



Sandia Water Initiative Overview

www.sandia.gov/water





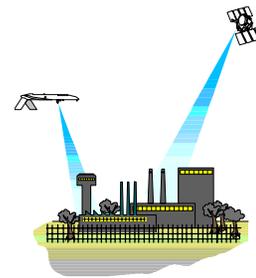
Sandia National Laboratories has four primary mission areas

Safety, Security, & Reliability Of Nuclear Weapons

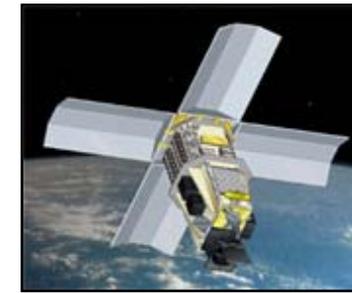


Safe, Secure, Reliable Weapons

Reduction of Vulnerability to Weapons of Mass Destruction



Detection



Surveillance

Safety, Security, & Reliability of Critical Infrastructures

Energy



Transportation



Environment



Water



Information

Enhancing National Security Measures



Architectural Surety



Bomb Disablement



Sandia Science and Technology is represented in 10 Councils





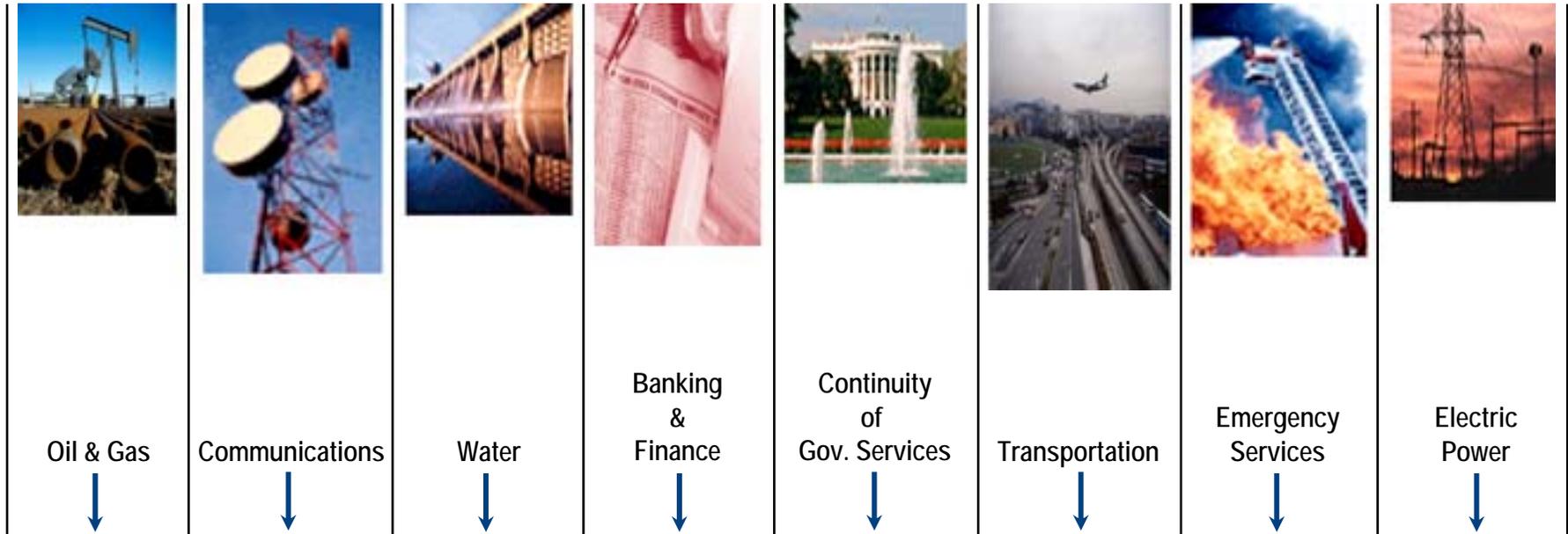
Sandia – in Round Numbers (as of February 2002)

- **7,700 full-time employees**
 - ~6,800 in New Mexico
 - ~900 in California
- **600 buildings, 5M square feet**
- **1,450 Ph.D.'s, 2,100 Masters**
 - 54% engineering
 - 29% science and mathematics
 - 17% computing and other
- **Annual budget \$1,700M**





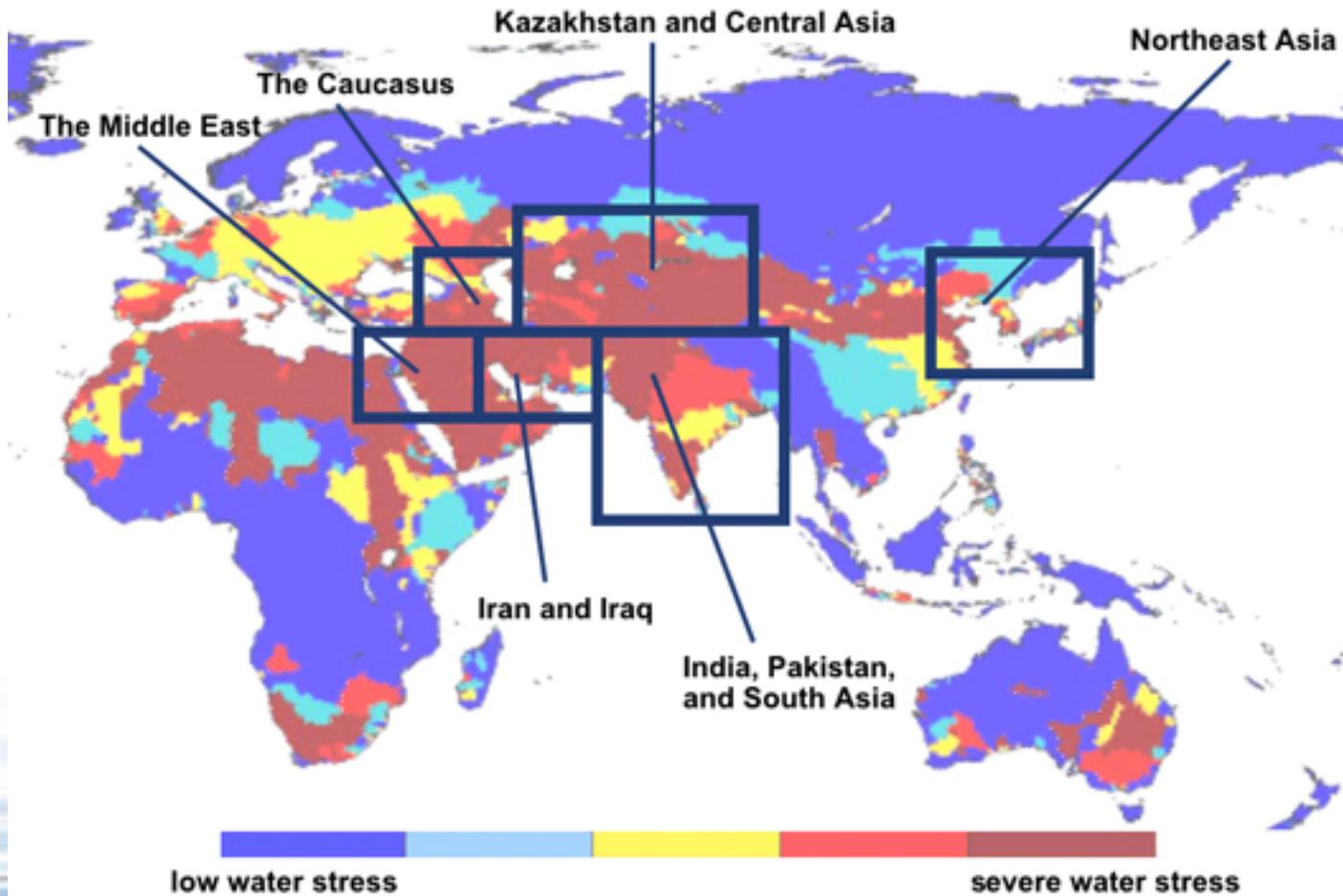
Sandia assesses the safety, security and reliability of individual infrastructures and interdependencies among multiple infrastructures



Interdependencies among infrastructures are a major vulnerability



Severe water-related stress is a significant issue in every region where proliferation of weapons of mass destruction is a major U.S. concern





Water shortages along the US-Mexico border have created a major stress in US-Mexico relations and these shortages are expected to become more severe

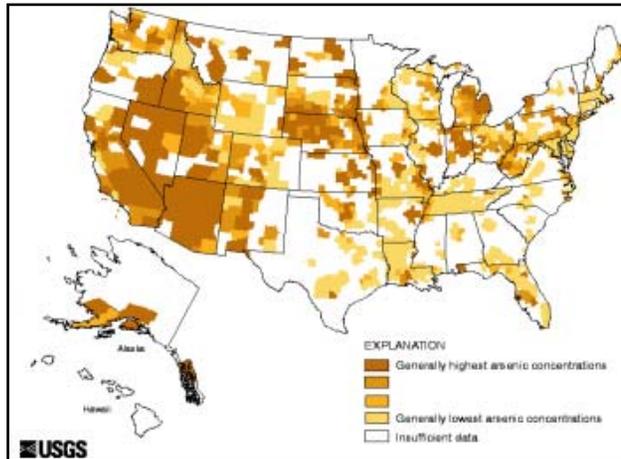
- **Ciudad Juarez and El Paso pump from the same aquifer.**
Hydrologic studies project that Ciudad Juarez will begin running out of fresh water in 5 years and El Paso in 25-30 years.
- **Mexico's under delivery of ~1.5 million acre-feet under the US – Mexico Water Treaty of 1944 has created an issue at the Bush-Fox level.**





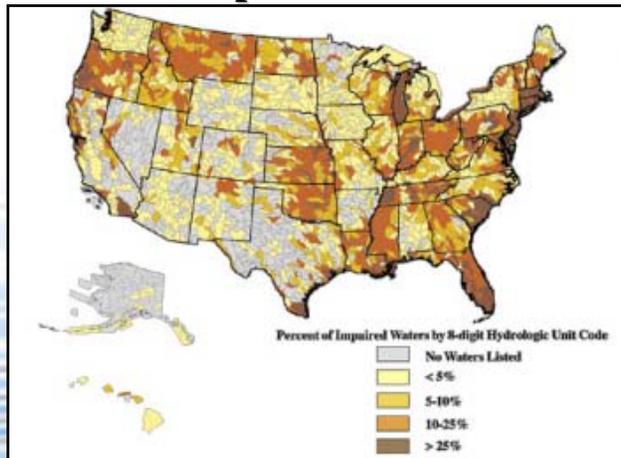
Stricter water quality standards and deteriorating water quality are driving major increases in water treatment costs

Arsenic in the United States

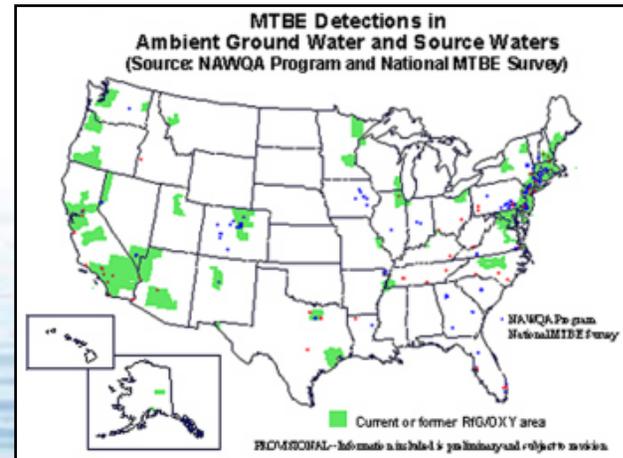


- Annualized estimated costs for meeting 10ppb arsenic standard range from \$195M/yr (EPA) to \$675M/yr (AwwaRF)
- *What's Next?*
- **“More Waters Test Positive for Drugs”**

TMDL “impaired” water in US



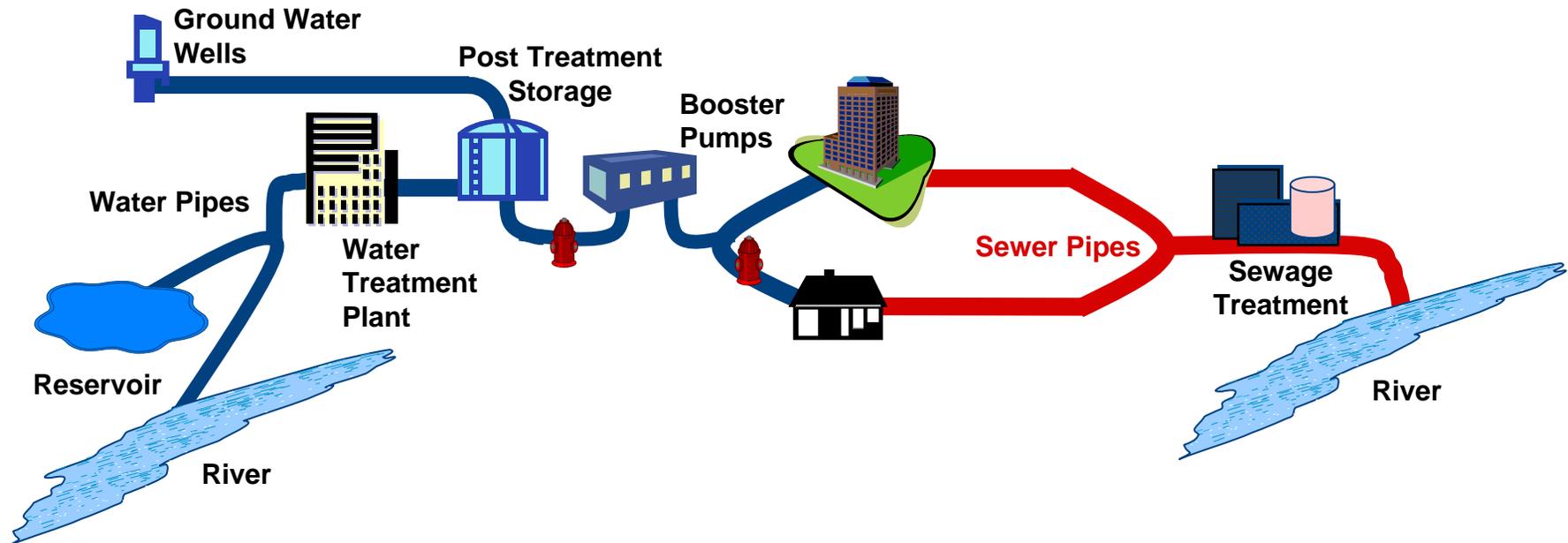
MtBE contamination in US





U.S. water infrastructure faces large uncertainties in the character of threats and nature of system vulnerabilities

Source → *Treatment* → *Distribution* → *Sewer/Treatment* → *Discharge*



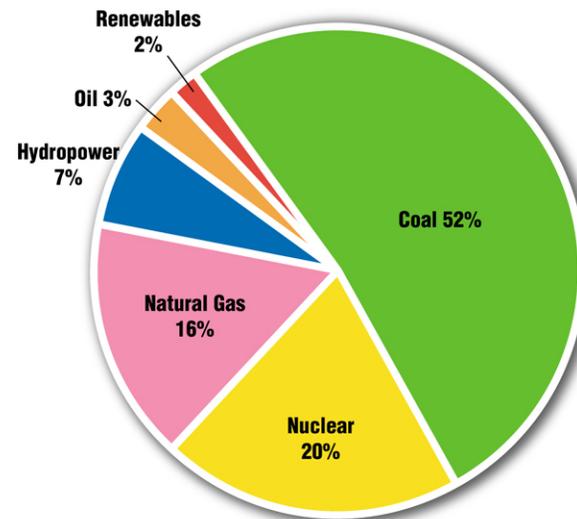
- **Potential for intentional contamination:** at source, in treatment, in distribution system, and in massive amounts by wastewater release
- **Distribution system (post-treatment) presents the greatest challenges** through numerous and dispersed access points



Energy and water are highly interdependent infrastructure elements, yet they are currently are managed independently

- Thermoelectric power production requires 190 billion gallons/day, accounting for 45% of all freshwater withdrawals (with 75% return rate)
- Energy industry is second largest consumer of water (after agriculture)
- Utility industry faces as much as \$70 B in additional water-related costs
- The entire energy cycle—fuel extraction, refining, conversion, and waste disposal—impacts water quantity and quality
- Energy consumed worldwide for delivering water is 7% of total world energy consumption (equal to the total amount of energy consumed by Japan and Taiwan combined)

Electricity generation by fuel source



Each kWh from coal requires 3.3 gallons of water. This means that each person in the US indirectly uses 36,300 gallons of water yearly for electricity use, roughly equal to that consumed by all other domestic uses combined.



“Water is essential for life.”

- **Sandia is solving technological challenges innate to water safety, security, and sustainability.**
 - **Growing water shortage at global and US scales**
 - **Transboundary water management issues**
 - **Deteriorating water quality**
 - **Water infrastructure vulnerability**
 - **Energy and water interdependencies**

“Water promises to be to the 21st century what oil was to the 20th century: the precious commodity that determines the wealth of nations”

Fortune Magazine, May 2000

“The next World War will be over water”

Ismail Serageldin, Vice-President of the World Bank, From Every Drop for Sale by J. Rothfeder, 2001



Sandia Water Initiative

“protecting water sources and water distribution systems”



“assuring the water we drink is free of contaminants”

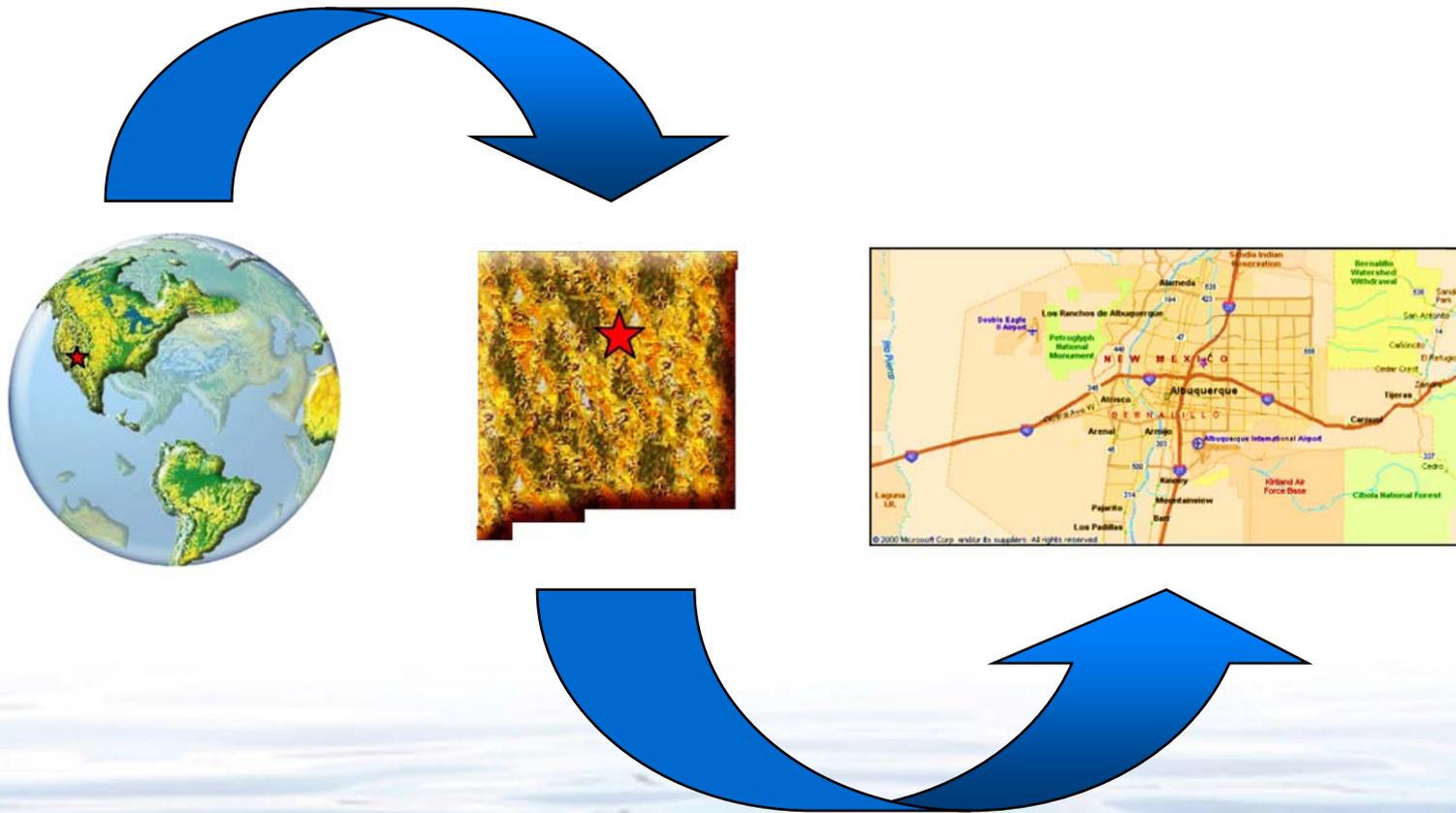


“supplying sufficient water now and in the future”





Water issues exist at all levels: from Global, to New Mexico, to Albuquerque





Significant progress has been made building external relationships and partnerships

Universities

University of New Mexico
New Mexico State University
New Mexico Tech
University of Arizona
(NFS/SAHRA)

Congress

New Mexico Delegation
Energy and Water
Energy and Natural Resources
Environment and Public Works
Transportation & Infrastructure
Science

Water Associations

Assoc. Met. Water Agencies (AMWA)
AWWA Research Foundation
American Society of Civil Engineers

Water Sector

Public Utilities
Water Engineering
Sensor/Monitoring Technologies
Water Treatment Technologies

Other Organizations

Los Alamos National Lab
National Energy Technology Lab
New Mexico Water Groups

*...however,
More partnership work
Is needed...*

Federal Agencies

Environmental Protection Agency
Bureau of Reclamation (DOI)
US Geological Survey (DOI)
Department of Energy
Dept. of State (IBWC, IJC)
Homeland Security (TBD)

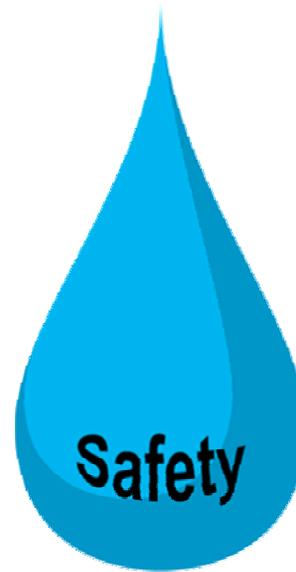


Technical work in 5 focus areas maps to the core themes of Safety, Security, and Sustainability

<i>Research & Technology Areas:</i>	Safety	Security	Sustainability
Treatment Technology	Arsenic, MtBE, et al.	Exploratory Analysis	Desalination
Infrastructure Risk	Dual-Use Ties with Security	Infrastructure Risk Assessment Methodology & Threat Analysis	Infrastructure Redesign & Design Standards
Real-Time Monitoring	Sensors for Regulated Contaminants	Sensors for Chem-Bio Contaminants	Int'l Cooperative Monitoring Projects & Low Flow Sensors
Decision Modeling	Distribution System Contaminant Modeling	Distribution System Contaminant Modeling	Multi-Stakeholder Decision Modeling
Interdependency Analysis		Critical Mission Interdependencies (component of Risk Assessment, e.g. Fire)	Energy-Water

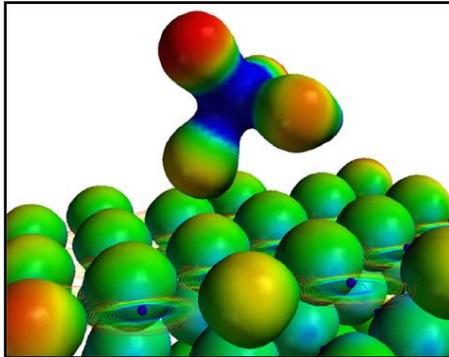


Water Treatment Technology: Safety



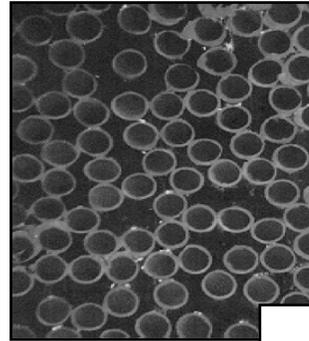


Advances in water treatment technology will have significant impact on safety, security, and sustainability



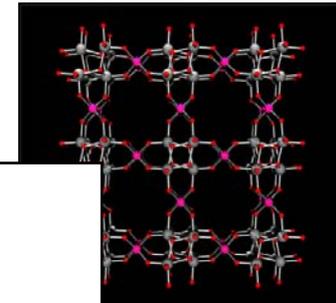
Design of arsenic-specific chemical filter materials using molecular simulation

Safety:
Cost-effective contaminant removal technologies

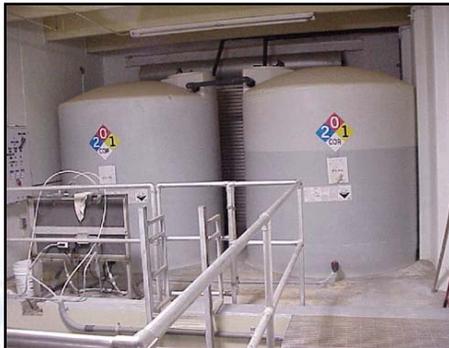


Pervaporation

Sustainability:
Next-generation desalination technologies

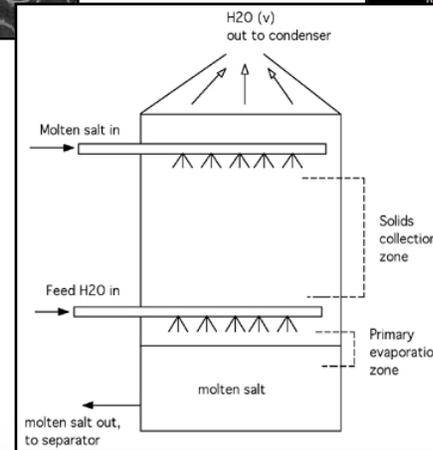


In situ crystallization



Integrated chem/bio treatment technologies

Security:
Future treatment strategies for reducing vulnerability of water infrastructure



Direct contact distillation

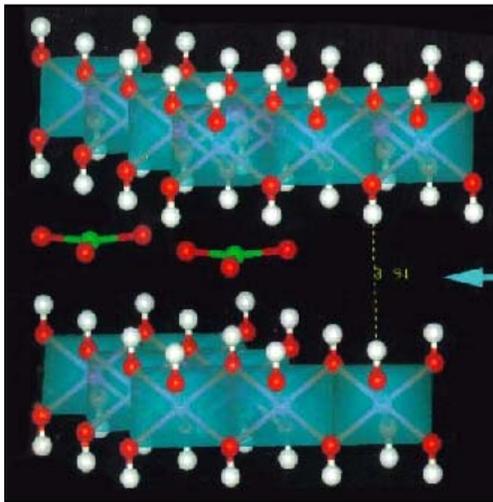
Point of use (rather than centralized) treatment technologies



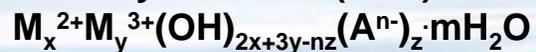
Sandia arsenic treatment research draws on molecular simulation and experience from environmental clean-up and repository design

Granular Filter Media

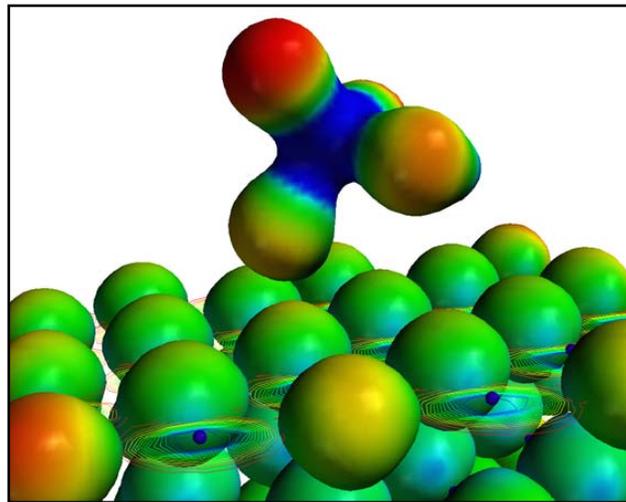
Mesoporous Sorbents



Hydrotalcite (LDH)



Specific Anion Nanoengineered Sorbents (SANS)



Mixed metal oxides selectively trap arsenic with high efficiency

Solid-Liquid Separations

Rapid Reaction Magnesium Oxide Treatment



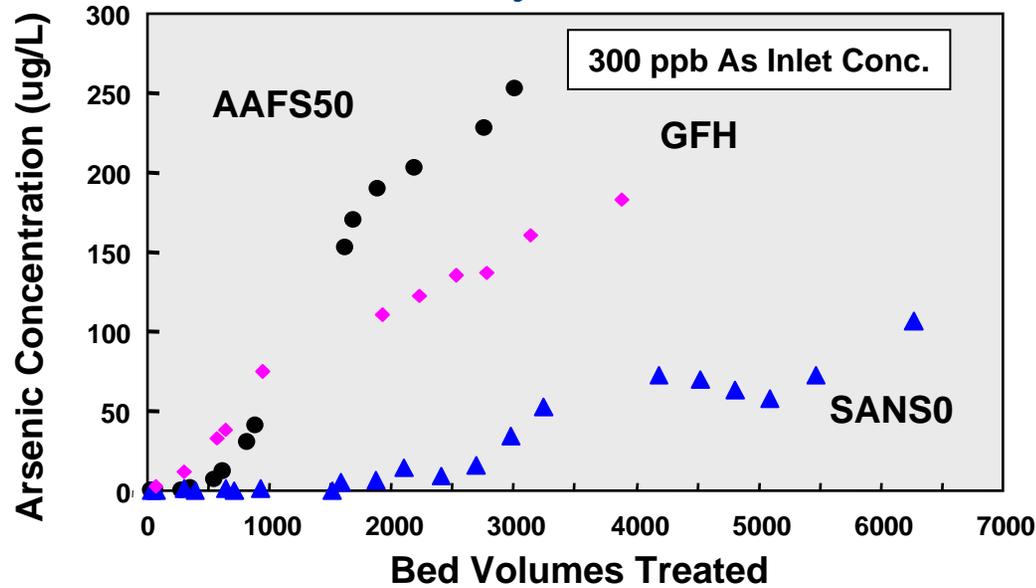
Separation of $\text{Mg}(\text{OH})_2$ from water after arsenic sorption

Goal: Develop technology that reduces overall arsenic treatment costs

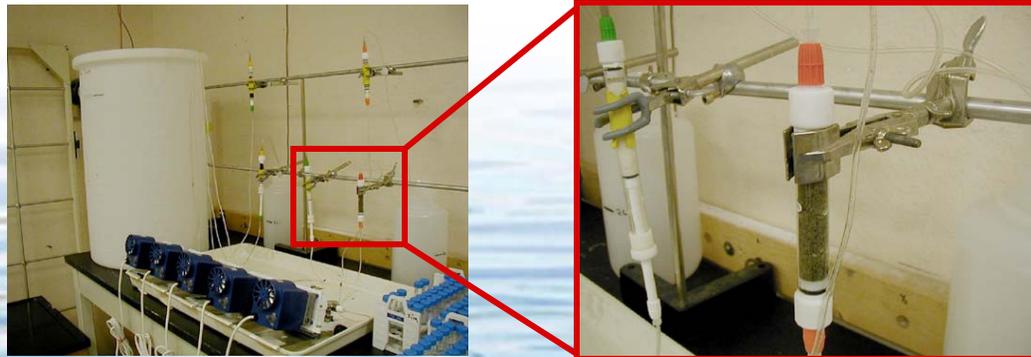


Sandia mixed metal oxide materials have approximately 10x the arsenic removal capacity of commercially available materials at laboratory scale

Laboratory Column Tests

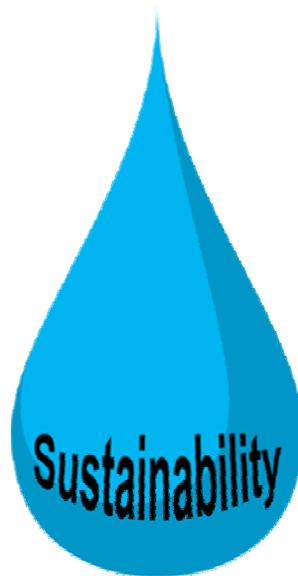


SANS Materials Pass Toxicity Characteristic Leaching Procedure (TCLP)



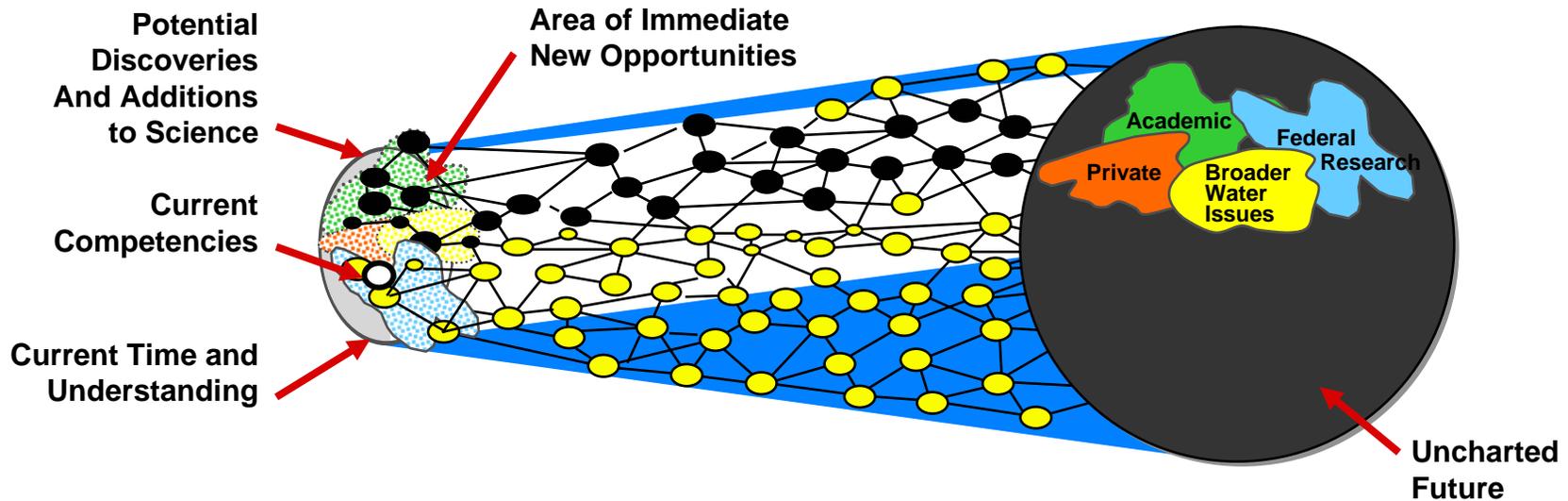


Water Treatment Technology: Desalination





Sandia and the Bureau of Reclamation are developing a 20-year technology roadmap to drive desalination research to develop major cost saving technology breakthroughs



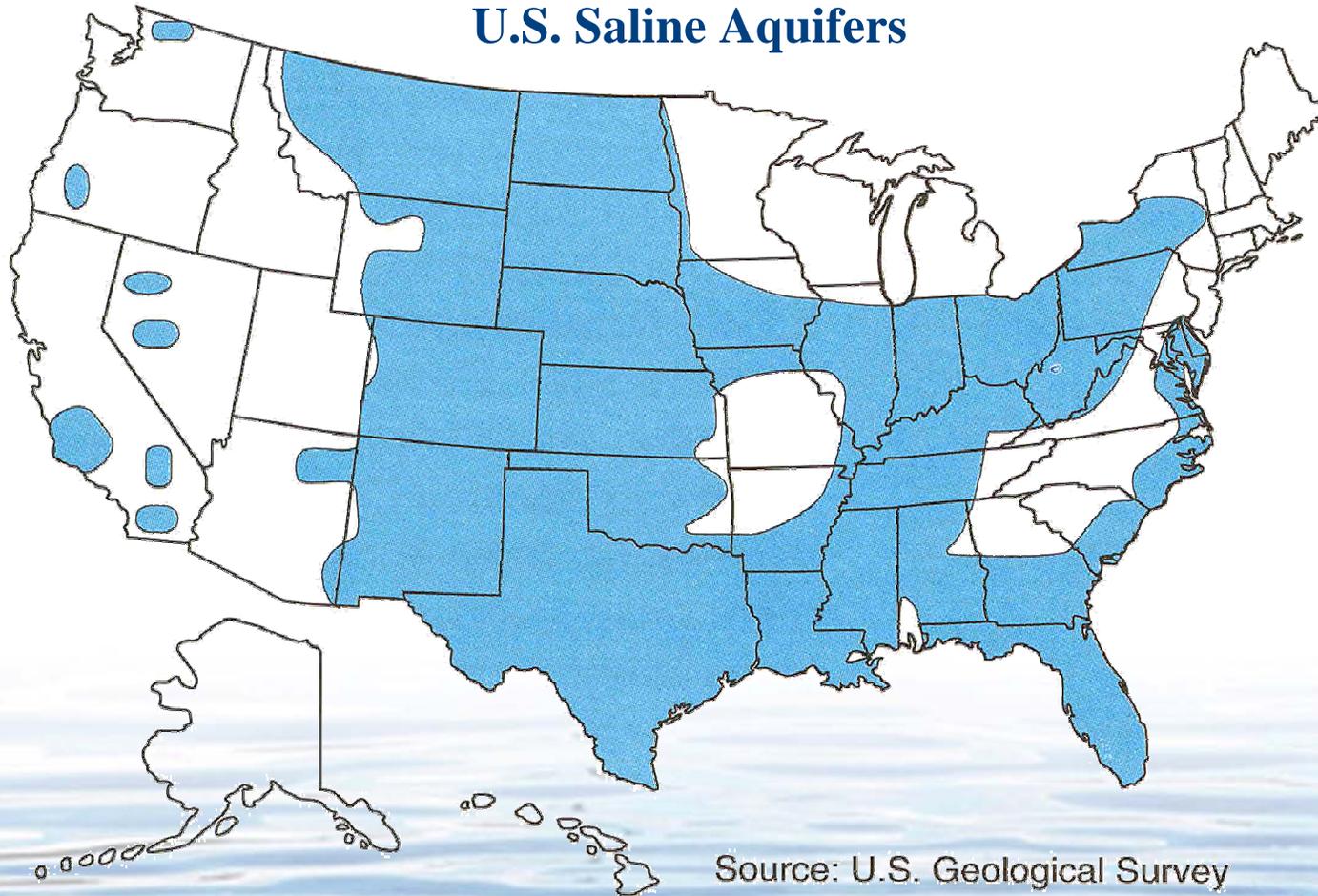
Unfolding Future Events and Technologies →

- Michael Gritzuk - Director Water Services, Phoenix
- Anita Highsmith - Highsmith Environmental Consultants
- Gary Wolff - Economist, Pacific Institute
- William Blomquist - Political Scientist, Indiana University
- David Furukawa - Desalination Consultant
- Lisa Henthorne - Desalination Consultant
- Peter Fox - Reuse, Arizona State University
- Thomas Jennings - Desal R&D, International Programs, Bureau of Reclamation
- Kevin Price - Desalination R&D Program Manager, Bureau of Reclamation
- Thomas Hinkebein - Innovative Desal R&D, Brine Disposal, Sandia National Laboratories



In addition to seawater, many countries have major inland, brackish water resources

U.S. Saline Aquifers



Source: U.S. Geological Survey



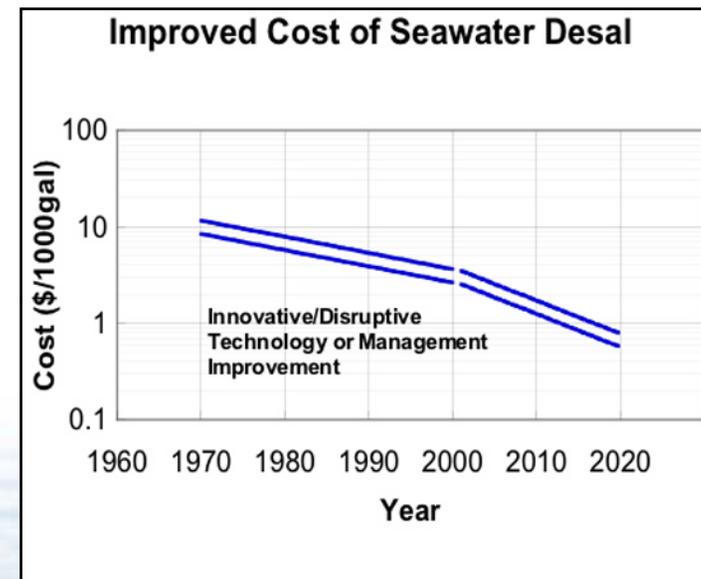
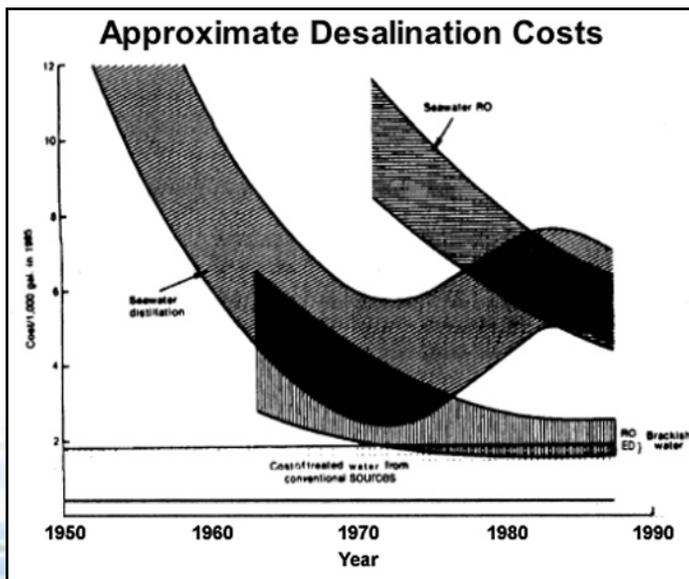
Driving vision for technology roadmap: U.S. water supply must be safe, sustainable, and affordable

Today's reference costs:

- \$0.50 - \$2.00 (municipal water in US)
- \$0.01 - \$0.18 (western irrigation)
- \$0.05 - \$0.08 (ground water costs)

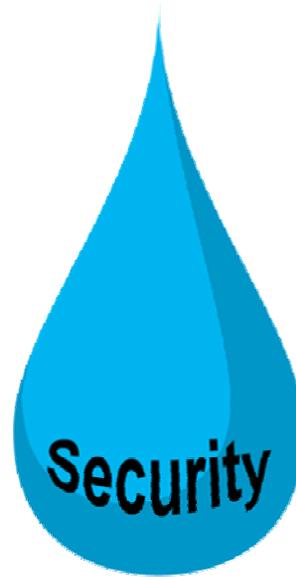
Key technology opportunities:

- Lower energy salt removal processes
- By-product/concentrate disposal
- Alternative energy sources



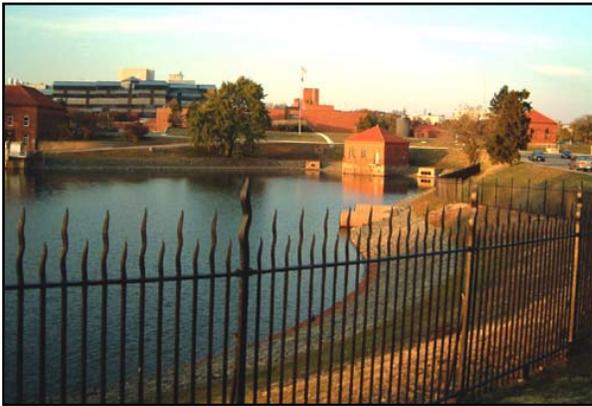


Water Infrastructure Risk Assessment





Water infrastructure vulnerability assessment activities have been greatly accelerated since 9/11/01



Satellite network distributed training on security assessment for water utilities

Vulnerability assessments of Major U.S. metropolitan water systems



Ongoing development of “train the assessor” training course for spring 2002



Hands-on vulnerability assessment training workshops in major cities across the U.S.





Water infrastructure protection strategies laid out in November 14, 2001 congressional testimony



Near-Term (*assess water system vulnerabilities*)

- vulnerability assessments; training
- threat definition
- short-term risk reduction
- information protection issues
- complete methodology for waste water

Intermediate-Term (*protect water systems*)

- real-time, early warning monitoring systems
- physical system improvements
- SCADA system improvements
- technologies for management of compromised systems

Long-Term (*reconfigure water systems*)

- alternative system designs that reduce consequences
- advanced treatment technologies
- security driven design standards
- education of future system designers



Highest priority challenges for water infrastructure security

- **Simultaneously meet the extreme near-term demand for vulnerability assessments, execute highest priority near-term follow up, and initiate longer-term, more robust strategies**
- **Develop a more comprehensive understanding of threats to water systems and translate this information to useful design basis threats**
- **Develop effective real-time monitoring systems and associated security management strategies for water distribution systems**
- **Identify and develop strategies and technologies for management of compromised systems**

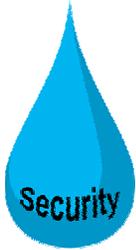


Real-Time Monitoring





Emerging water sensor technologies enable real-time monitoring and real-time management, a key strategy in multiple water arenas



Water Infrastructure Attack Protective Monitoring

- Early warning river/source monitoring
- Treatment system integrity
- Distribution system integrity



Water Quality Monitoring

- Inflow - efficient monitoring of regulated contaminants in source water
- Outflow - efficient monitoring of regulated contaminants in treated water
- Treatment process optimization

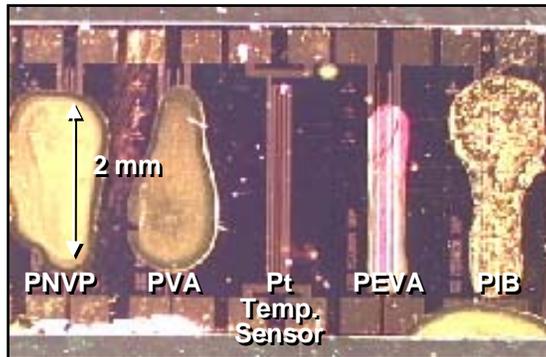


Quantifying and Managing Water Sources

- Comprehensive source water quantification
- Real-time management of water flow/distribution
- Transparent verification of treaty/agreement allocations



Chemiresistor sensors will provide real-time, in situ monitoring of volatile organic compounds



**Chemiresistor Array
(4 Different Polymer Films)**

- **Continuous in situ monitoring of volatile organic compounds (toxic chemicals, explosives, etc.)**
 - **Polymer film with conductive particles forms chemically sensitive resistor**
 - **Extremely small, low-power system with no pumps or valves**
 - **Sensor array can provide analytic discrimination**



Waterproof sensor package for monitoring well or cone penetrometer

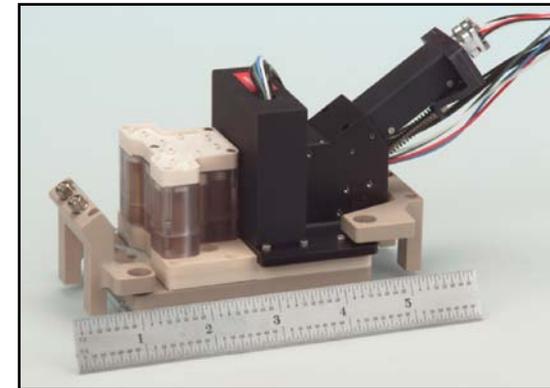


Field testing and commercialization are presently under way



Sandia's μ ChemLab technologies are being tested to meet major needs in real-time water monitoring

- **Biotoxins**
 - Primary application in water security monitoring
 - Separation/detection technology successfully demonstrated
- **Regulated contaminants (organics and metals)**
 - Primary application in water safety/quality monitoring and process optimization
 - Have started work on translating analytic methods from literature to μ ChemLab
- **Microbes/viruses**
 - Application to both water security and safety/quality
 - Development of front end processing of samples is under way



Liquid μ ChemLab working prototype



Gas μ ChemLab field prototype



International Cooperative Monitoring: Cooperative problem-solving and management of shared water resources

Today

A Vision for the Future

Technology and Tools

- sample collection
- laboratory analysis
- basic decision models

Sensors, Monitoring, Modeling, Data Analysis

- real-time data collection
- In situ data analysis
- detailed watershed modeling
- real-time remote monitoring

Decision Analysis

- macroscopic modeling
- management scenarios

Cooperative Activities

- confidence building through joint data collection
- Small-scale scientific collaborations
- initial efforts to model key watersheds

- shared scientific understanding of critical transboundary watersheds
- implementation of “active” watershed monitoring and analysis systems
- cooperative regional management and decision-making

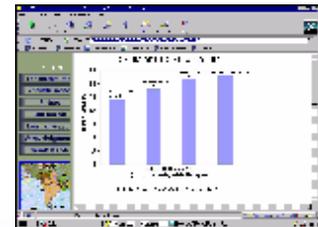
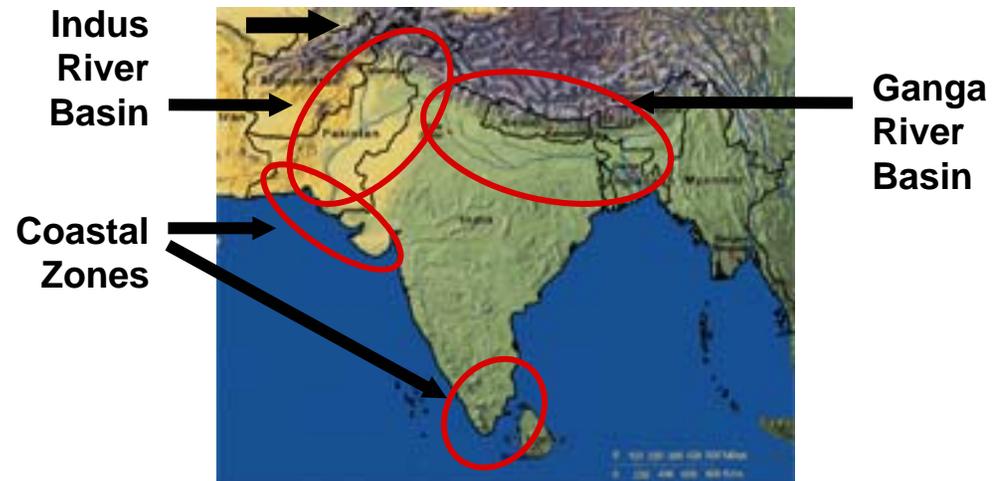
Key Regions: Middle East, India/Pakistan, China, NE Asia, Central Asia, Caucasus, US/Mexico



South Asia transboundary water quality monitoring

GOAL: Assess water quality throughout South Asia and promote transboundary watershed analysis and cooperation

- **Data collected by 6 partners in 5 countries and shared on a dedicated web site since 1999**
 - **India, Pakistan, Nepal, Bangladesh and Sri Lanka**
 - **Additional partners, parameters and analysis beginning in 2001**
- **Sponsors: DOE, USAID and U.S. State Department Office of Environmental Affairs**

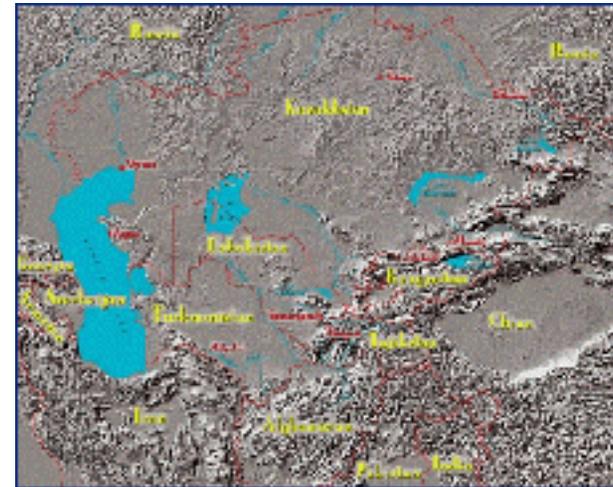




Transboundary river monitoring in Central Asia: The NAVRUZ Experiment

GOAL: Investigate existence of waterborne radiation to strengthen nonproliferation and build regional confidence and cooperation

- **Monitoring along Syr Darya, Amu Darya, and major tributaries in Central Asia**
- **Partners include scientists and technical experts from Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan**
- **Sample water, vegetation, sediment, and adjacent soil**
- **Analyze for radionuclides and basic water quality parameters**
- **Share data via the CMC Internet site**



Participants in The Navruz Experiment during sample collection training.



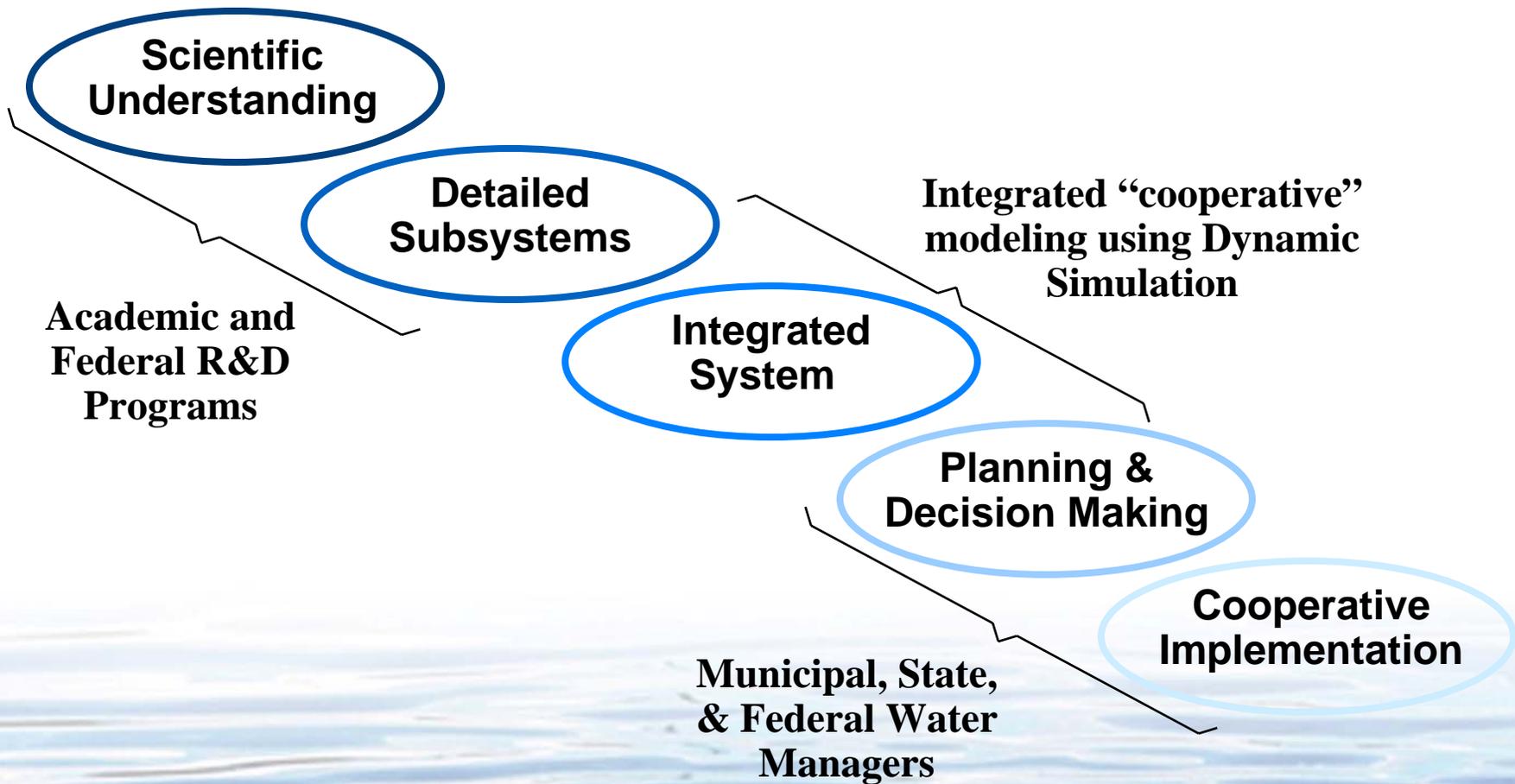


Multi-Stakeholder Decision Modeling





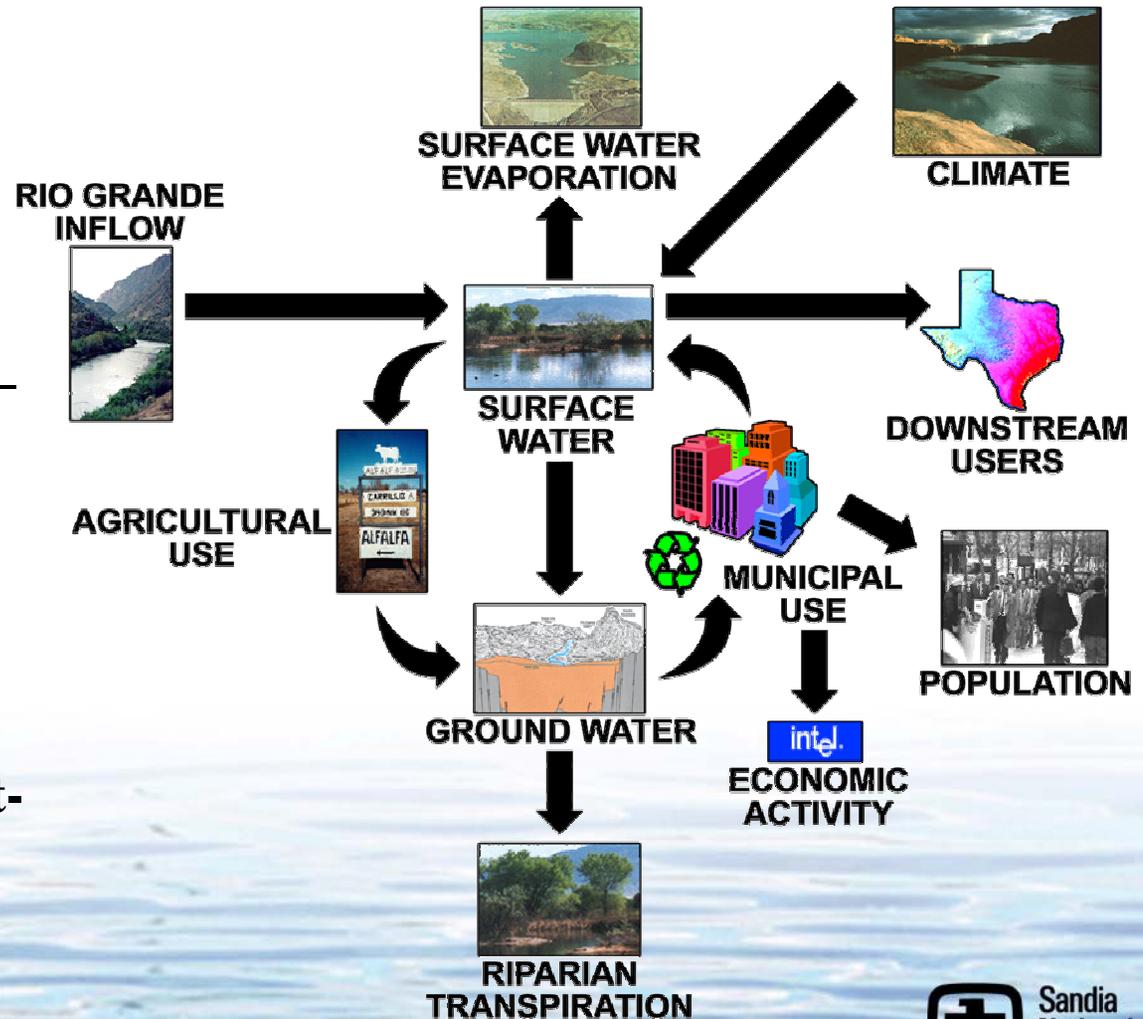
Integrated “cooperative” modeling fills the major gap between detailed research/subsystem models and policy/decision making people and process





Dynamic simulation tools provide the software platform for direct stakeholder engagement in building system-level decision models

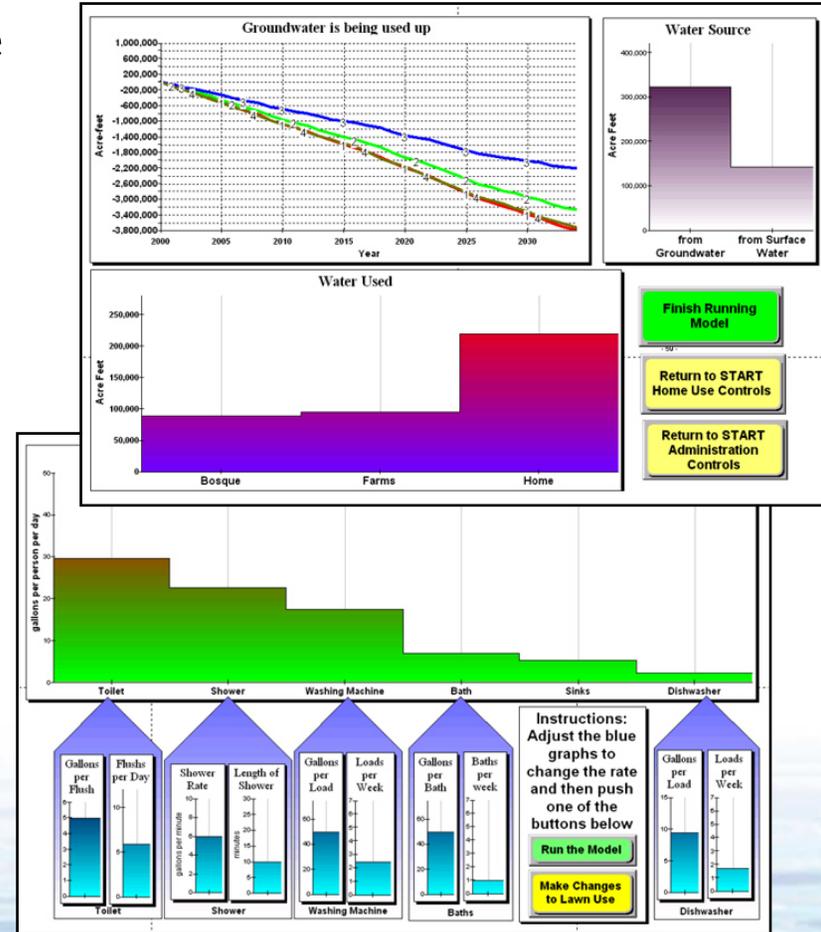
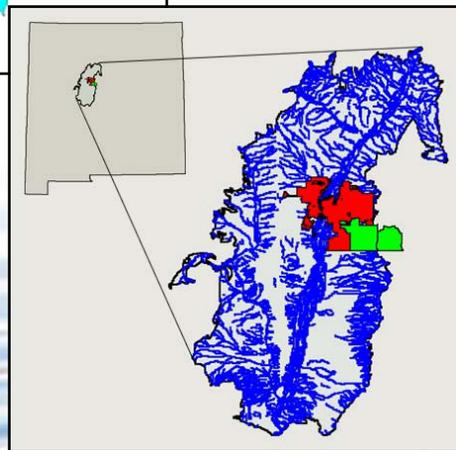
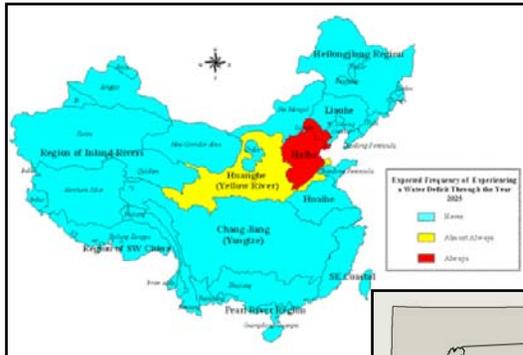
- Addresses all resource allocations
- Holistic
- Implement models on commercial software
- Accessible to the public – conceptually and direct manipulation
- Accommodates uncertainty for decision makers
- Easily modified for what-if decision making





Dynamic simulation models have been built at a variety of basin scales and hydrologic system types

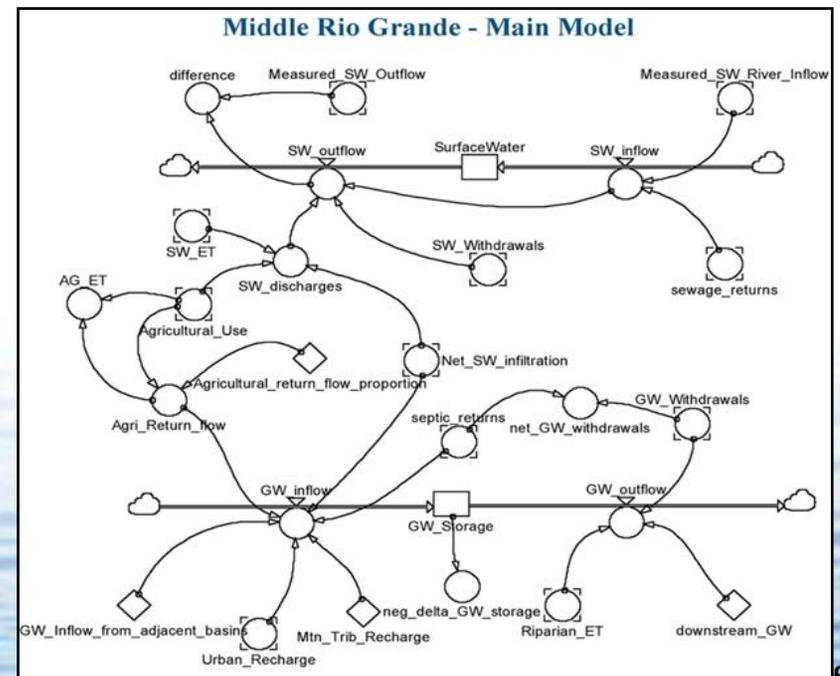
- China water and agriculture
- Middle Rio Grande Basin
- Estancia Basin





Middle Rio Grande Basin model is being created through a partnership of UNM Utton Law Center and Water Assembly and Council of Governments

- SNL partners with UNM Utton Center, MRGCOG administrators, MRGWA members
- Cooperative model development with Assembly
- Goals:
 - Evaluate Alternative Management Strategies
 - Educate the Public about Issues
 - Assist in consensus building
- March Public Meetings
- Merge with State Engineers Balance Model
- Summer 2002 begin assessment alternatives





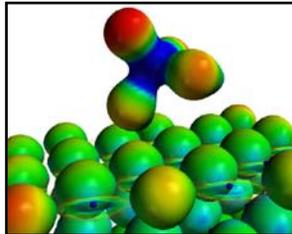
Laboratory Directed Research & Development (LDRD) Investments





Investments in water-related LDRD's are laying the groundwork in multiple water focus areas

Started in FY01



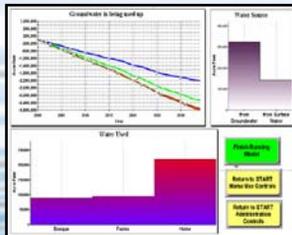
Specific anion nanoengineered sorbents for water purification



Novel approaches for arsenic removal from water



Micro-chemical sensors for volatile contaminants

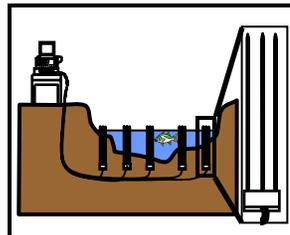


Innovative technologies for active water management

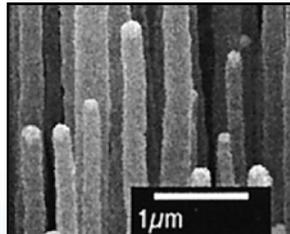
Started in FY02



Water desalination combined programs

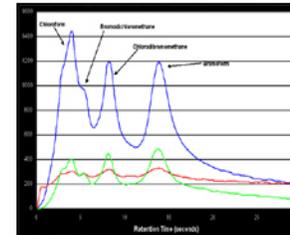


Remote, real-time monitoring of ephemeral streams

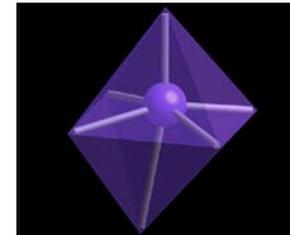


Nanoelectrode array sensors for regulated contaminants

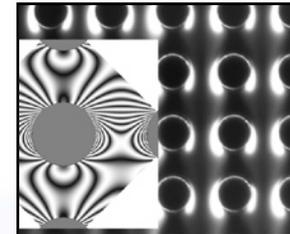
Starting in FY03



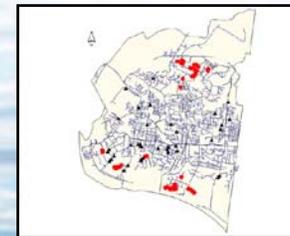
Real-time discriminatory sensors (for THMs)



Sequestration of pathogens on nanoengineered surfaces



Preconcentrator for live water-borne pathogens



Transport simulation of chem/bio/rad attack



Sandia Water Initiative Web Site

www.sandia.gov/water