The Ground Water Protection Council

Coal Bed Methane Produced Water Quality and Treatment

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Demonstrated Economics of Managed Irrigation for CBM Produced Water

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Outline

- Managed Irrigation and Beneficial ReUse
- Factors that Influence Cost
- Reduce Cost by Careful Evaluation
- Managed Irrigation Project Example

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Managed Irrigation

- Alternate water management strategy to direct discharge
- Benefits
  - ReUse of CBM produced water
  - Enhances native vegetation and agricultural production
  - Streamline permitting process (if any)

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Beneficial ReUse is Possible

- Reduce SAR effects with proper design and management of irrigation system
- Cost effective if factors controlling cost are understood and managed

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Factors that Influence the Cost of Managed Irrigation Systems

- Water Chemistry
- Water Volume
- Site Soil Chemical and Physical Properties
- Irrigation Season Limitations

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Water Chemistry

- Factors
  - CBM production water typically has an elevated Sodium Adsorption Ratio (SAR)
  - High Na concentration relative to Ca and/or Mg
  - Sodium (Na) concentrations range from 500 - 1000 mg/l
  - Bicarbonate (HCO_3^+) range from 1000 - 3500 mg/l
- Influence on Cost
  - Requires the addition of amendments to put water back into balance
  - Each water quality has to be considered as unique
  - Resulting in a unique cost and amendment combination to manage SAR of the soil

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Water Volume

- Factors
  - Initial flow rate and rate of decay are estimated
  - Permit conditions
    - summer application /winter discharge
    - summer application/winter storage
    - year round application

- Influence on Cost
  - Volume of water requiring amendments
  - Type and cost of water application equipment
  - Method of amendment application
    - Field Application vs In-line Injection

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Soil Chemistry

- A majority of soils in the Powder River Basin contain low “free” calcium concentrations
  - No natural source of Ca to balance high Na concentration in water
  - Requires a soil or water amendment (typically gypsum)

- Bicarbonate concentration in water limits the saturation point of Ca
  - Additional amendments to maintain soil pH and increase Ca solubility in soil (commonly sulfur)

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Soil Physical Properties

- Water application rate is dependent on the soil infiltration rate
  - Soil with higher infiltration rates can accept more water per unit time
- Sandy soils have relatively higher infiltration rates
  - Less reactive
- Clay content of soil decreases soil infiltration rates
  - Increases reactivity

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Irrigation Season Limitations

- Spring and Fall
  - Low evapotranspiration rates may reduce daily application rates
- Summer
  - Higher evaporative losses
  - High plant transpiration
  - Requires higher daily application rates to maintain soil moisture
- System design must accommodate variations in seasonal limitations

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Stepwise Approach to Managed Irrigation

Water Chemistry

Soil Assessment

Application Method

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Reduce Cost by Careful Evaluation

- Project Development and Design
- Soil and/or Water Amendment
- Capital Equipment and Operation
- System Operation and Maintenance

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Project Development

- Desktop Evaluation
  - Determines the cost and feasibility of managed irrigation for a particular water quality and flow rate
  - Go - No Go Decision

- Field Soil Assessment
  - Evaluate and identify site specific soil properties
  - Refine feasibility and cost evaluation
  - Basis for irrigation equipment design

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System Design

- Select method of amendment delivery
  - field applied or in-line injection
- Selection, design and layout of water application equipment
- Pipeline and pump design

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Soil and/or Water Amendment Cost

- Volume of Amendments
  - Function of Water Quality and Flow Rate
  - Soil properties

- Method of Amendment Delivery
  - Field application of amendments
  - In-line injection
    - Sulfur Injection (Sulfur burners or sulfuric acid)
    - Ca Injection (Gypsum or Calcium Chloride)

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Equipment
System Design

- Evaluate variety of different methods of water application based on:
  - Flow rate and flow rate reduction
  - Soil physical and chemical properties (soil infiltration and reactivity)
  - Number of acres required to accept volume of flow (limited by the hydraulic properties of the soil)

- Balance between initial equipment cost and operational labor cost for the site specific soil application rate

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Evaluate Managed Irrigation Equipment Options

Wheel Line/Sideroll

Solid Set

Travelers

Center Pivots

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Equipment and Operational Labor Cost Comparison

- 12,500 bbl/day (365 gpm) flow rate
- 100 acre system
- 0.25 in/hr instantaneous application rate

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Equipment and Labor Cost Summary

Equipment	Equipment & Installation Cost/Acre or Unit	Number of Units or Sets	Total Equipment Cost	Labor[1] / Month	Total Labor over 7 month Growing Season	Total Cost Year 1
Wheel line	$10,000	3 systems	$30,000	$1,700 - $14,400	$62,700	$92,700
Solid Set	$2,000	2 - 25 ac.	$100,000	$5,040 - $10,080	$55,440	$155,440
Solid Set	$2,000	4 - 25 ac.	$200,000	$500 - $750	$4,500	$204,500
Traveler	$25,000	4 travelers	$100,000	$2,400 - $4,800	$26,400	$126,400
Center Pivot	$1,125	2 - 50 ac	$112,500	$500 - $750	$4,500	$117,000

Note:

[1] Labor cost based on $30/hour.

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System Operation and Management

- Irrigation scheduling
  - Distribute water uniformly
  - Maintain vertical migration of water
- Soil Sampling
  - Monitor soil chemistry
- Produced water sampling
  - Amendment adjustments
- Amendment
  - Application scheduling and adjustments

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All Solutions are Site Specific

- Water or soil amendments are specific to the water chemistry
- Soil characteristics
- Equipment selection
  - infiltration rate of soil
  - cost to install and operate

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Managed Irrigation Project Example

- Current flow rate 12,500 barrels/day (365 gpm)
- Sodium-900 mg/l Bicarbonate 2500 mg/l
- 4 center pivots over 100 acres
- Field applied sulfur and gypsum amendments
- Amendments applied for every 6 to 7 inches of produced water applied
- Summer application with permitted winter discharge

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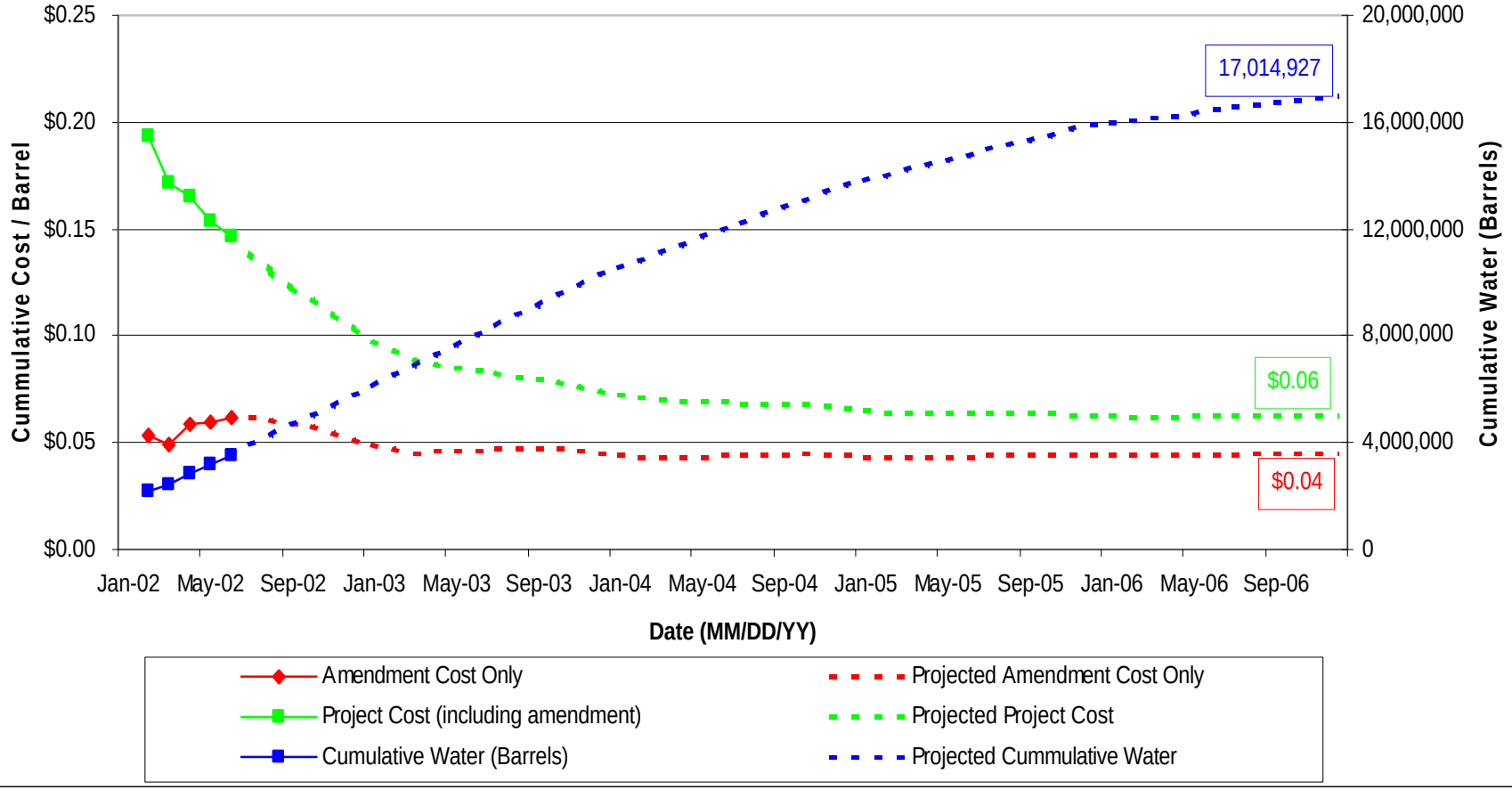
Managed Irrigation Cost[1]

[1]Projected Cost based on current flow rate (12,500 BBL/D with a 25% flow reduction per year beginning in 2004)



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Evaluation of Project Cost

- For a 12,500 barrel/day system
  - Ultimate amendment cost approximately 4 -5 cents per barrel
  - Design, development, equipment, operation and monitoring adds approximately 2 to 3 cents per barrel
  - Final cost dependent on total volume of water and rate flow reduction

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Reduced Project Cost if

- Water quality contained less bi-carbonate
- Soil contained a higher percentage of sand
- Field areas larger and contiguous
- Grass harvested and sold
- Irrigation equipment moved or sold at completion of project

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Project Costs Summary

100 acre system
12,500 bbl/day (17 M bbl lifetime production)

- Design & Equipment Cost $0.005 to 0.01 / bbl
- Amendment Cost $0.04 to $0.06 / bbl
- O&M and Management $0.02 to $0.04 / bbl

- Overall Project Cost $0.06 to $0.11 / bbl

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Summary

- Managed Irrigation provides a Beneficial ReUse
- Factors that Influence Cost
- All solutions are site specific
- Project cost can be reduced by implementing a stepwise evaluation and system design
- Project Example
  - Amendment cost 4 -5 cents per barrel
  - Development, design, equipment, operation and monitoring additional 2 to 3 cents per barrel

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Managed Irrigation

Turning this...

… into this...

…with CBM produced water.

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