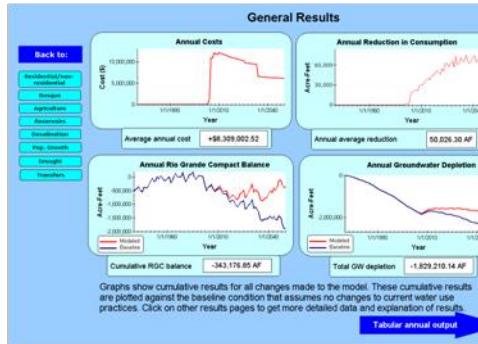


Exceptional service in the national interest

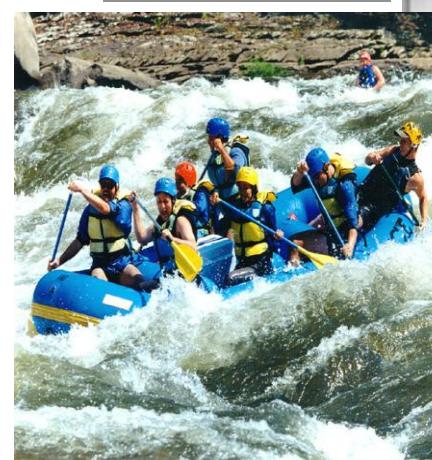
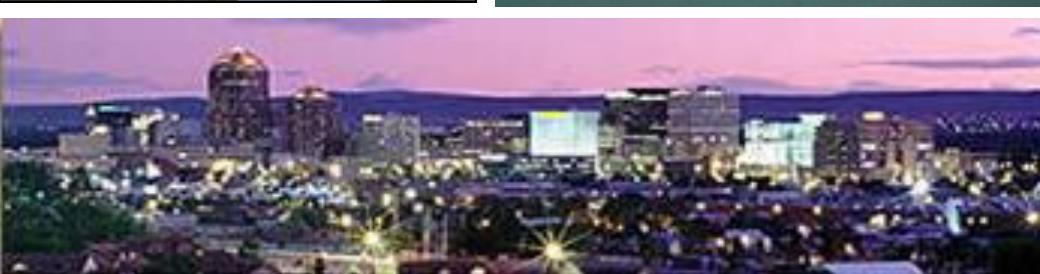


Systems Modeling and Decision Support Tools

Vincent Tidwell

Earth Systems Department

Resource Management



A Process of Balancing Tradeoffs

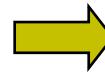
Balancing Tradeoffs

- Public Participation
 - Growing desire by stakeholders to engage in resource management and planning processes
 - Litigation often occurs where special interests are excluded from the discussion
 - Where trust erodes interests can become polarized

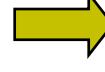
Balancing Tradeoffs

To Turn Information into Insight

- Goal is informed decision-making
- Ground decision process in best available science
- Create a shared basis for decision-making

2002								
JAN	34880	---	7.1	35170	0	1630	0	
FEB	30580	---	6.5	29140	0	224	0	
MAR	43210	---	318	35340	3100	478	0	
APR	59010	6720	0.9	46680	4010	121	0	
MAY	75750	7000	284	62450	4260	424	0	
JUN	74340	6680	71	59130	4160	248	12	
JUL	58800	5150	16	45970	3510	90	0	
AUG	56160	4690	2	45960	3370	437	0	
SEP	35910	4120	2.8	29680	2350	2610	69	
OCT	23180	3370	4.2	18540	1300	619	6.7	
NOV	21880	---	2.8	20510	106	1170	0	
DEC	26180	---	1.4	25740	0	1900	0	
total	539880	37730	716.7	454310	26166	9951	87.7	

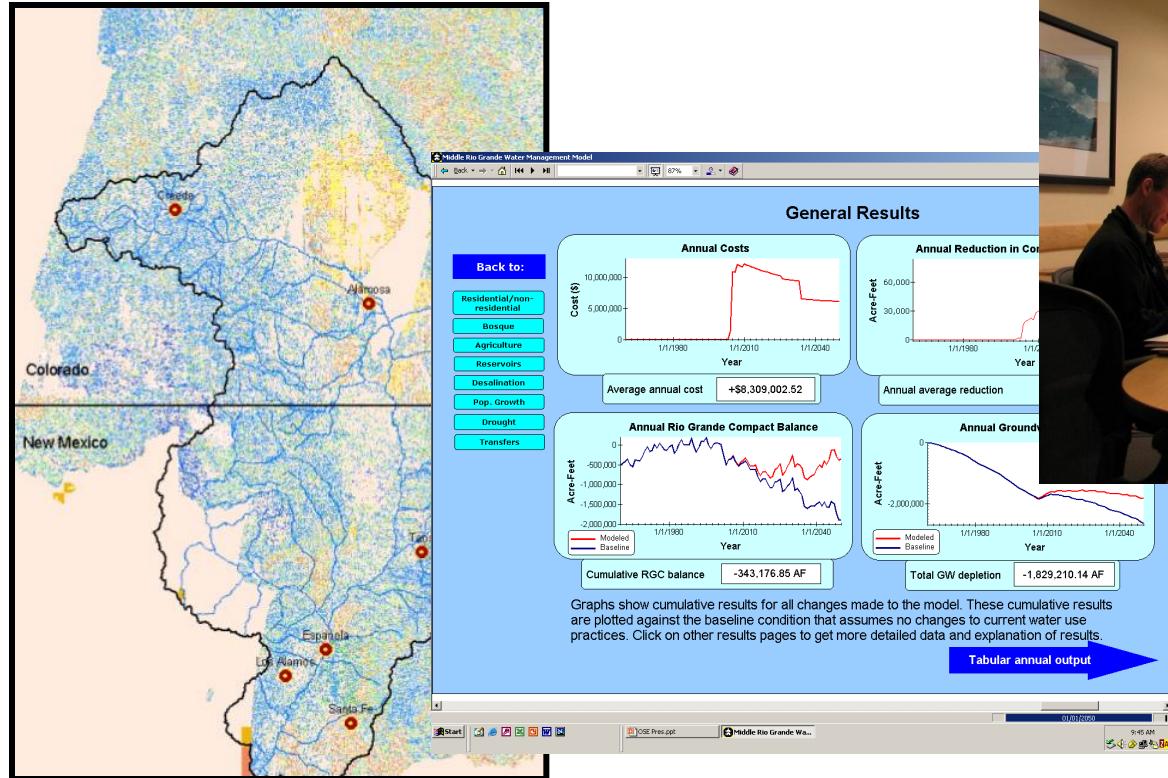
2003								
JAN	29080	---	2.2	26550	0	1830	0	
FEB	27660	---	2.5	24660	789	1380	0	
MAR	37510	4960	5.3	28940	2610	3590	0	
APR	55730	4900	6.8	42770	3830	9400	0	
MAY	69270	4550	142	57920	3380	5300	24	
JUN	61830	4840	508	47000	3920	560	130	
JUL	61710	4670	434	46360	3650	19	34	
AUG	48220	4040	665	38230	2340	898	103	
SEP	29500	4130	262	21510	2500	1750	44	
OCT	23840	2980	261	17720	1540	9210	0	
NOV	26950	223	42	24810	136	377	0	
DEC	36450	0	3.7	33370	0	800	0	
total	507750	35293	2334.5	409840	24695	35114	335	

2004								
JAN	30800	0	3.9	30200	0	802	0	
FEB	30300	0	2.9	27640	0	783	0	
MAR	71970	3800	5	59250	3540	6170	0	
APR	85870	4290	143	78130	3020	17470	388	
MAY	144000	5880	902	144200	4160	4720	0	
JUN	65560	5510	496	54170	3510	1080	2.8	
JUL	51080	4840	412	40820	3520	1950	69	
AUG	43010	4870	396	32150	3090	825	546	
SEP	38080	3890	358	29550	2730	784	43	
OCT	25410	---	344	20530	---	---	---	
NOV	42500	---	158	39630	845	437	0	
DEC	50500	---	111	---	---	1170	0	
total	679080	33080	3331.8	556270	24415	36191	1048.8	



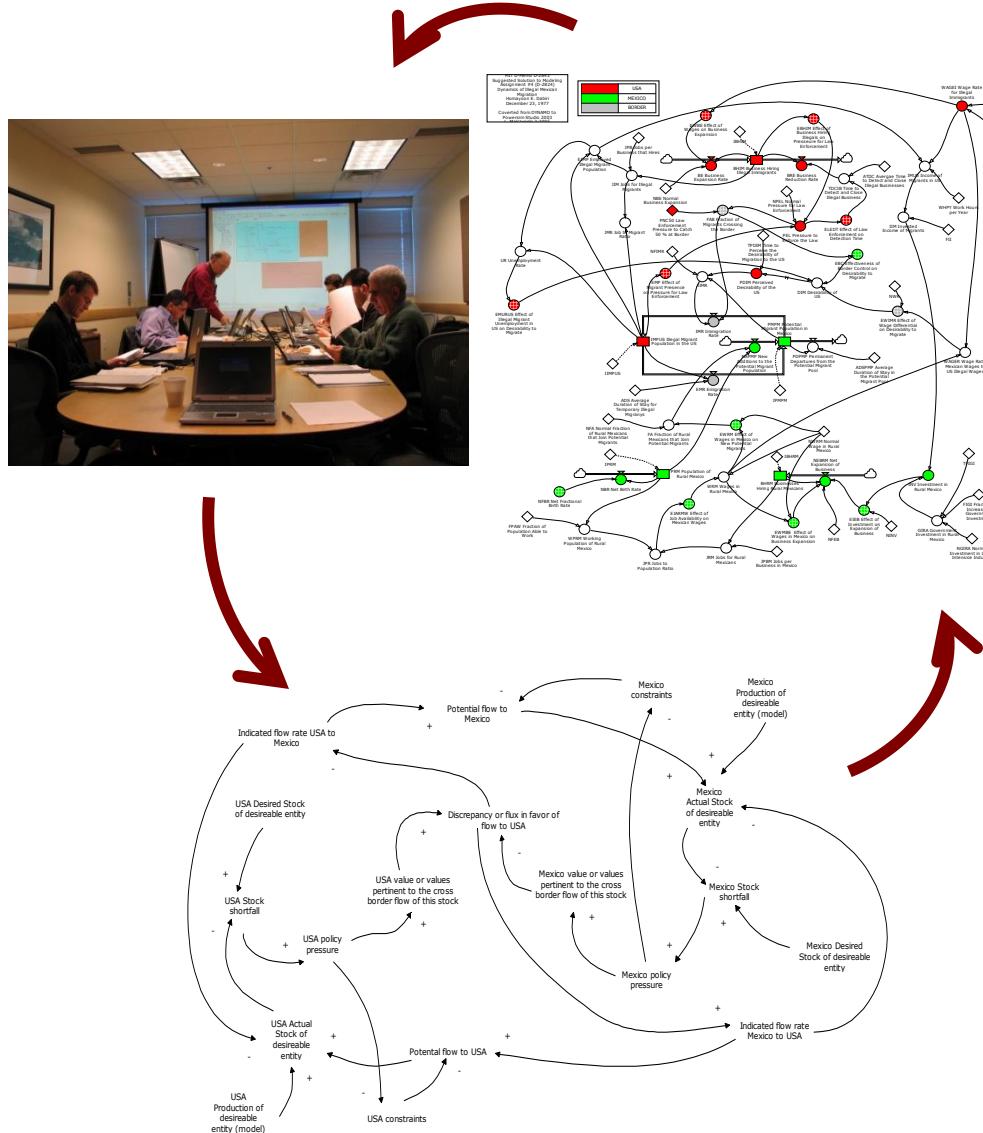
Balancing Tradeoffs

- Informed basis for decision making
- Tools and process that is vetted in a transparent decision environment



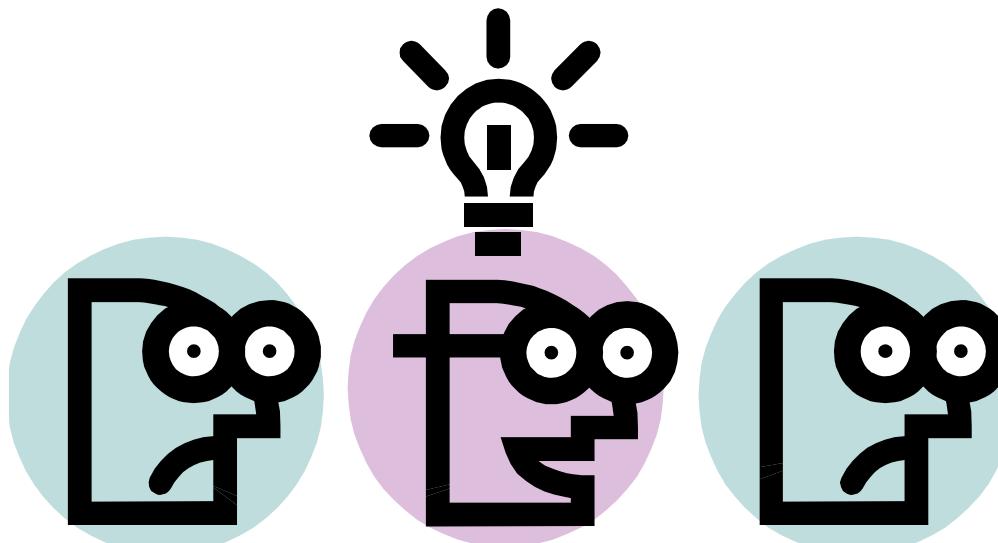
Collaborative Modeling: Process

- Process of engaging decision-makers and stakeholders in:
 - Model development, and
 - Decision analysis.
- Purpose of broad input includes:
 - Expand knowledge base,
 - Structure group thinking/discussion,
 - Stimulate group learning, and
 - Ultimately lead to improved advocacy.



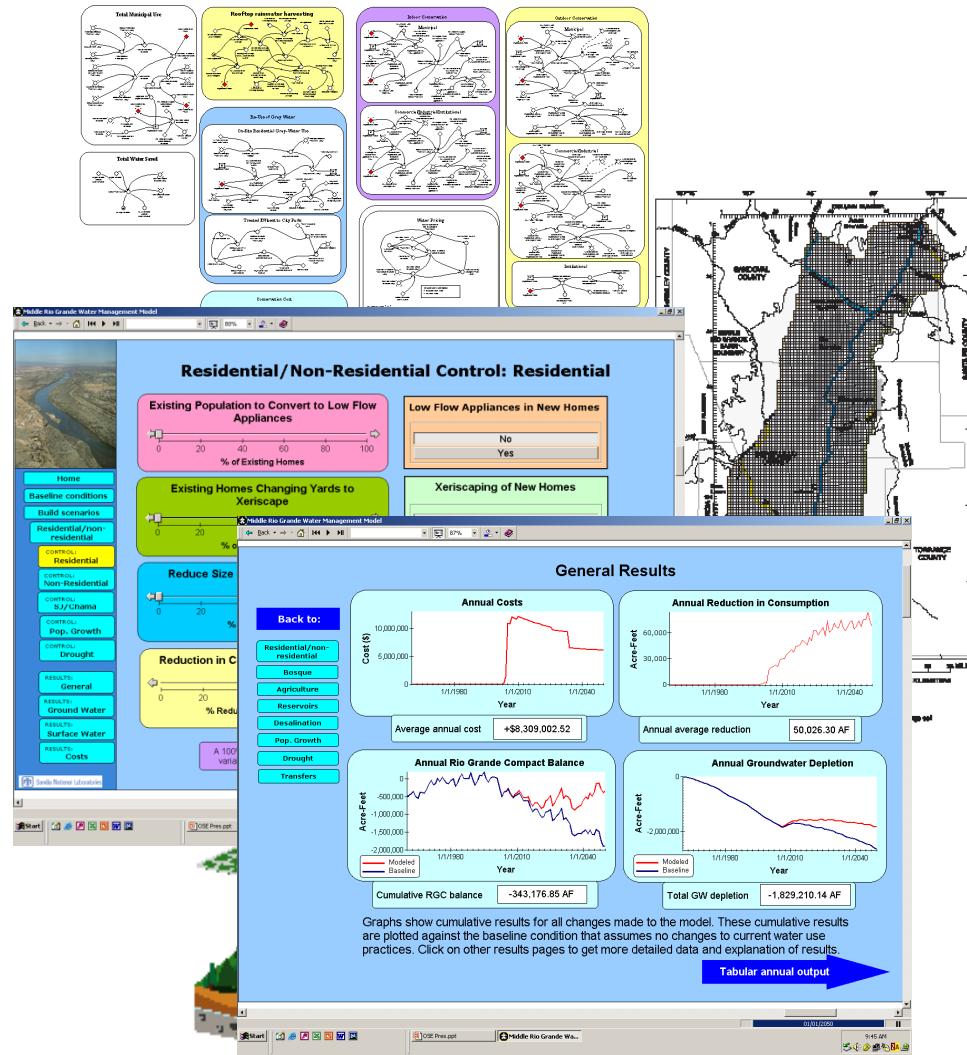
Collaborative Modeling: Process

- Why engage with stakeholders and decision makers?
 - Establish transparency,
 - Improved consensus in product,
 - Stakeholders add value to model,
 - Structure group thinking/discussion,
 - Stimulate group learning.



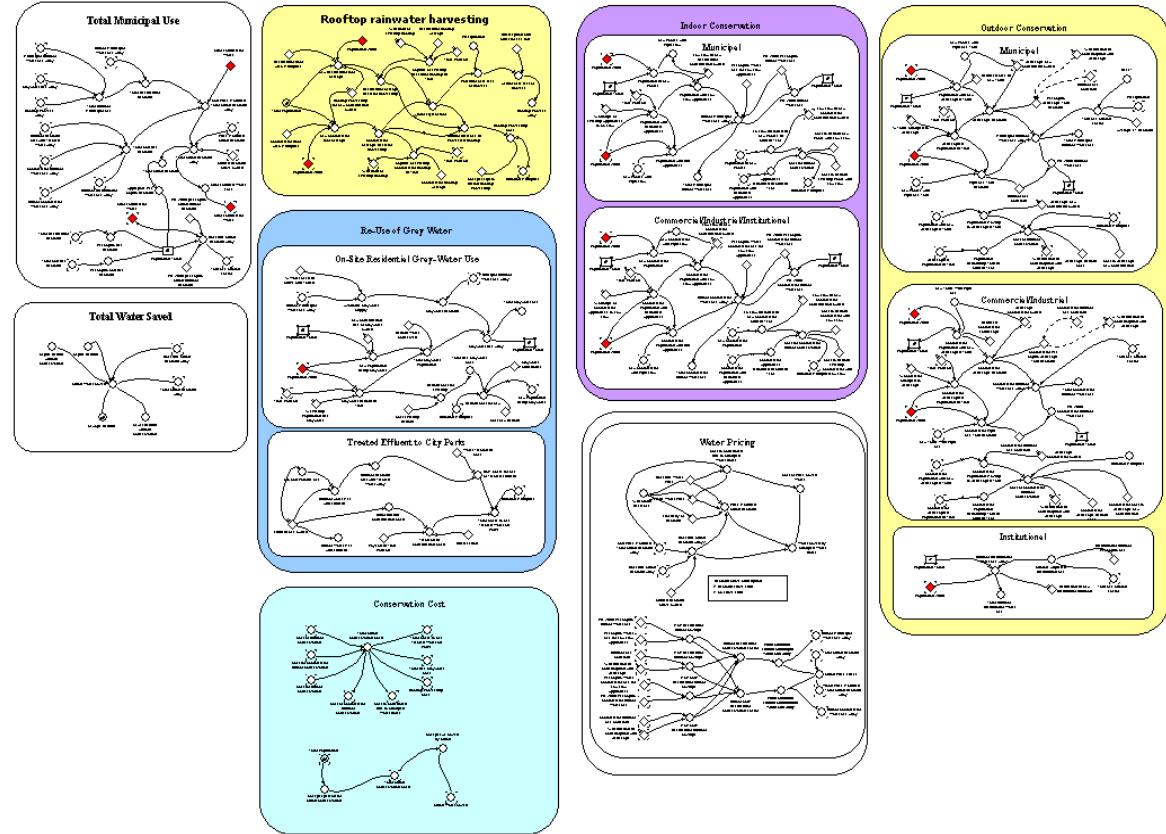
Cooperative Modeling: Tools

- System management,
 - High resolution,
 - Detailed physics,
 - Focused scope, and
 - Time intensive.
- System planning,
 - Low resolution
 - Scale appropriate physics,
 - Broad scope, and
 - Interactive.



Collaborative Modeling: System Dynamics

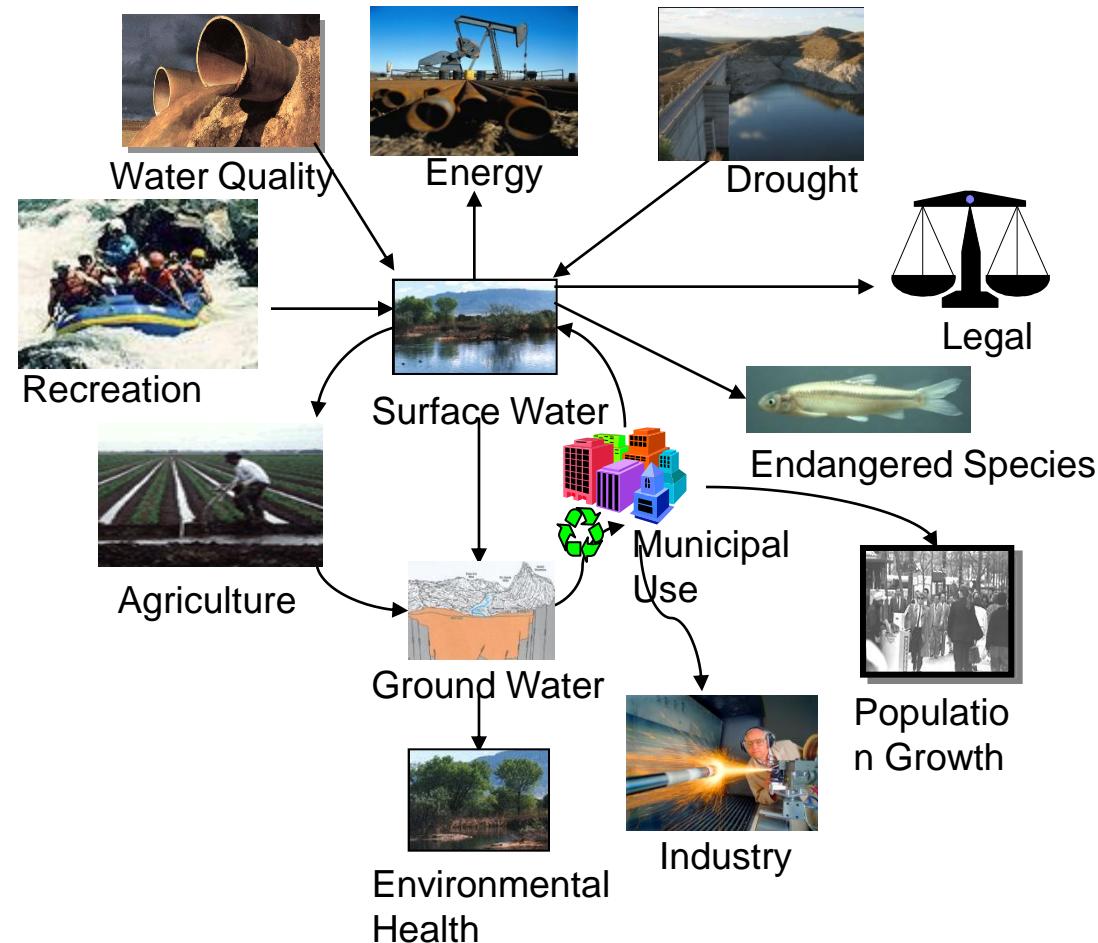
- We employ System Dynamics, which provides a formal framework for managing multiple interacting subsystems, each of which vary in time
- With system dynamics we are able to quantify feedback, time delays, and coupling between subsystem components



Focus is on ***Dynamic Complexity*** rather than ***Detail Complexity!***

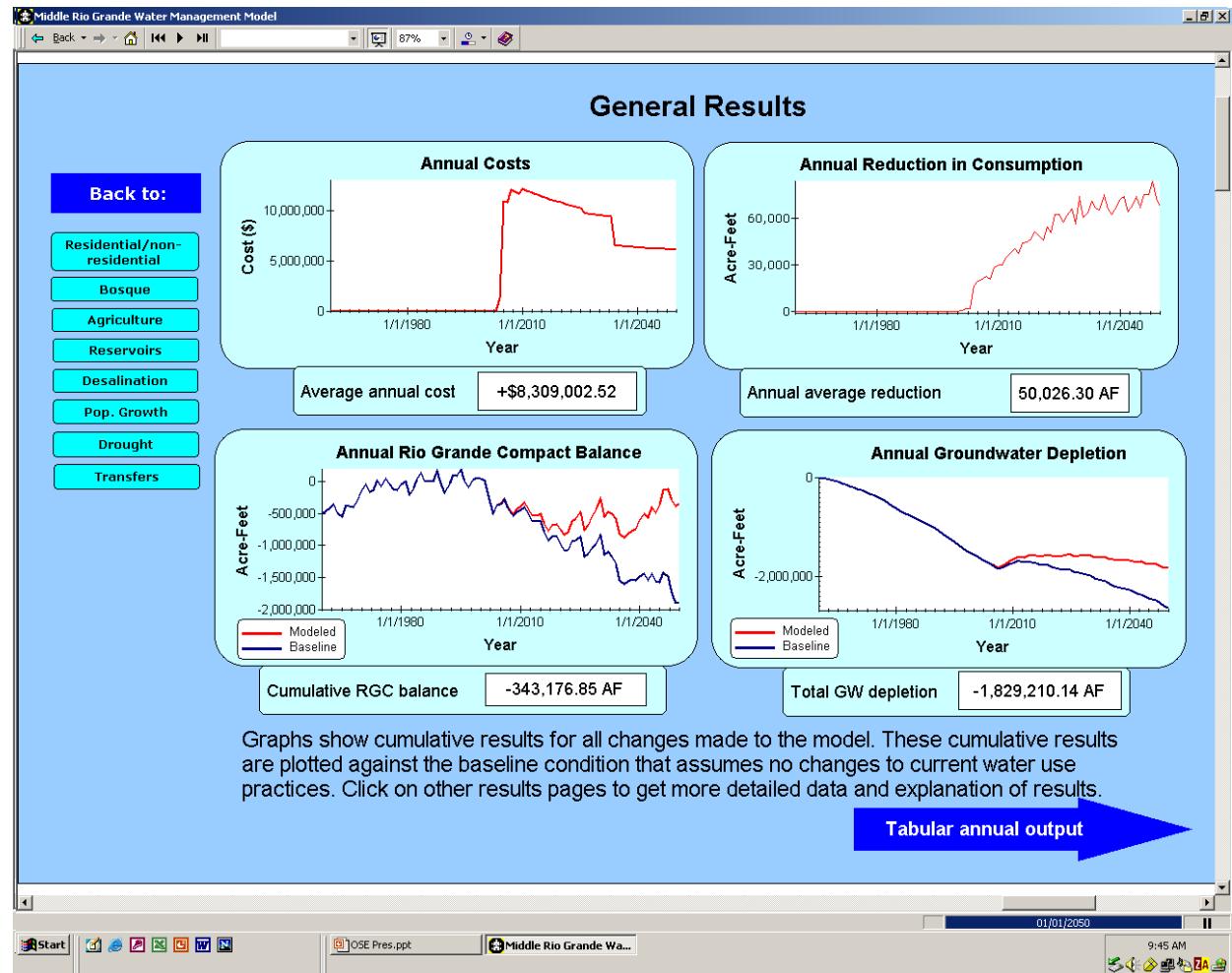
System Dynamics: Integrative Modeling

- Provides a framework for integrating over the broad range of factors influencing resource management



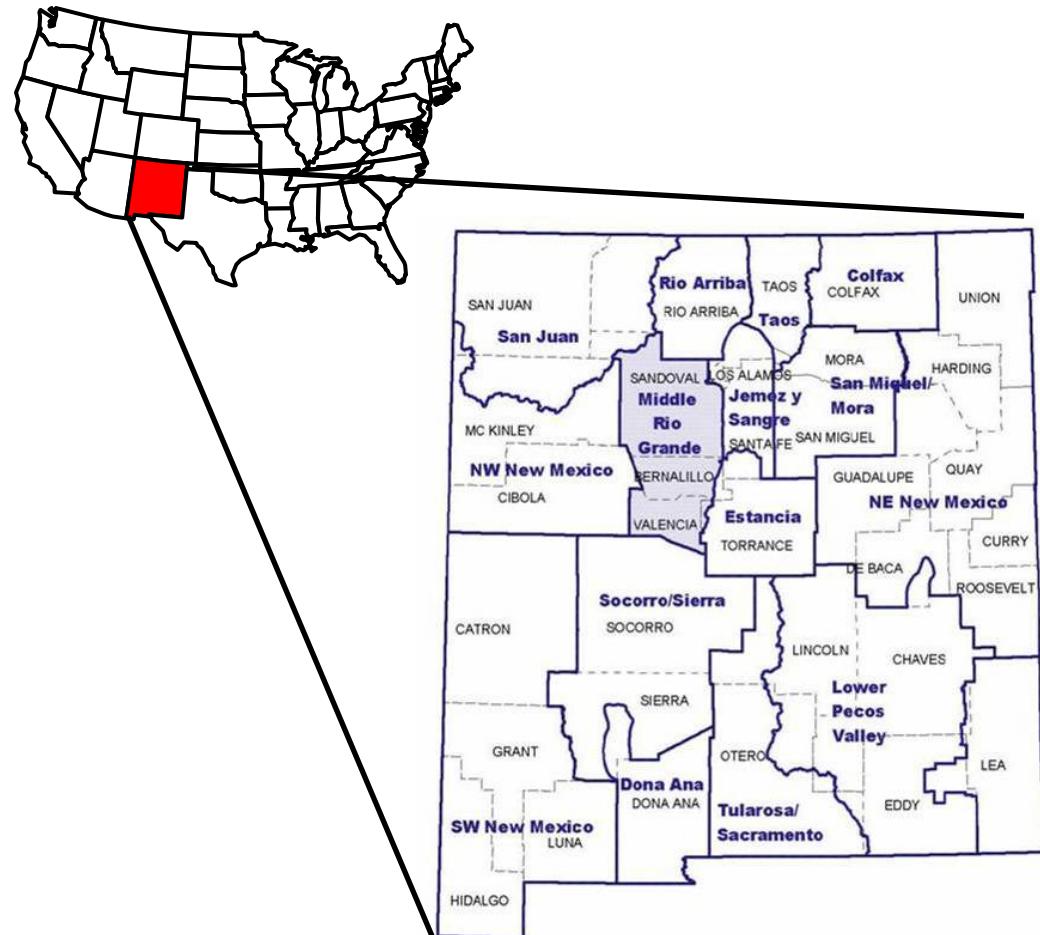
System Dynamics: Interactive Modeling

- Broadly accessible
 - PC based
 - User friendly interfaces
 - Computations in seconds to minutes
- Provides interactive environment for scenario testing



Middle Rio Grande Water Assembly

- Three county planning region
 - Bernalillo
 - Sandoval
 - Valencia
- Total population of ~750,000 including Albuquerque, Rio Rancho, Belen, Bernalillo and Los Lunas



Phase I Objectives

- 1. What is the region's available water supply?**
- 2. What is the region's future water demand?**
- 3. How will the region balance supply with demand?**
 - What actions can be taken?
 - Which are acceptable to the community?
 - How can they be implemented?



Planning horizon of 50 years!

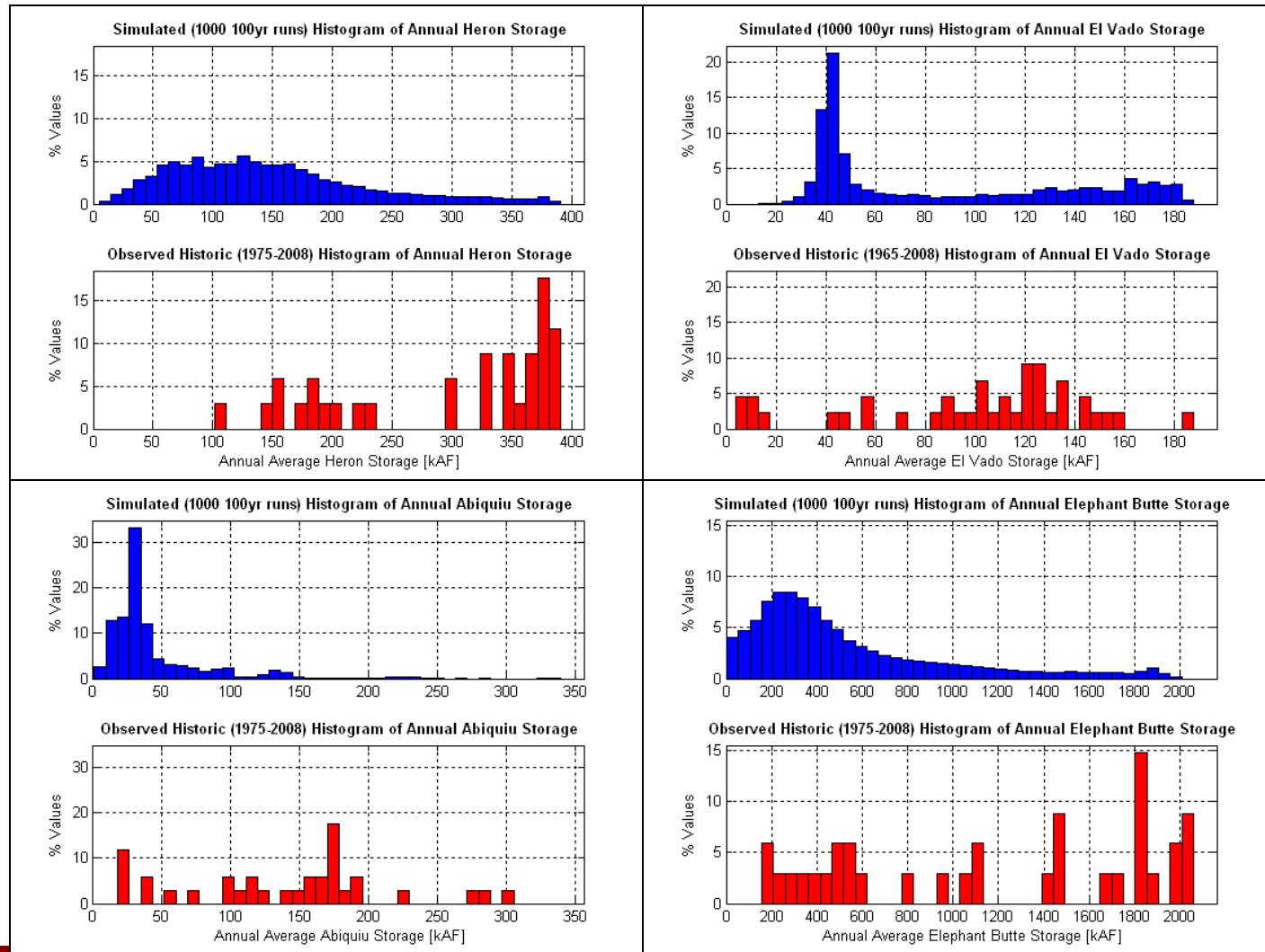
Model Development Process

- Assembled a “Cooperative Modeling Team” including members from:
 - Each Water Assembly constituency group,
 - Middle Region Council of Governments (MRCOG), and
 - Utton Transboundary Resources Center, UNM
- Team meets every other week to:
 - Conceptualize model components,
 - Identify external sources of expertise and data, and
 - Review the model
- Community engagement
 - Expose community to model
 - Public forums,
 - Educational venues, and
 - Community events
 - Interactions with the professional community



Model results: stochastic hydrology - reservoir storage

Use the model to run 1000, 100 year long climate sequences based on 400 years of tree ring data:



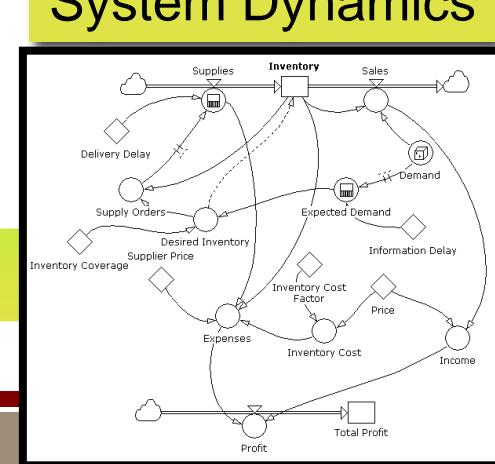
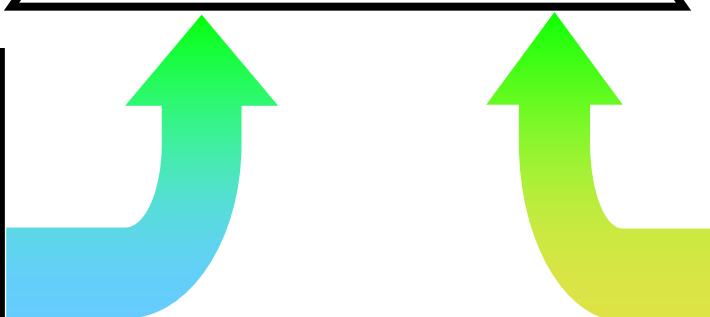
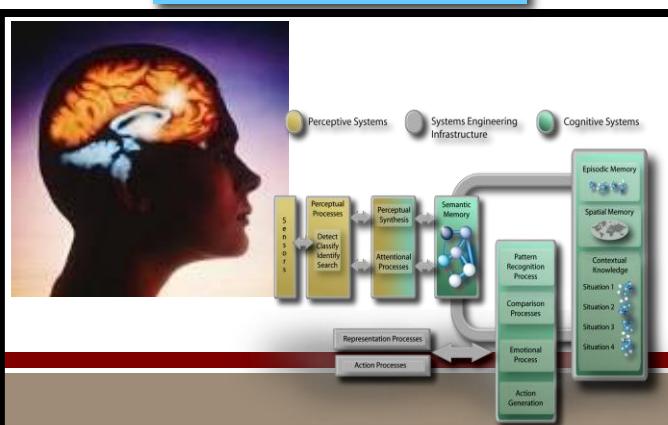
Decision Insight into Stakeholder Conflict for ERN (DISCERN)



Approach: Develop an decision support system that integrates agent-based models of stakeholder decision-making with traditional system dynamics models of resource constraints and economics, with advanced processes and tools (e.g., automated learning, serious gaming) for expedited data capture.

Agent Based
Modeling

System Dynamics



Serious Game Interface

- Water Wars Serious Game
 - SimCity style game
 - Built on Intel's Opensim gaming environment
 - SNL's integrated model serves as the "physics" to the game interface
 - Game is served over the web
- Game provides automated data capture on stakeholder behavior
- Game play controlled to expose desired action
- Game modes:
 - Multi player
 - Man against machine
 - Hybrid



Project Objectives

- Develop an integrated Energy-Water Decision Support System (DSS) that will enable planners to analyze the potential implications of water stress for transmission and resource planning.
- Pursue the formulation and development of the Energy-Water DSS through a strongly collaborative process between Western Electricity Coordinating Council, Electric Reliability Council of Texas, Western Governors' Association, and Western States Water Council.
- Exercise the Energy-Water DSS to investigate water transmission planning scenarios.



Project Partners

- Sandia National Laboratories
 - Vincent Tidwell
 - Barbie Moreland
 - Howard Passell
- Argonne National Laboratory
 - John Gasper
 - John Veil
 - Chris Harto
- Electric Power Research Institute
 - Robert Goldstein
- National Renewable Energy Laboratory
 - Jordan Macknick
 - Robin Newmark
 - Daniel Inman
 - Kathleen Hallett
- Idaho National Laboratory
 - Gerald Sehlke
 - Randy Lee
- Pacific Northwest National Laboratory
 - Mark Wigmosta
 - Richard Skaggs
 - Ruby Leung
- University of Texas
 - Michael Webber
 - Carey King



**Sandia
National
Laboratories**



EPRI | ELECTRIC POWER
RESEARCH INSTITUTE



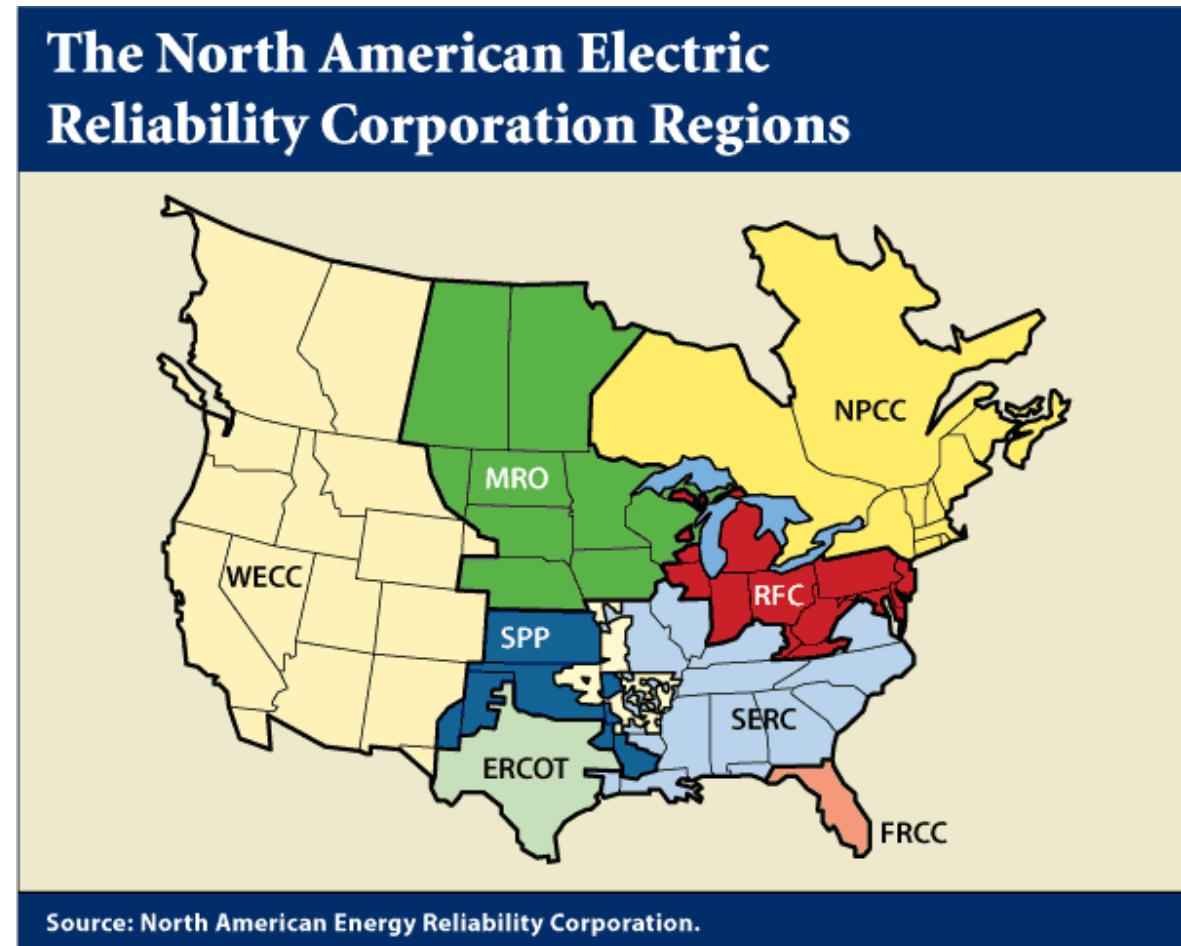
INL Idaho National Laboratory



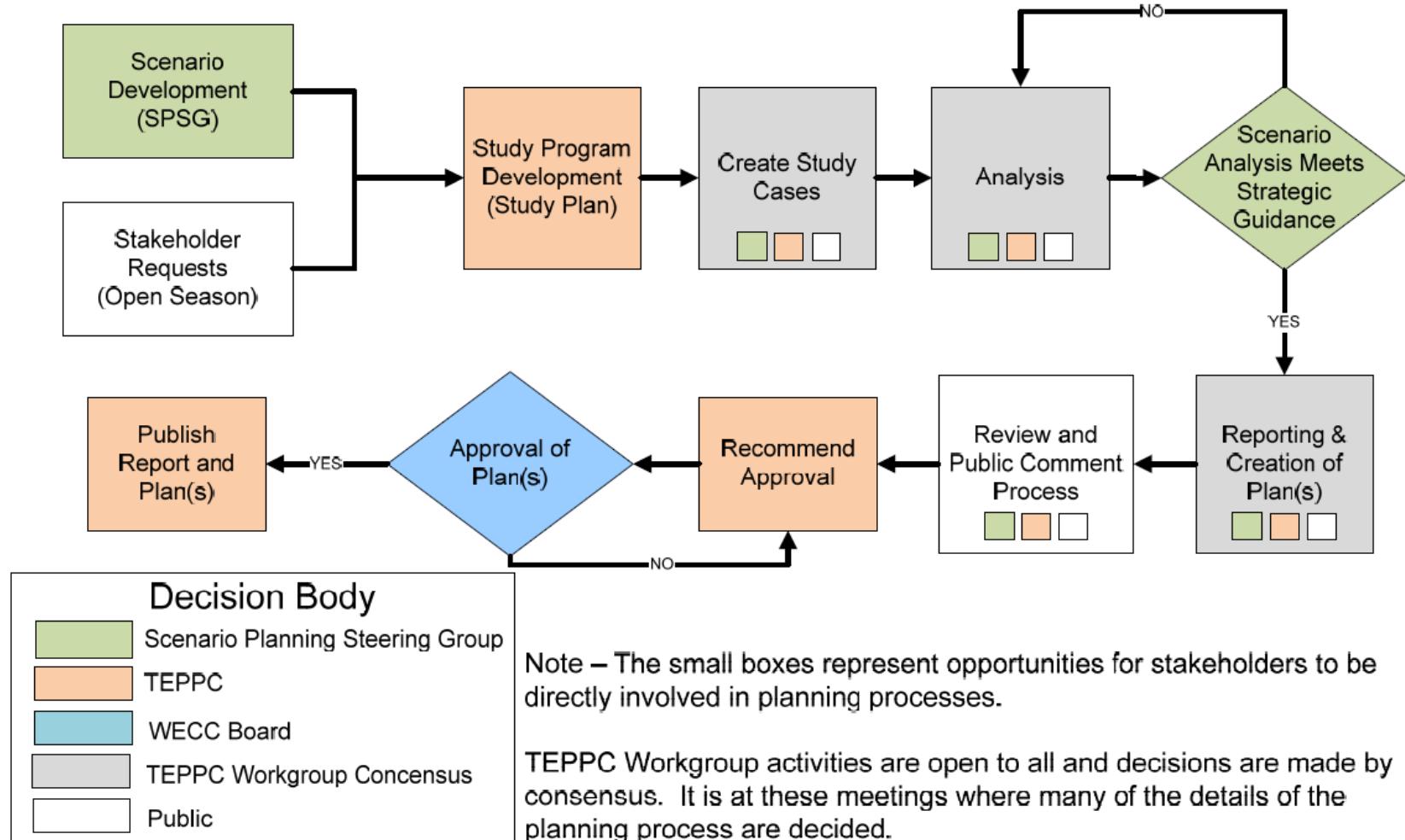
 Pacific Northwest
NATIONAL LABORATORY

Project Domain

- Project duration:
 - 24 months for WECC
 - 18 months for ERCOT
- Planning horizon is to 2030



Transmission Planning



Informing Decisions

Identify areas of potential siting risk due to limited water availability

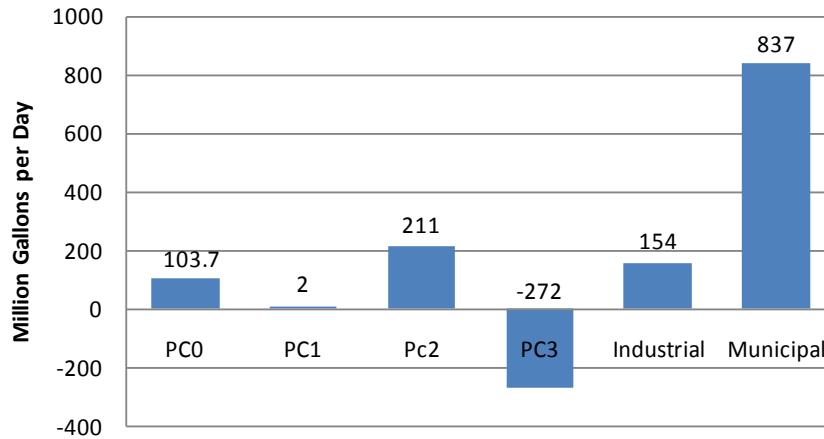
Use drought analysis to consider power plant and electric system vulnerabilities

Identify and develop technological or management options for planners and policymakers to account for water availability when siting electric generation

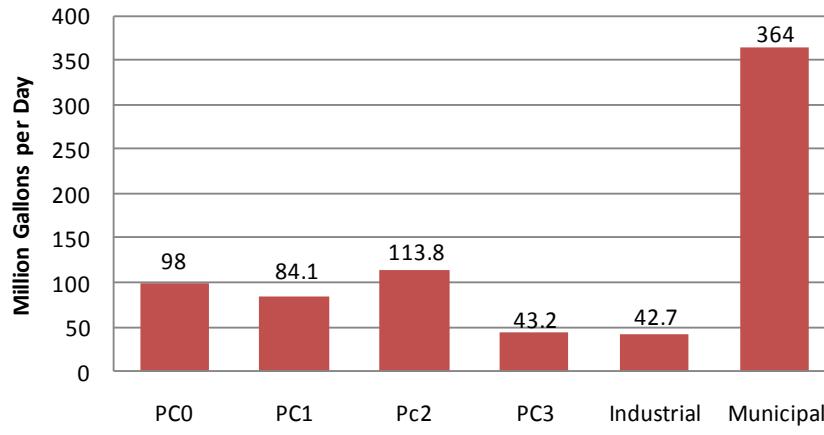
Prepare governors, industry, and regulators to understand long-term challenges and trade-offs

Initial WECC Scenario Analysis

New Withdrawal 2010-2020



New Consumption 2010-2020



2010 WECC Transmission Scenarios

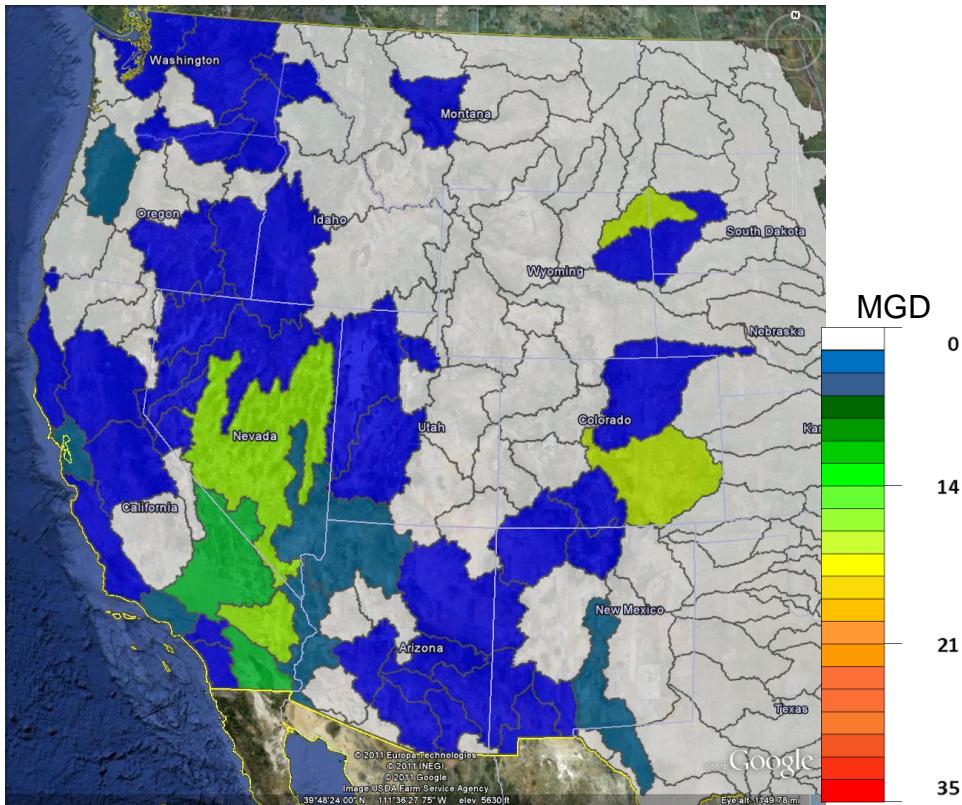
- WECC 2010 Reference Case
- High Load
- High DSM Scenario
- Carbon Reduction Scenario

Initial results produced by Sandia National Laboratories ; NREL assisted in developing metrics for water use/consumption by generation technologies

Caveat: All results are still preliminary and are being provided for illustrative purposes

Initial WECC Scenario Analysis

Thermoelectric Consumption



2010 WECC Transmission Scenarios

- WECC 2010 Reference Case
- High Load
- High DSM Scenario
- Carbon Reduction Scenario

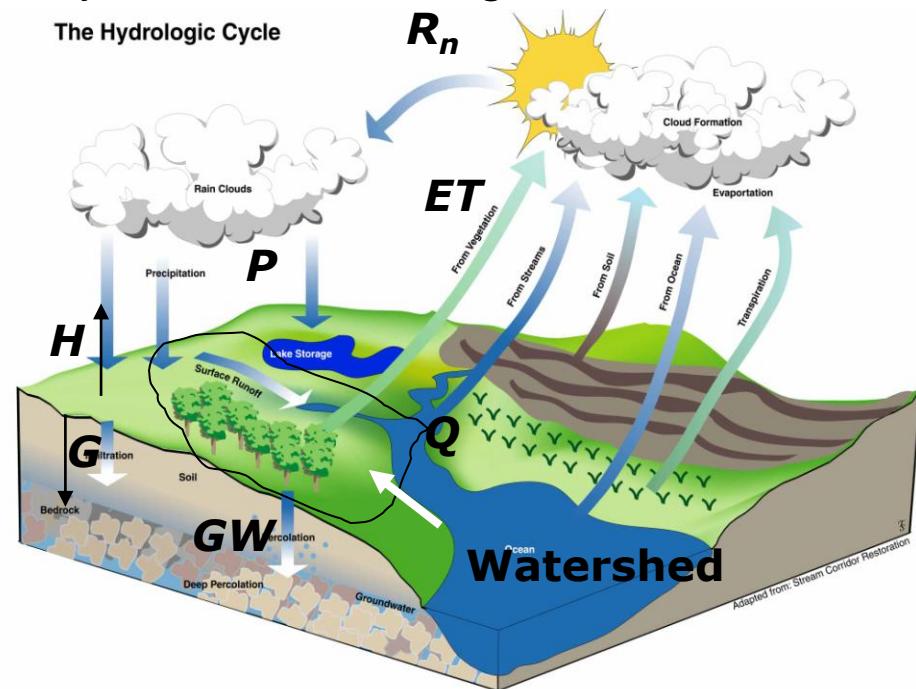
Initial results produced by Sandia National Laboratories ; NREL assisted in developing metrics for water use/consumption by generation technologies

Caveat: All results are still preliminary and are being provided for illustrative purposes

Water Availability Indicators

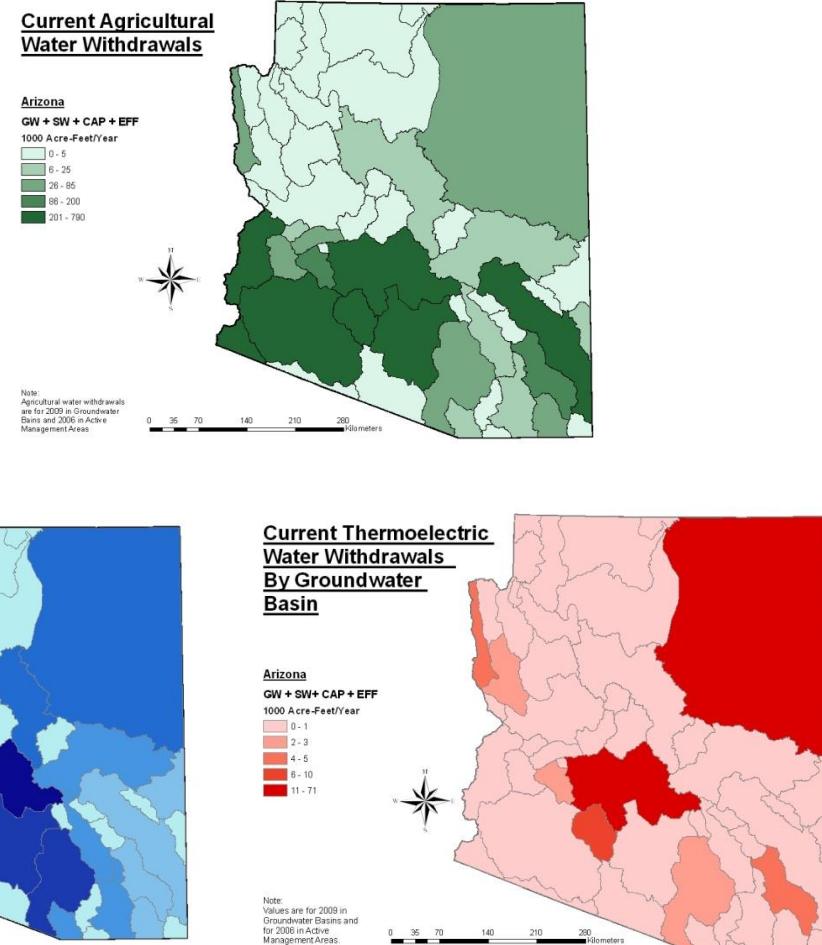
- ***Water Demand***
 - ***Water Supply***
 - ***Drought Vulnerability***
 - ***Institutional Factors***
 - ***Value of Water***
- Physical Water

Physical Water Budget

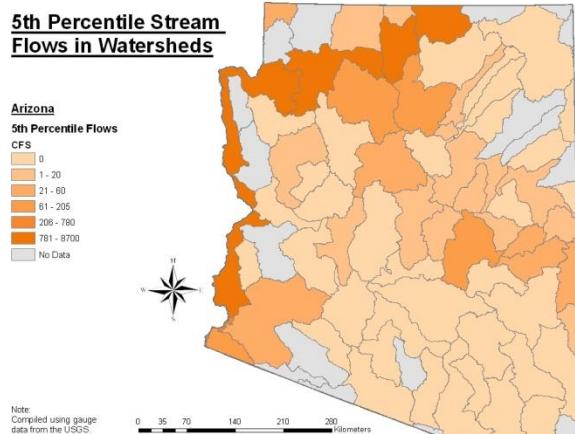


Water Availability Indicators: Demand

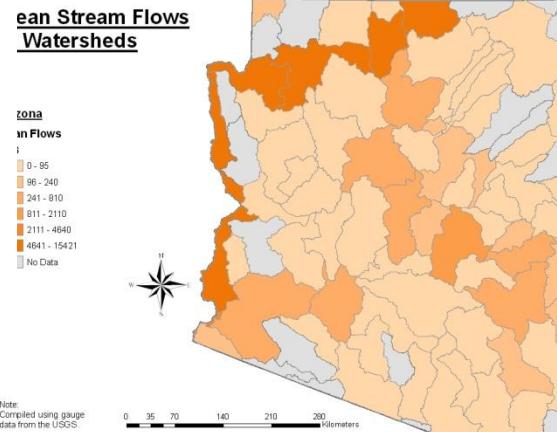
- ***Focus on withdrawals***
- ***Estimate consumption from withdrawals***
- ***Disaggregate by:***
 - ***8-digit watershed***
 - ***Sector***
 - ❖ ***M&I***
 - ❖ ***Agriculture***
 - ❖ ***Evaporative***
 - ❖ ***Instream***
 - ***Water source***



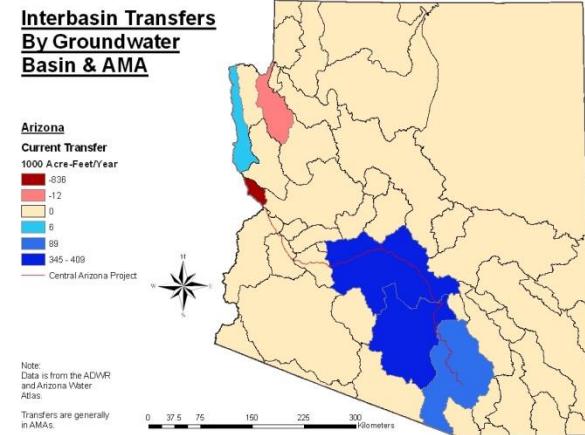
Water Availability Indicators: Supply



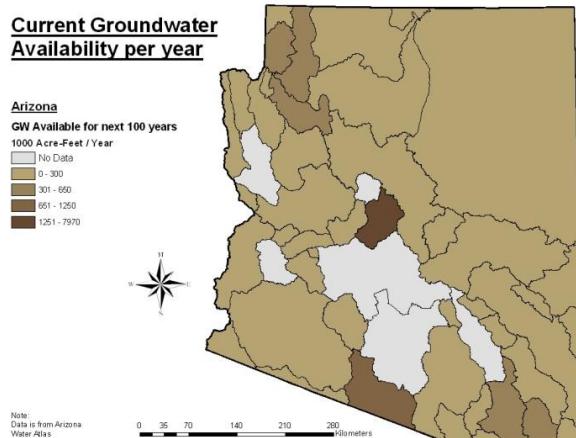
Mean Gauged Streamflow



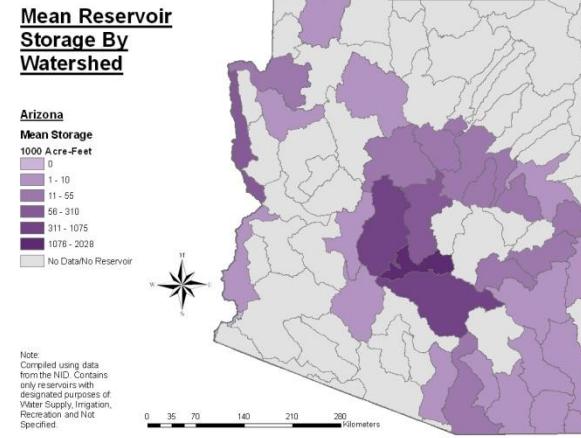
Annual Low Flow



Interbasin Transfers

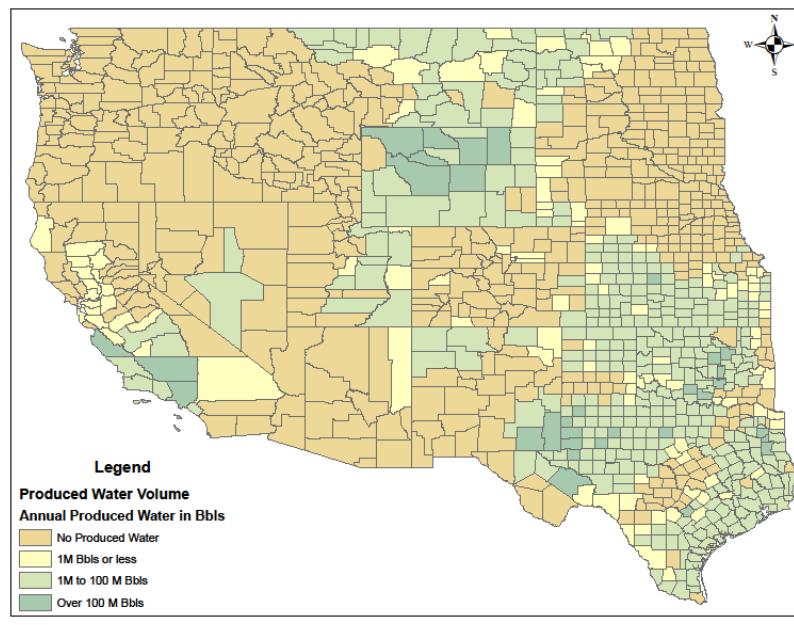
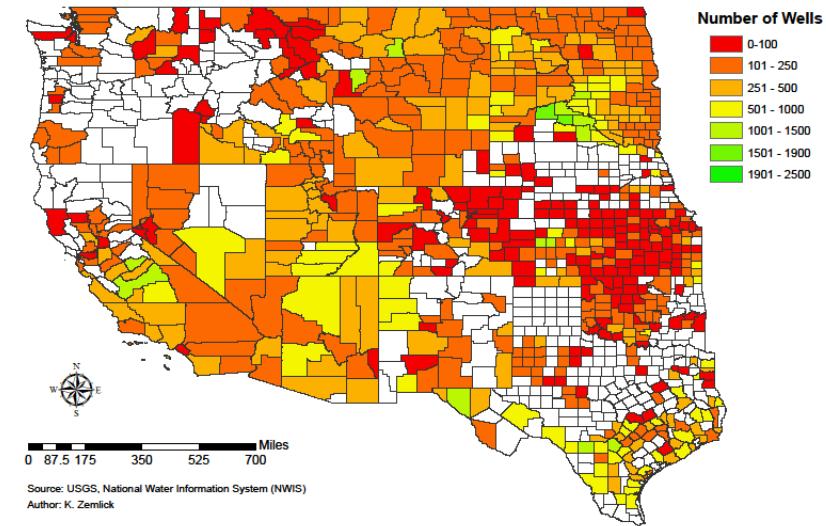
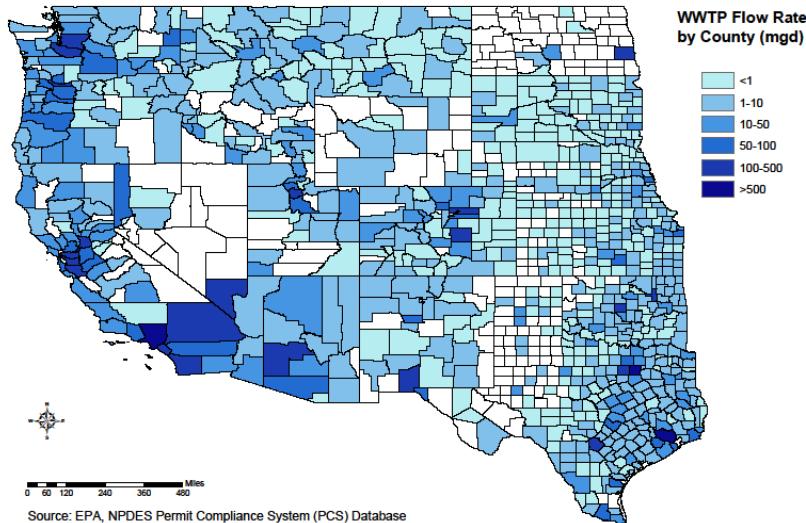


Non-Tributary Groundwater



Reservoir Storage

Water Availability Indicators: Supply



Water Availability Indicators: Institutional Factors

Current Groundwater Availability per year

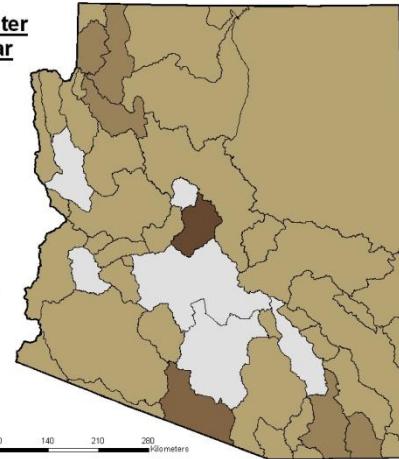
Arizona
GW Available for next 100 years
1000 Acre-Feet / Year

No Data
0 - 300
301 - 600
601 - 1250
1251 - 7970



0 35 70 140 210 280 Kilometers

Note:
Data is from Arizona
Water Atlas



Unappropriated Water

Status of Water Claims for Indian Communities

Arizona
Status

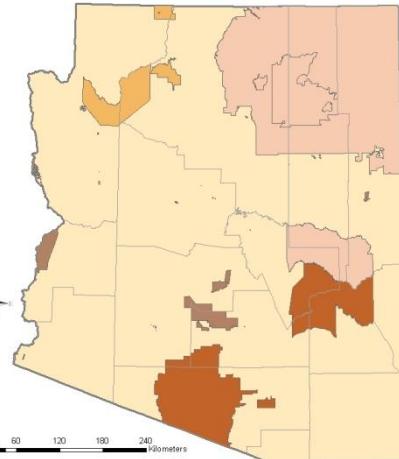
In Negotiations
Settled
Settled/Unresolved
Unresolved



0 30 60 120 180 240 Kilometers

Note:
Settled/Unresolved = Portions
of claims have been settled,
while others remain unresolved.

Status as of Sept. 2010



Indian Water

Adjudicated Surface of Water Basins

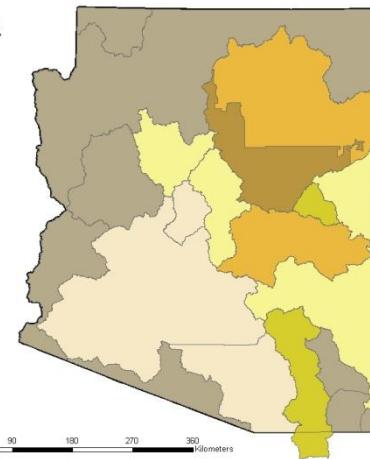
Arizona
Status of Adjudication Process

ACTIVE
FINAL
NONE
ONGOING
PENDING
PRELIMINARY



0 45 90 135 180 225 270 315 Kilometers

Note:
Includes agreements with
other states and Mexico



Adjudication Status

Groundwater Basins & Special Management Areas

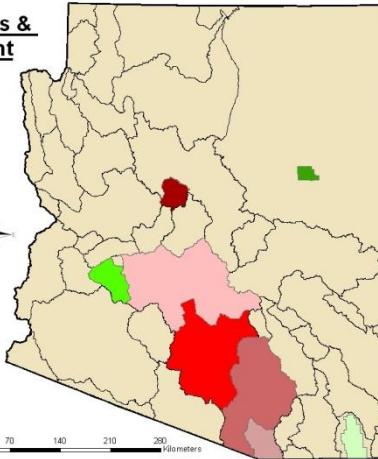
Arizona
Type

Groundwater Basin
Douglas INA
Harquahala INA
Joseph City INA
Phoenix AMA
Pinal AMA
Prescott AMA
Santa Cruz AMA
Tucson AMA



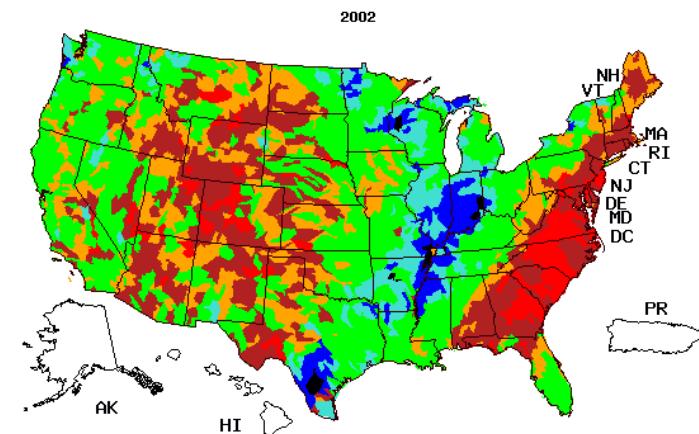
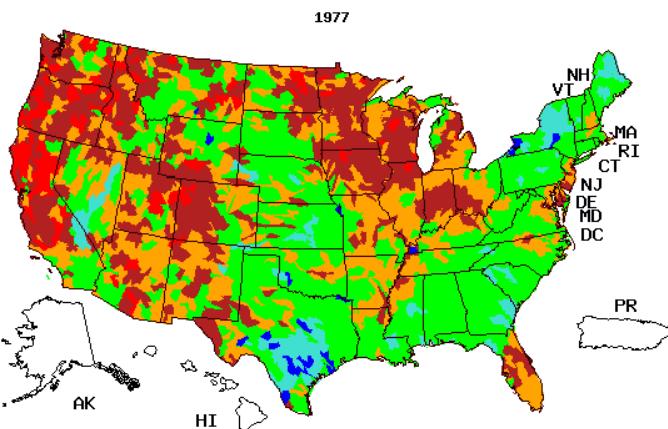
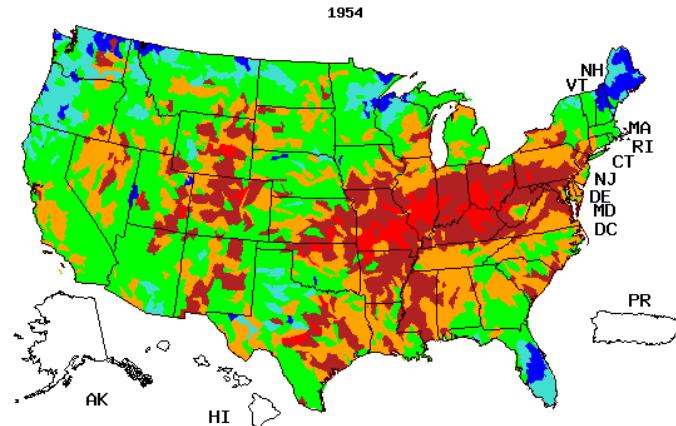
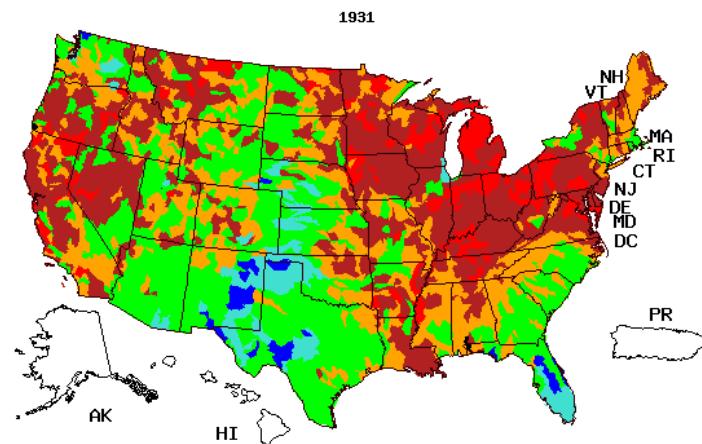
0 35 70 140 210 280 Kilometers

Note:
INA = Irrigation Non-Expansion Area
AMA = Active Management Area



Administrative Control Areas

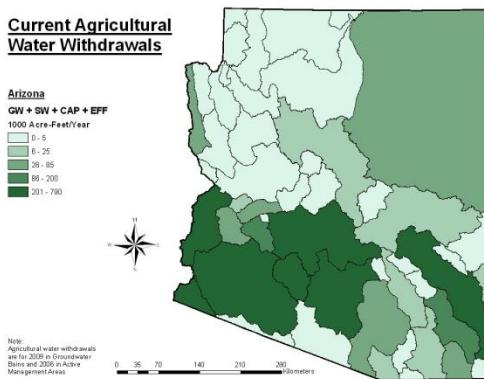
Regional Pattern of Severe Drought



Explanation -- Percentile Range							
Lowest	< 10	10 - 24	25 - 75	76 - 90	>90	Highest	No data

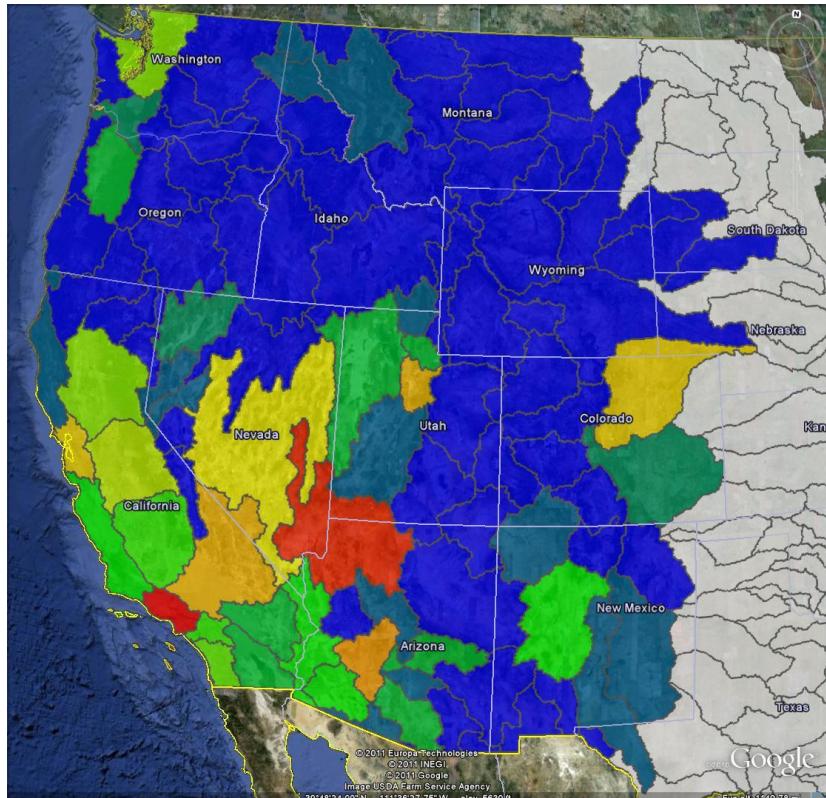
Water Availability Indicators: Value of Water

- Historic value of leased and sold water rights
- Economic value of water
- Cost of backstop technology

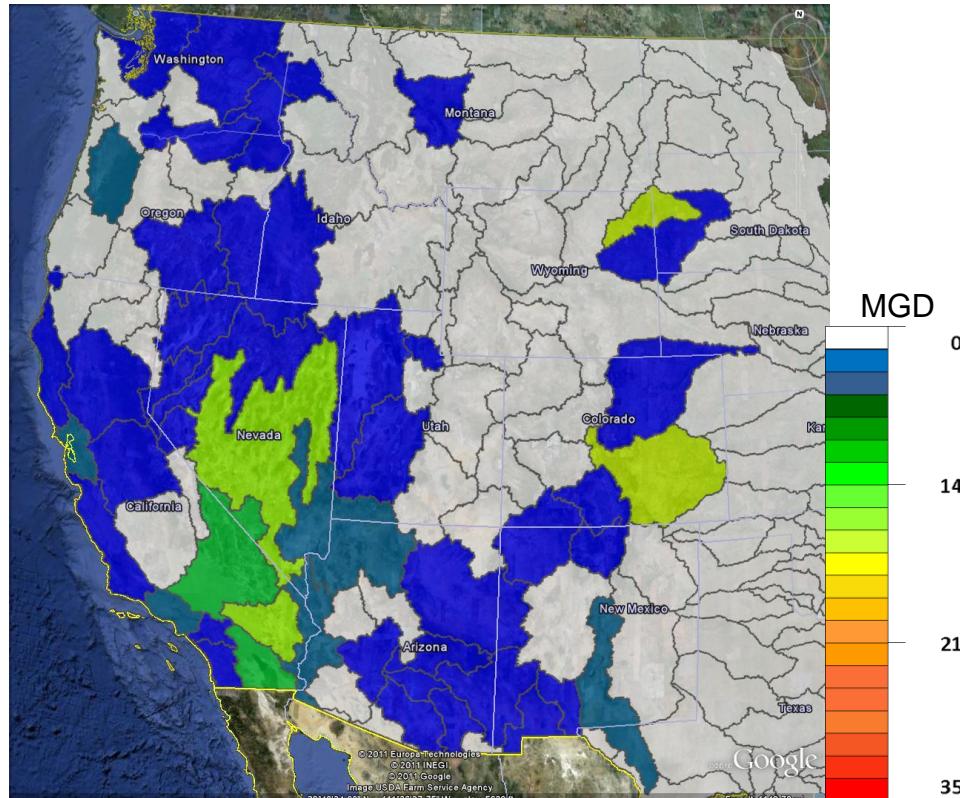


Growth in Non-Thermoelectric and Thermoelectric Consumption 2010-2020

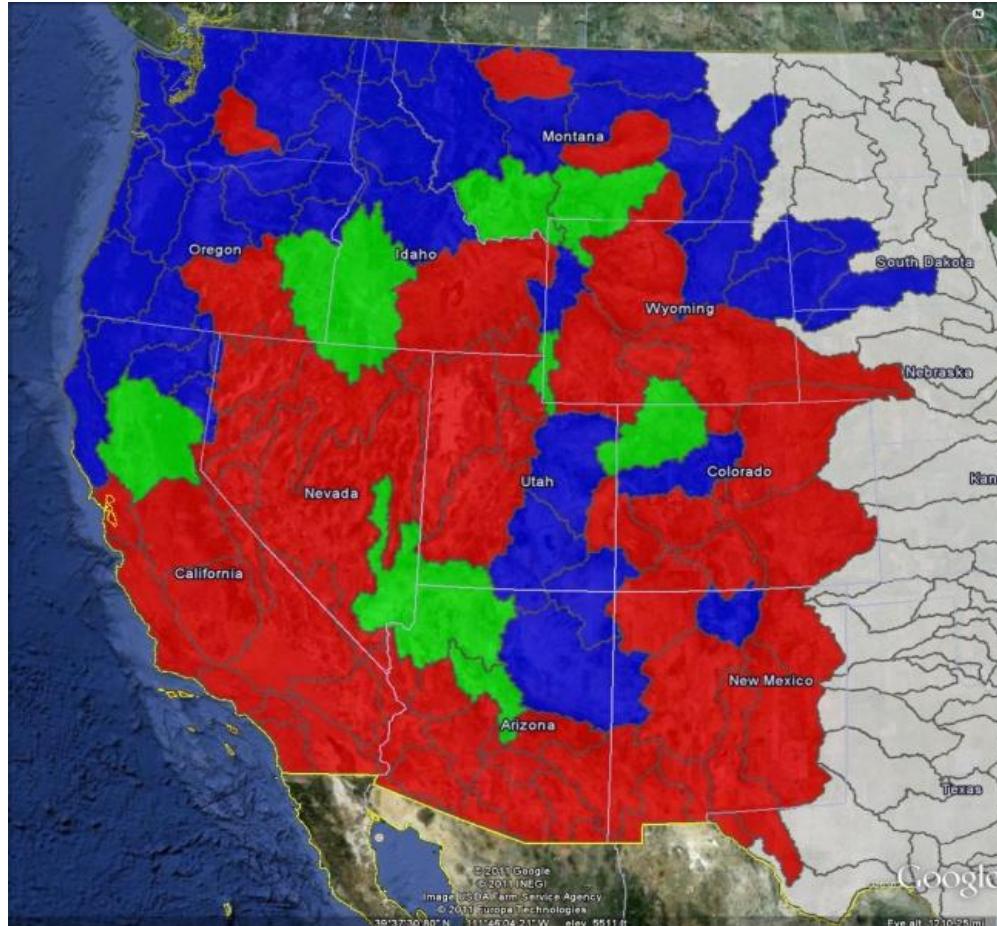
Non-Thermoelectric Consumption



Thermoelectric Consumption



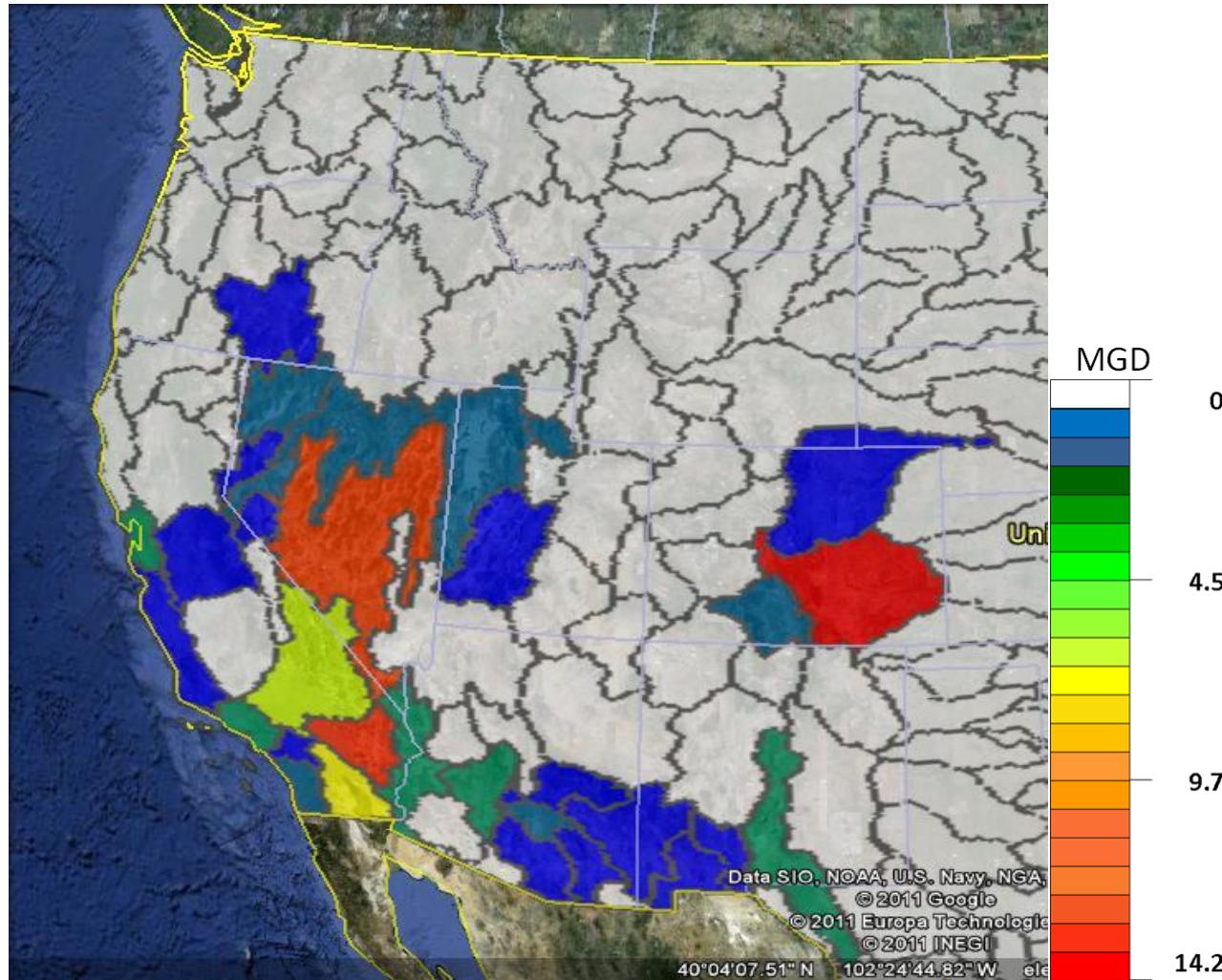
Regions Prone to Water Stress



Supply Consumption

	1-2
	2-3
	>3

New Power Plant Water Consumption in Basins with Limited Water Availability 2020



HydroSCOPE:

Hydropower Seasonal Concurrent Optimization for Power and the Environment tool

HydroSCOPE is an integrated simulation and optimization tool for:

- Helping operators, planners, and policy makers balance water use and environmental performance against power generation and earned revenue
- Ensuring that current operations are consistent with seasonal scale (1 to 6 month) forecasts
- Reducing costs through better planning
- Performing tradeoff and scenario analysis to identify operational improvements, detect unnecessary constraints, and/or improve operational rule-sets



<http://www.water.ca.gov/swp/facilities/Oroville/index.cfm>

Optimization and Simulation

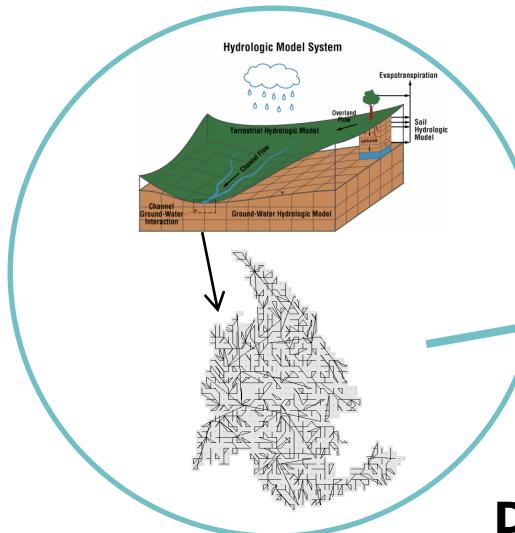
- Increase power production by optimizing operations within the myriad of constraints
- Allow for rapid evaluation of new technologies and management options
- Evaluate new development within the regulatory framework



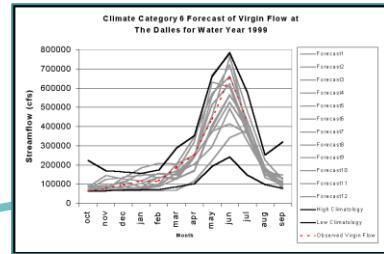
http://www.ag.unr.edu/saito/research/Blue_Mesa.htm

Hydropower Optimization Toolset

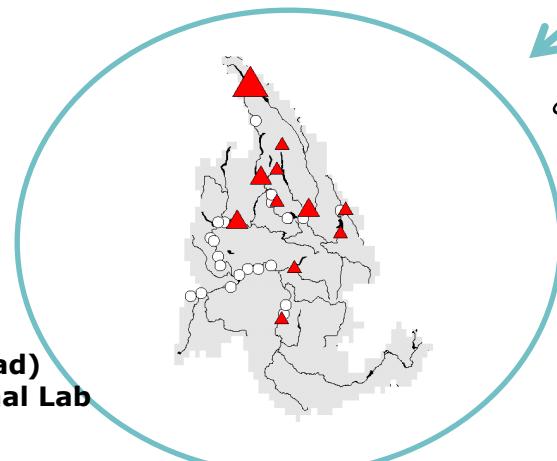
PNNL Hydro-Climatic Forecast



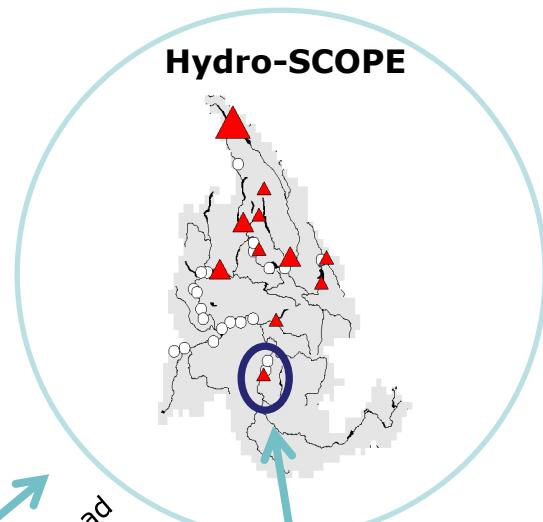
Ensemble forecast



ANL Day Ahead Scheduling



SNL Seasonal Operation

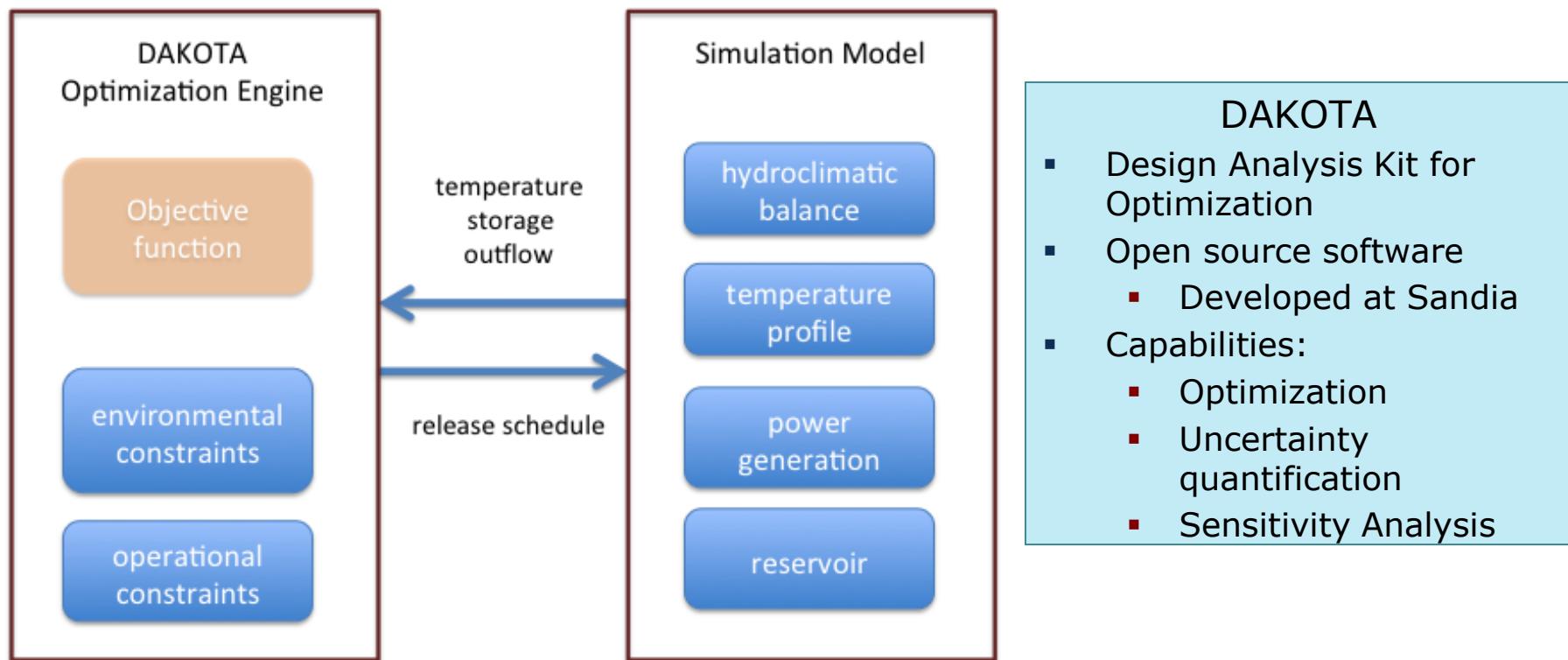


ANL *Environmental Performance*

ANL = Argonne National Lab (Lead)
 PNNL = Pacific Northwest National Lab
 SNL = Sandia National Lab

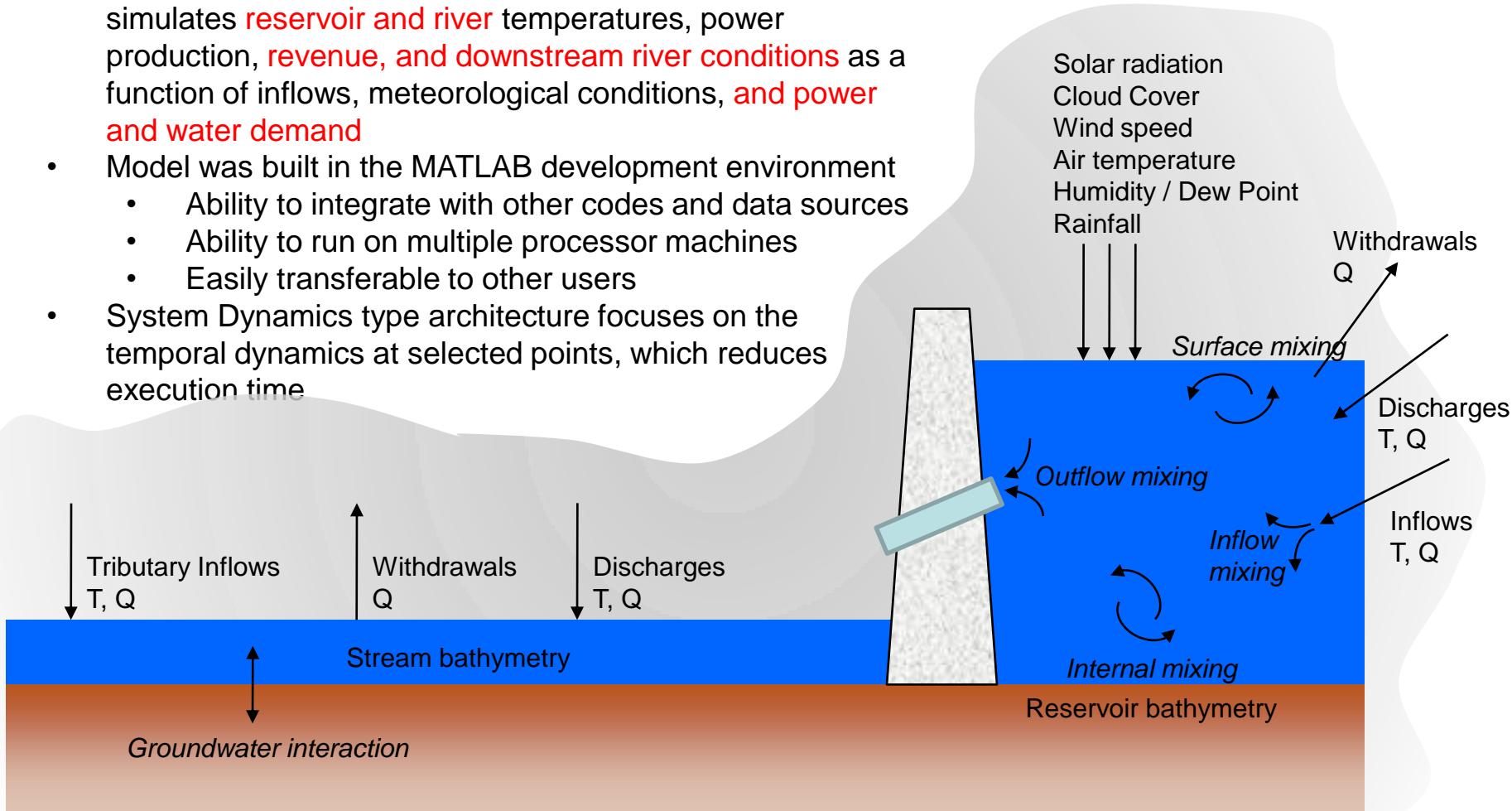
HydroSCOPE Optimization

- Simulation engine calculates temperature and flow conditions for multi-project, basin-scale systems
- Simulation output is seamlessly integrated with Sandia's DAKOTA optimization software for performing multi-objective, multi-variate optimization
- Designed for 1 – 6 month simulation periods
- Optimization is used to set release schedules for each project in the system



Simulation Model

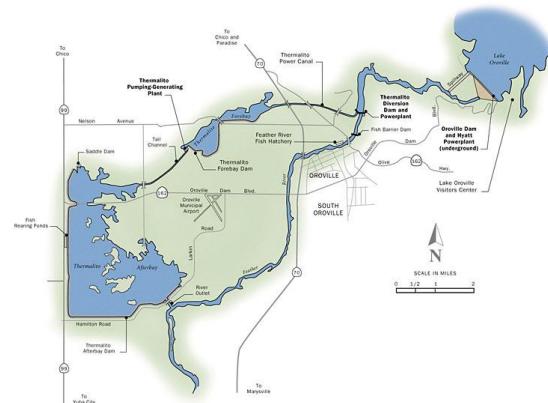
- Coupled 1-d reservoir and river routing model that simulates **reservoir and river** temperatures, power production, **revenue, and downstream river conditions** as a function of inflows, meteorological conditions, **and power and water demand**
- Model was built in the MATLAB development environment
 - Ability to integrate with other codes and data sources
 - Ability to run on multiple processor machines
 - Easily transferable to other users
- System Dynamics type architecture focuses on the temporal dynamics at selected points, which reduces execution time



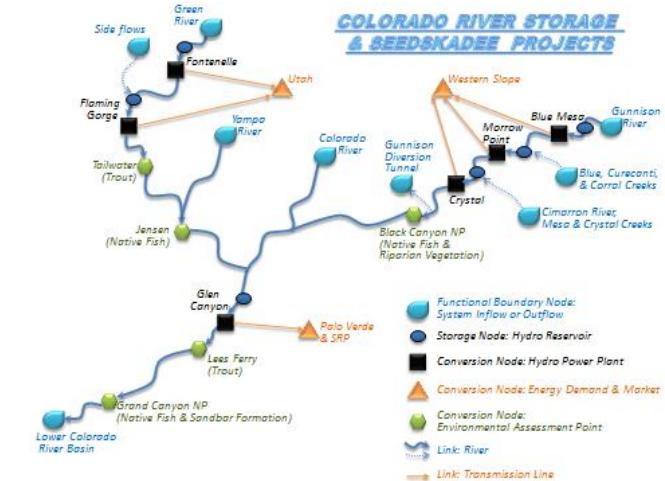
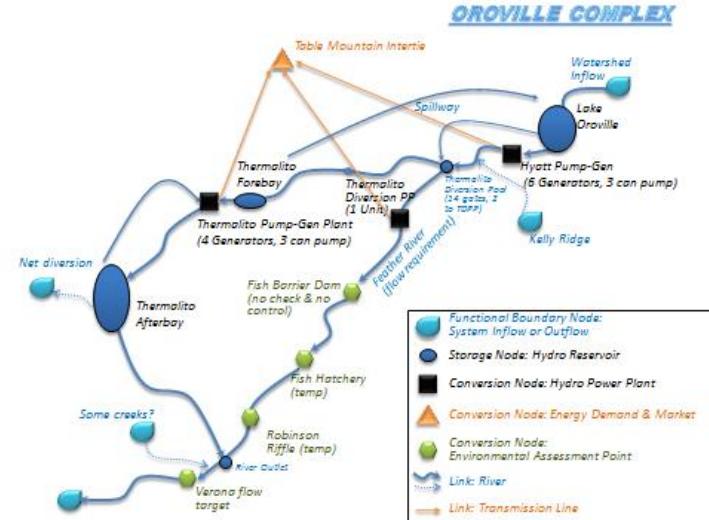
Toolset Demonstration

The Hydropower Optimization Toolset is being tested at two sites, the **Upper Colorado River Storage Project (UCRSP)** and the **Oroville Complex on the Feather River in California**.

Each of these sites brings unique challenges and should allow for a comprehensive test for each of the tools. Other demonstration sites are being actively pursued. Completion of the toolset and the demonstrations is scheduled for the end of 2012.



<http://www.water.ca.gov/swp/facilities/Oroville/index.cfm>



SNL Decision Support Systems

	Active projects (as of 11/2010)	Past projects beginning in 1992
Domestic	<ul style="list-style-type: none"> • Upper Rio Grande Simulation Model • Energy, Power & Water Simulation Model • SunCity Model • Water, Energy and Carbon Sequestration Model • Gila Basin-Az Water Settlement Model • Electrical Grid Storage Valuation Model • Alternative Liquid Fuels Simulation Model • Electricity Generation Cost Simulation Model • Virtual Water Market Model • Geothermal Energy Tradeoff and Scenario Analysis Model • Transition to Renewable Energy – County of Maui • Cut-off Grade Determination for Potash Mining in New Mexico • Validation and Verification of VISION Civilian Nuclear Fuel Cycle Model 	<ul style="list-style-type: none"> • U.S. Energy and GHG Gas Model • Sandia-GM Biofuel Deployment Model • Renewable Energy Systems & Learning Model • String of Pearls Model • Middle Rio Grande Cooperative Water Model • Nambe Pueblo Water Budget Model • Hydrogen Futures Simulations Model • Barton Springs Urban Growth and Groundwater Sustainability Model • US-Mexico Border Permeability Model • Upper Rio Hondo Water Availability Model • Biofuels Feasibility Modeling & Analysis Project • Algae Biofuels Techno-Economic Modeling and Analysis Project • Climate Change Risk Assessment Model • Willamette Basin Temperature TMDL Model • Insurgency as a Business Enterprise
International	<ul style="list-style-type: none"> • Strategy for Water and Land Resources in Iraq Model • US-Canada Algae Biofuel Co-Location Model • Libyan Water-Energy-Food Model • Strategic Water Allocation Demonstration Model for the Canterbury Region of New Zealand • Spent Fuel Management – Taipower Taiwan 	<ul style="list-style-type: none"> • China Energy and GHG Gas Model • India Energy and GHG Gas Model • Electricity Generation Cost Simulation Model • Iraq Water-Energy-Food Model • The US/Mexico Water Management Model • The Rainy River Model