System Dynamics Model of Water Consumption for Oil Shale Development

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Location of the Green River Formation Oil Shale and Its Main Basins

Inset area

Utah

Colorado

Wyoming

SOURCE: Adapted from Smith, 1980.
RAND MG414-2.1
Headlines

• “We do not know how much water will be needed for a large oil shale industry or how those water demands will affect other water users.” Governor of Colorado, Bill Ritter, 2008

• “...how much water would be required for commercial oil shale development ...?” DOI Sec. Salazar Feb 25, 2009
Pilot Scale Plant Results
Barrels of Water per Barrel of Oil

• Paraho Process
  – 2.27 to 2.71 (OTA, 1980)
  – 1.3 (Shale Oil Information Center, 2009)

• Unocal Commercial Demonstration Plant
  – 2.77 (OTA, 1980)
  – Net water producer (Shale Oil Information Center, 2009)

• OSEC
  – 1 to 1.5 (http://www.oilshaleexplorationcompany.com/faq.asp)
System Dynamic Modeling

Conceptualization:

1. Define the purpose of the model.

2. Define the model boundary and identify key variables.

3. Describe the behavior or draw the reference modes of the key variables.

4. Diagram the basic mechanisms, the feedback loops, of the system.

Example of Shell In-situ Oil Shale Recovery Process

Plan View

Buffer width
Freeze wall spacing
Retort length
Retort width
Production well density
Heater spacing
Well completion rate
Number of drill rigs

Cross Section

Depth to water
Depth of frz wall
Height of retort

INL Idaho National Laboratory
Building the Model

- The water usage can be scaled by:
  - Number of wells
  - Surface areas
  - Subsurface volumes
  - Product production rate

- The system can be represented by:
  - Single subsurface shale
  - Rectangular shapes
  - Sequential events

- The parameter distributions can be described by simple functions
Model inputs

- retort dimensions
- retort properties

Model calculations

- Construction
- Operation
- Reclamation

Model outputs

- Potable water
- Amount of water in \( f \) / (Dewater_rate)
Model Scaling

- **buffer length**
- **retort width**
- **retort length**
- **depth to water**
- **height of retort**

**Calculations**:
- **frz wall width**
- **frz wall length**
- **Frz wall lgt**
- **Frz Area**
- **depth of frz wall**
- **calc frz wall all**
- **calc area of retort**
- **calc vol of retort**
- **Frz wall surface area**
- **Frz wall volume**
- **calc vol of retort**
Timeline

Construction

Well Constr.
General Constr.
Dewater

Operation

Heating & Production

Reclamation

Filling
Subsurface Flushing
Surface Reclamation

Potable Water Consumption
Note: Diagram for illustration only, do not cite.
Construction

Operation

Reclamation

Water Usage (Million gallons)

Time (days)

Straight Ratio

SD Model

Consumption

Production

Note: Diagram for illustration only, do not cite.
How to use this information

1. Identification of large water consumption phases
How to use this information

2. Learning tool to identify/discuss unconventional energy water linkages
How to use this information

3. Identify uncertainty in water consumption

- Moisture content
- Retort length
- Number of drill rigs
- Porosity
- Permeability
- # of shale layers
- Fisher assay values
- Rates of pumping
- Consumptive water use
- Number of production wells
- Buffer zone
- Shale properties
- Well spacing
- Depth to water
- Recycling of water
How to use this information

4. Link output into Basin Analysis models
   - Different recovery methods
   - Different start times
   - Different sizes

[Diagram showing water usage and basin analysis models]
How to use this information

5. Extend to:
   - water quality,
   - salinity,
   - CO2,
   - energy inputs
Summery

- Large uncertainty in water use in oil shale resource energy development
- We built a system dynamic model for water consumption for oil shale
  - Dynamic water usage
  - Identify water use phases
  - Discussion tool
  - Uncertainty analysis
  - Linkage to other models
  - Extendable to answer other questions
- To be used as a tool for:
  - decision makers,
  - energy developers,
  - environmental groups

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