Produced Water Management: Challenges and Opportunities

Jonathan Brant, Director CEPWM
William Bellamy, Deputy Director

CENTER OF EXCELLENCE
IN PRODUCED WATER MANAGEMENT

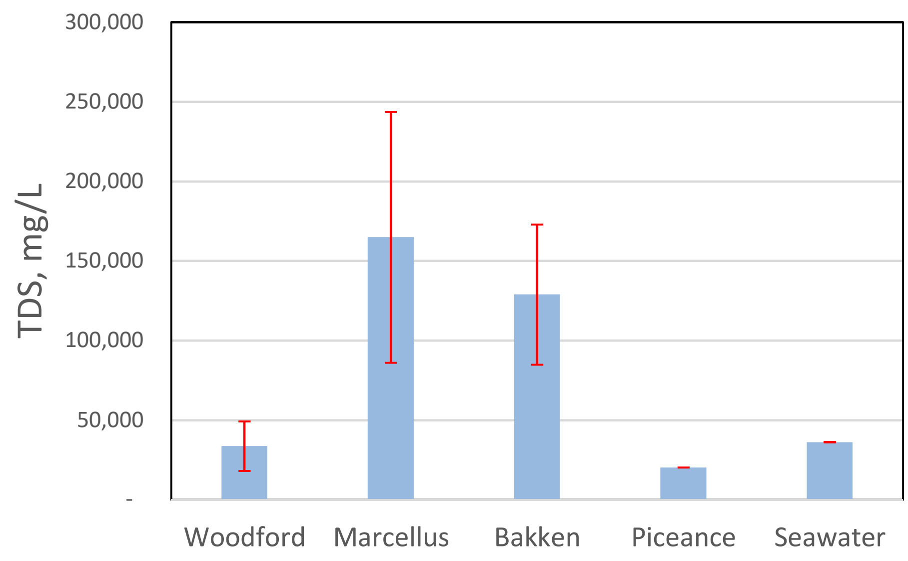
UNIVERSITY OF WYOMING

Areas of Emphasis at the Center

- Research and Development
  - Clients Include
    - Industry – service providers
    - Government
  - Research is basic in nature – not ready for immediate field implementation
- Applied Research
  - Clients Include
    - Industry – O&G, service providers
    - Government support of small and innovative businesses
  - Research at the implementation stage – demonstrate value to support field implementation
- Mix of Both Development and Applied

Produced Water

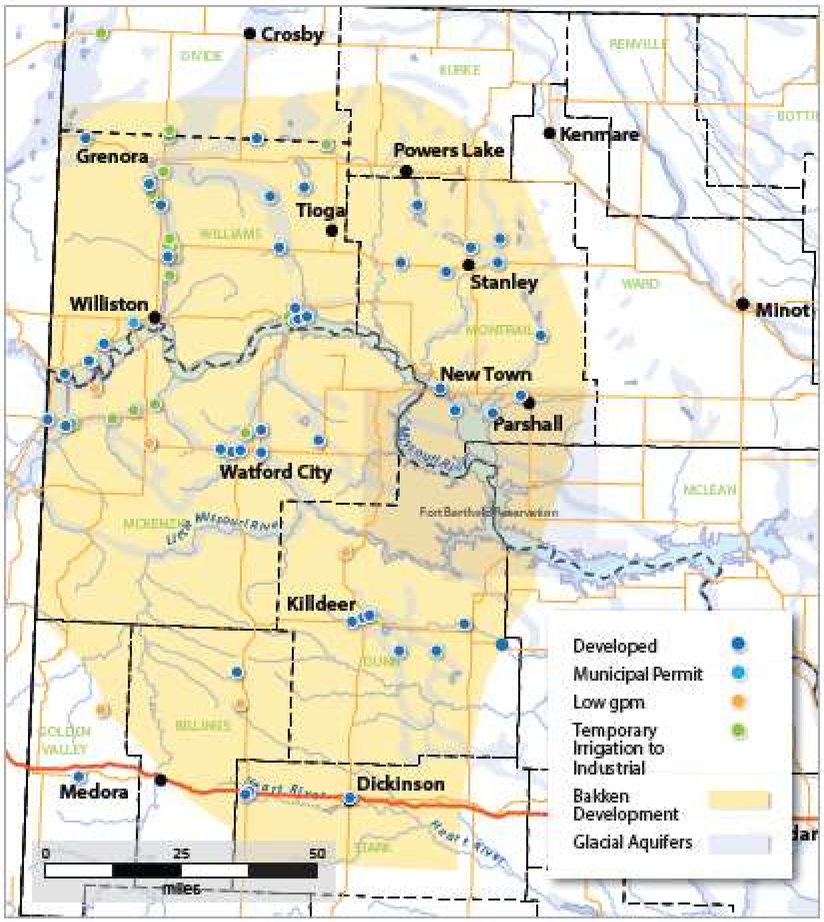
- **Produced water** – all water generated during oil and gas production
  - Sum(fracturing fluids, formation water)
  - 21 billion bbl/yr in U.S. (1M wells)
    - ~3:1 to 8:1 water:oil
- WQ is highly variable
  - Salts, minerals, metals, O&G, radionuclides, and organics



UNIVERSITY OF WYOMING
CEPWM

Why manage produced water?

Operating Water Depots (as of September 11, 2012)



Example Cost - Water Disposal Wells

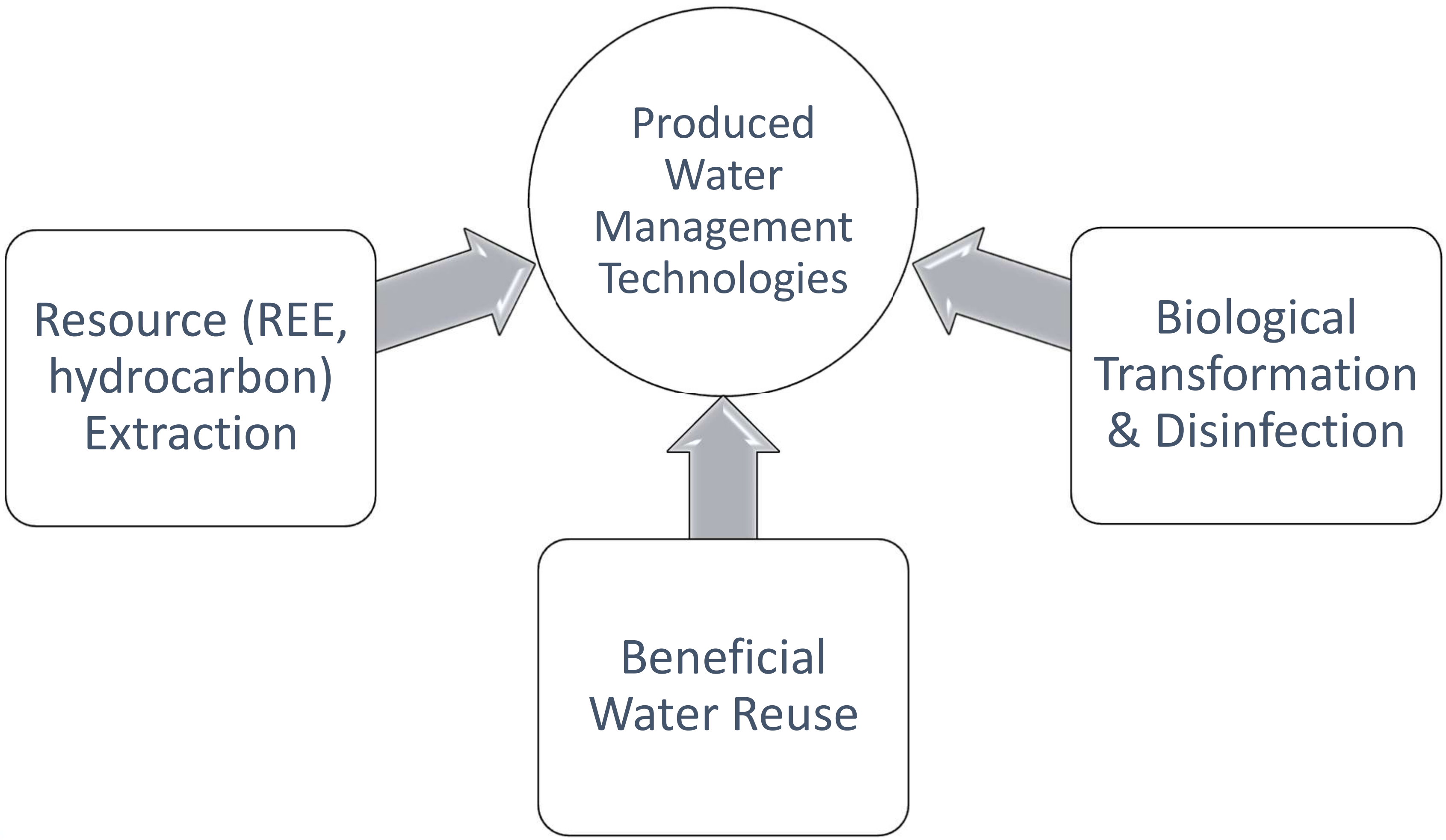
1. Water Acquisition
   - 1 to 5 MG/well for fracturing
   - Competition for limited supplies
   - $6 to $25/1,000 gal
2. Disposal
   - $0.50 to $2.50 per bbl for deep well injection (SWD)
3. Transportation $1.00 / barrel / hour (average)
   - Trucking SWD's plentiful (TX) — $0.50 - $1.00 / barrel
   - SWD's scarce (PA) — $4.00 – $8.00 / barrel

Environmental Considerations

1. Surface/subsurface contamination
2. VOC to atmosphere
3. Solids disposal
4. Geotechnical considerations

UNIVERSITY OF WYOMING
CEPWM

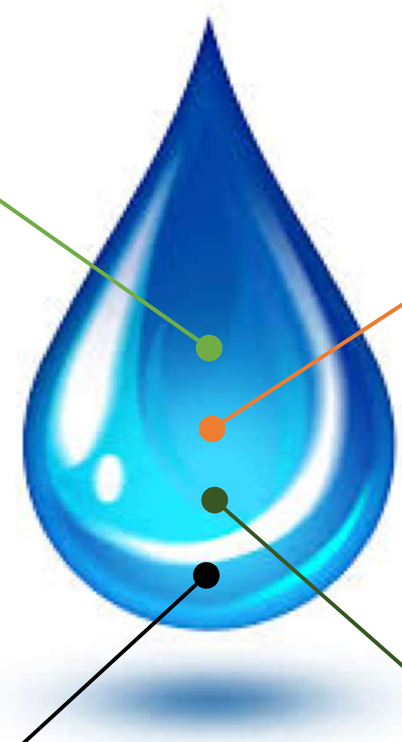
CEPWM Current Research Areas



Beneficial Resource Extraction Opportunities

Precious Metals –

- Lithium, iodine and uranium
- Rare earth elements (REEs)



Water – 2.4 BG/day

- Fracking
- Irrigation
- Stream augmentation
- Industrial process make-up

90k acres irrigated w/ 50k acre-feet of PW in CA

Tx A&M used 4:1 blend of PW to irrigate cotton (GW conservation)

Other –

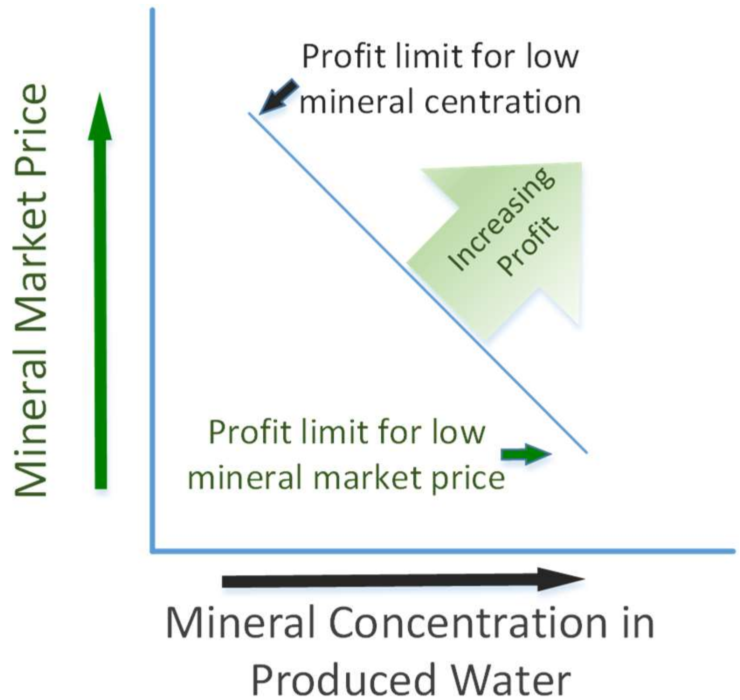
- Hydrocarbon recovery, $$
- Methanol + other additives for reuse
- Energy production (heat & chemical potential)

Minerals –

- NaOH production from $NaHCO_3$ w/ membrane electrolysis
- Na, K, Mg, and Ca

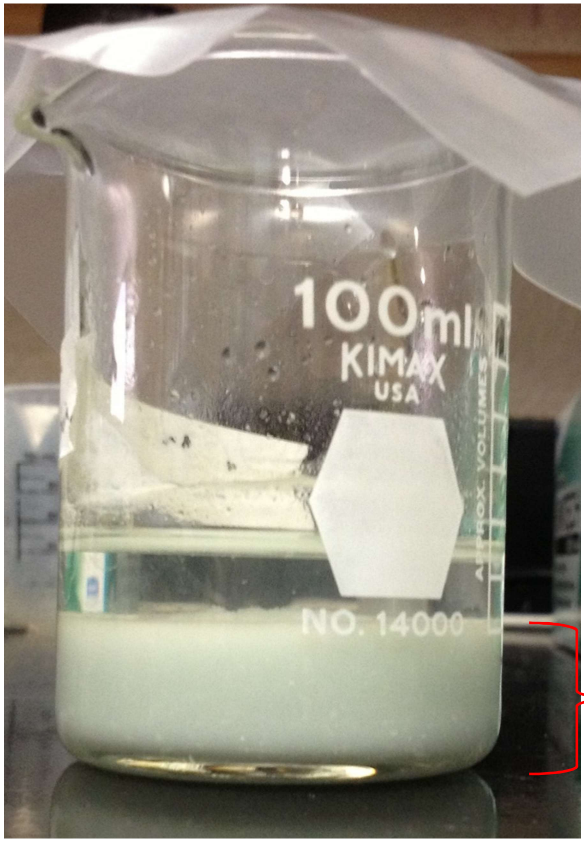
UNIVERSITY OF WYOMING
CEPWM

Resource Extraction Challenges



Making the risks of resource extraction worth it?

Complex and Evolving Water Quality



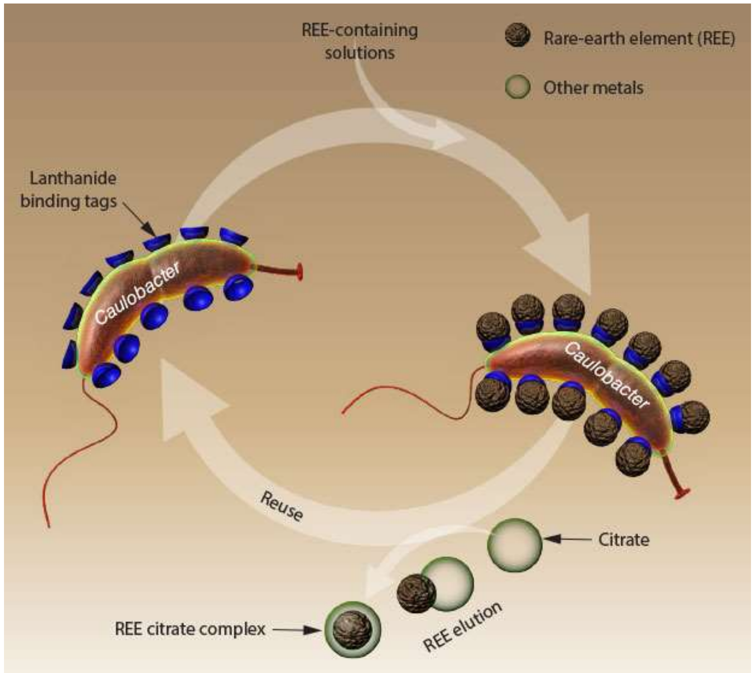
Precipitated Solids from 50 mL Sample

Produced Water from Marcellus Shale
TDS = 320,000 mg/L
Hardness = 75,000 mg/L
Lithium = 230 mg/L

UNIVERSITY OF WYOMING
CEPWM

Biological Management

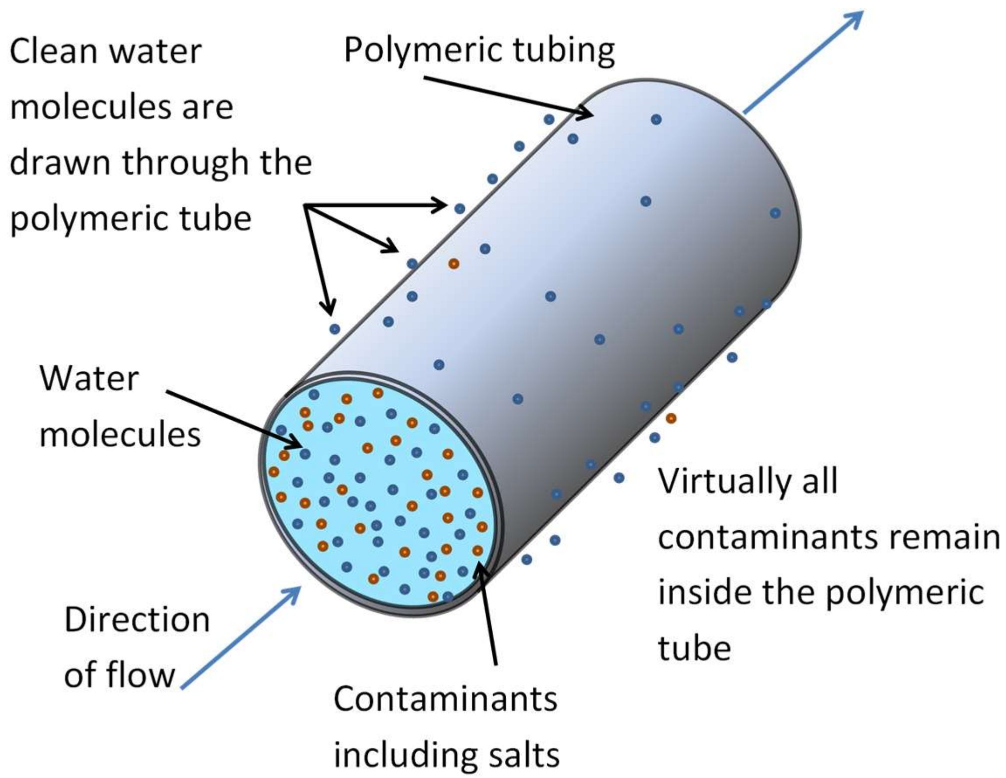
- Bio-activity is a concern and an opportunity for down hole and above ground activities
- Application of biocides (down hole) has resulted in resistant organisms
  - Increases in quantity and types of chemicals sent down hole (environmental contamination)
  - Biological attack of well casings and components / formation plugging ~ system failure & environmental risk
  - Development of non-chemical based disinfection strategies
- Opportunity = Genetic engineering of microbes for resource recovery and water treatment
  - Rare earth element recovery using biological uptake and harvesting

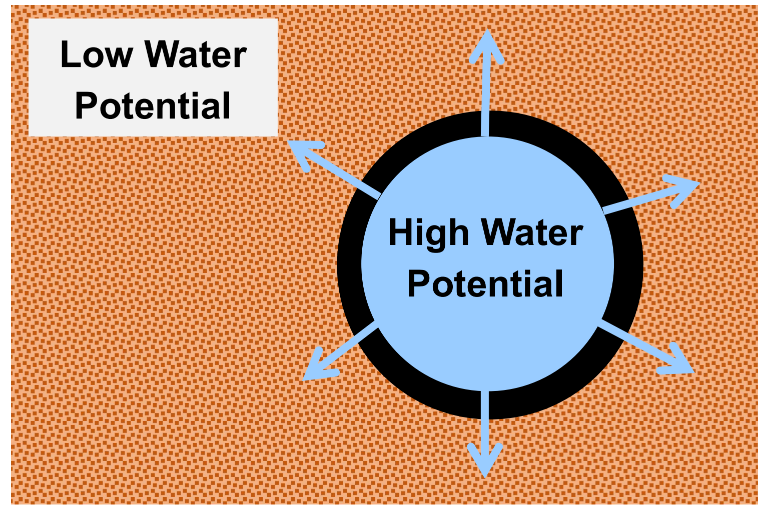


Source: https://str.llnl.gov/april-2016/schwegler

Broadening the Water Reuse Portfolio

Pervaporation irrigation

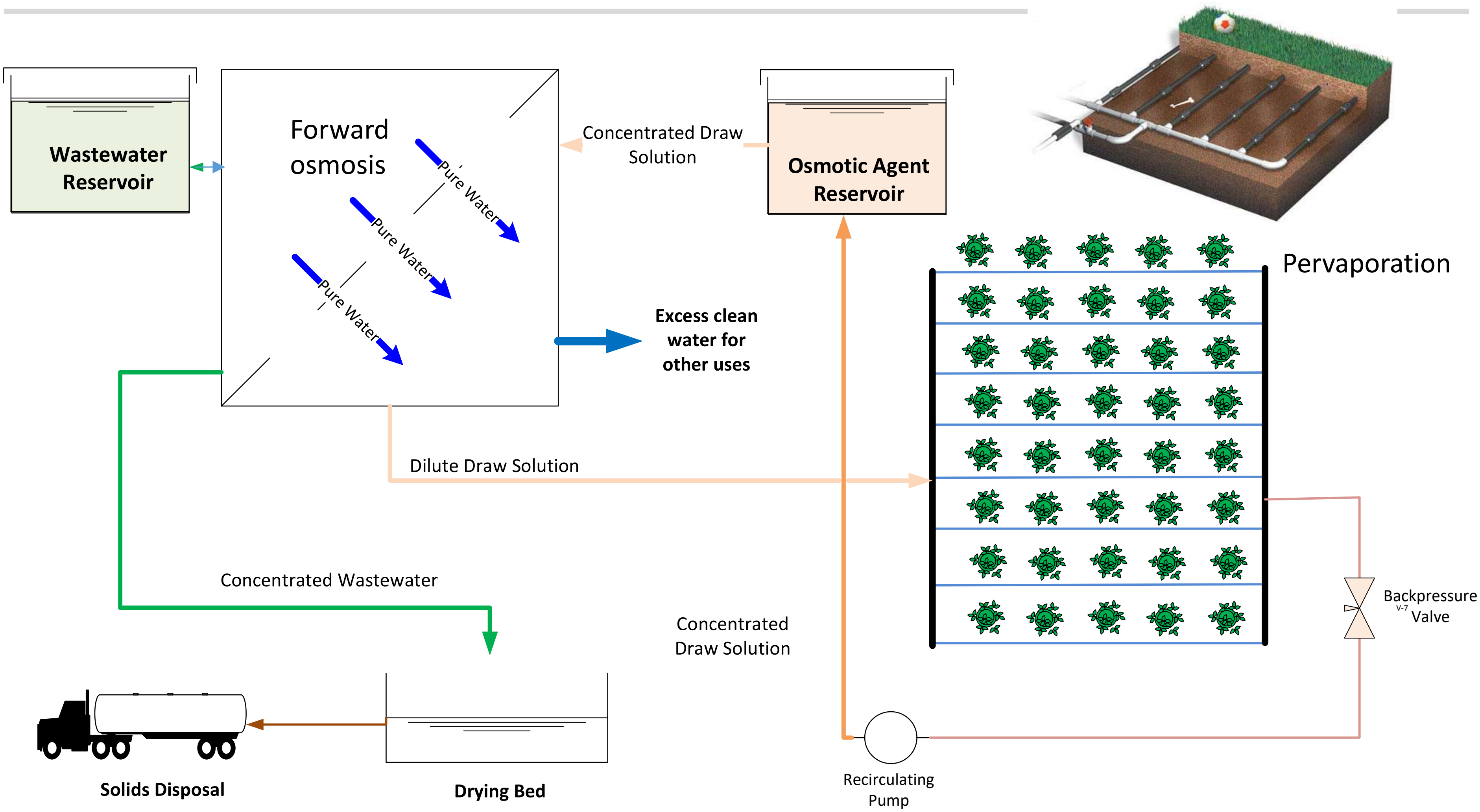




$$J_w = \frac{L_w v_w}{\delta_w}\left\{\left[\frac{RT}{v_w} ln\, a_{w,f} - (\psi_c + \psi_o + \psi_g)\right] + (p_f - p^*)\right\}$$

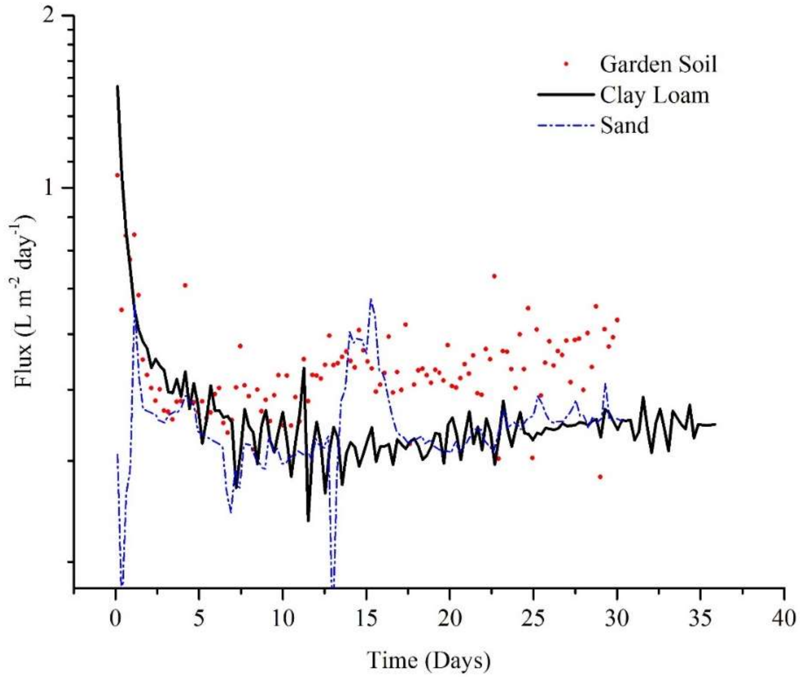
UNIVERSITY OF WYOMING
CEPWM

Pervaporation system



UNIVERSITY OF WYOMING CEPWM

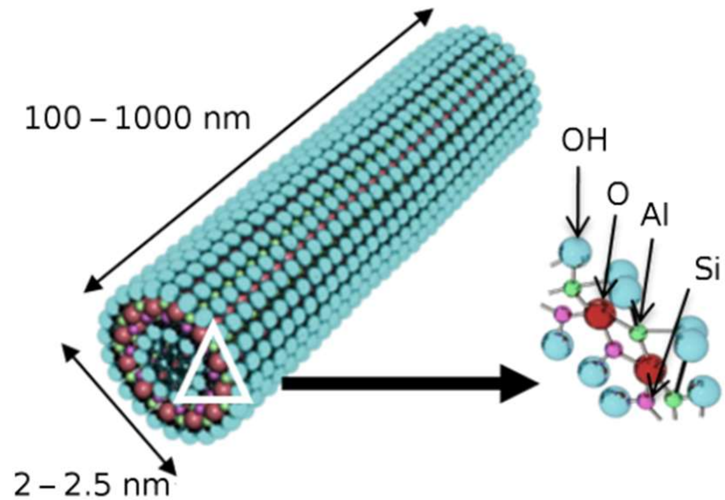
Soil Water Potential and Flux

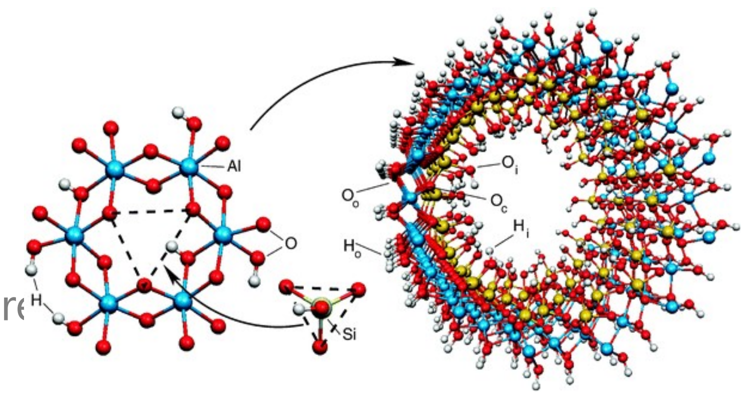


UNIVERSITY OF WYOMING
CEPWM

Imogolite Nanotubes for Oil/Water Separation

- **<u>Imogolite</u>** - mineral (aluminum silicate) that forms nanotubes
  - Rigid / straight structures as opposed to “spaghetti” structures formed by Carbon Nanotubes
  - “Simple” synthesis techniques relative to Carbon Nanotubes
- **Modifiable physical and surface properties**
  - Interior and exterior surface chemistry modified by grafting
  - Precursor (Si, Ge) determines opening diameter
  - Length controlled by pressure and temperature conditions

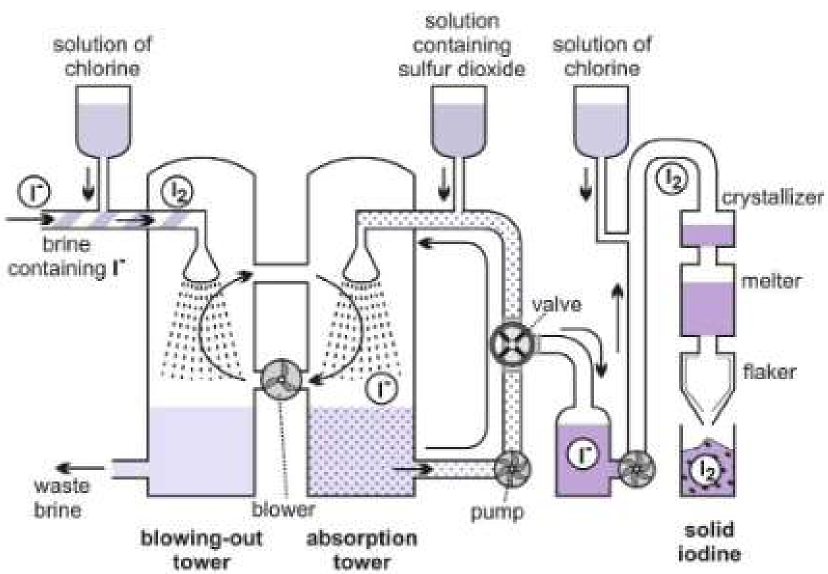




<u>Credit</u>: Creton et al. (2008).

UNIVERSITY OF WYOMING
CEPWM

Iodine Recovery from Produced Water

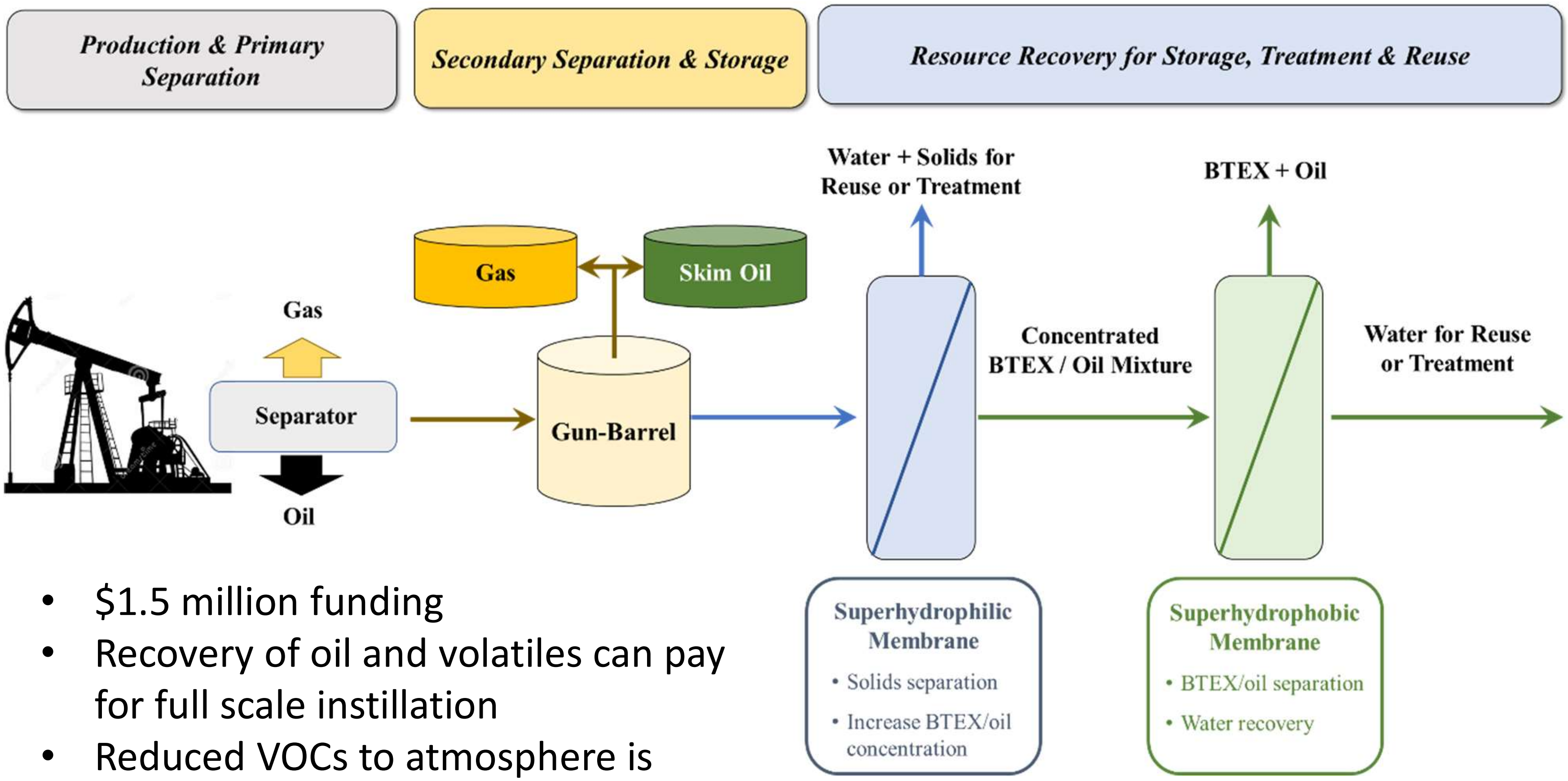


Kanto Natural Gas Development Co., Ltd.

Iofina ® iodine removal facilities

UNIVERSITY OF WYOMING
CEPWM

Latest DOE Award



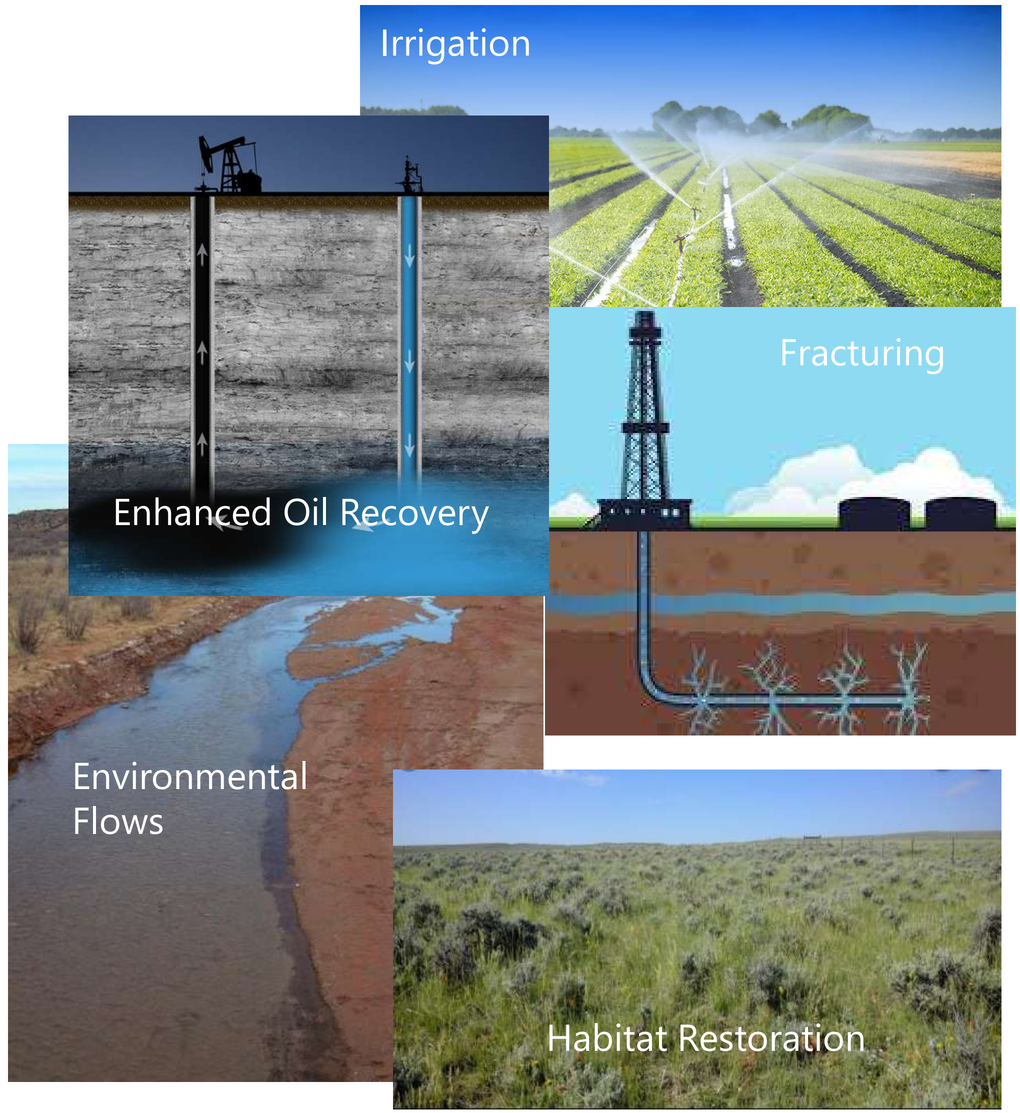
- $1.5 million funding
- Recovery of oil and volatiles can pay for full scale instillation
- Reduced VOCs to atmosphere is significant environmental benefit
- High quality water for reuse

University of Wyoming
H2O Systems, Inc./Triton
Water Midstream, LLC

UNIVERSITY OF WYOMING CEPWM

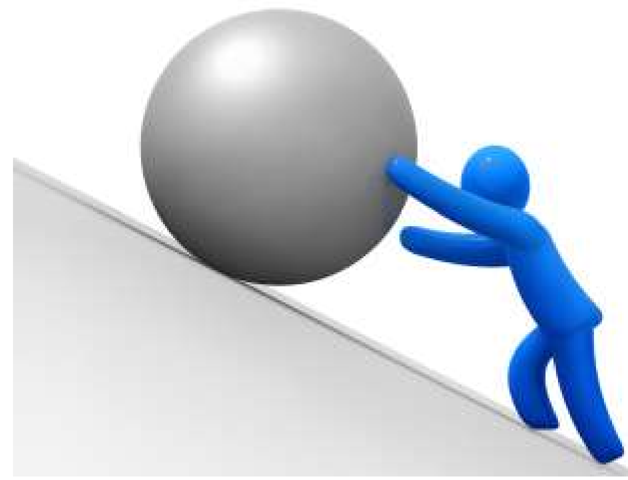
Water Reuse Opportunities

- Many reuse opportunities
  - Tailored water quality production!
- Making potable water is not a primary goal
  - Regulatory hurdles
  - Cost of treatment
  - Transportation of finished water (temporally variable sources)



Water Reuse Challenges

- Spatial and temporal variability in produced water quality
  - No one size fits all approach!
  - Ensuring effluent quality meets standards
  - Smart (reactive) processes required
  - Mobile systems
- Matching water sources to water users
  - Transportation of the “finished” water is a challenge
- “Unique” water constituents prompts pilot testing needed to prove that approaches are viable
  - Scant funding for such “research” endeavors
- **Cost!**



Motivating water users and producers to enter the water reuse market is perhaps the greatest challenge to water reuse!

UNIVERSITY OF WYOMING
CEPWM

Benefits of partnering with the Center-- Our teaming capabilities

- **DESKTOP ANALYSIS:**
  Determine the technical, economic, and business implications of potential technology applications, creating a clear understanding of potential applicability, cost, and benefits prior to extensive application of testing
- **BENCH SCALE STUDIES:**
  Simulate full-scale operations prior to a more expensive pilot or demonstration scale evaluations - capabilities include a full suite of organic, inorganic, biological, and separation technologies used to treat, extract resources, reduce volume, improve reuse opportunities (e.g., fracking formulation), and provide regulatory compliance for produced waters.
- **PILOT AND DEMONSTRATION SCALE EVALUATIONS:**
  Assess evolving technologies and combinations of existing technologies used to treat, reuse, extract resources, and dispose of produced waters. Like the bench scale capabilities, these include organic, inorganic, biological, and separation technologies; all of which are possible approaches to reduce produce water management costs and provide benefits to society and the environment.
- **ECONOMIC AND TECHNICAL MODELING:**
  Develop and conduct modeling to assess the technical, operational, managerial, aspects of specific approaches to produced water management; technology integration, capital and operations cost, environmental benefits and impacts, and managerial requirements.
- **REGULATORY ASSESSMENT AND EVALUATION:**
  Review approaches to compliance as well as a review of proposed regulations and the implications for operations, changes in technology, and sustainability of the regulatory development.
- **VALIDATION OF COMMERCIAL TECHNOLOGIES:**
  Validate claims concerning a technology's capabilities and total costs. Technology evaluation capabilities include a combination of desktop, bench scale, pilot scale, and demonstration studies.

Questions?

University of Wyoming
Dept. Civil & Architectural Engr.
1000 E. University Avenue
Laramie, WY 82071

Jonathan Brant
Phone: (307) 766 – 5446
Email: jbrant1@uwyo.edu

William Bellamy
Phone: (303) 807 - 2195
Email: wbellamy@uwyo.edu

CENTER OF EXCELLENCE
IN PRODUCED WATER MANAGEMENT