SLIDES: Groundwater Declines, Climate Change and Approaches to Adaptation

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Western Water Law, Policy and Management
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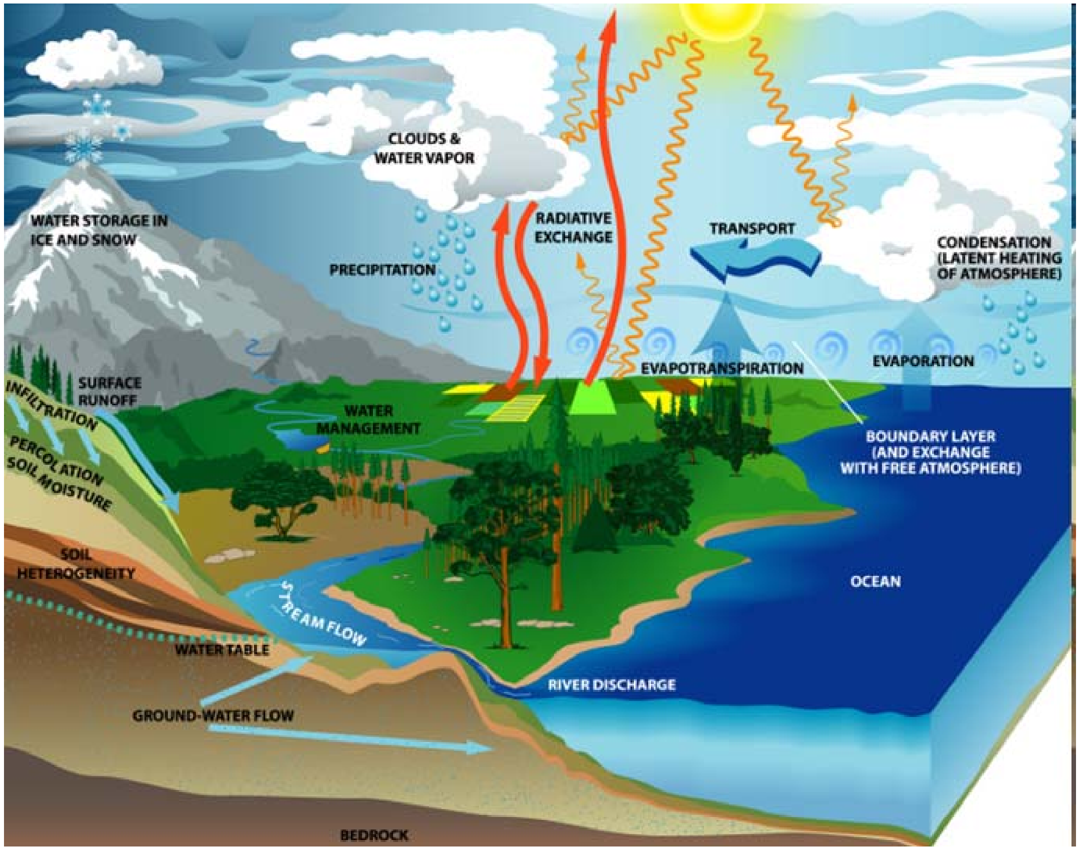
Groundwater Declines, Climate Change and Approaches to Adaptation



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Katharine Jacobs, Director
Arizona Water Institute

With thanks to Stan Leake, USGS

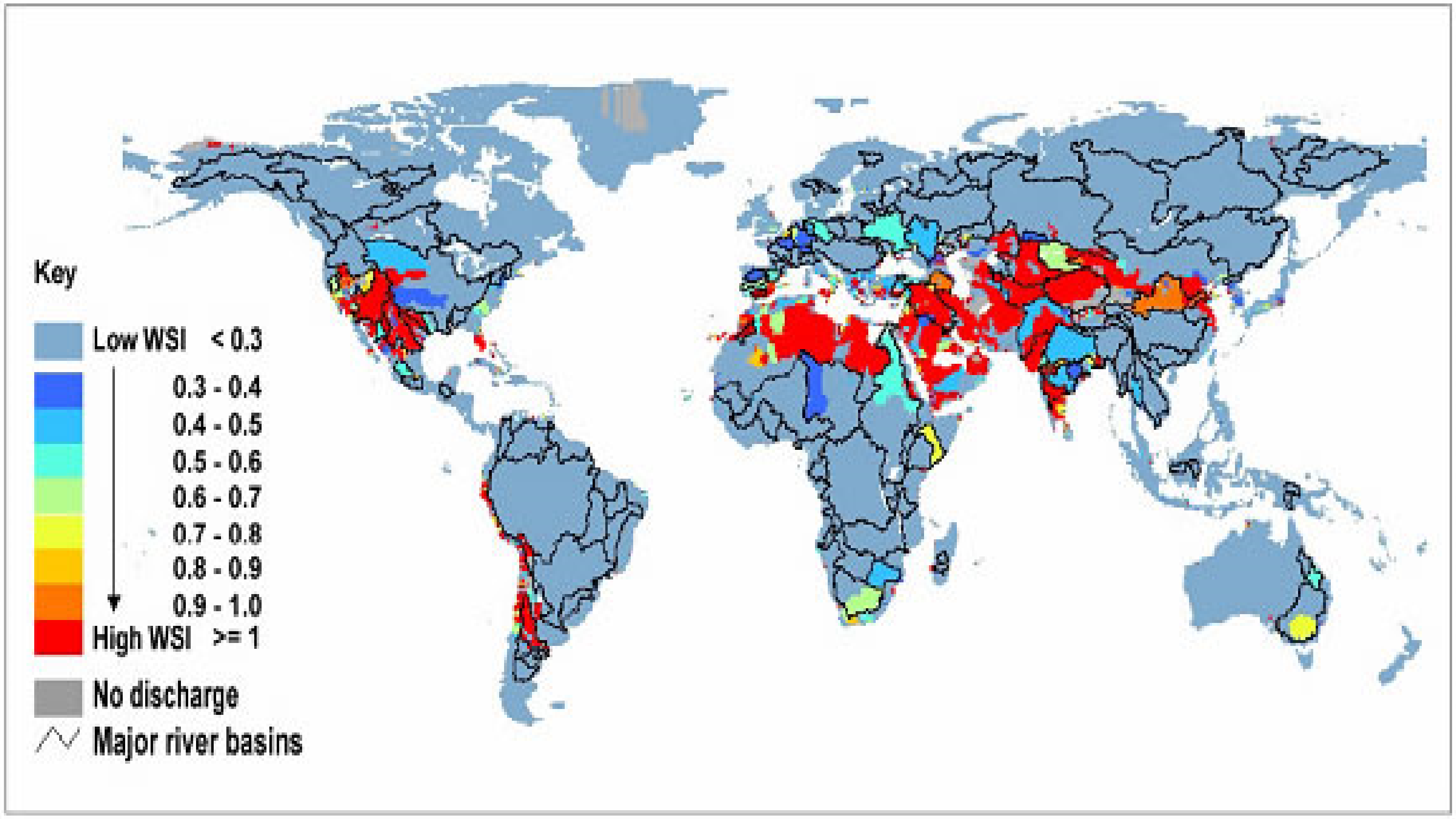
Arizona Water Institute

A consortium of Arizona's three universities focused on water sustainability through research, technical assistance, education and technology development

The role of groundwater in an age of increasing variability

- Groundwater declines as a measure of existing stress
- Implications of climate change for water supplies generally
- Implications for groundwater specifically
- Arizona case study
- Adaptation options – a thought experiment

Groundwater declines



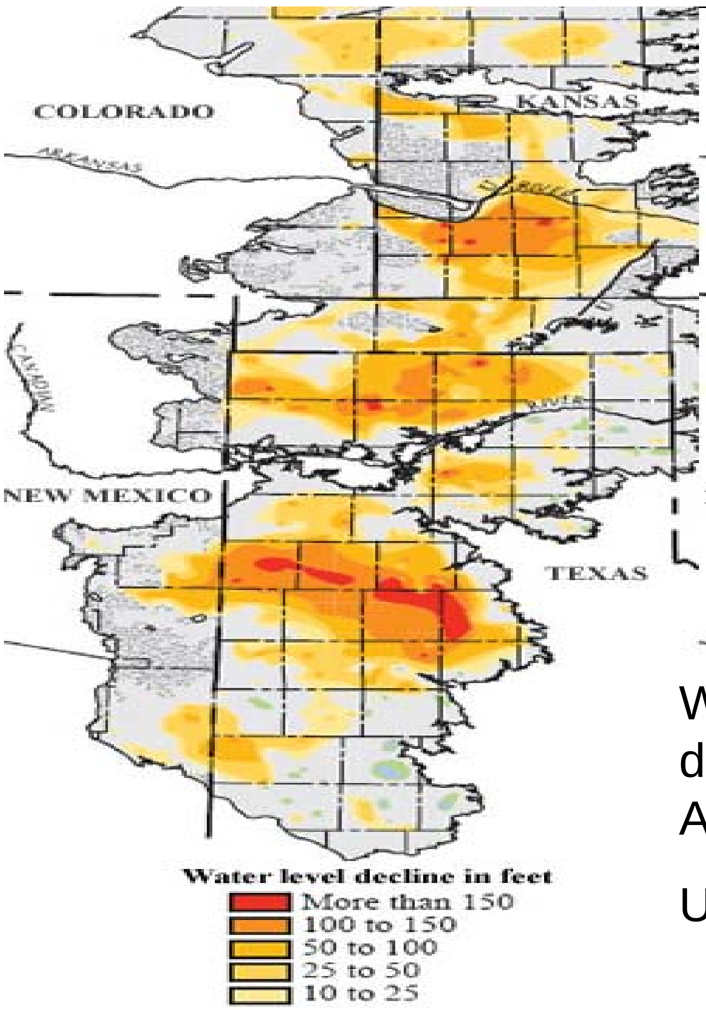
Source: International Water Management Institute (IWMI)

DETAIL 2: "...groundwater depletion is a phenomenon of the twentieth century, made possible by the availability of electricity and cheap pumps."

Groundwater depletion - USGS

"Ground water is a valuable resource both in the United States and throughout the world. Where surface water, such as lakes and rivers, are scarce or inaccessible, ground water supplies many of the hydrologic needs of people everywhere. In the United States it is the source of drinking water for about half the total population and nearly all of the rural population, and it provides over 50 billion gallons per day for agricultural needs."

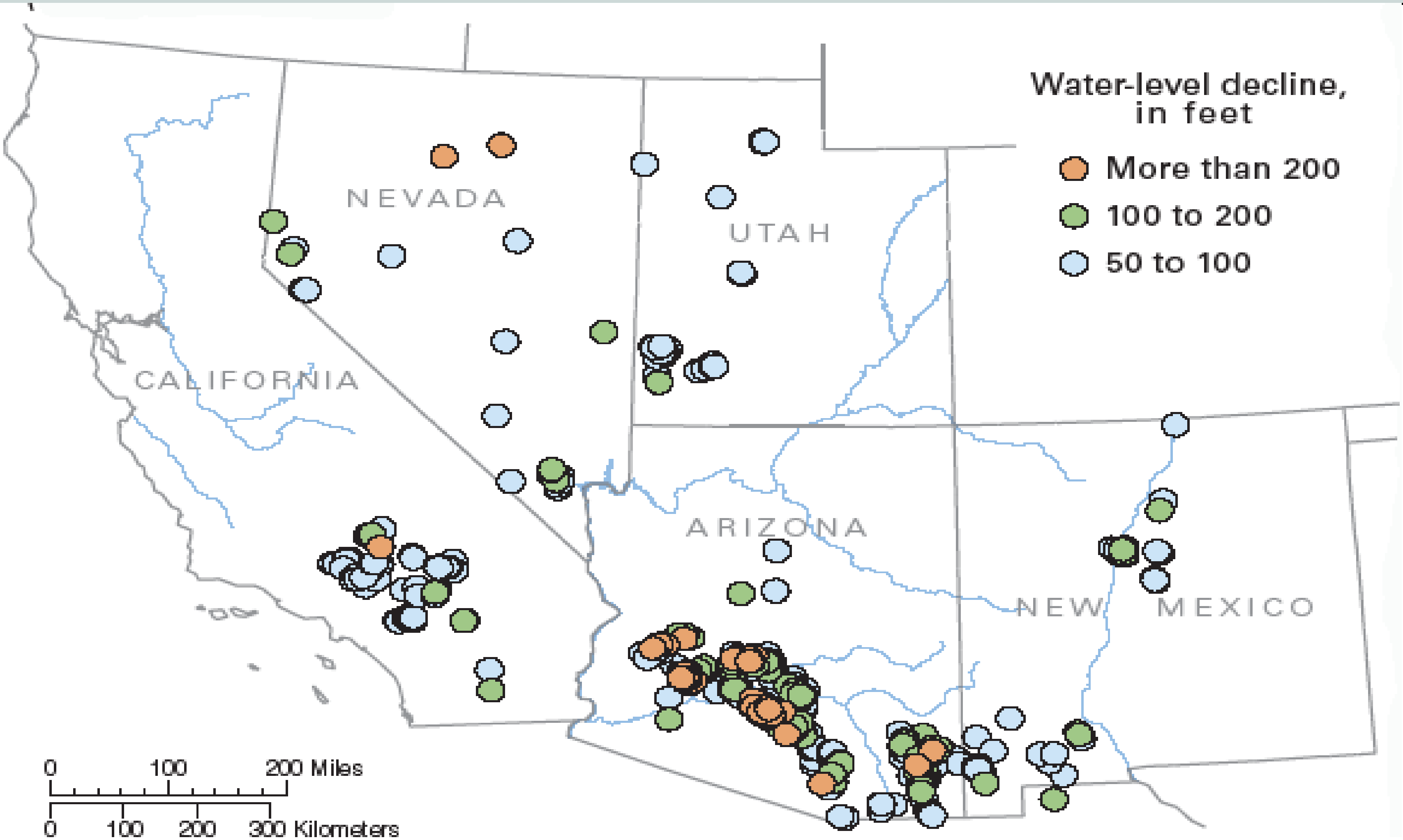
Groundwater declines in the Ogallala



Water levels in the high plains have declined up to 170 feet (Ogallala Aquifer)

USGS 2007-3029

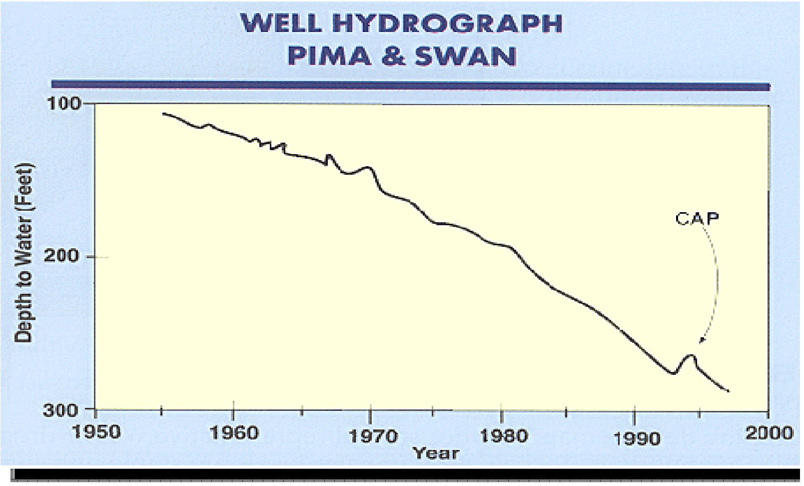
Groundwater declines in the Southwest

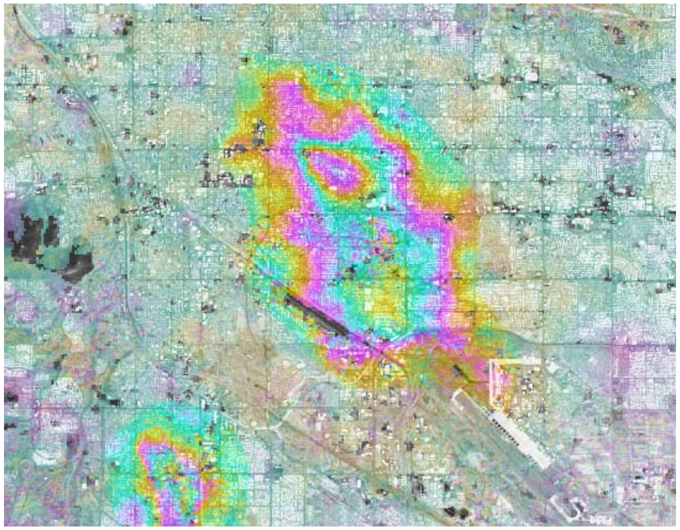


Leake et al., 2000 USGS

Mining groundwater leads to…

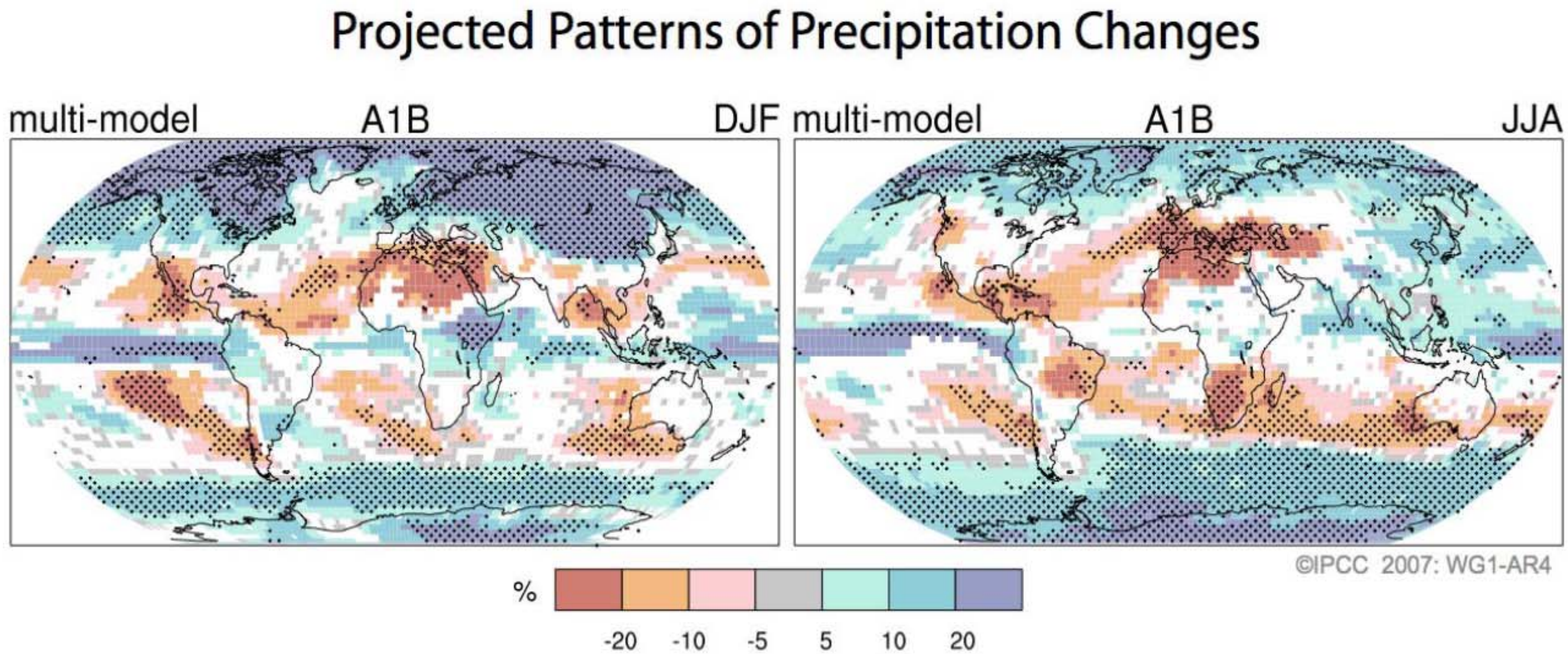
- Lowering of the groundwater table
- Higher pumping costs and well deepening
- Impacts on surrounding wells
- Poorer water quality
- Impacts on riparian areas
- Subsidence of the land surface
- Economic concerns





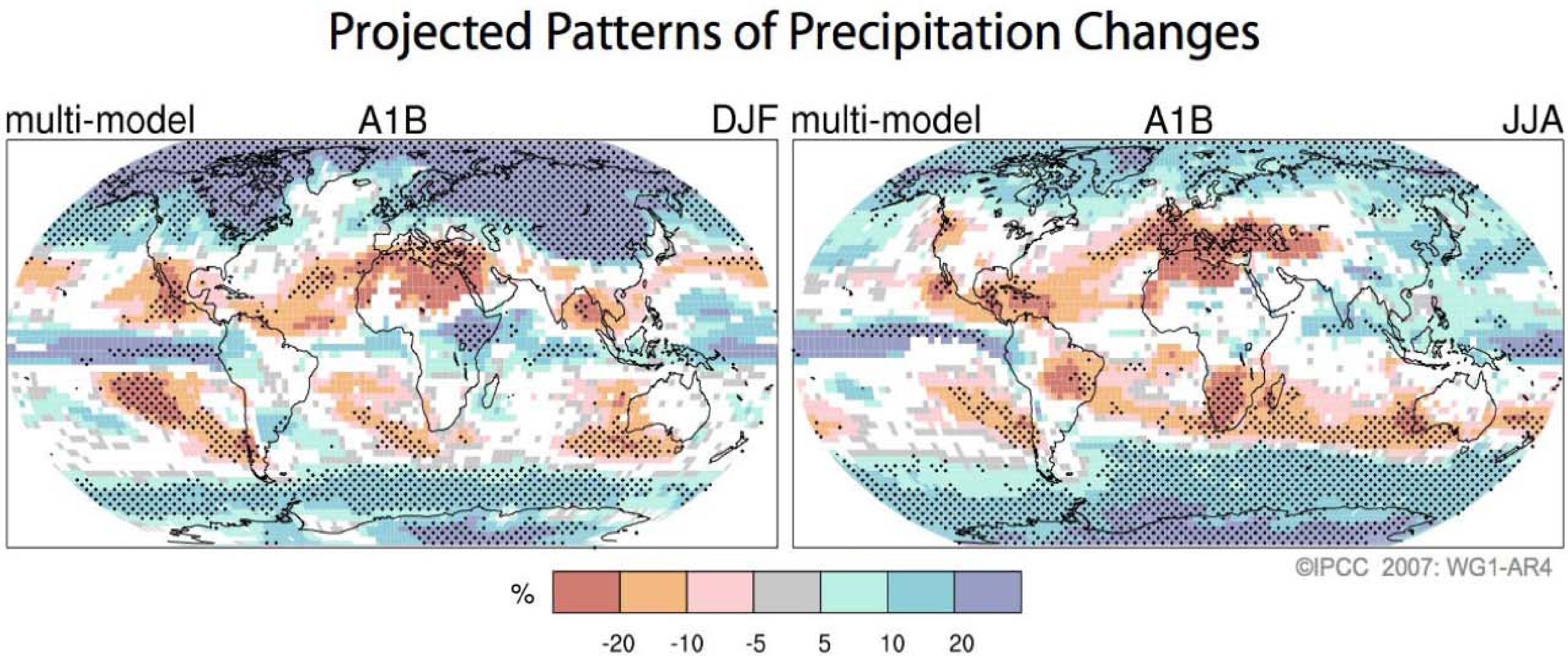
Radar interferogram 1997 to 2000

News from the International Panel on CC

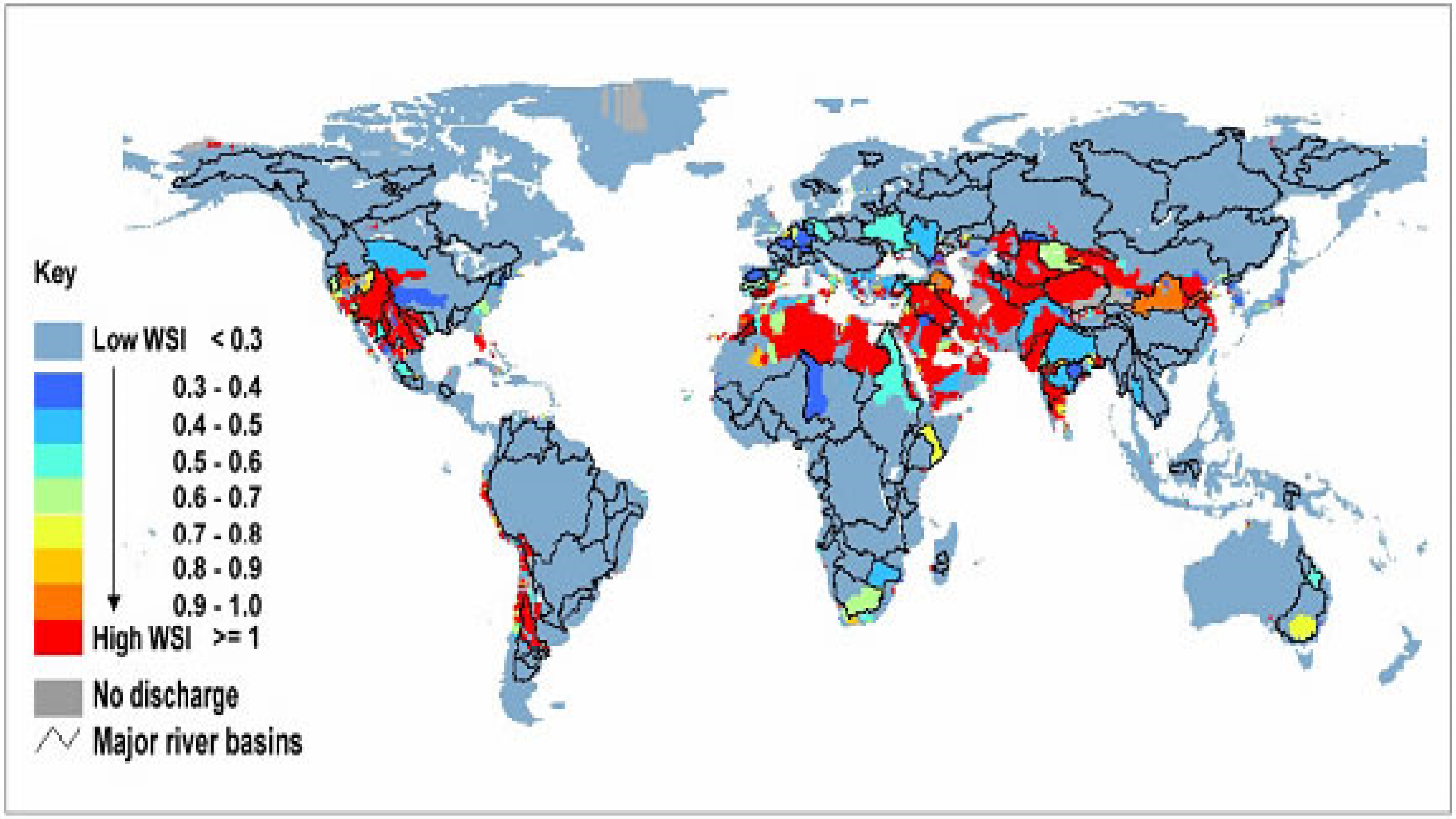


- Warming is “unequivocal’
- The Southwest is getting drier
- The impacts are more visible
- The mechanisms are better understood, especially in winter

Increased Climate Stress in Mid-latitudes



Groundwater Declines



Source: International Water Management Institute (IWMI)

DETAIL 2: “...groundwater depletion is a phenomenon of the twentieth century, made possible by the availability of electricity and cheap pumps.”

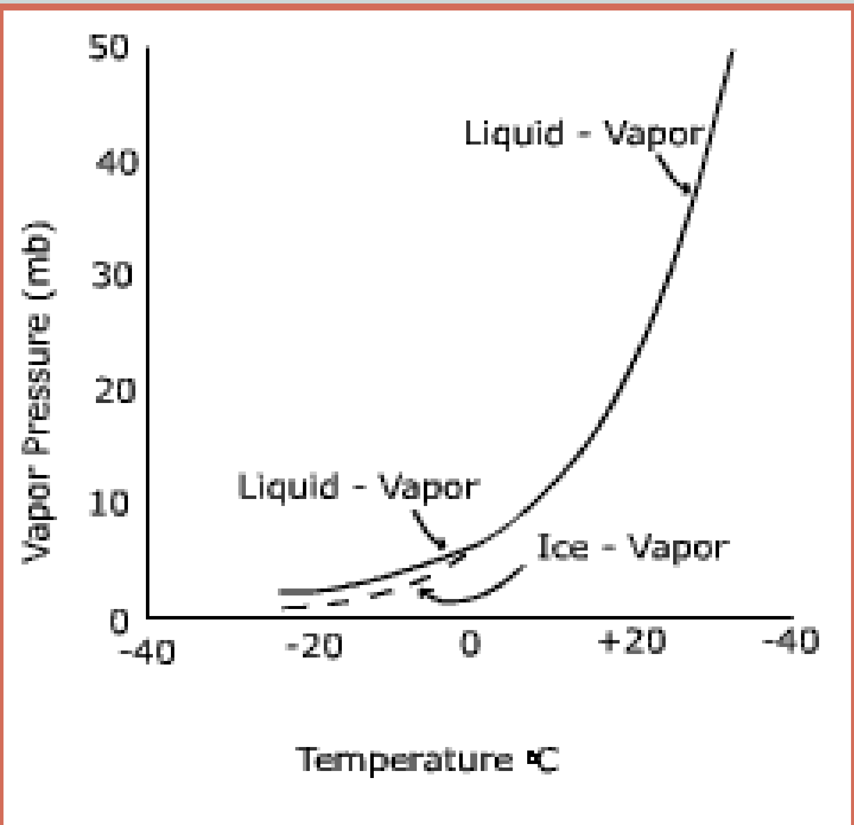
Impacts of Climate Change on Water Sector

Climate change will affect

- Snowpack, rain vs. snow
- Timing and seasonality of surface water runoff
- Groundwater-surface water interactions
- Water temperature
- Water quality
- Extreme events
- Rate of change; thresholds

Climate Change Impacts on Water

- Temperature is a hydrologic variable affecting both supply and demand



Saturation curve showing the relationship between vapor pressure and temperature

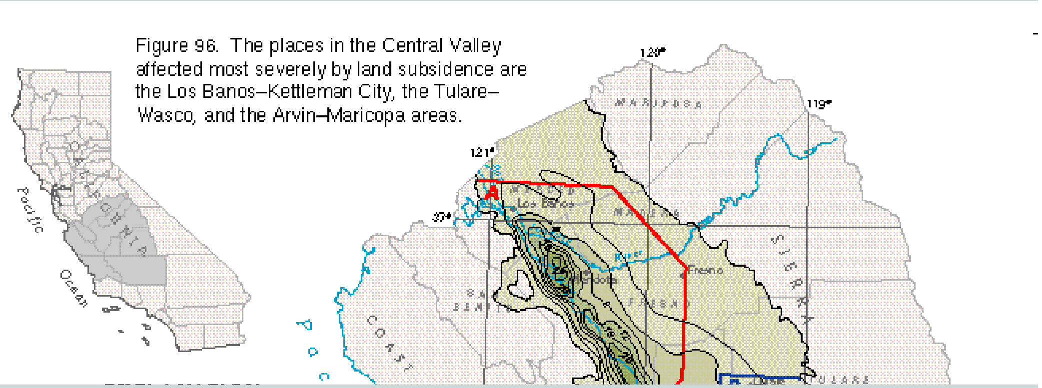
The impact of temperature on water supply is non-linear

Climate Change Impacts on Water

- Projected climate change impacts on flows in the Colorado are significant; possible 20% reduction in runoff by 2050 (XRISA Study).

30% chance of empty reservoirs by 2050

California – Poster Child for Overlying Stresses



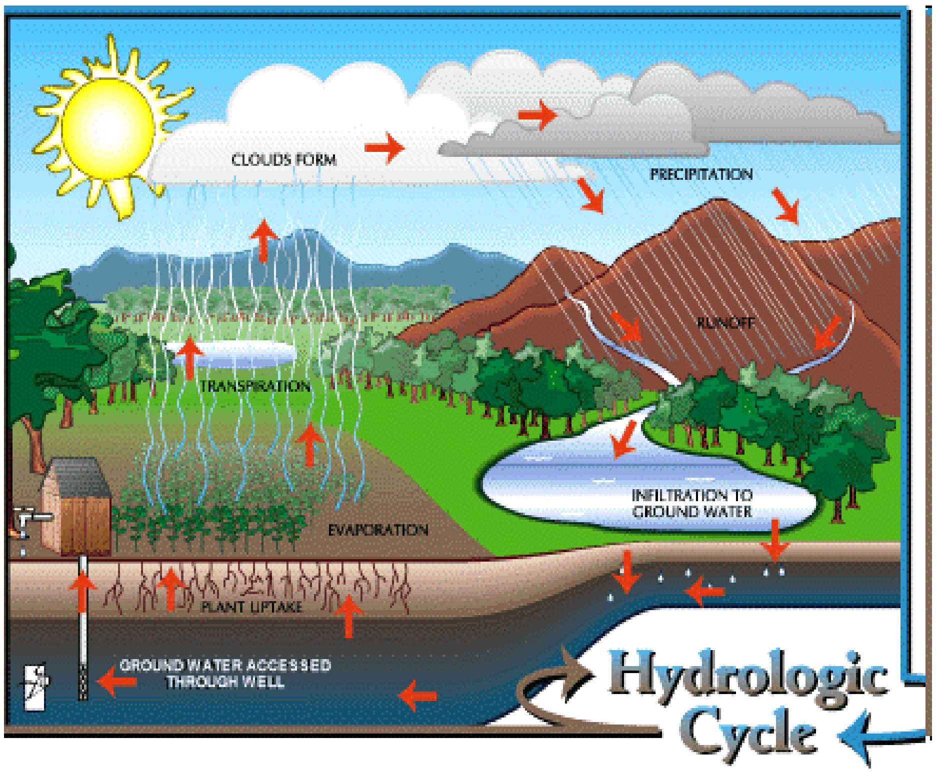
California case … the importance of context

- Decreased snowpack, significant change in runoff patterns
- Increased salinity in coastal aquifers
- Delta management issues, sea level rise, subsidence, failing dikes, etc
- Endangered species
- Wainger decision: institutional and legal constraints

What about effects on Groundwater?

There are a lot more questions than there are answers…but

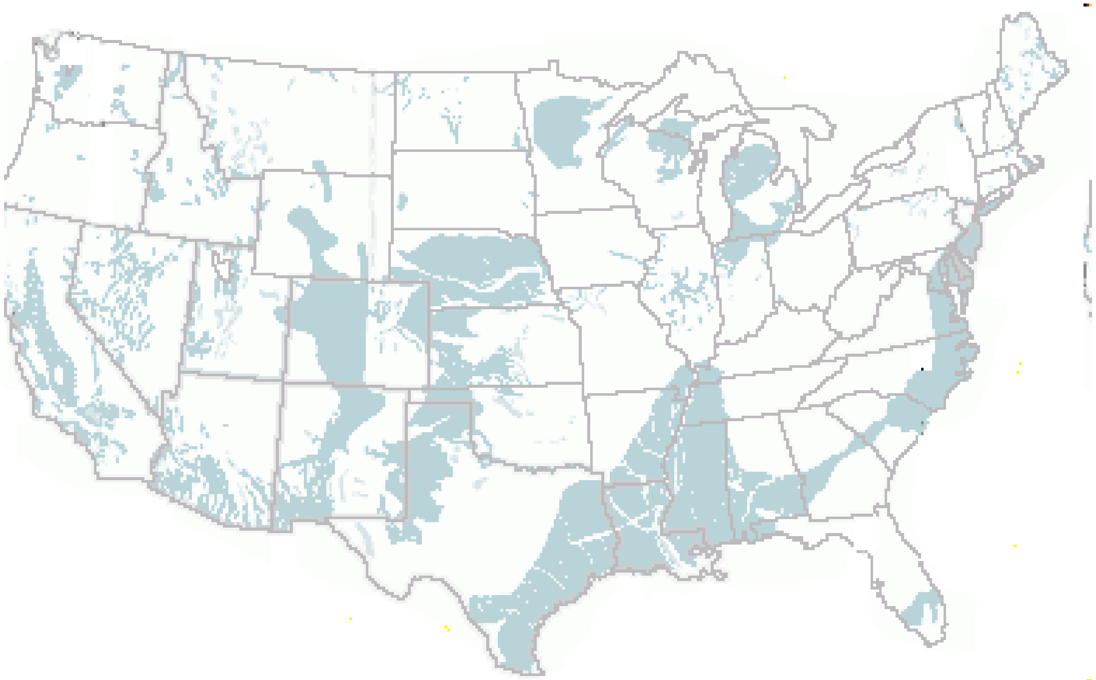
- We know more about temperature than precipitation, and
- We know that reductions in surface flows are likely to reduce recharge…



EPA.gov

What about effects on Groundwater?

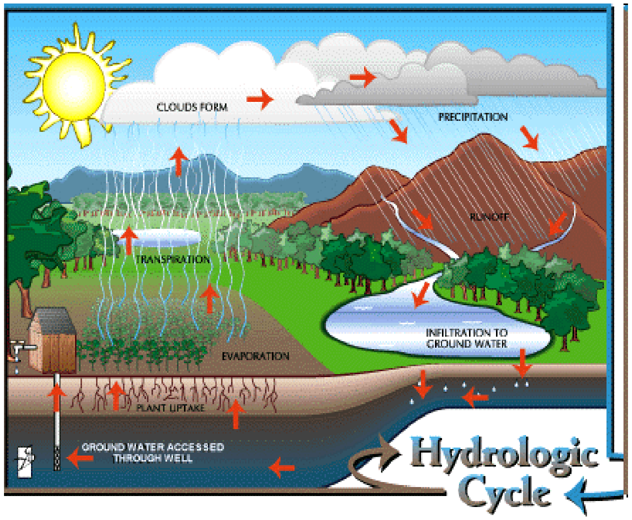
- We know that when surface water is scarce that groundwater pumping rates increase…



Areas where subsidence has been attributed to ground-water pumpage (Land Subsidence in the United States, USGS Circular 1182)

What we don't know:

- Implications of changes in seasonality of runoff on recharge rates?
- Temporal and spatial changes in demand and supply?
- Increased recharge during flood events?
- Decreased recharge during drought?
- Changes in availability of alternative supplies (e.g. surface water, effluent)?



EPA.gov

What we don't know:

- How will increases in fire frequency and magnitude affect sedimentation and recharge rates?
- Changes in water quality, eg fire, dust, sediment: gw quality implications not clear?
- Role of changes in vegetation in hydrologic cycle at the landscape scale?

AZ DEQ

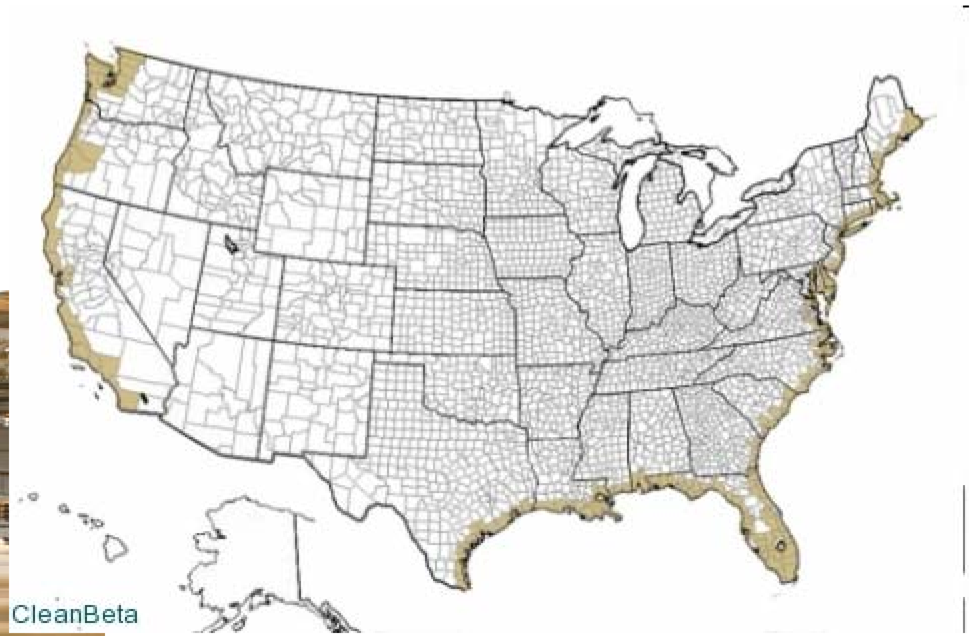
What we don't know:

- Effects of changes in energy supplies and costs? Availability of hydropower?
- Will surface water shortages result in more groundwater pumping at a time when energy costs are increasing?
- How will cap and trade or carbon tax affect the economics of water supply?
- Global economic trends eg shifts in agricultural production?

NOAA

Increased Salinity and Groundwater?

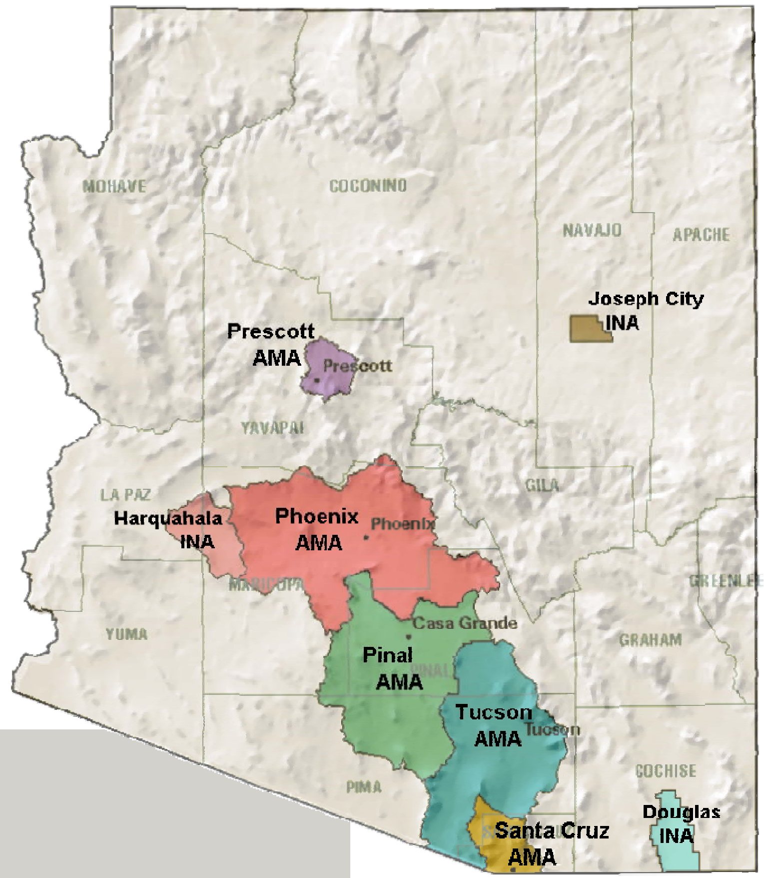
Implications of overdraft, reuse and sea level rise



Salt Water Intrusion in US Aquifers, Clean Beta

Arizona Case Study - The 1980 Groundwater Management Act

- Established Active Management Areas (AMAs)
- Set long-range water management goals (Safe Yield)
- Established GW rights system

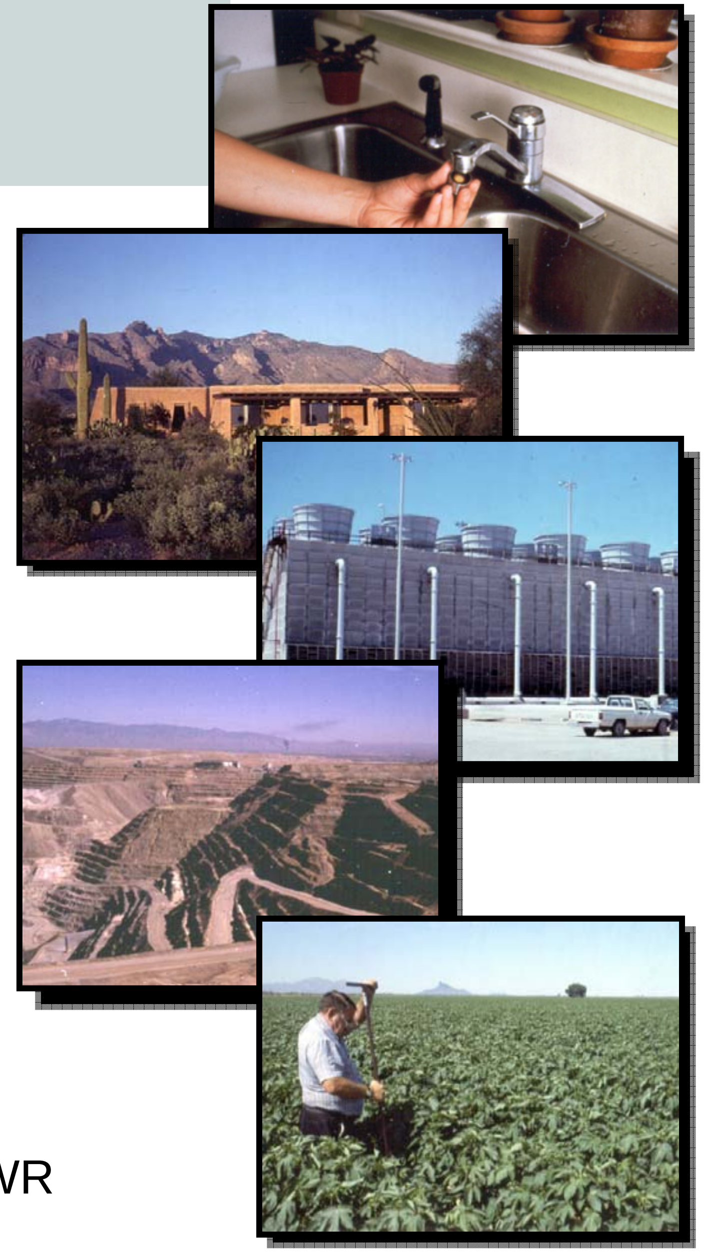


ADWR

AMAs:
Groundwater rights and permits
Well metering, annual reports and fees
Mandatory conservation for large users
Assured/adequate water supply for subdivisions
No new agriculture

AMA Groundwater Management Plans

- Every 10 years, though 2025
- Increasingly stringent requirements for municipal water providers, farmers, large industrial users (mines, golf courses, electric power, etc).
- Long-range projections of supply/demand



Courtesy ADWR

Tucson AMA *GWMC Format*		*DRAFT, SUBJECT TO REVISION* 1998	2005	2025
MUNICIPAL (includes exempt wells)				
DEMAND		160,500	194,500	247,100
SUPPLY	Groundwater	150,800	97,500	63,000
	CAP (direct use; credit recovery; repleni	200	83,400	146,400
	Effluent	9,500	13,300	37,700
INCIDENTAL RECHARGE		56,100	14,000	13,100
INDUSTRIAL				
DEMAND		57,500	54,200	75,400
SUPPLY	Groundwater	56,800	52,500	70,700
	CAP (direct use & credit recovery)	0	200	0
	Other surface water	0	400	
	Effluent	700	1,100	4,700
INCIDENTAL RECHARGE		6,900	5,700	7,600
AGRICULTURAL				
DEMAND		94,800	94,100	57,200
SUPPLY	Groundwater	70,900	66,700	44,200
	Groundwater (*in lieu*)	22,900	16,400	10,000
	CAP (direct use; no *in lieu*)	0	11,000	0
	Effluent	1,000	0	3,000
INCIDENTAL RECHARGE		19,000	18,800	8,700
INDIAN				
DEMAND		100	14,200	16,000
SUPPLY	Groundwater	100	800	200
	CAP (direct use; no *in lieu*)	0	13,400	15,800
	Effluent	0	0	0
INCIDENTAL RECHARGE		0	2,800	3,200
OTHER				
DEMAND	Riparian	3,700	3,700	3,700
SUPPLY	Cuts to the aquifer	2,300	15,300	45,200
	Net natural recharge	62,000	62,000	62,000
OVERDRAFT				
TOTAL		**158,900**	**119,000**	**52,000**
ADDITIONAL RECHARGE FOR FUTURE USE*				
OTHER	Net artificial recharge	22,700	102,900	13,500

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Draft 2005 TAMA Water Budget

What are the implications of climate change on the water budget of the Tucson AMA?

Potential Climate Change Impacts on Arizona Water Management Programs

- Well spacing and well impact regulations
- General Industrial Use Permits
- Recharge Permits
- Assured Water Supply Program
- Adequate Water Supply Program
- Management Plan Development
- Safe-yield analyses
- Watershed management activities, eg San Pedro sustainability goal

Why is the Assured/Adequate Water Supply Program so Important?

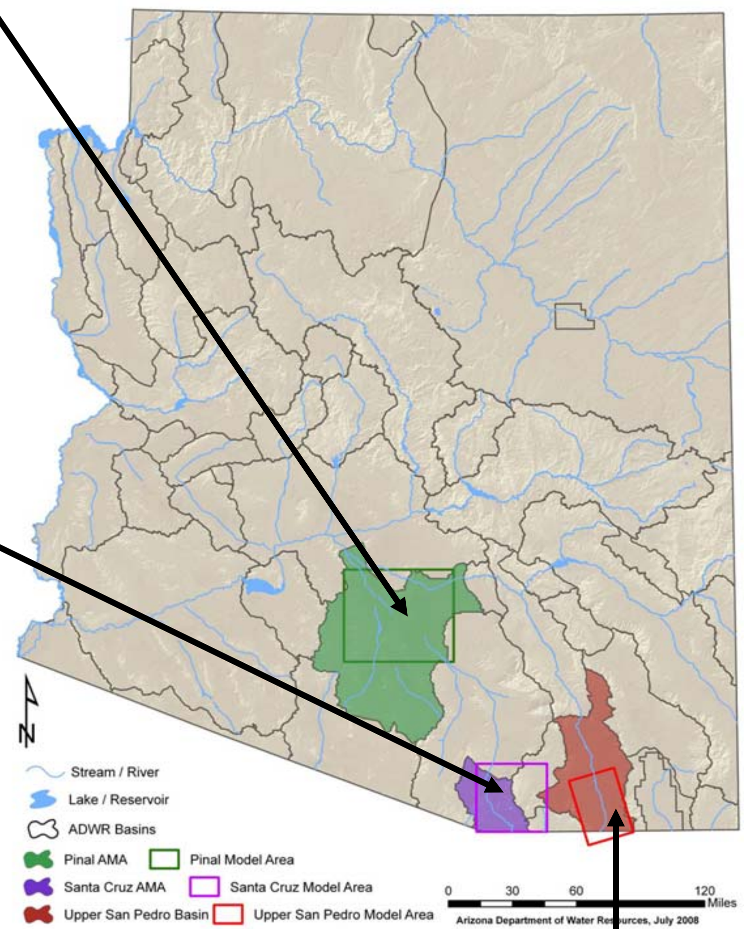
- It requires the fastest growing sector to use renewable supplies
- It focuses on the sector with the greatest ability to pay
- In AMAs, it protects groundwater for future use
- Heavily dependent on modeling physical availability of groundwater

Potential Climate Change Impacts on AWS

- Changes in reliability of surface water supplies – more focus on the “continuous availability” criterion – and on back-up supplies and drought planning
- Increases in rate of water level declines
- Increased number of “drought declarations” in which allowable groundwater pumping increases; implications for safe-yield
- Need to increase long-term storage credits to firm M&I and Indian supplies

Impacts likely to Vary by Basin

- Pinal AMA natural recharge and natural discharge (ET) insignificant parts of the water budget in most years
- Santa Cruz AMA water budget changes dramatically based on precipitation and flooding events
- San Pedro goal - sustainability of flows - means slight changes in seasonality could have big impacts



Transmission of Climate Signals through Groundwater Systems (Leake)

Changes in flow from climate change could be seen rapidly in surface runoff, but timing of changes in groundwater systems is highly dependent on factors including

- Changes in near-surface evapotranspiration
- Time for changes in recharge to move through the unsaturated zone
- Propagation of changes through the saturated zone to areas of groundwater discharge

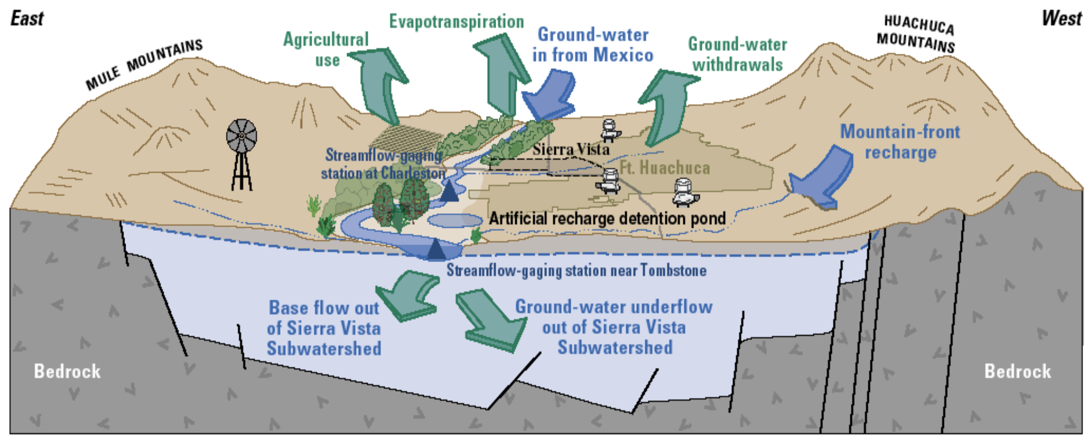
Transmission of Climate Signals through Groundwater System– San Pedro model (2006)

– Recharge at periphery

– Discharge occurs in riparian system

– Test - increased recharge by 25 percent, tracked changes in outflow through time

– Analysis considers only saturated GW transmission



Simulated annual water budget for a ground-water-flow model — Values are in acre-feet per year

GROUND-WATER INFLOW

	Estimated range	2002 Estimates	2011 Projections
—Natural recharge	11,200–16,000	15,000	15,000
—Underflow from Mexico	3,000–3,400	3,000	3,000
—Total		18,000	18,000

GROUND-WATER OUTFLOW

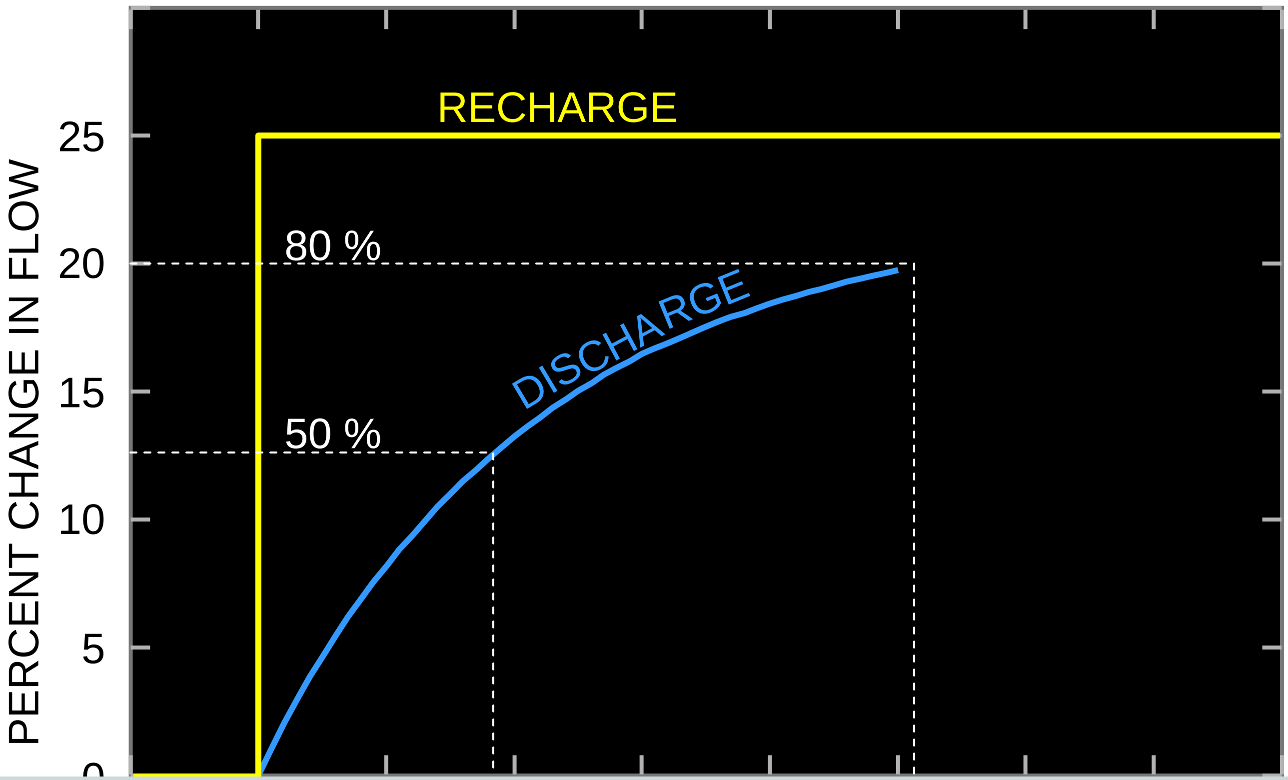
	Estimated range	2002 Estimates	2011 Projections
—San Pedro base flow	3,250–6,290	3,250	3,250
—Net ground-water withdrawals		16,500	18,600
—Riparian and wetland evapotranspiration	6,230–7,700	7,700	7,700
—Ground-water underflow at Tombstone streamflow-gaging station	300–440	440	440
—Total		27,900	30,000

ANNUAL STORAGE CHANGE (no management measures)

—2002 Estimated	–9,900
—2011 Projected	–12,000

USGS

Lag Effect in Transmission of Climate Signals through Groundwater—San Pedro Results



However, additional groundwater pumping in the context of climate change could have a much more immediate effect…

Groundwater Adaptation Opportunities

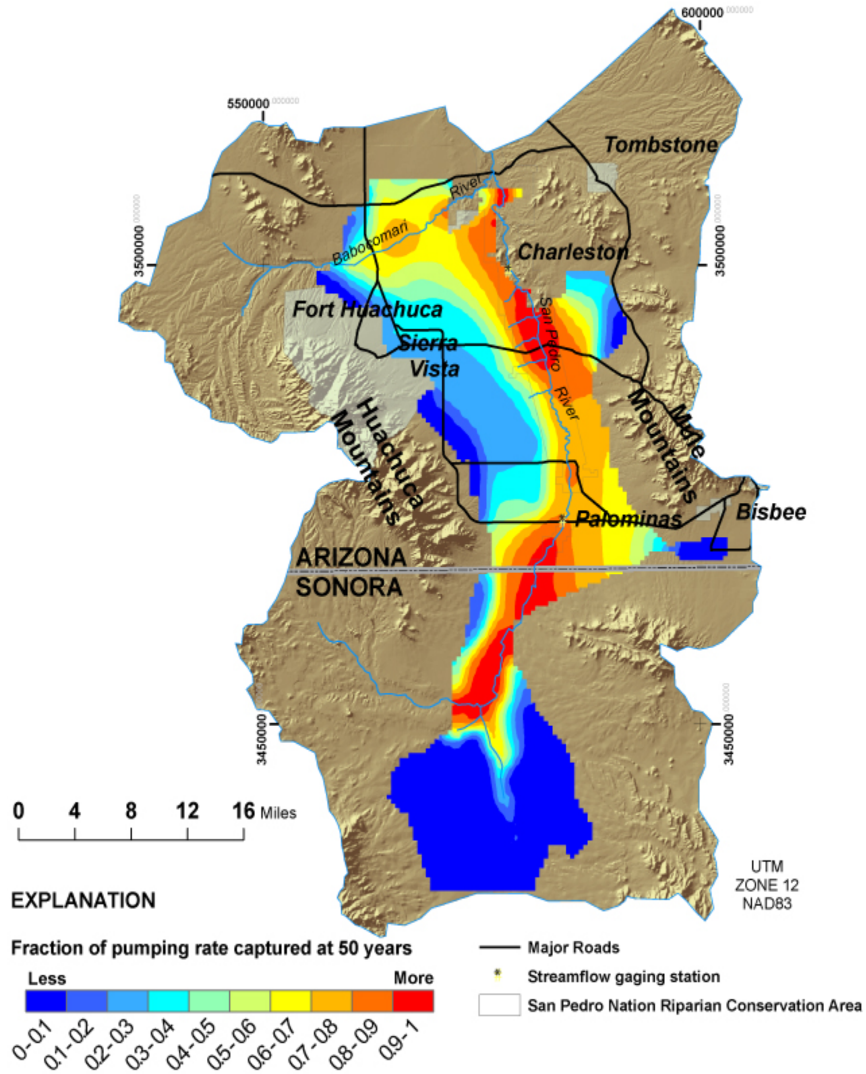
Protection for groundwater-dependent users and riparian areas

- Conservation?
- Well spacing
- Pumping limitations in vulnerable areas
- Land use planning integrated with water supply
  - Zoning and easements
  - Transferable development rights
  - Assured water supply
  - Water harvesting and reuse
- Recharge (and recovery)
- Environmental flow banks (in a groundwater context)

Adaptation: Tools for Connecting Land Use and Water Supply

San Pedro Capture Map
Stan Leake, Don Pool, and Jim Leenhoutsl

USGS



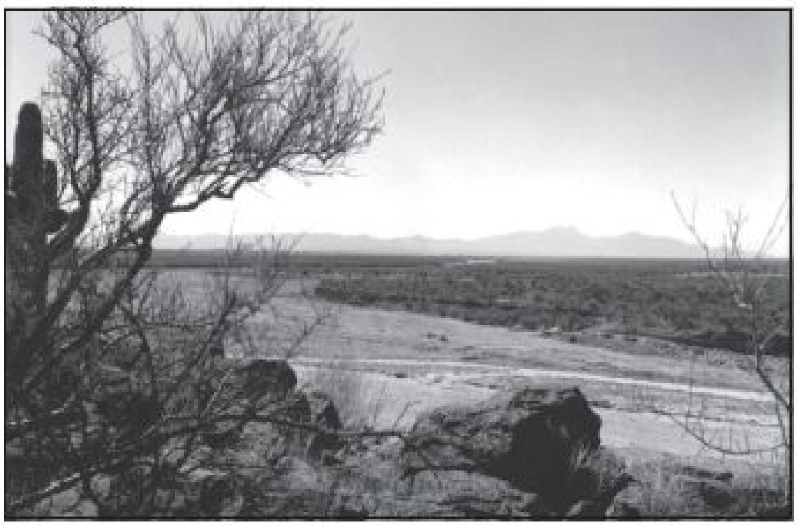
Groundwater Adaptation to Climate Change

- **Acknowledge**
  - Buffer value increases with scarcity and extremes
  - GW-SW connections
  - Higher ET leads to lower recharge
  - Aquifer storage, optimizing conjunctive use are key tools (but rely on surplus supplies)
- **Establish**
  - Enforceable GW rights systems
  - Monitoring for Adaptive Management
- **Re-evaluate**
  - Hydrologic assumptions: the past is not an analogue for the future
  - Engineering assumptions re: changes in means and extremes, potential for non-linear changes

Adaptation Approaches and Policy Issues

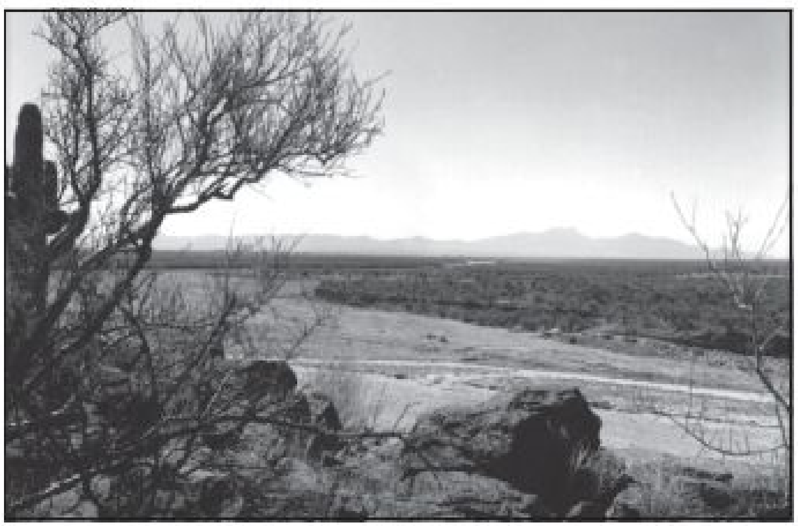
- Managing existing and future risk
- Dealing with uncertainty: Avoiding analysis paralysis, focusing on what we do know rather than what we don’t, managing expectations
- Acknowledging
  - Complexity and interconnectedness of social and environmental systems, implications for biodiversity
  - The global context
  - The role of economic incentives (and *disincentives*)
  - Potential for unintended consequences
  - The potential for crossing thresholds

Adaptation: Research



- Understanding changes in the hydrologic cycle
- Modeling surface water-groundwater connections
- Overcoming institutional barriers to good management
- Identifying monitoring and prediction needs for non-stationarity

Adaptation: Research



- Building credible future scenarios
- Understanding:
  - How much water is enough for the environment
  - Energy implications for groundwater
  - Water quality impacts of climate change

America's CLIMATE CHOICES

The "Main Committee" will provide recommendations that integrate the work of the four panels

Four focused panels will be convened to study and write separate in-depth reports on these four questions:

1. What can be done to limit the magnitude of future climate change?
2. What can be done to adapt to the impacts of climate change?
3. What can be done to better understand climate change and its interactions with human and ecological systems?
4. What can be done to inform effective decisions and actions related to climate change?

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