



# An Integrated Framework for Treatment and Management of Produced Water



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**CSM/RPSEA FORUM**

**Technologies for Mitigation of Environmental Impact of Oil and Gas Operations**

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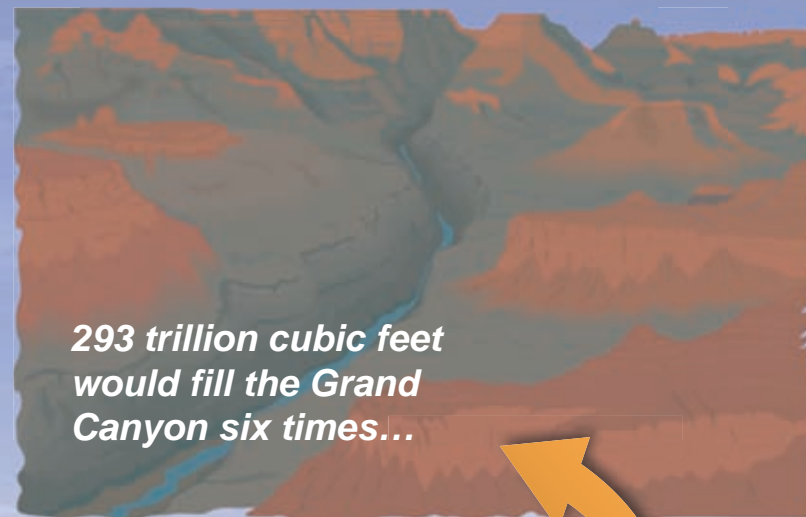
# Overview

- ▶ **Current Practices and Challenges Associated with the Management of Produced Water**
- ▶ **Opportunities and Technical Challenges**
- ▶ **Research Approach of a new RPSEA Project**
- ▶ **Conclusions**



# Produced Water Facts

- ▶ “Unconventional Onshore Gas Resources”
  - Coal bed methane
  - Gas shales
  - Tight sands
- ▶ The majority of these resources are found in the arid western states
- ▶ Volume of “technically recoverable” gas in the continental US:



***293 trillion cubic feet***





# Produced Water Facts

Volume of “technically recoverable” gas:

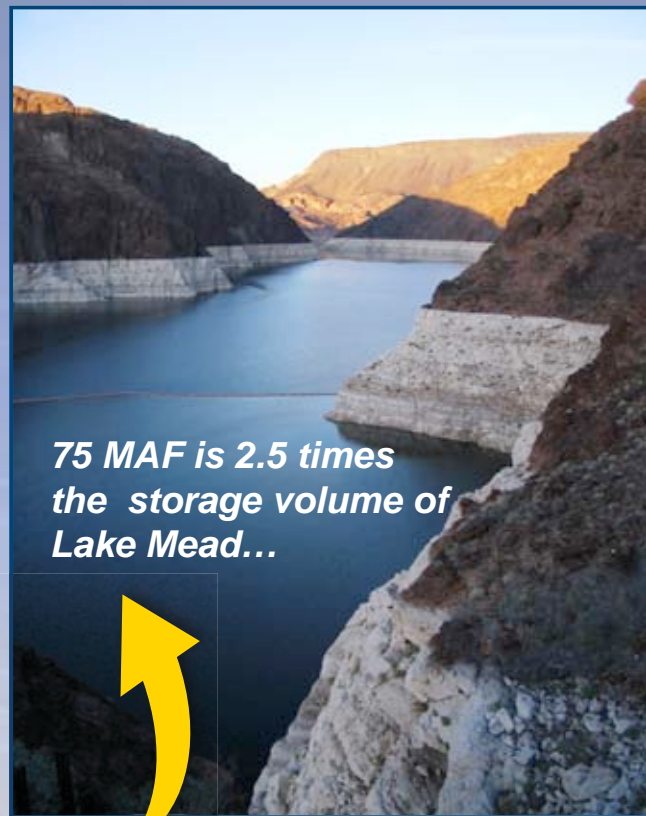
***293 trillion cu ft***

Average CBM produced water:

***2 barrels per 1000 cu ft***

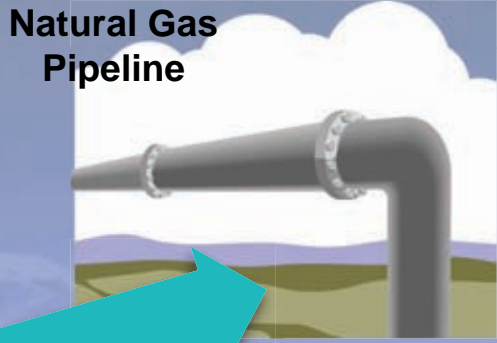
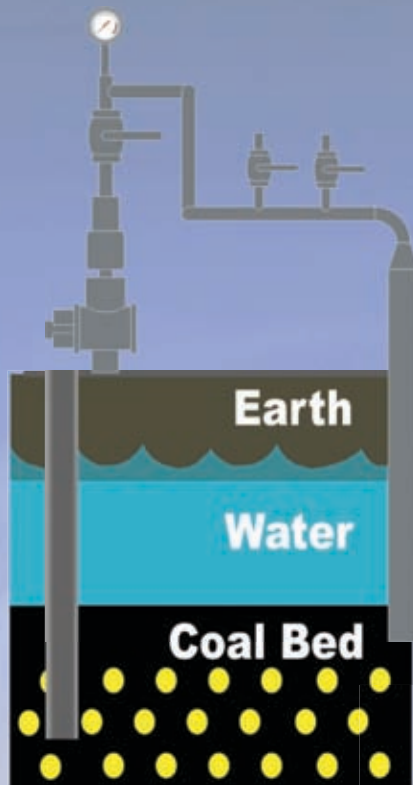
Water from unconventional  
gas production:

***75,000,000 acre feet!***

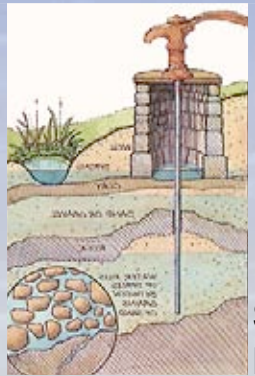
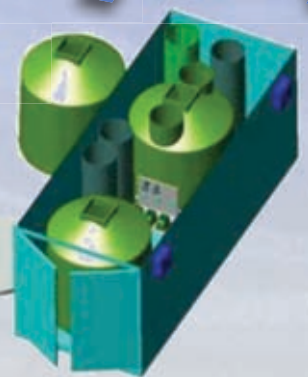


*75 MAF is 2.5 times  
the storage volume of  
Lake Mead...*

# Coal Bed Methane (CBM) Produced Water: The Options...



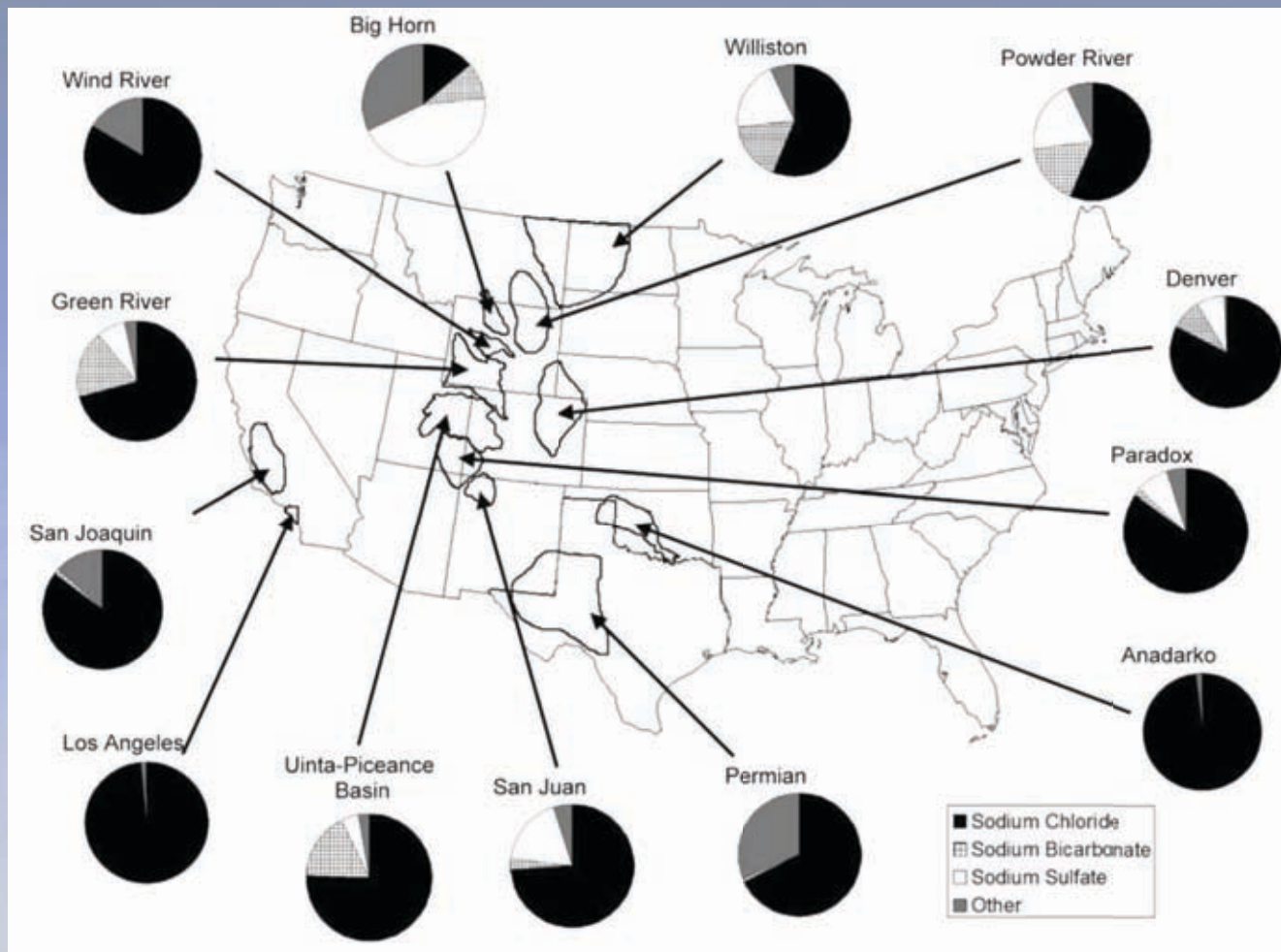
Treatment for Beneficial Reuse...



Reinjection Well

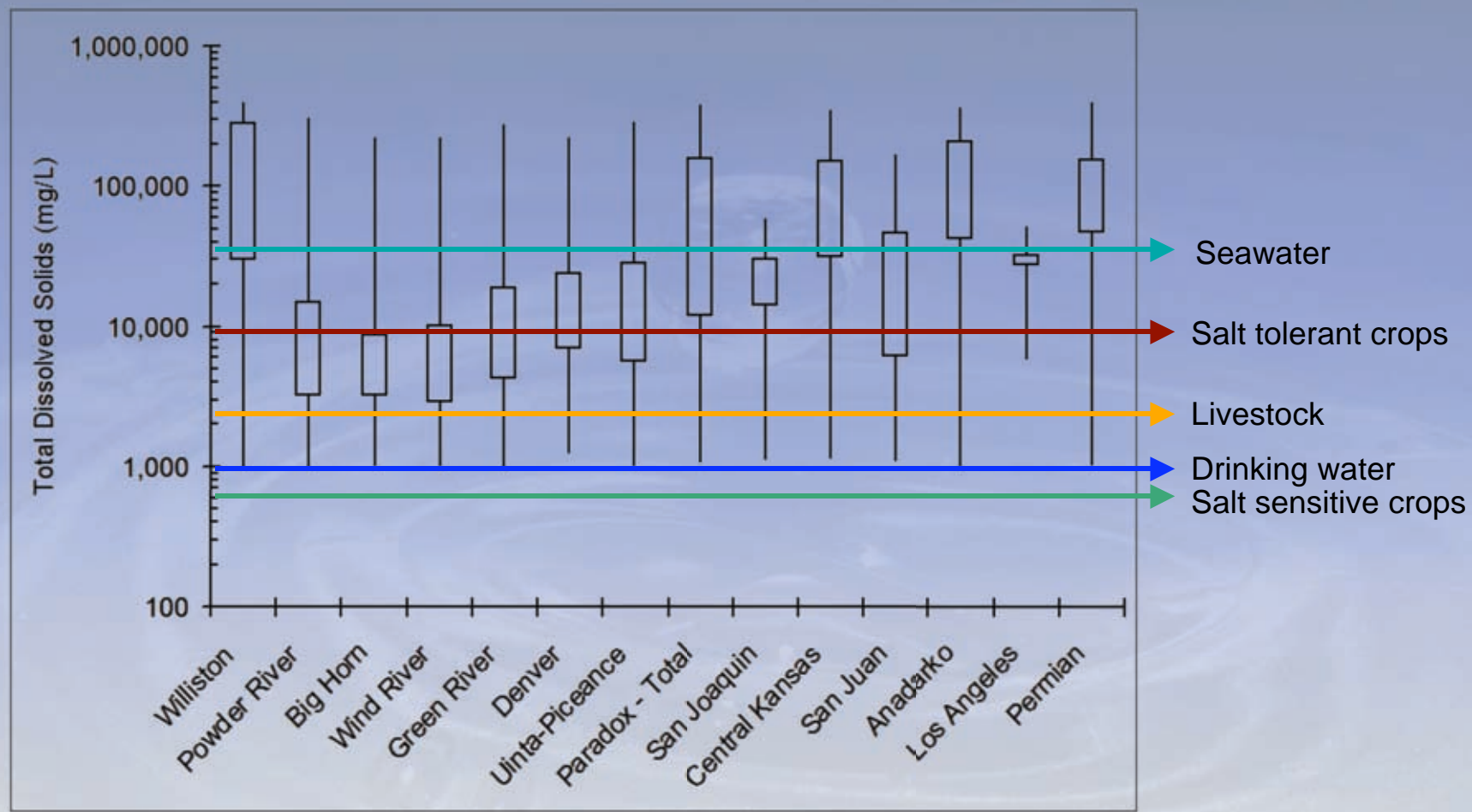


# Produced Water Quality: Salt Composition



Benko and Drewes (2008), *Env. Eng. Science* 25, 2, 239

# Produced Water Quality



Benko and Drewes (2008), *Env. Eng. Science* 25, 2, 239

# Produced Water Management

- ▶ **Current practices**
  - Deep-well injection
  - Impoundments
  - Off-site trucking
  - Surface discharge
  - Treatment
- ▶ **Management practices driven by price of gas and disposal costs**
- ▶ **Environmental concerns**
  - Harmful to aquatic life
  - Damage to vegetation



*Constructed Wetland*



# Cost of Produced Water Management

Management Option	Estimated Cost (\$/bbl)	Estimated Cost (\$/AF)
Surface discharge	\$0.01 - 0.80	\$80 - 6,200
Evaporation pits	\$0.01 - 0.80	\$80 - 6,200
Shallow reinjection	\$0.01 - 1.33	\$80 - 10,600
Constructed wetlands	\$0.001 - 2.00	\$8 - 16,000
Class II disposal wells	\$0.05 - 2.65	\$400 - 21,000
Higgins Loop (IX)	\$0.05 - 0.20	\$400 - 1,550
Softening/Filtration/IX/RO	\$0.06 - 0.27	\$470 - 2,100
Freeze/thaw evaporation	\$2.65 - 5.00	\$21,000 - 40,000
Commercial hauling	\$1.00 - 5.50	\$8,000 - 44,000

(Jackson and Myers, 2002; ALL Consulting, 2006)

# Challenges for Widespread Beneficial Use

## ▶ Transient Location

- Distance between produced water sources and end users
- High cost of water transfer

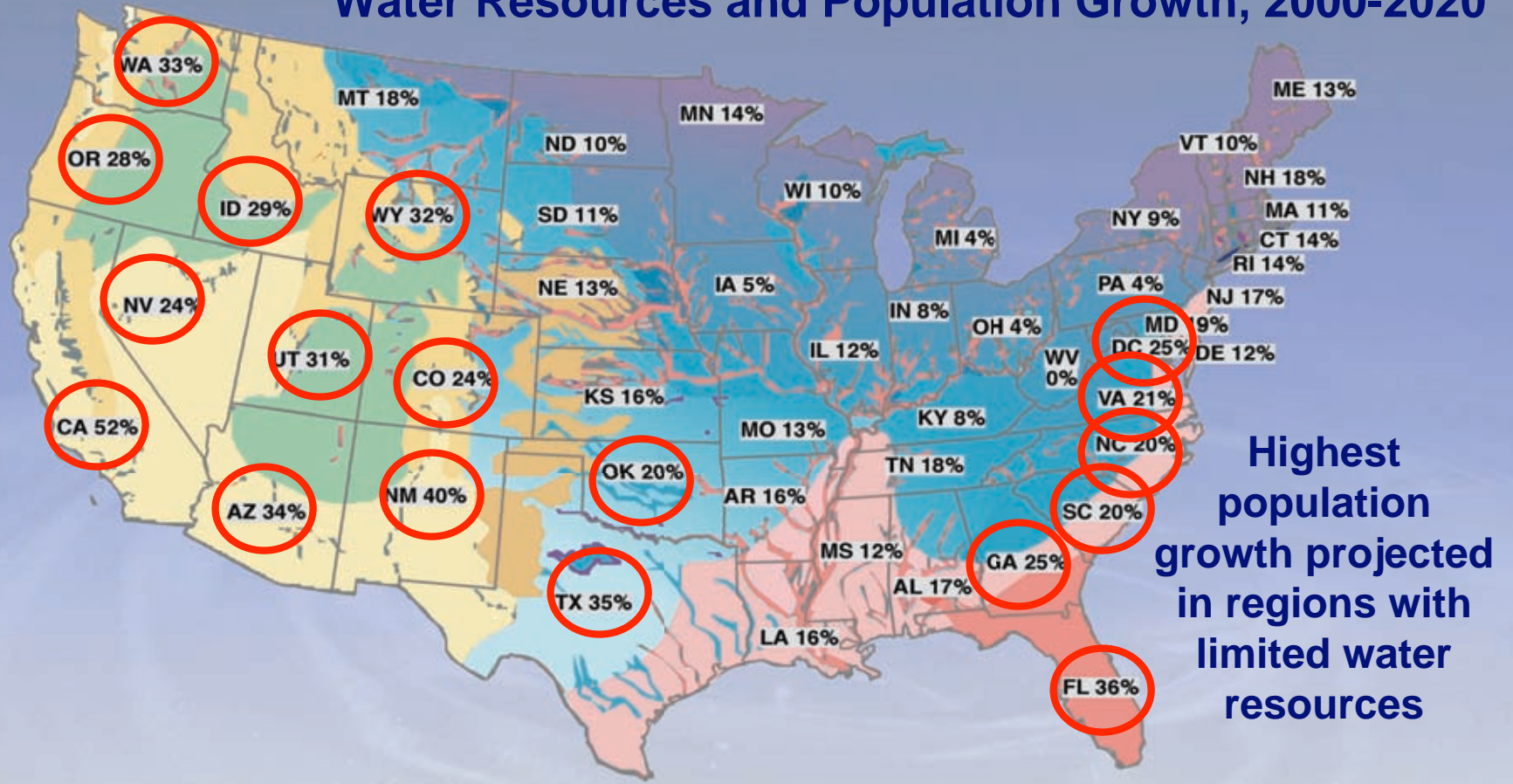
## ▶ Operational Issues

- Fluctuating gas prices might deter investments in treatment technology
- Complexity of water rights issues
- Variation of environmental, water quality and permitting requirements among states
- Challenges in identifying, quantifying, mitigating, and compensating impacted third parties
- Uncertainties and liability issues regarding conveyance and end use
- Barriers between private management of gas and oil resources and the public management of water resources



# U.S. Population Growth and Water Availability

## Water Resources and Population Growth, 2000-2020



**Highest population growth projected in regions with limited water resources**

Source: DOE/NETL (M. Chan, July 2002)

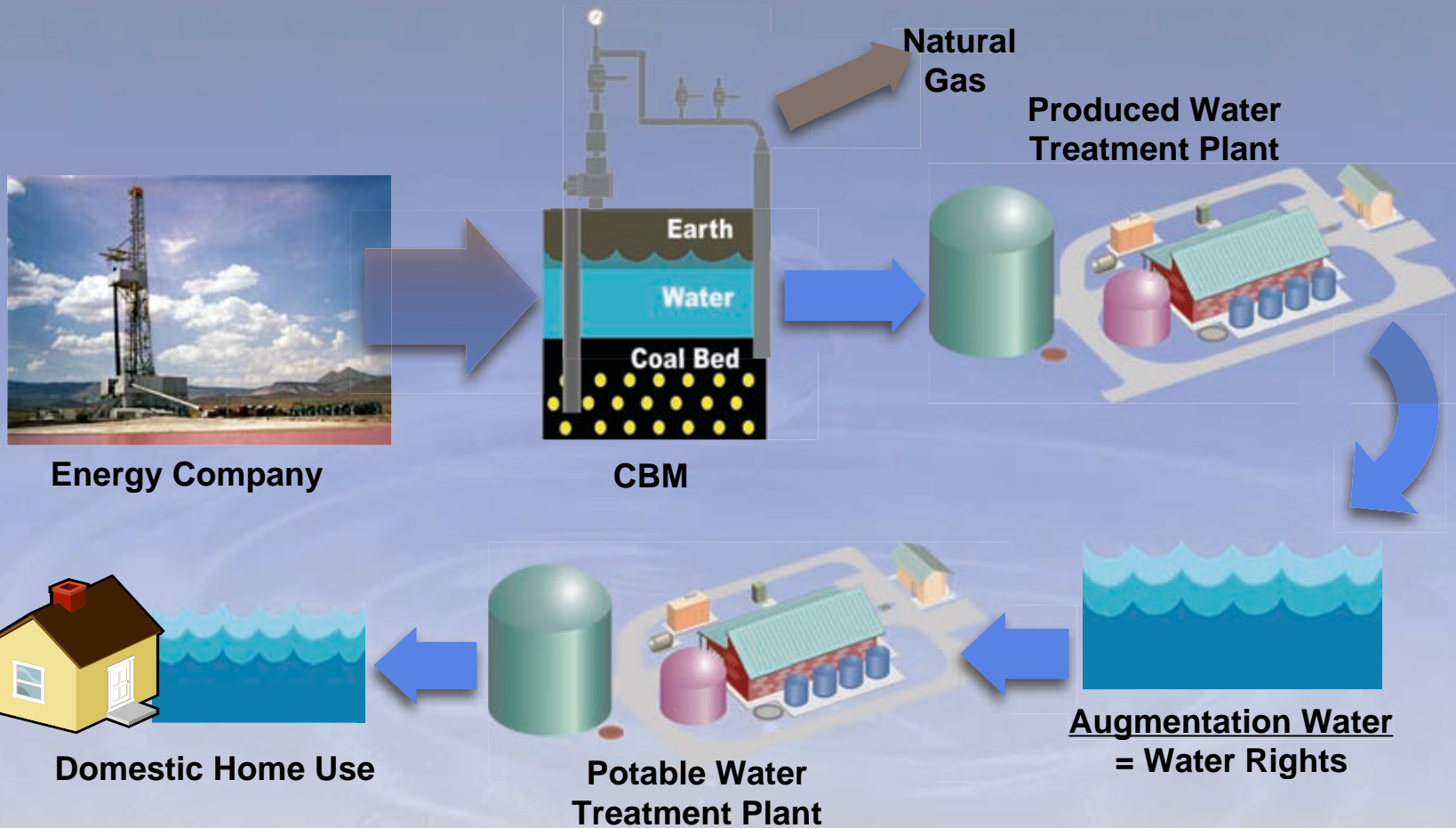
Less Water More Water




## Produced Water - *What is It?*

- ▶ It depends on your perspective....
- ▶ To the oil & gas industry....*it's a pain.*
- ▶ To the environmental groups....*it's a concern.*
- ▶ To the regulators....*it's a challenge.*
- ▶ To the water industry/landowners....*it's a resource.*
- ▶ To RPSEA....*it's an opportunity to develop more cost-effective and environmentally sound strategies for management and treatment of produced water; leading to increased gas production.*

# Produced Water: Potential Utilization





# **An Integrated Framework for Treatment and Management of Produced Water**

## **Project Goal**

- ▶ *Develop an integrated guidance framework that will link the composition of produced water to beneficial use applications and identify the most cost-efficient, environmentally sound, and most beneficial strategies for management and treatment of produced water from CBM and gas shale operations*

## **Relationship to the Goals/Objectives of RPSEA**

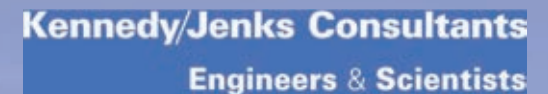
- ▶ The proposed integrated guidance framework has the potential to substantially reduce the overall costs and enhance gas recovery and economic viability of CBM and gas shale fields while minimizing potential environmental impacts
- ▶ Techniques and methods developed provide needed guidance to the industry in selecting the most cost-efficient management and treatment strategies for handling produced water by considering the site-specific conditions of CBM and gas shale operations


**Project Schedule: June 2008 - September 2010**

# An Integrated Framework for Treatment and Management of Produced Water

## ► Core Research Team:

- Colorado School of Mines
  - PIs: Jörg Drewes, Tzahi Cath, Pei Xu
- Kennedy/Jenks Consultants
  - PI: Jim Graydon
- Argonne National Laboratory
  - PIs: John Veil and Seth Snyder
- Stratus Consulting
  - Bob Raucher
- Technical Advisors:
  - Dave Stewart, Stewart Environmental Consultants
  - Jeff Cline, Cline Energy Consultants






# An Integrated Framework for Treatment and Management of Produced Water


## ▶ Industry Advisory Council (IAC):

- **Anadarko Petroleum Corporation**
  - David Gomendi
- **Chevron**
  - John Wind and De Vu
- **Marathon Oil Company**
  - Brian Hodgson
- **Petro-Canada Resources (USA)**
  - Chuck Pollard
- **Pinnacle Gas Resources**
  - Terry Webster
- **Pioneer Natural Resources**
  - Jerry Jacob and Steve Schreck
- **Triangle Petroleum Corporation**
  - Ron Hietala
- **Petroglyph Operating Company**
  - Tom Melland
  
- **Technical Experts/Advisors:**
  - Jeff Cline, Cline Energy Consultants
  - Dave Stewart, Stewart Environmental Consultants



# An Integrated Framework for Treatment and Management of Produced Water

- ▶ **Task 1 - Classification of Produced Water Treatment Technologies and Management Strategies**
  - Characterize and classify produced water qualities into different categories of treatability
  - Determine produced water quantities (by basin and resource; gas/water ratios; current disposal/use strategies; etc.)
  - Compile a comprehensive database on existing and emerging desalination technologies, hybrid configurations, and concentrate management strategies
  - Develop a beneficial use matrix considering natural and engineered conveyance systems, water qualities of beneficial non-potable and potable uses, and quantity and quality of residuals generated



# An Integrated Framework for Treatment and Management of Produced Water

## ▶ **Task 2 - Selection of Treatment Technologies for Produced Water**

- Explore most appropriate and cost-efficient technologies for treatment of produced water considering water composition categories (Task 1)
- Identification and evaluation of **robust, reliable, low-maintenance, modular treatment technologies** as well as **brine management and disposal strategies** (considering both well-established conventional as well as emerging desalination technologies)
- Develop cost modules for management options



# Treatment Design Considerations (Task 2)

## ▶ Geographical Issues

- Water generated at **individual wells or well clusters**
- Limited **conveyance** systems
- Difficult to **supply chemicals** and **dispose of brine**

## ▶ Operational Issues

- Harsh conditions
- Minimal operator involvement and maintenance
- Small footprint to minimize site remediation
- Modular design to adjust to different production rates
- Mobility
- Wide range of contaminant concentrations



# Technological Challenges: Pretreatment

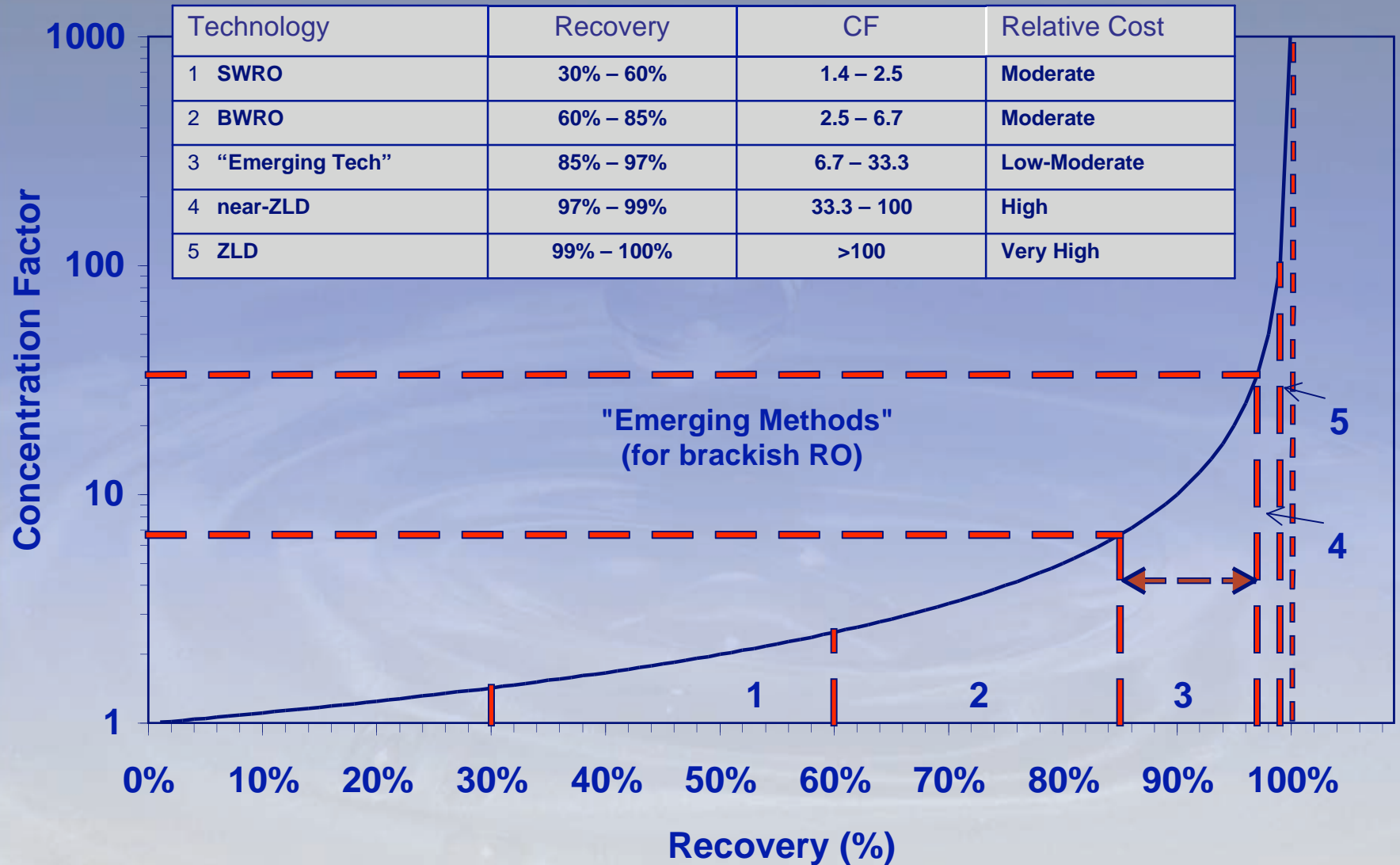
- ▶ **Suspended solids**
- ▶ **Dissolved solids and residual hydrocarbons**
- ▶ **Temperature**
  
- ▶ **Pretreatment solutions:**
  - **Current approaches:**
    - **Coagulation/flocculation with granular media filtration**
    - **Polymeric membranes**
  - **Novel approaches:**
    - **Ceramic microfiltration and ultrafiltration**
    - **Membrane distillation**
    - **Advanced on-site oxidation (UV/H<sub>2</sub>O<sub>2</sub>)**




# Treatment Technologies

- ▶ **Currently only 1.4% of produced water is treated**
- ▶ **Predominant sodium bicarbonate make-up**
  - Higgins Loop (continuous IX)
- ▶ **Predominant sodium chloride make-up**
  - Integrated membrane systems
    - MF or UF followed by RO or NF
  - Conventional pre-treatment followed by RO
    - Coagulation/flocculation followed by RO
- ▶ **Novel Approaches**
  - Temperature tolerant NF membranes
  - ED/EDR
  - Forward Osmosis
  - Capacitive Deionization (CDI)
  - Advanced evaporation processes and solar ponds

# Technological Challenges: Treatment





# **An Integrated Framework for Treatment and Management of Produced Water**


- ▶ **Task 3 - Field Validation of Viable Treatment Processes for Produced Water**
  - **Pilot-scale treatment trains will be designed, assembled and tested at representative production sites for field-scale validation**
  - **Data will be analyzed to determine the effectiveness, robustness, and ease of operation of treatment strategies**
  - **Preliminary cost estimates for the design of full-scale facilities will be developed; providing an economic framework for decision analysis**



# The Need for an Integrated Approach

*“All water management and planning takes place in the context of economic, social, environmental, and political factors, and these factors are far more important than technological desalination process constraints in limiting the potential for desalination to help meet anticipated water supply needs.”*


*Desalination: A National Perspective*  
National Research Council (2008)



# An Integrated Framework for Treatment and Management of Produced Water

## ▶ **Task 4 - Assessment of Management Options**


- Besides technical issues, this task will explore through **cost/benefit analyses** and **life-cycle assessments** the multiple conditions that have to be fulfilled in order to establish **beneficial use** from a regulatory, political, environmental, economic, and legal standpoint
- Develop a **structured decision process** that identifies, evaluates, and, where possible, quantifies the regulatory requirements, benefits, risks, and costs of each management option (“Draft Integrated Decision Framework”)
- Conduct a series of **Stakeholder workshops** to solicit key information, refine and confirm the decision framework, establish evaluation criteria, share treatment technology research results, and develop incentive-based beneficial use approaches



# **An Integrated Framework for Treatment and Management of Produced Water**

## **▶ Stakeholder Advisory Committee (SAC):**


- **Awwa Research Foundation (AwwaRF)**
- **Bureau of Land Management (BLM) - Colorado**
- **Cline Energy Consulting**
- **Colorado Energy Research Institute (CERI)**
- **Colorado Oil and Gas Conservation Commission**
- **Family Farm Alliance**
- **Black Hills Center for American Indian Health**
- **Petroglyph Operating Company**
- **Southern Nevada Water Authority**
- **Stewart Environmental Consultants**
- **Trout Unlimited**
- **U.S. Bureau of Reclamation (BOR)**
- **U.S. Environmental Protection Agency (EPA)**
- **Veolia Water**
- **WaterReuse Association (WRA)**
- **Western Governors' Association**



# An Integrated Framework for Treatment and Management of Produced Water

## ▶ **Task 5 - Development and Validation of Guidelines**

- Develop **guidelines for management of produced water** leading to beneficial use of produced water as a practical, adaptable and robust tool for CBM and gas shale operators
- Guidelines will incorporate the **Integrated Decision Framework** to provide CBM and gas shale operators with a technically sound, objective basis for identifying and quantifying the benefits and costs of various management options
- Approach will also promote clear communication of the cost-benefit analysis to the industry, regulatory, environmental, and public stakeholders
- **Case studies (2)** will be selected to illustrate application of the Integrated Decision Framework and provide practical information on “lessons learned”



# **An Integrated Framework for Treatment and Management of Produced Water**

## **▶ Technology Transfer**

- Workshops with the Industry Advisory Council and Stakeholder Advisory Committee**
- Conference presentation and technical publications**
- Interactive website (developed by ANL/CSM)**
- Proposed Unconventional Gas Produced Water Management Conference in 2010 (or earlier)**



# Summary

- ▶ Over two billion gallons of water are generated each day as a by-product of oil and gas production in the U.S.
- ▶ The cost of management and disposal of this water ranges from \$0.01/bbl to over \$5.00/bbl (\$80/AF to over \$40,000/AF)
- ▶ The value of new water resources is growing dramatically in the U.S. and globally
- ▶ The quality of produced water is highly variable spatially and temporally
- ▶ Treatment technologies are available but need to be adapted for remote sites
- ▶ Significant opportunities exist for beneficial use if economic and institutional barriers can be lowered



# An Integrated Framework for Treatment and Management of Produced Water

## Contacts

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