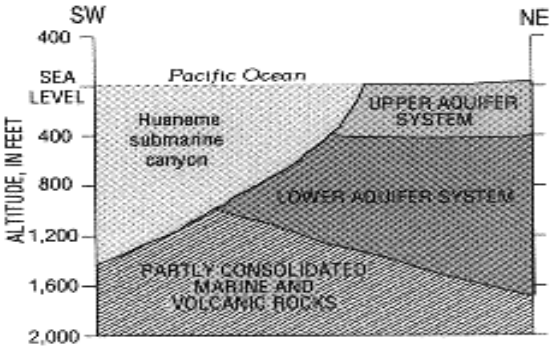
Principles

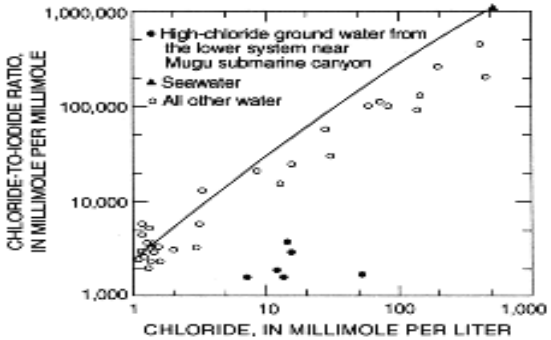
- Holistic Management is critical
  - Watershed based characterization and management
  - Adequate data, managed Jointly
  - Full system models and analysis
  - Joint management decisions / cooperative implementation

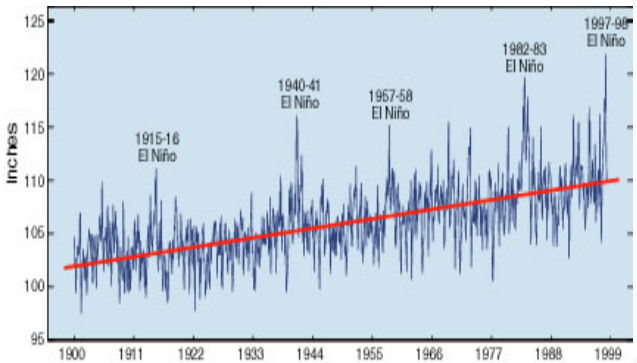


Characterization

- Aquifer Characterization is the most critical component and requires understanding of:
  - Geography (location in space)
  - Internal geometry (geologic units, connections between units, faults, preferential paths)
  - Water Sources (recharge, discharge zones)
  - Flow transmitting properties (conductivity)
  - Storage Capacity (porosity and volume)
- Characterization is a standard component of any groundwater resource study
- Unique issues:
  - Density driven flow
  - Sources of Chloride (sea water, deep water)
  - Sea-level change, subsidence issues
  - Off-shore mapping, drilling, sampling is important but more difficult than on-shore
  - Mapping discharge zones (sub-ocean) are more difficult off shore.







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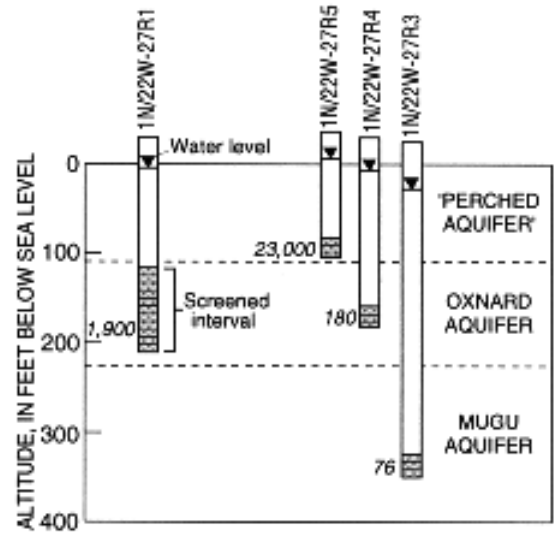
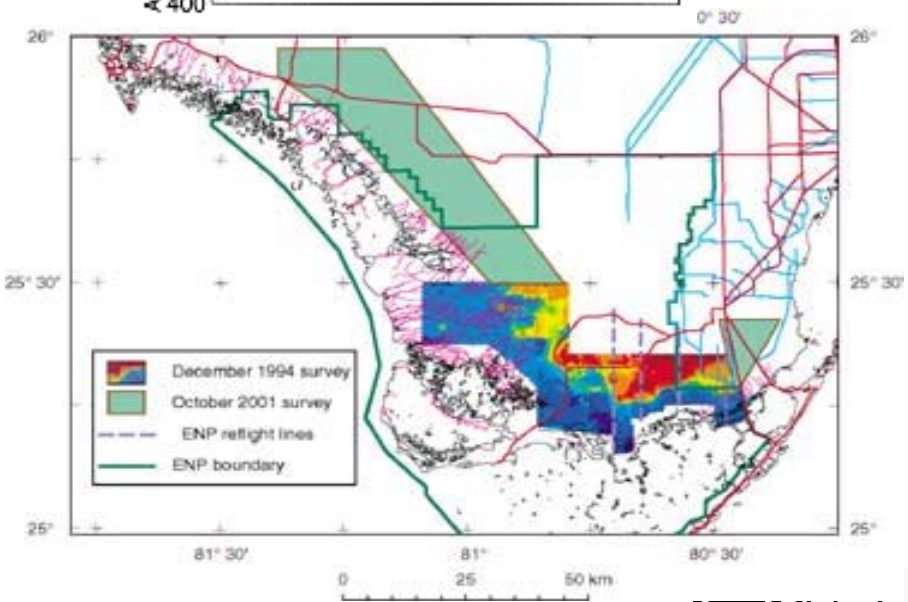
Characterization

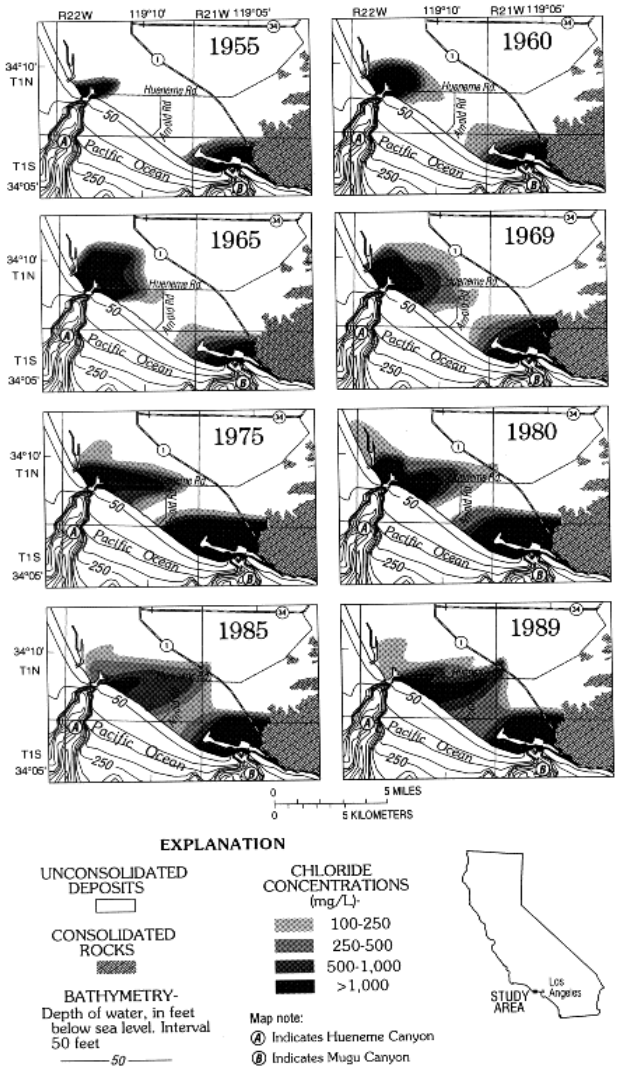
- Critical Tools / Activities
  - Drilling with high-resolution core
  - Geochemical Mapping and isotope analysis
  - In-situ hydrologic testing (pump tests)
  - Water age dating
- New Tools
  - High resolution geophysical mapping of salinity concentrations





Characterization

- **The primary Objective of Characterization is to develop a detailed conceptual understanding of the overall system**
  - **Geometry of basin**
  - **Amounts of water in storage and their current water quality**
  - **Relationship of surface water and groundwater**
  - **Time history of saline intrusion**
  - **Response of fresh-saline water interface to various stresses like pumping**
  - **Etc.**



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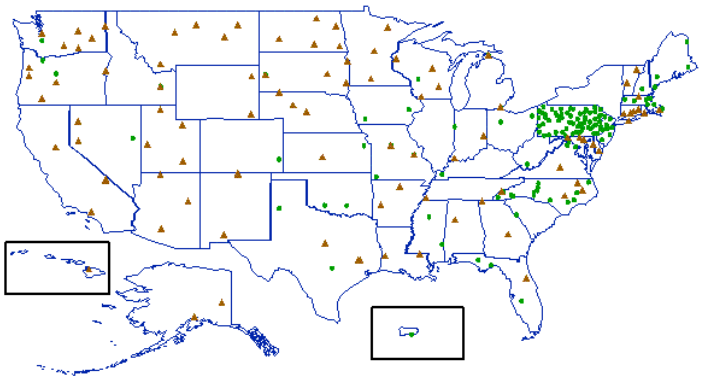
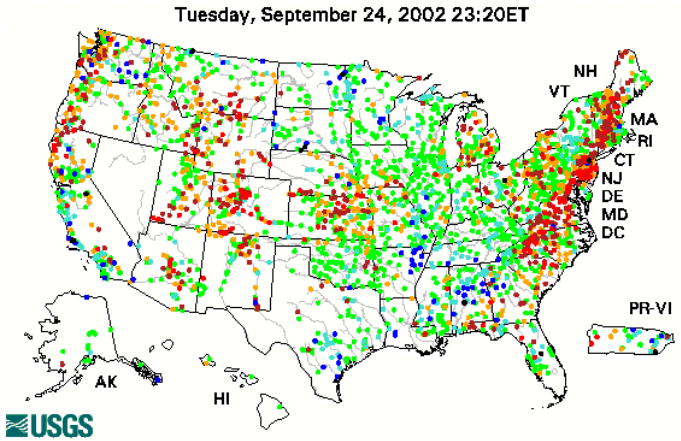
Shared Data Management

- Data Intensive
- Frequently Data is inadequate leaving large uncertainties
- Long-term program – requiring data management
- Share data across organizations and responsibilities





Critical Issues On US-Mexico Border:

- Need greater exchange of data / information
- Data must be accessible to all
- Metadata / quality of data must be defined

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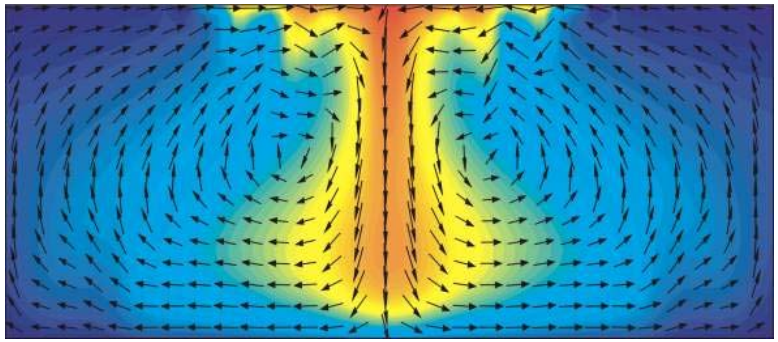
Complex Modeling

- Complex modeling helps integrate data and conceptual models
- Models are more complex than "standard" groundwater models



Codes

- SHARP (Quasi-3d, sharp interface)
- SUTRA (2D, 3D, variable-density/saturated flow, solute, energy)
- MOC (2D and 3D flow and transport; 2D, 2-constituent, variable density)
- HST3D (3D ground-water flow with heat and solute transport)
- WellMaster: A computer program to control well pumps)

http://water.usgs.gov/nrp/gwsoftware/

Issues on US-Mexico Border:

- Exchange of codes
- Cross training
- Integration of concepts and models for shared aquifers

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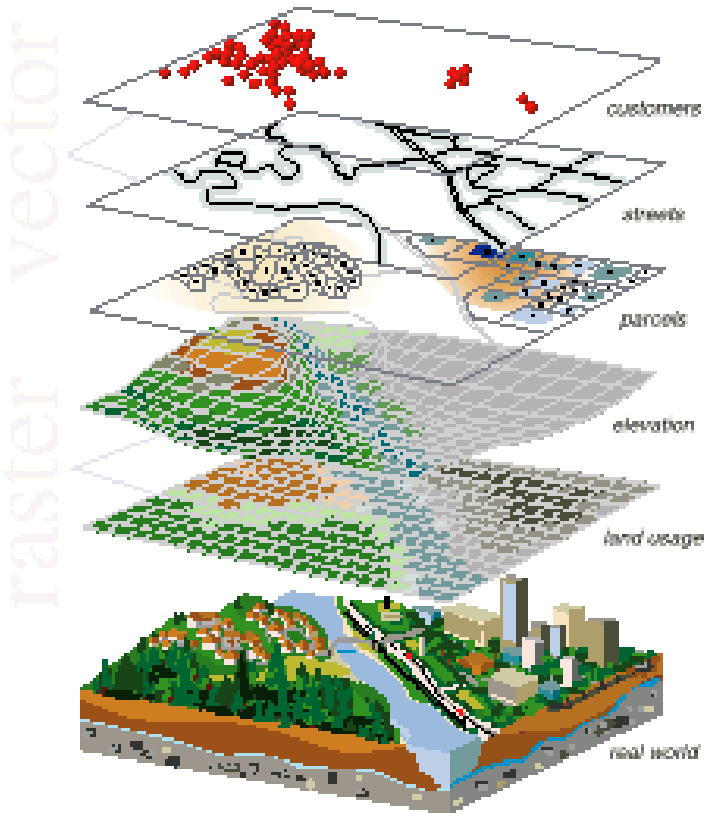
Optimized Management

- Most critical component is optimizing the management strategy and operations
  - Resource is limited
  - Intrusion is difficult to reverse

- Optimization involves control of:
  - Time and location of pumping
  - Balance between extraction rates verses recharge rates
  - Long-term demand
  - Land-use that affects water quantity and quality



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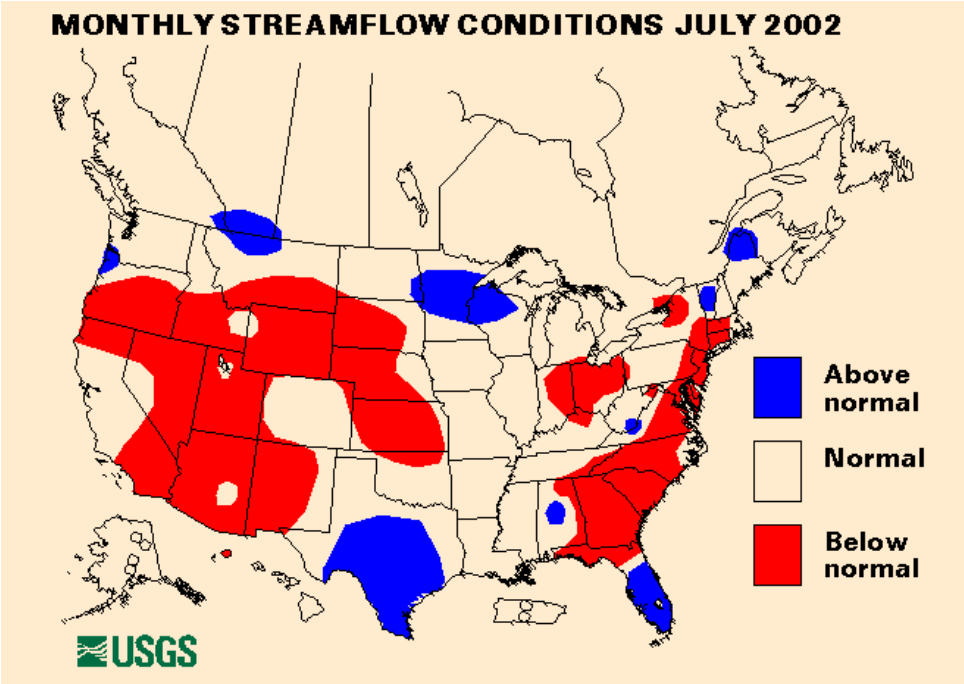
Shared Management Information

- In addition to sharing basic data, it is critical to share the integrated understanding with managers / community / water users.
- The information must be:
  - Accessible
  - Understandable

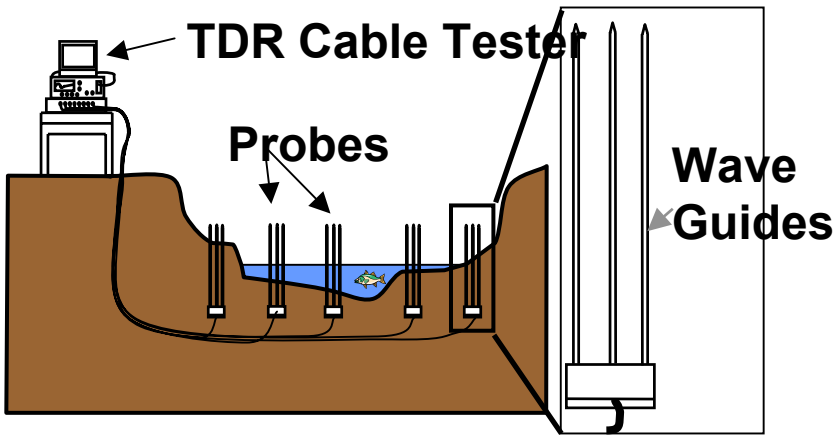


Shared Academic Information

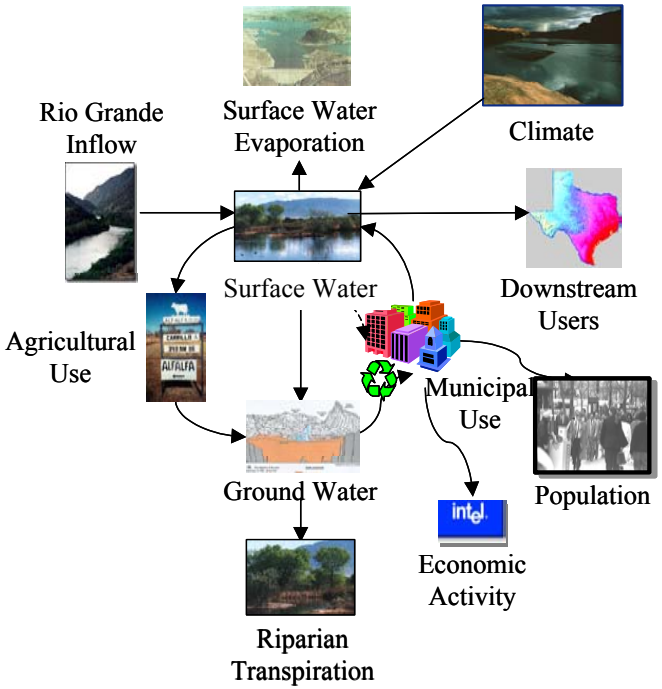
- **Professional and Management Meetings Provide one avenue for information exchange.**
- **Internet Work Groups / Web pages:**
  - http://ca.water.usgs.gov/water_quality/salt/
- **We need additional mechanisms.**
- **Meetings:**
  - **SWICA-M3-II:** The Second International Conference on Saltwater Intrusion and Coastal, Aquifers--Monitoring, Modeling, and Management, Merida, Mexico, Workshop March 27-29, Conference March 30-April 2, 2003.
  - **TIAC'03**, Congress, Coastal Aquifers Intrusion Technology, Mediterranean Countries, Alicante, Spain, 11-14 March, 2003.
  - **CMWR 2002**, XIV International Conference on Computational Methods in Water Resources, Delft, The Netherlands, June 23-28, 2002
  - **SWIM17**, 17th Salt Water Intrusion Meeting, Delft, the Netherlands, 6-10 May, 2002

Expanding Technology

Advanced Sensor Technology (chemical sensing)



Advanced Sensor Technology (Stage and Sediment Transport)



Integrated watershed modeling (System Dynamics)

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Suggestions

Collaborate on definition of overall groundwater resources along the entire length of the US-Mexico Border

Components:

- **Improve exchange of existing basic data and completed interpretations**
- **Develop a joint database on Mexico-US Border surface water and groundwater resources**
- **Share existing models / cross-train on techniques and applications**
- **Joint application / testing of emerging technology**
  - **Geophysical mapping of saline-fresh water interfaces**
  - **Integrated watershed modeling**
  - **Advanced sensors and monitoring**