The Ground Water Protection Council

Coal Bed Methane Produced Water Quality and Treatment

October 16 - 17, 2002
Colorado Springs, CO
Demonstrated Economics of Managed Irrigation for CBM Produced Water

R. Jonathan Paetz, P.G.
Cascade Earth Sciences

(www.cascade-earth.com)
Outline

• Managed Irrigation and Beneficial ReUse
• Factors that Influence Cost
• Reduce Cost by Careful Evaluation
• Managed Irrigation Project Example
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)
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
Outline

• Managed Irrigation and Beneficial ReUse
• Factors that Influence Cost
• Reduce Cost by Careful Evaluation
• Managed Irrigation Project Example
Factors that Influence the Cost of Managed Irrigation Systems

• Water Chemistry
• Water Volume
• Site Soil Chemical and Physical Properties
• Irrigation Season Limitations
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 (HCO₃⁺) 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
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
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)
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
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
Outline

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

Water Chemistry

Soil Assessment

Application Method
Reduce Cost by Careful Evaluation

- Project Development and Design
- Soil and/or Water Amendment
- Capital Equipment and Operation
- System Operation and Maintenance
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
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
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)
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
Evaluate Managed Irrigation Equipment Options

Wheel Line/Sideroll

Solid Set

Travelers

Center Pivots
Equipment and Operational Labor Cost Comparison

• 12,500 bbl/day (365 gpm) flow rate
• 100 acre system
• 0.25 in/hr instantaneous application rate
# Equipment and Labor Cost Summary

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

Note:

\(^1\) Labor cost based on $30/hour.
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
Outline

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

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

Turning this...

…into this...

…with CBM produced water.