Sand Coulee Abandoned Mine Reclamation
Acid Mine Drainage Source Control
Evaluation

David Donohue, HydroSolutions Inc
Tom Henderson, Montana DEQ

Mine Design, Operations, and Closure Conference
Fairmont Hot Springs, Montana
May 6-10, 2018
Project Sponsors

* Montana Department of Natural Resources and Conservation (DNRC)

* Montana Department of Environmental Quality (DEQ)

* U.S. Office of Surface Mining Reclamation and Enforcement (OSMRE)
Presentation Outline

* Sand Coulee Mining History
* Previous Investigations
* Source Control and Feasibility Evaluation
* Recent Investigations
  * Adit Flow, Monitoring Wells, and Bedrock Aquifer
  * Drainage Well Practicability
* Next Steps
Great Falls Coal Field
Sand Coulee, Stockett, Belt
Mining History

1888 - Sand Coulee Coal Company Incorporated
1905 – Cascade County is the largest coal producer in state
1927 – Mine reports indicate pumped water is “practically acid”
1934 – Tony Boyle injured working as a night foreman in Giffen mine
1941 – All business activities discontinued
Sand Coulee Mine in the 1890s
80 Years Later -
1970
Abandoned Mine Land Reclamation
Surface Mining Reclamation Control Act
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>pH</td>
<td>3.8</td>
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<tr>
<td>Acidity</td>
<td>1,400 mg/L</td>
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<tr>
<td>Aluminum</td>
<td>157 mg/L</td>
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<tr>
<td>Iron</td>
<td>2,330 mg/L</td>
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<tr>
<td>Sulfate</td>
<td>30 GPM</td>
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<tr>
<td>Flow Rate</td>
<td>30 GPM</td>
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</table>
Mining Coulee

pH 2.6
7,500 mg/L Acidity
764 mg/L Aluminum
756 mg/L Iron
9,570 mg/L Sulfate
7 GPM
Nelson Drain

“Practically Acid”

pH 2.5
9,100 mg/L Acidity
875 mg/L Aluminum
1,070 mg/L Iron
11,400 mg/L Sulfate
12 GPM
Sand Coulee Area Stratigraphy

- TD: 210 feet
- Kootenai FM: Sandstone, Mudstone, Claystone, Siltstone
- Basal Sandstone/Conglomerate
  - Coal/Carbonaceous shale
- Morrison FM: Mudstone, with interbedded lenses of limestone and sandstone
- Swift FM: Sandstone and Shale
- Madison Group: Limestone and Dolomite

- 160 feet
- 170 feet
- 360 feet
- 390 feet
Basal Kootenai Sandstone

Morrison Formation Coal
Contours of the top of the Morrison

Aquifer status of the basal Kootenai sandstone

Sand Coulee Well Field

From Osborne et al., 1987 MBMG Open File Report 197
GW flow in the Kootenai Sandstone

Coal dip

Sand Coulee Well Field

Mine Discharge
Sand Coulee Water System Restoration 2010 - 2016

Photo taken July 2015
Source Control Investigations

- DNRC Planning Grant to assess feasibility of groundwater interception (2013-2014)
- DNRC RDG Grant to conduct Hydrogeological Investigation and install pilot interception wells (2016-2019)

from Gammons et al., 2010 Chemical Geology 269 100–112
Source Control With Groundwater Interception Objectives

- Intercept uncontaminated groundwater up-gradient of the historic mine workings using gravity-driven drainage wells completed in the basal Kootenai sandstone.

- Thereby reduce leakage into and AMD emanating from the old mine workings.
Two well designs were considered, a horizontal or low angle well, and a vertical drainage well.

* Horizontal well installed using directional drilling technology.
* The vertical drainage well would be installed by a conventional water well contractor.
Kk-Kootenai Formation Stratigraphic Units
1. HORTHWELL Model Parameters
2. Dupuit-Forchheimer Model Parameters

Conceptual Cross Section for Horizontal Well Design

Not to Scale
Prepared By: R. Svirgen
Production Date: January 26, 2018
File: SandCoulee_Concept_XSection20180223.cdr
Conceptual Cross Section for Vertical Well Design

Kk-Kootenai Formation Stratigraphic Units
Potential effectiveness of both horizontal and vertical drainage wells were analyzed as part of the 2013-2014 DNRC planning grant.

The evaluation focused on estimating the yield of drainage wells and potential reduction in the amount of water discharging from the abandoned mine workings using drainage wells.
Results - Modeled Discharge Volumes from Drainage Wells

* Horizontal well model results
  * Six-inch diameter well: 104 to 225 gpm
  * Four-inch diameter well: 86 to 138 gpm

* Vertical well model results
  * Single drainage well: 52 gpm
  * Two drainage wells: 88 gpm
* Need accurate adit discharge measurements.
* Adit discharge rates affected by factors including precipitation events and seasonal and long-term climatic patterns.
* Site conditions (freezing winter conditions and the extremely low turbidity of the discharged water favored a design employing non-contact water stage measurement.)
Adit Discharge Equipment

- Four adit discharge sites – previous average flow rates of 6.6 to 30 gpm.
- Two molded fiberglass polyester 0.6’ HS-flumes
- One 3-inch Parshall flume
- One 0.5’ H-flume
- Senix ToughSonic Chem 10 Ultrasonic level sensor and Campbell Scientific CR300 data logger.
Kate’s Coulee SC-8
Miner’s Coulee SC-1
Non-contact Stage Measurement
Winter Operation
Adit Discharge Measurements

Miner's Coulee SC-1 Discharge

GPM

0  5  10  15  20  25

1-Nov  21-Nov  11-Dec  31-Dec  20-Jan  9-Feb  1-Mar  21-Mar  10-Apr  30-Apr
Private Well Inventory
Potentiometric Surface Map
Kootenai Sandstone Aquifer

- Surveyed Well, Groundwater Elevation (Fall 2017)
- Surveyed Well, Groundwater Elevation Not Contoured
- Well Not Found, Historic 1980’s Groundwater Elevation
- Groundwater Elevation Contour (20ft Interval)

Legend:
- Dark Blue Line: Underground Mine Workings

- Christopher Kunkel - Kk 3615.66
- MW-101K 3548.16
- MW-104K 3558.30
- L1 Deep 3611.84
- MW-103K 3612.80
- Harvey LaRocque domestic 3647.98
- LaRocque stock 1 North 3662.29
- LaRocque stock 2 South 3666.52
- MW-102K 3669.87
- C5 Medium 3580.88
- C4 3568.70

Scale:
- 0 Feet
- 500 Feet
- 1,000 Feet

Direction:
- North

HydroSolutions®
Possible Lineaments
* Preliminary hydrogeologic evaluation (well and survey data) led to identifying six feasible well locations

* H-3, H-5, H-6
Gravity-driven vertical drainage wells provide additional installation opportunities when compared with gravity-driven horizontal wells.

Compared with the horizontal wells, a vertical drainage well is not dependent on elevations providing natural drainage at the spud location.

A vertical drainage well connecting the Kk1 aquifer directly to the Madison aquifer would be less expensive than a horizontal well.
* Sand Coulee public water supply (PWS) Wells No. 5 and 6 provide relevant data to evaluate a vertical well.
* The top of the Madison limestone is between 375 and 400 feet bgs.
* Groundwater was encountered in the Madison limestone at a depth between 453 and 532 feet.
* So approximately 78 to 142 feet of unsaturated Madison limestone is present before groundwater is encountered in the Madison Formation.
Vertical Drainage Well Locations

* Given the surface elevations found within the drainages and the head encountered in Kk, more opportunities to locate pilot vertical interception wells exist up-gradient of all mines.

* Recommended locations include
  * Within Sand Coulee near MW-102K,
  * The vicinity of MW-103K which is just up-gradient of the Gerber Mine workings, and
  * On the bench above Sand Coulee near MW-101K, upgradient of Mount Oregon Mine
Conclusions And Recommendations

* Moving forward with planning for one horizontal drainage well up to about 2,000 feet long, and
* One to three vertical drainage wells.
* Horizontal wells are more technically challenging, and are more expensive but a single installation could have a larger effect on AMD prevention than any single vertical drainage well.
* More potential opportunities exist for vertical drainage wells which could be added incrementally to achieve a desired level of AMD control.
Current Schedule

* Continue maintenance and calibration of adit discharge monitoring equipment
* Coordination with landowners
* Follow up with regulatory agencies on permitting needs
* Solicit interest and abilities from drilling companies
* Prepare drill bids
* Drill pilot wells - late summer
Thank you

David Donohue
davidd@hydrosi.com
406-443-6169

HydroSolutions
www.Hydrosi.com

Tom Henderson
406-444-6492

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www.deq.mt.gov