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An Integrated Framework for Treatment and Management of CBM Produced Water

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Argonne National Laboratory

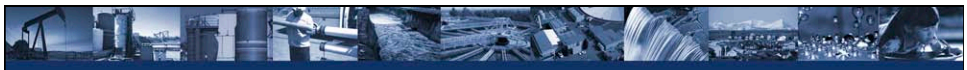
Bob Raucher and Jim Henderson, Stratus Consulting

Wayne Buschmann, Eltron Research

17th International Petroleum and Biofuels Environmental Conference (IPEC)

San Antonio, TX, September 1st, 2010

RPSEA
Research Partnership to Secure Energy for America



Outline

- Current practices and challenges associated with management and beneficial use of produced water
- Opportunities and technical challenges
- Guidance needed for beneficial use
- An integrated framework approach to facilitate beneficial use
- Concluding remarks

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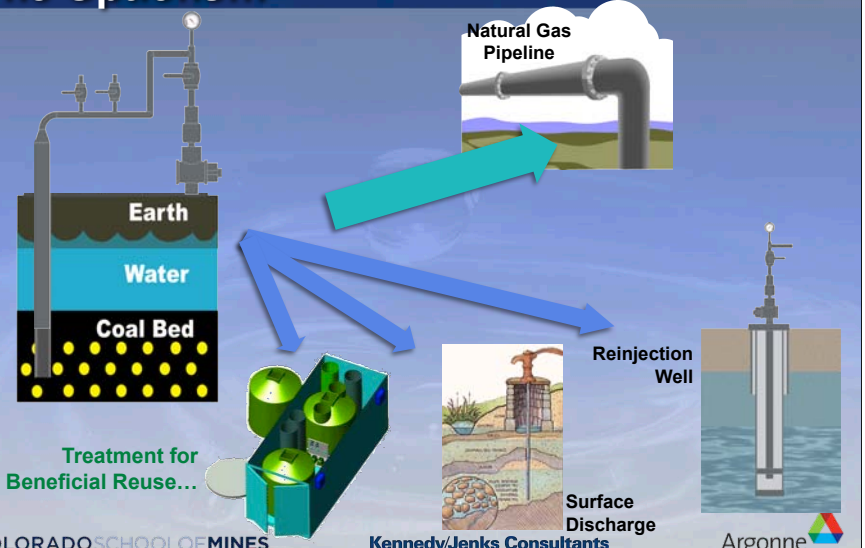
Coal Bed Methane (CBM) Produced Water: The Options…



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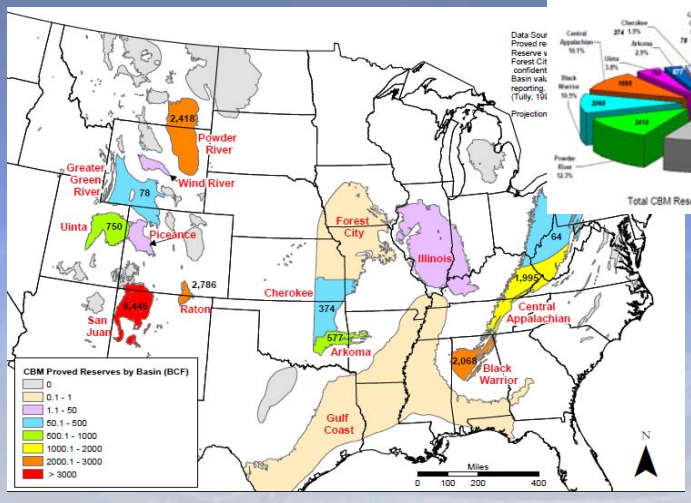
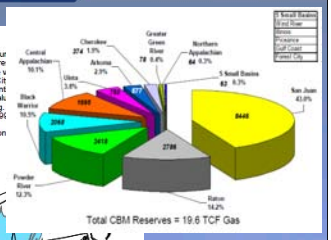
CBM Proved Reserves (BCF) By Basin





Source: EIA 2006

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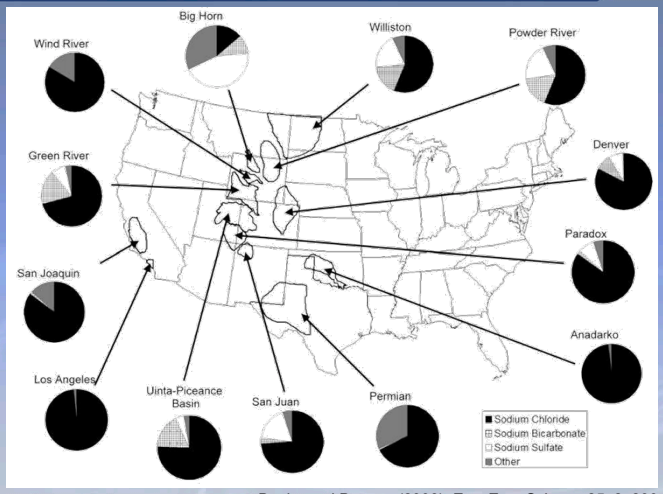
Produced Water Quality: Salt Composition



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

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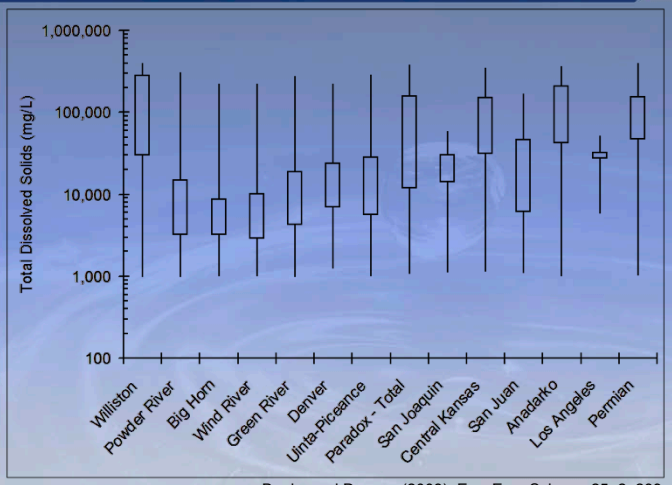
Produced Water Quality



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

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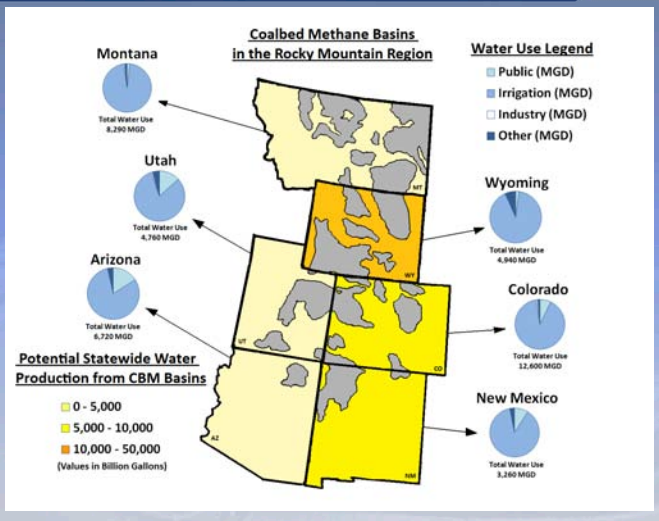
Produced Water Quantity by Basin



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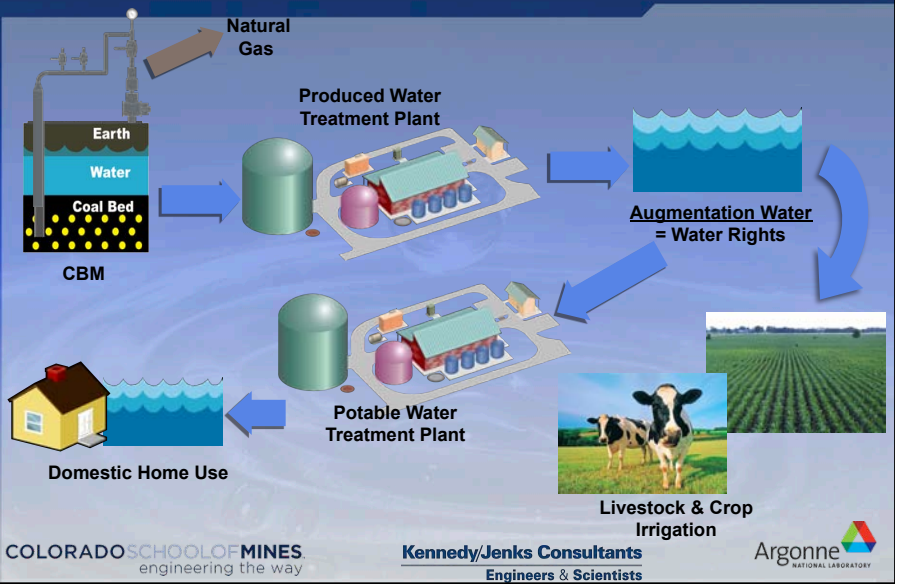
Produced Water: Potential Utilization



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Produced Water as a Water Supply

Reliable Resource

- Drought-proof
- Presently unused
- Non-tributary water not subject to water right limitations

Long Term Supply

- Oil and gas development 30-70 more years
- Water resource could continue to be mined

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Challenges for Widespread Beneficial Use

Geographic Challenges

- Long distances between produced water sources and end users
- High cost of water conveyance infrastructure

Gas Market Challenges

- Fluctuating gas prices might deter investments in treatment technology

Regulatory Challenges

- Complex water rights
- Interstate variations in environmental regulations and permits
- Difficult to assess the quantity and scope of mitigation and compensation owed to 3rd parties
- Liability and uncertainties associated with conveyance and end use
- Institutional boundaries between private management of oil and gas resources and public management of water resources

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An Integrated Framework for Treatment and Management of Produced Water

Colorado School of Mines / AQWATEC
- Principal Investigators: Jörg Drewes, Tzahi Cath, Pei Xu

Kennedy/Jenks Consultants
- Principal Investigators: Jim Graydon and Jean Debroux

Argonne National Laboratories
- Principal Investigators: John Veil and Seth Snyder

Stratus Consulting
- Bob Raucher, Jim Henderson

Eltron Research
- Wayne Buschmann

Technical Advisors
- Dave Stewart, Stewart Environmental Consultants
- Jeff Cline, Cline Energy Consultants

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An Integrated Framework for Treatment and Management of Produced Water

Project Goal

- ***Develop an integrated guidance framework that links 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 operations***

Project Schedule:
September 2008 - March 2011

Rocky Mountain Region Major Coalbed Methane Basins

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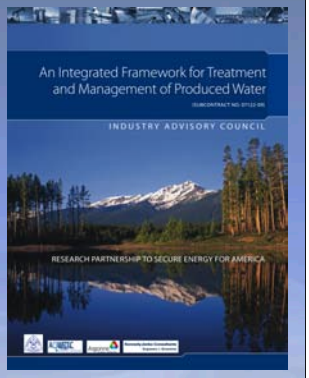
- **Industry Advisory Council (IAC):**
  - 10 medium- and large-size gas producers
  - Major CBM players in the Rocky Mountain region
- **Technical Experts/Advisors:**
  - Jeff Cline, Cline Energy Consultants
  - Dave Stewart, Stewart Environmental Consultants



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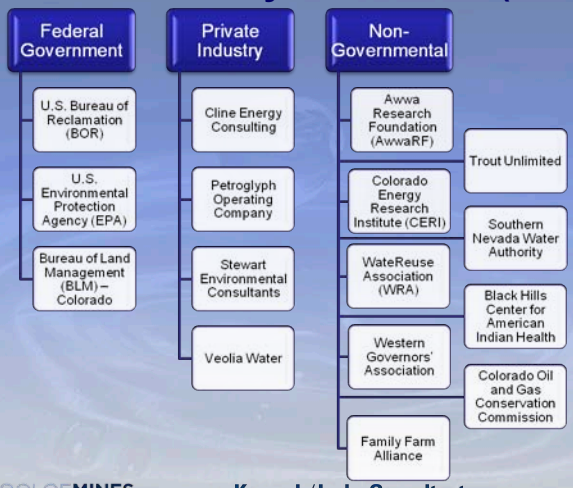
- **Stakeholder Advisory Committee (SAC):**



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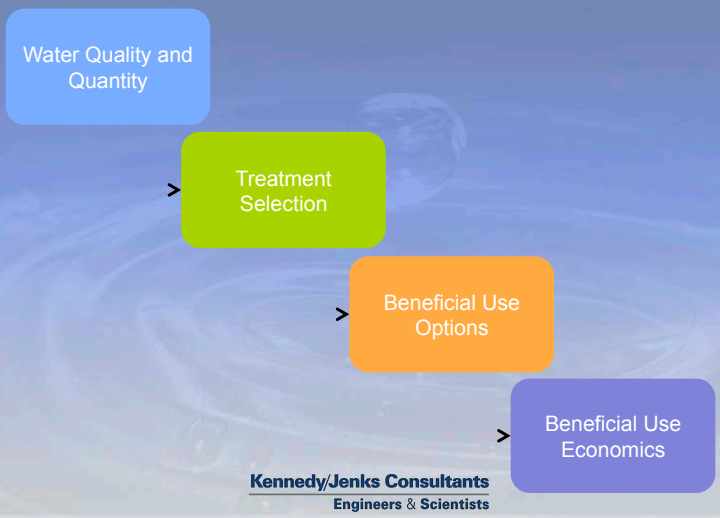
The Integrated Framework

http://aqwatec.mines.edu/produced_water/tools



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An Integrated Framework for Treatment and Management of Produced Water

Project Overview

- **Task 1 - Classification of Produced Water Qualities and Management Strategies**
  - Characterize and classify produced water qualities across different basins/formations: Water Quality Module (WQM)
  - Determine produced water quantities (by basin and resource; gas/water ratios; current disposal/use strategies; etc.)
  - 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
  - Address regulatory requirements among different locations

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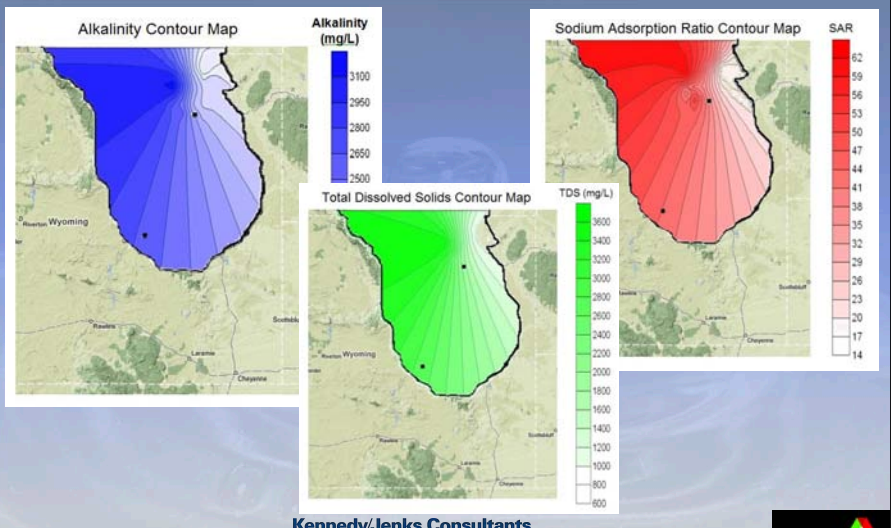
Produced Water Quality: Powder River



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- **Task 2 - Selection and Testing of Treatment Technologies for Produced Water**
  - Identification and evaluation of robust, low-maintenance, modular pre-treatment and desalination technologies as well as brine management and disposal strategies (considering both well-established conventional as well as emerging desalination technologies):
    Treatment Technology Assessment Report
  - Explore most appropriate and cost-efficient technologies for treatment of produced water considering water quality of produced water and targeted beneficial use: Treatment Selection Module (TSM)
  - Pilot-scale treatment trains are currently being designed, assembled and tested at laboratory setting and representative production sites for field-scale validation
  - Develop cost modules for management options

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Technology Assessment Report

An Integrated Framework for Treatment and Management of Produced Water

TECHNICAL ASSESSMENT OF PRODUCED WATER TREATMENT TECHNOLOGIES

1st EDITION

RPSEA Project 07122-12

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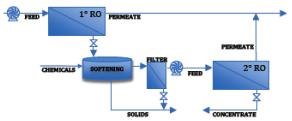
November 2009

Dual Reverse Osmosis with Chemical Precipitation

Dual reverse osmosis (RO) with chemical precipitation employs both physical (purification through a semi-permeable membrane) and chemical precipitation methods to enhance water recovery beyond that of a single stage RO process. This method is used when high recovery is desired when desalinating hard water. Concentrated brine generated from the first stage RO is treated (softened) with lime ($Ca(OH)_2$) or caustic soda (NaOH), and/or soda ash (Na_2CO_3) to precipitate calcium as $CaCO_3$, magnesium as $Mg(OH)_2$, and to a lesser extent co-precipitate colloidal and dissolved silica. Specific chemicals can be used to precipitate targeted sparingly soluble salts. Precipitation of these constituents reduces the likelihood of membrane scaling in the second stage RO. RO membranes are capable of achieving high removal of monovalent ions (e.g., sodium, potassium, chloride, etc.), divalent and multivalent ions (e.g., calcium, magnesium, sulfate, iron, arsenic, etc.), and many organic constituents from the feed stream. The dual RO with chemical precipitation technology is primarily used for brackish water desalination, where a removal of multivalent ions and increased water recovery are desired. An illustration of the process is shown below.



Summary of technical assessment of dual RO with chemical precipitation

Criteria	Description/Rationale
Status of Technology	Pilot tested at municipal desalination plants. Not previously employed for CBM produced water treatment.
Feed water quality bins	Total dissolved solids application range from 1,000 mg/L to 35,000 mg/L. High removal of monovalent and divalent ions, metals, and organics is achievable. System is likely to achieve additional silica removal through co-precipitation.
Product water quality	Permeate water quality depends on feed water salinity and operating conditions. Pilot studies reported 94% rejection of total dissolved solids.
Recovery	Product water recovery is estimated to exceed 90%.
Energy use	No data is currently available.
Chemical use	Chemical demand of lime ($Ca(OH)_2$) or caustic soda (NaOH) depends on water chemistry and the quantity of calcium and magnesium targeted for removal. Chemical cleaning rates depend on feed water quality. Membrane cleaning will be triggered when certain operating conditions are exceeded, and may require the use of NaOH, Na_4EDTA, or HCl.

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- **Task 3 - Assessment of Management Options**
  - Explore through cost/benefit analyses the multiple conditions that have to be fulfilled in order to establish beneficial use from a technical, regulatory, political, environmental, economic, and legal standpoint:
    Beneficial Use Screening Module (BSM)
  - Develop a structured decision process that identifies, evaluates, and, where possible, quantifies benefits, risks, and costs of each management option:
    Beneficial Use Economic Module (BEM)

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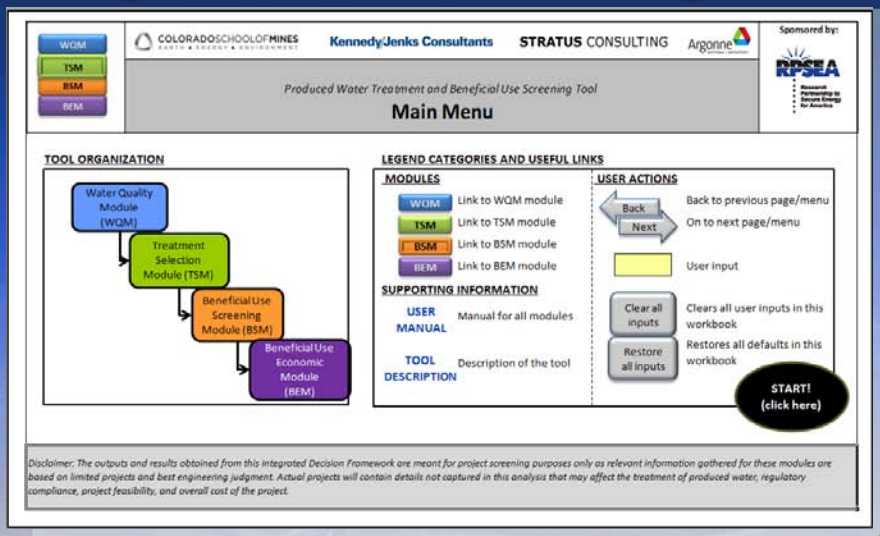
Integrated Framework Screening Tools



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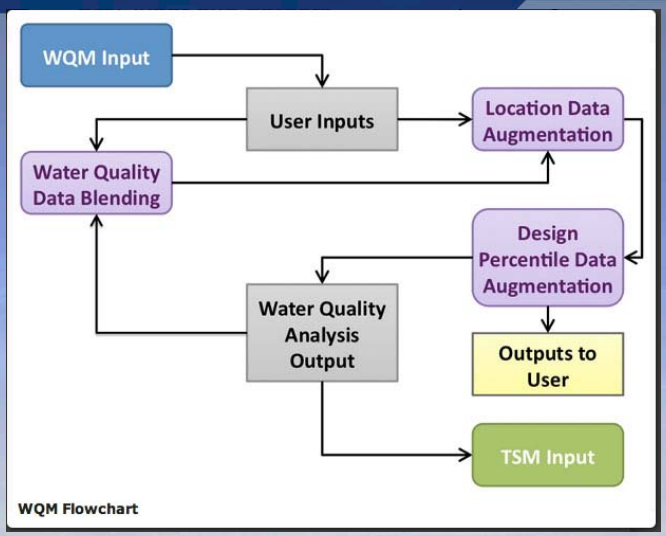
Water Quality Module



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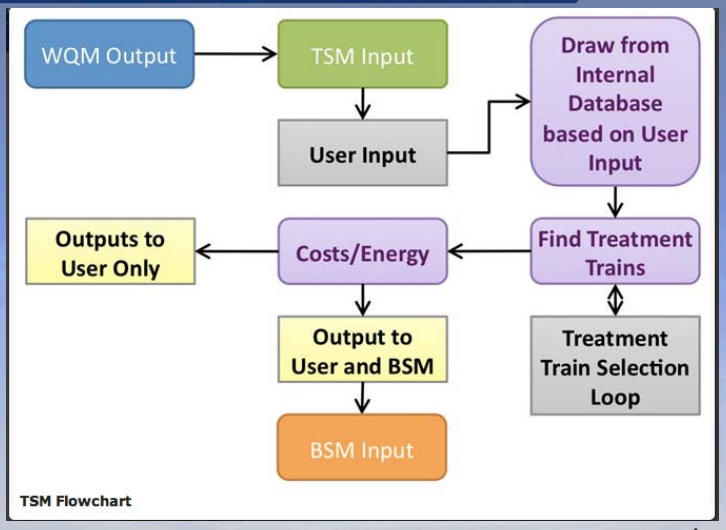
Treatment Selection Module



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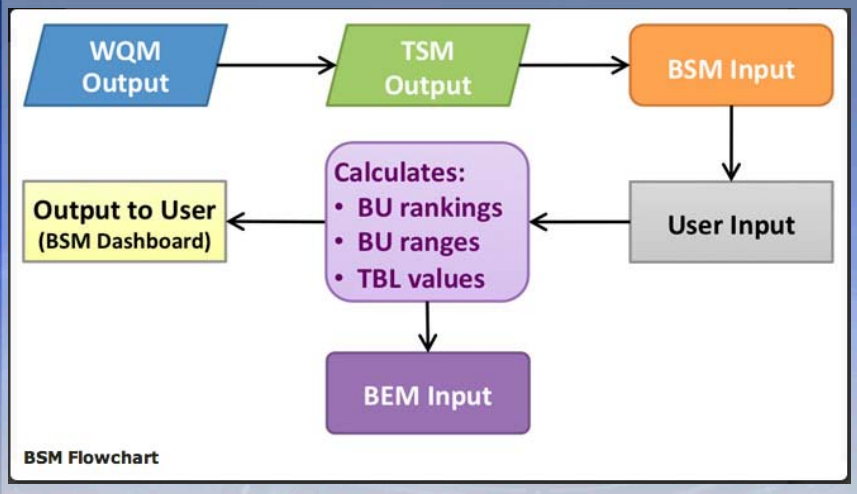
Beneficial Use Screening Module



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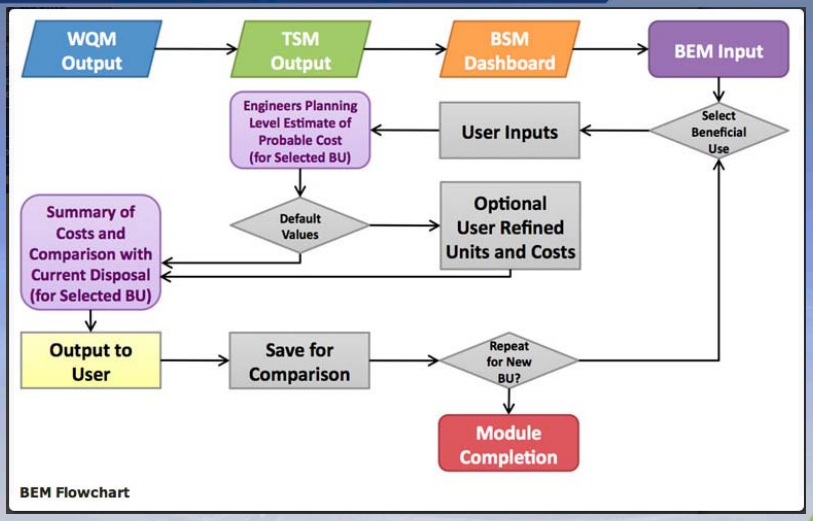
Beneficial Use Economic Module



BEM Flowchart

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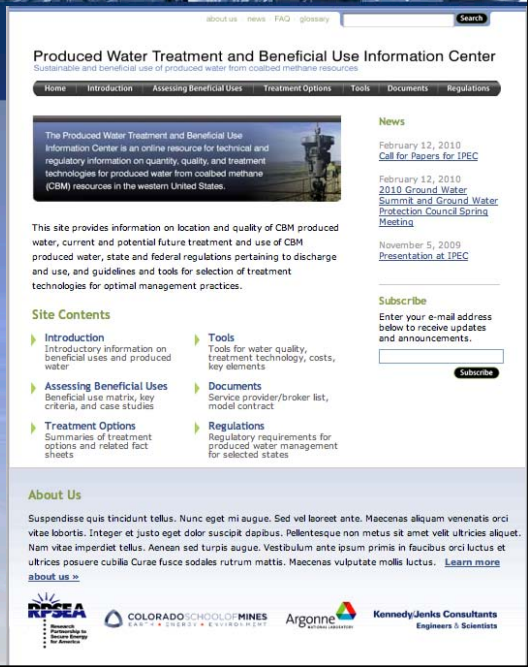
http://aqwatec.mines.edu/produced_water

Project Website



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- **Task 4 - Field Validation of Viable Treatment Processes for Produced Water**
  - Bench/pilot-scale treatment trains were designed, constructed and being tested at representative production site for field-scale validation
  - Data is being analyzed to determine the effectiveness, robustness, and ease of operation of treatment strategies
  - Testing results will provide validation of the integrated decision making framework

Concluding Remarks

- **Unconventional natural gas production will increase**
- **CBM produced water represents significant unconventional freshwater resource for the next 20-70 years**
- **Treatment, conveyance, and storage are needed**
- **Water rights and liability are biggest issues**
- **Third parties might function as water purveyors**
- **Integrated Framework Tools can assist in facilitating beneficial use**

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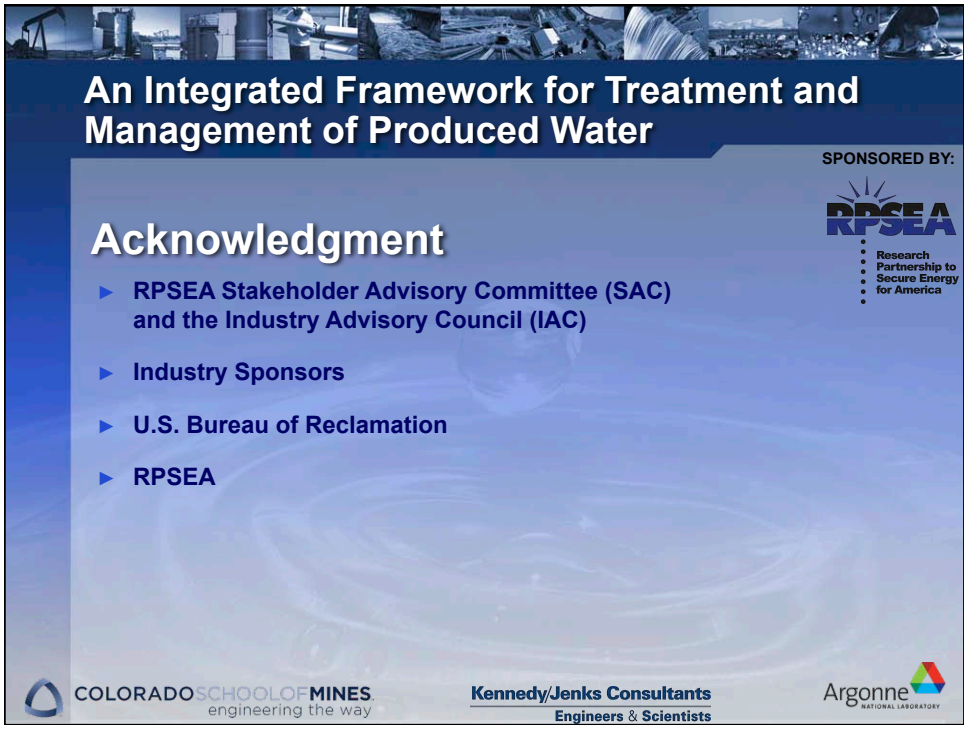
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