Sand Coulee Abandoned Mine Reclamation Acid Mine Drainage Source Control Evaluation

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Tom Henderson, Montana DEQ

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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)

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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

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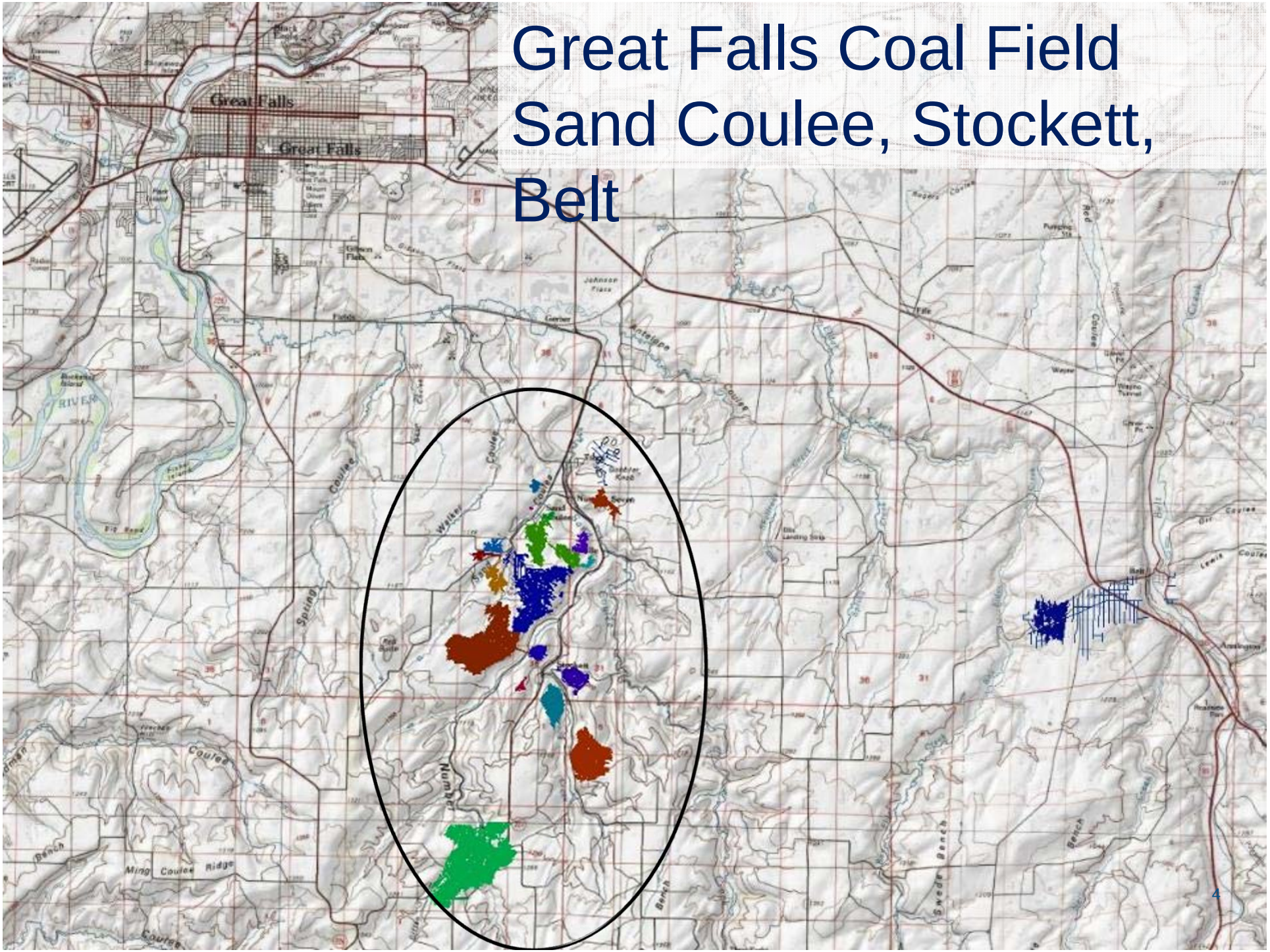
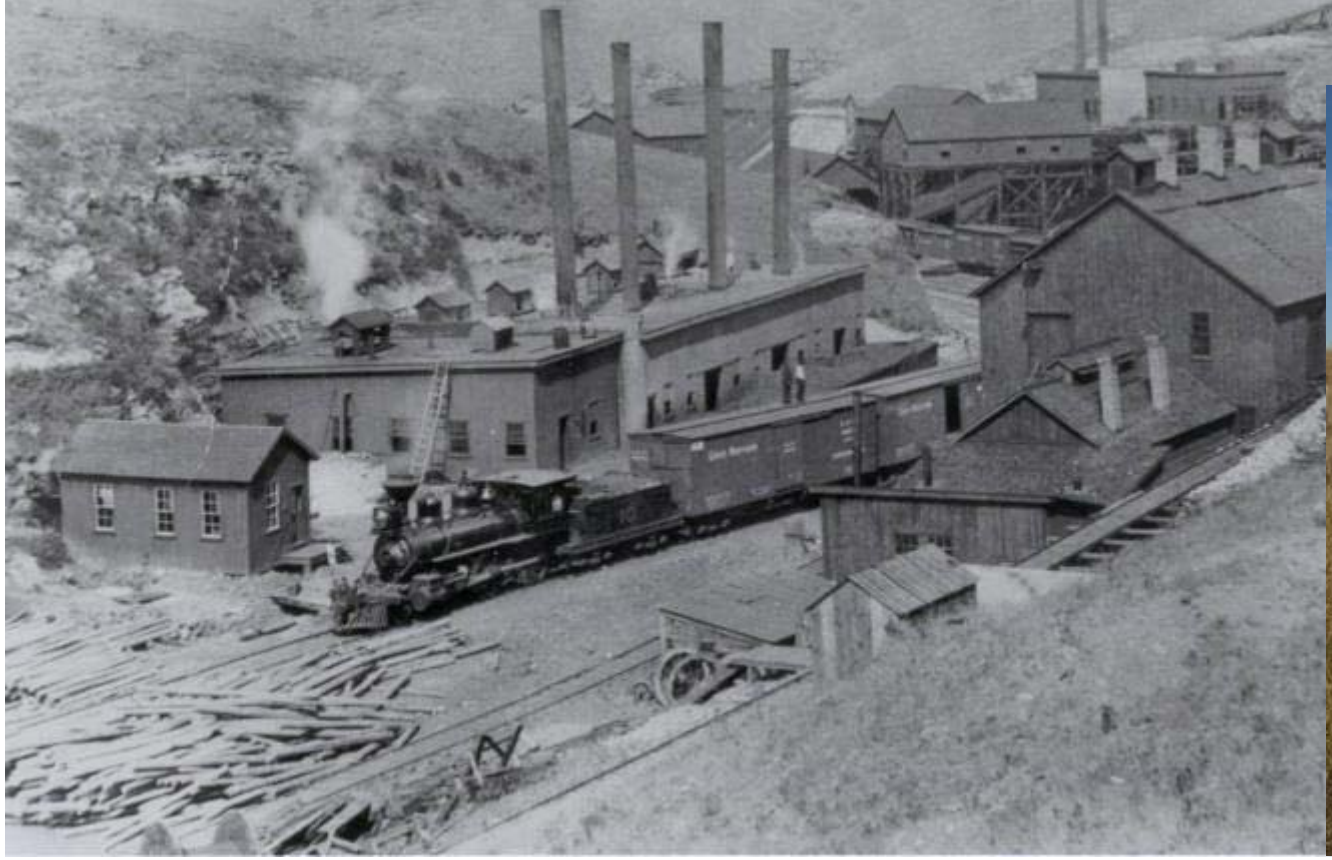
Great Falls Coal Field Sand Coulee, Stockett, Belt

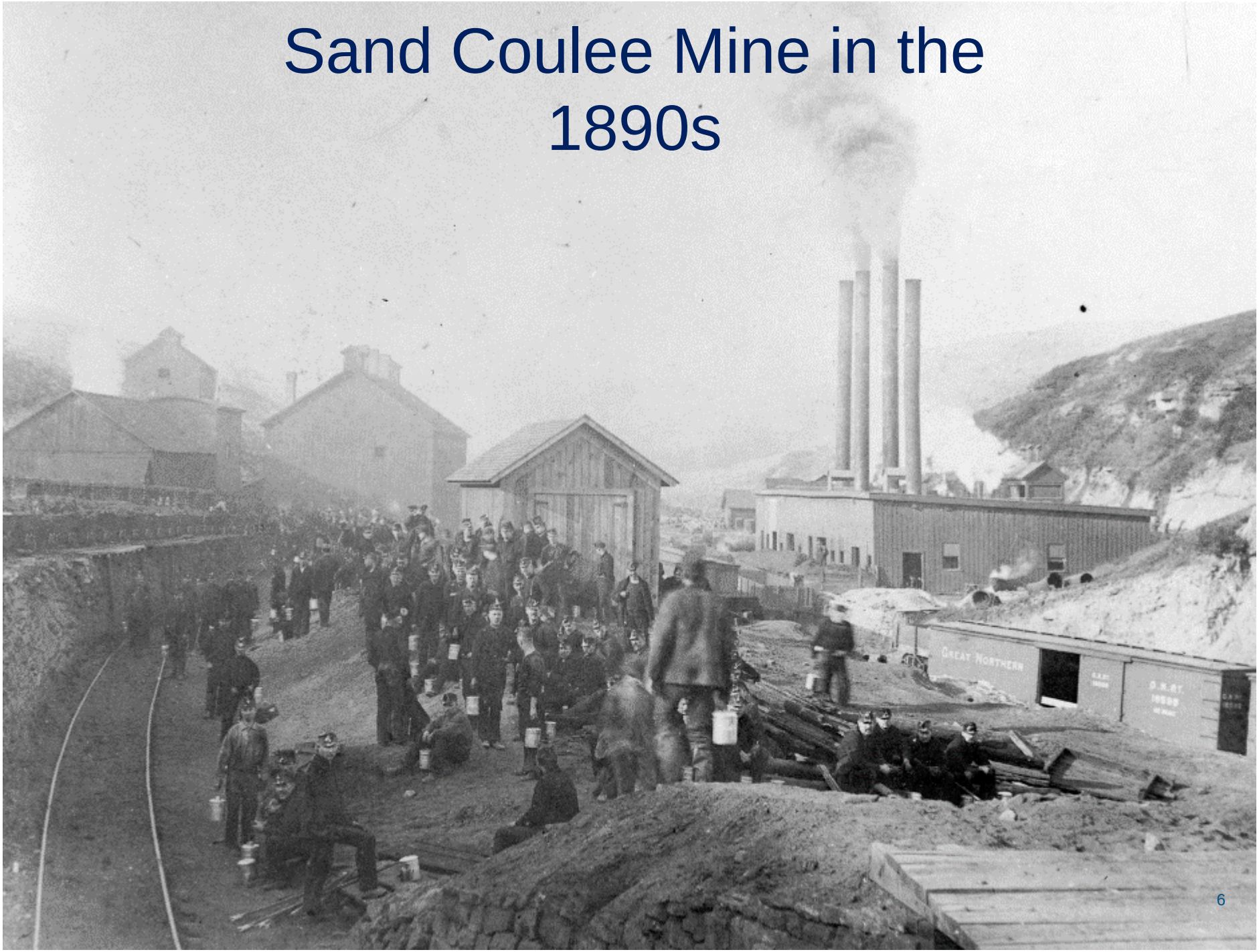


Mining History

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



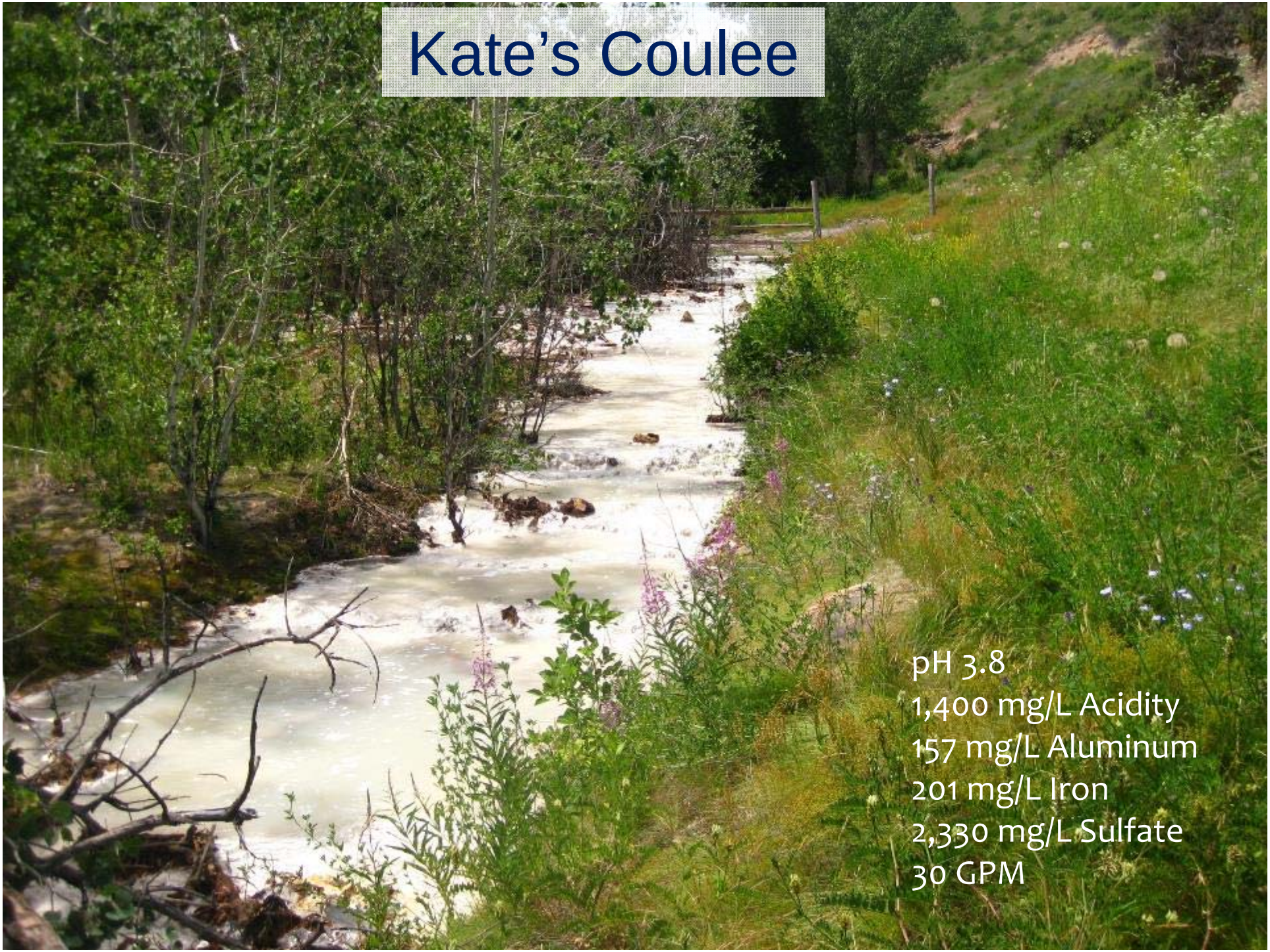
Sand Coulee Mine in the 1890s



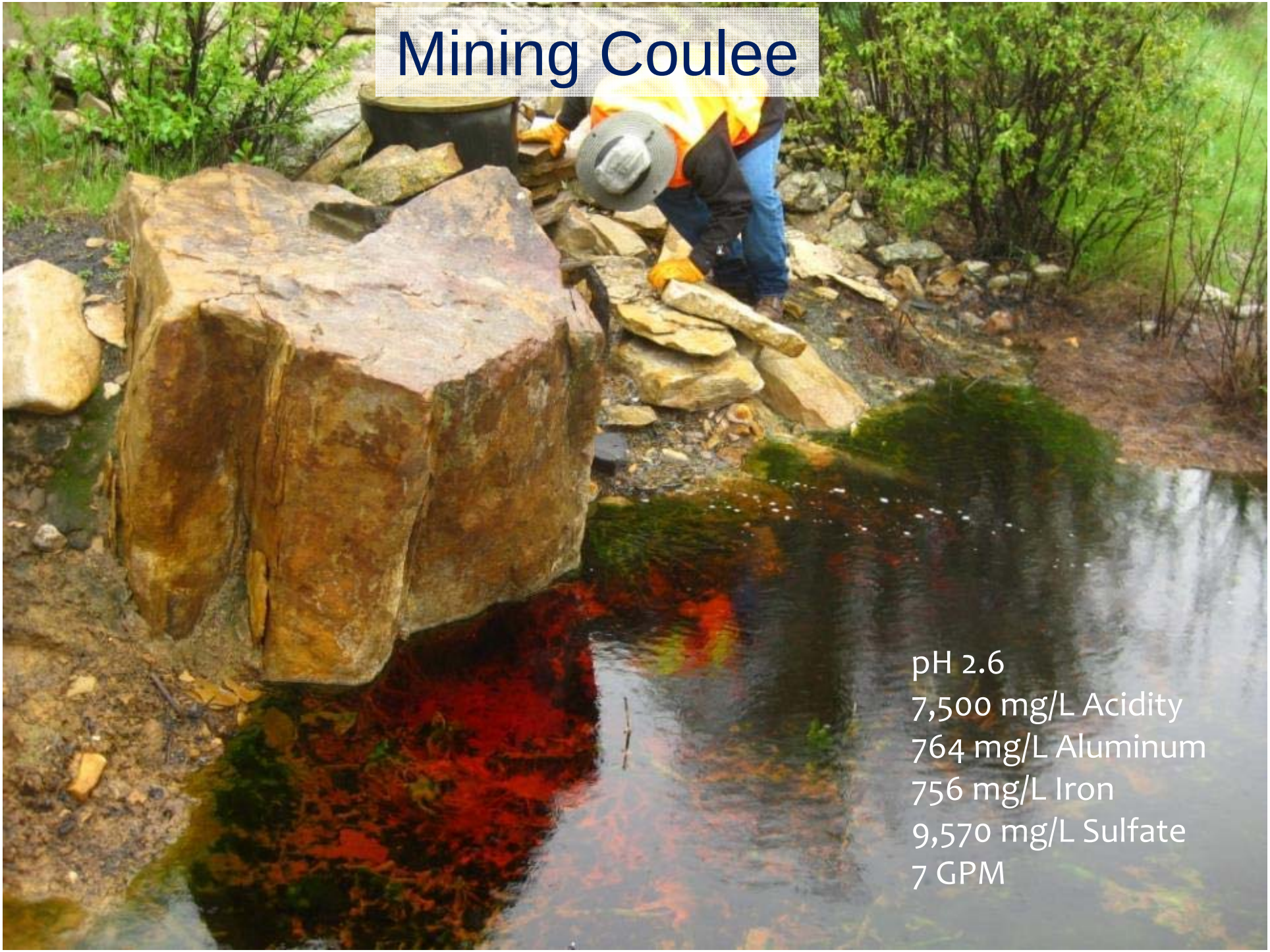

80 Years Later -
1970

Abandoned Mine Land Reclamation
Surface Mining Reclamation Control Act

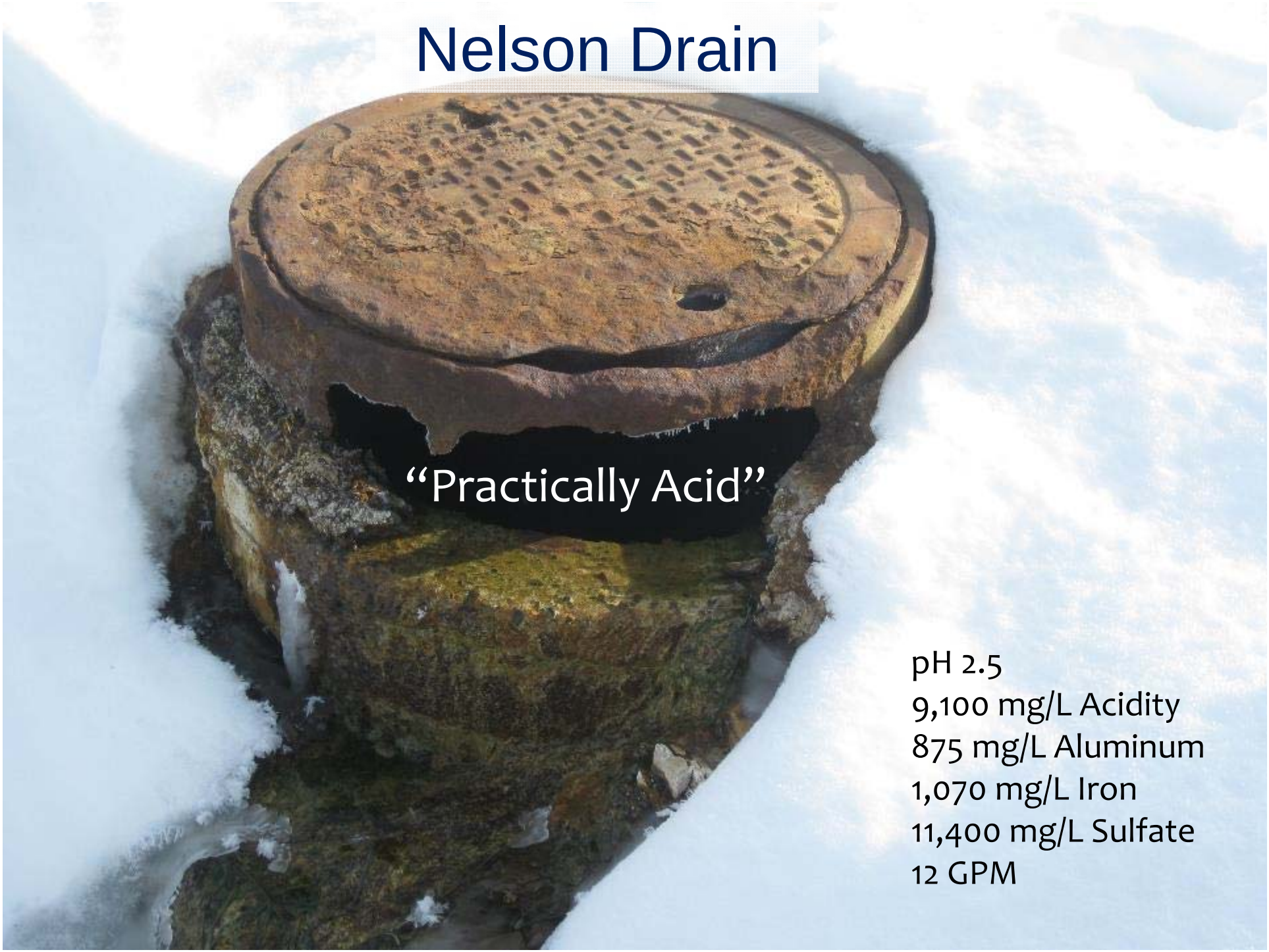
Kate's Coulee



Mining Coulee

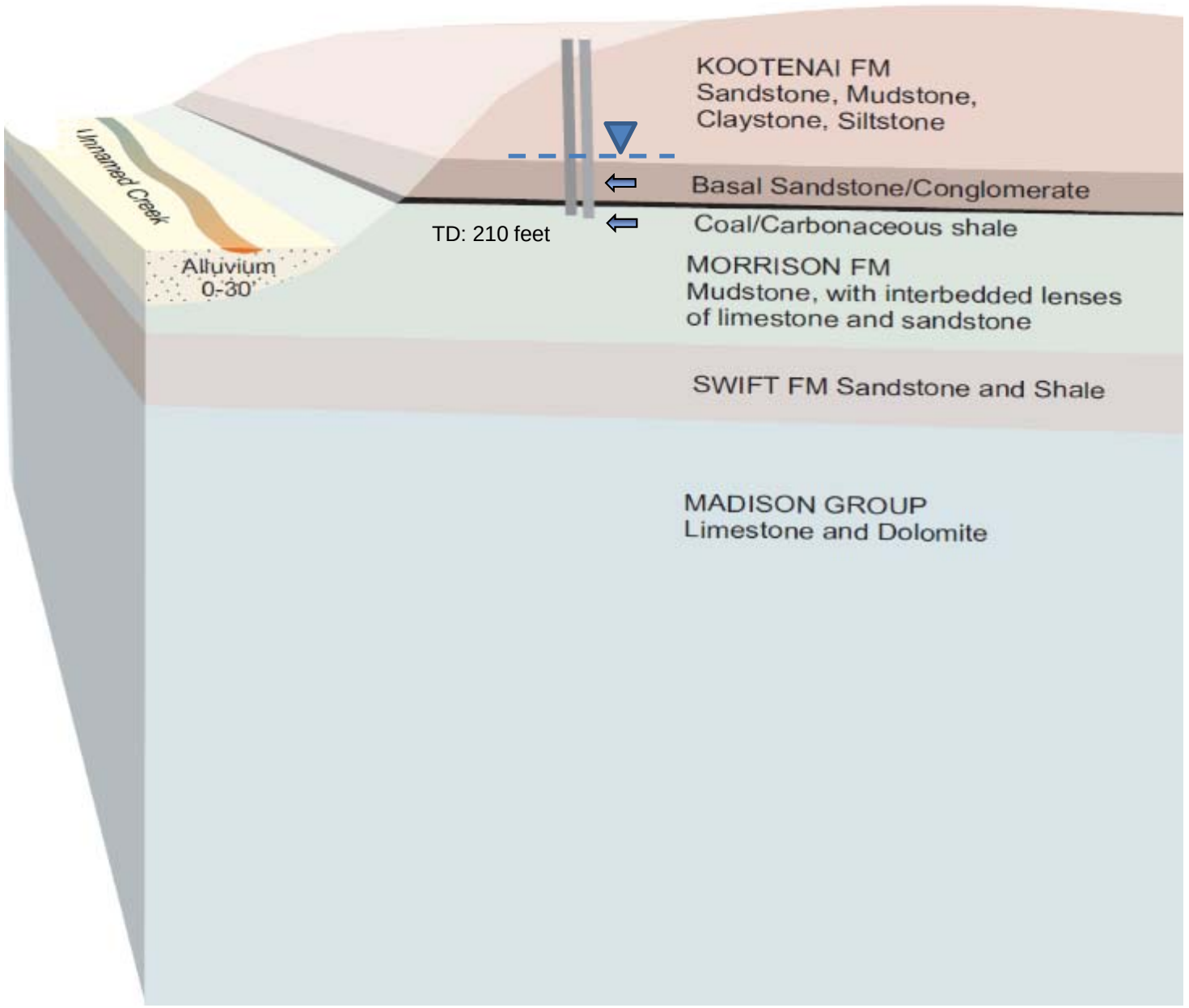


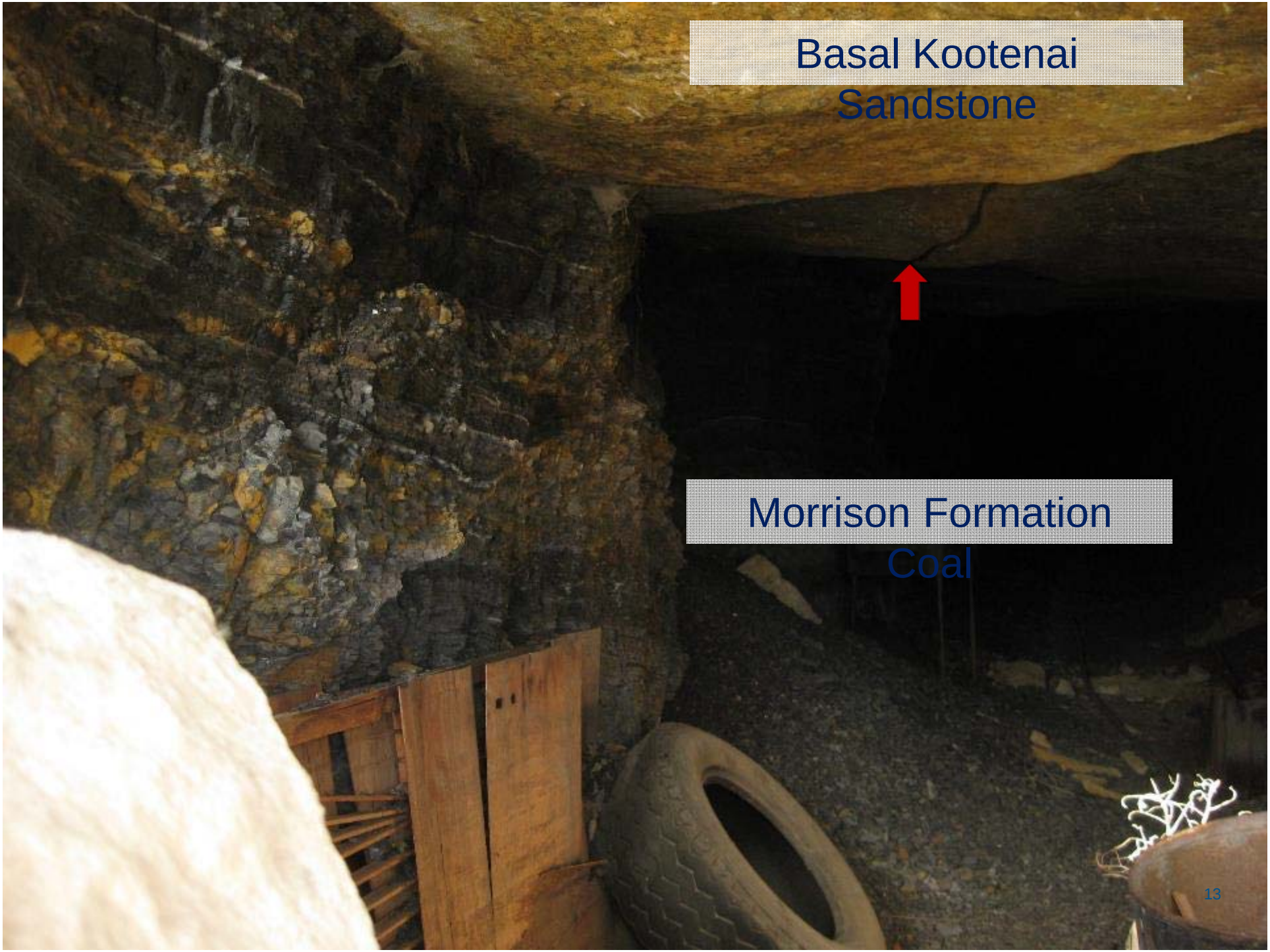
Nelson Drain



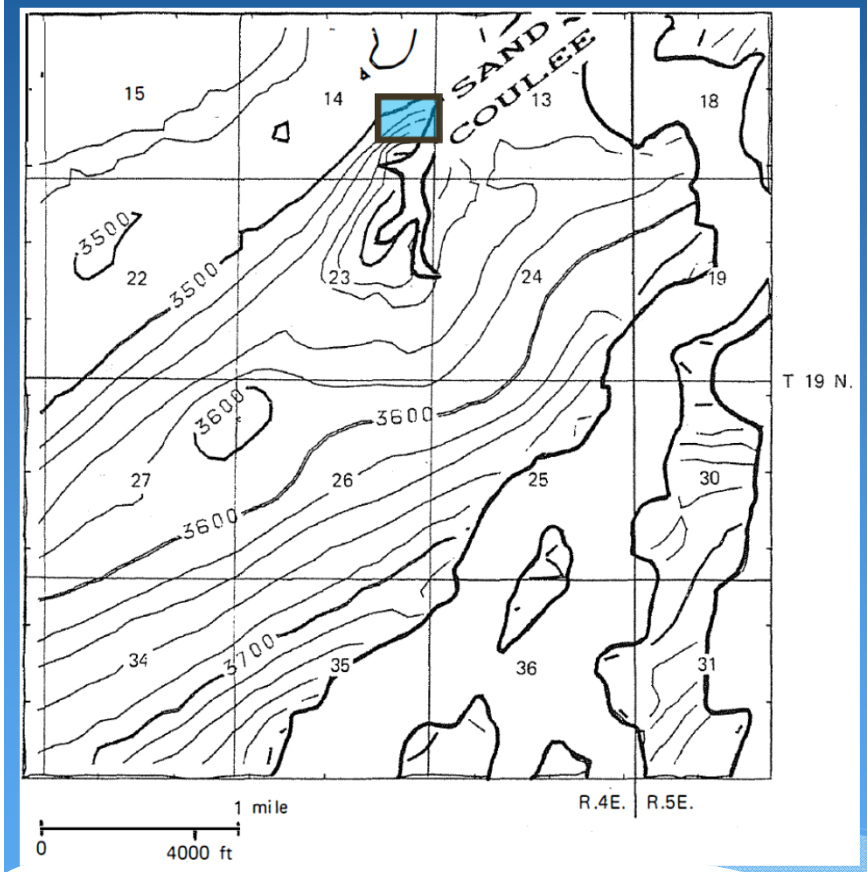
pH 2.5
9,100 mg/L Acidity
875 mg/L Aluminum
1,070 mg/L Iron
11,400 mg/L Sulfate
12 GPM

Sand Coulee Area Stratigraphy

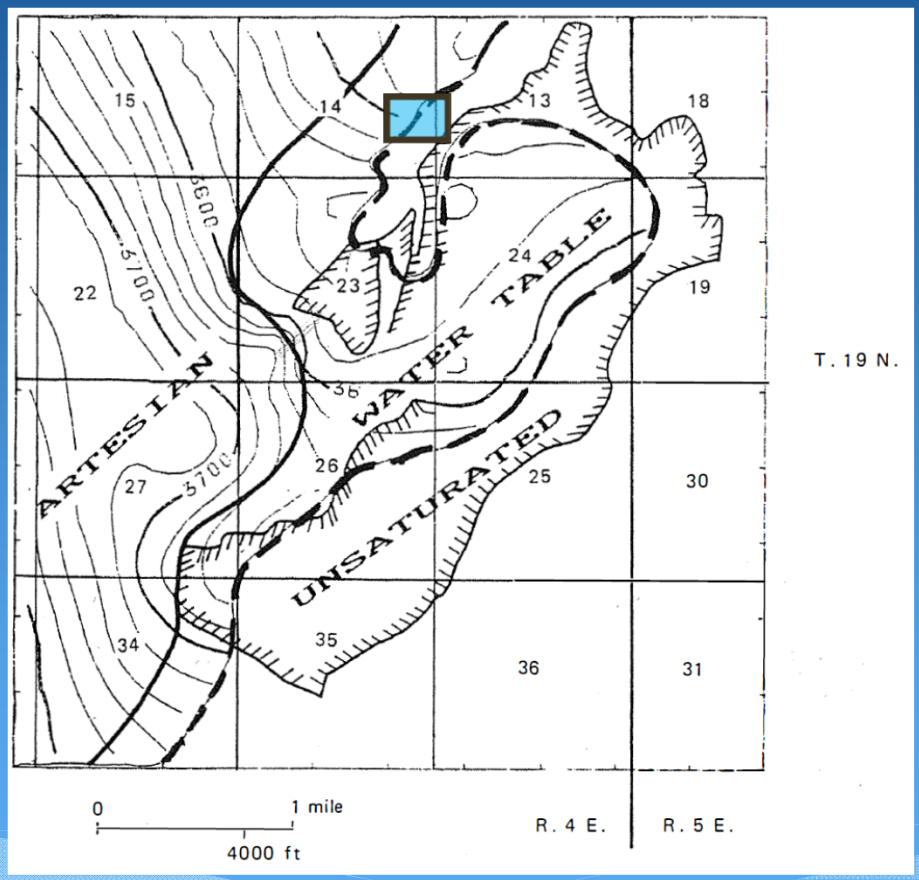



Basal Kootenai
Sandstone
Morrison Formation
Coal

Contours of the top of the Morrison

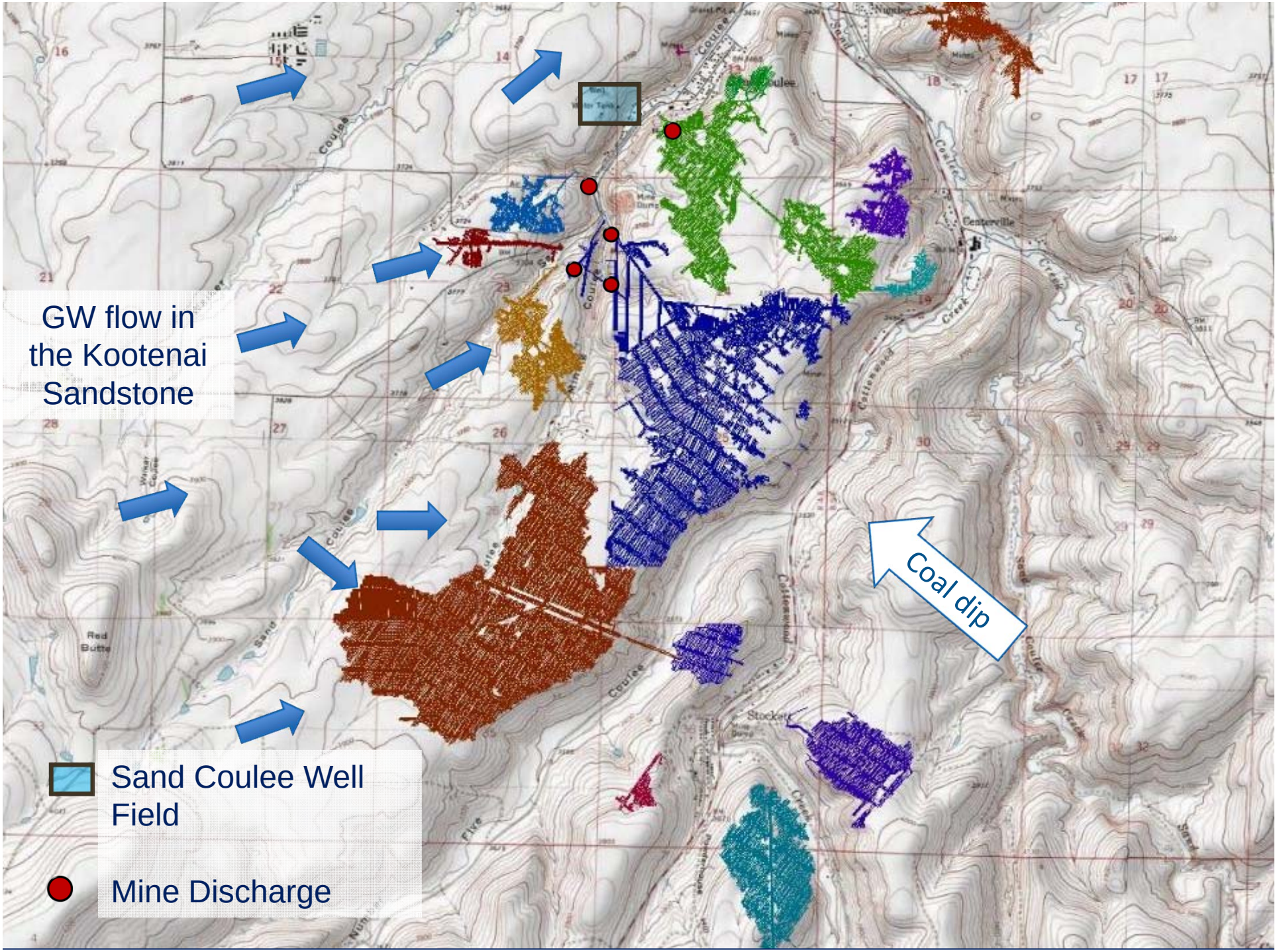


Aquifer status of the basal Kootenai sandstone



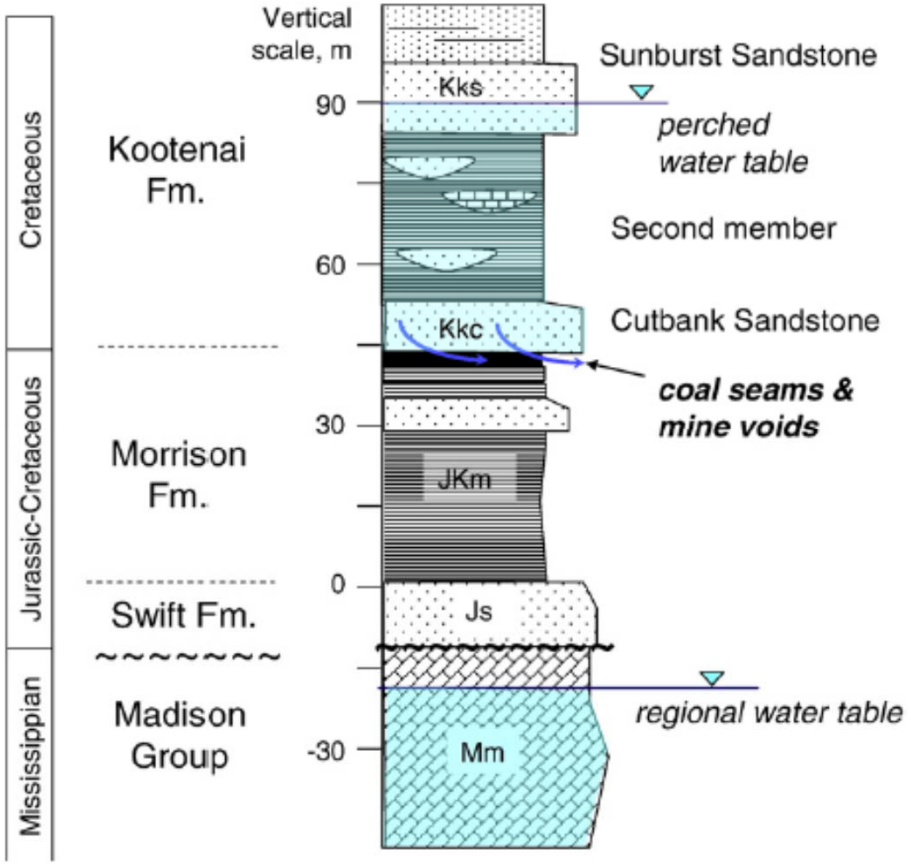
Sand Coulee Well Field

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

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.

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Conceptual Well Design

* 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.

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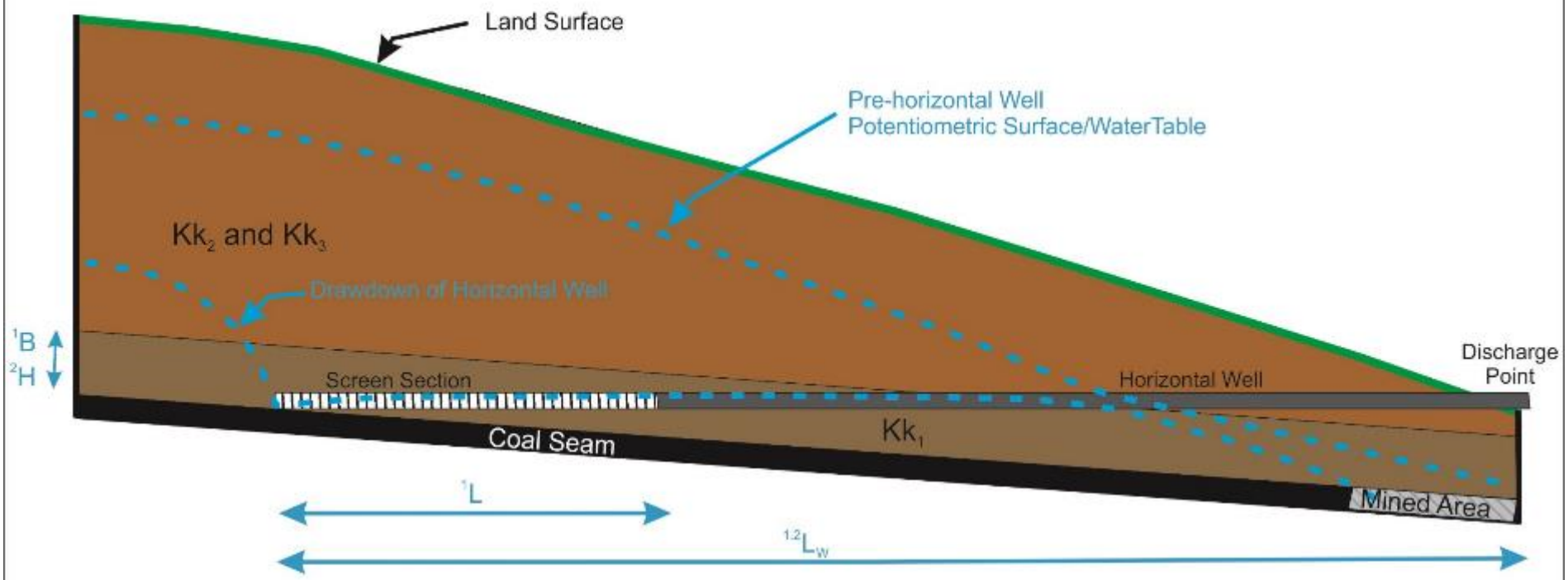

Kk-Kootenai Formation Stratigraphic Units
[1]HWELL Model Parameters
[2]Dupuit-Forchheimer Model Parameters

Conceptual Cross Section for Horizontal Well Design

Not to Scale
Prepared By: R. Svingen
Production Date: January 26, 2018
File: SandCoulee_Concept_XSection20180223.cdr

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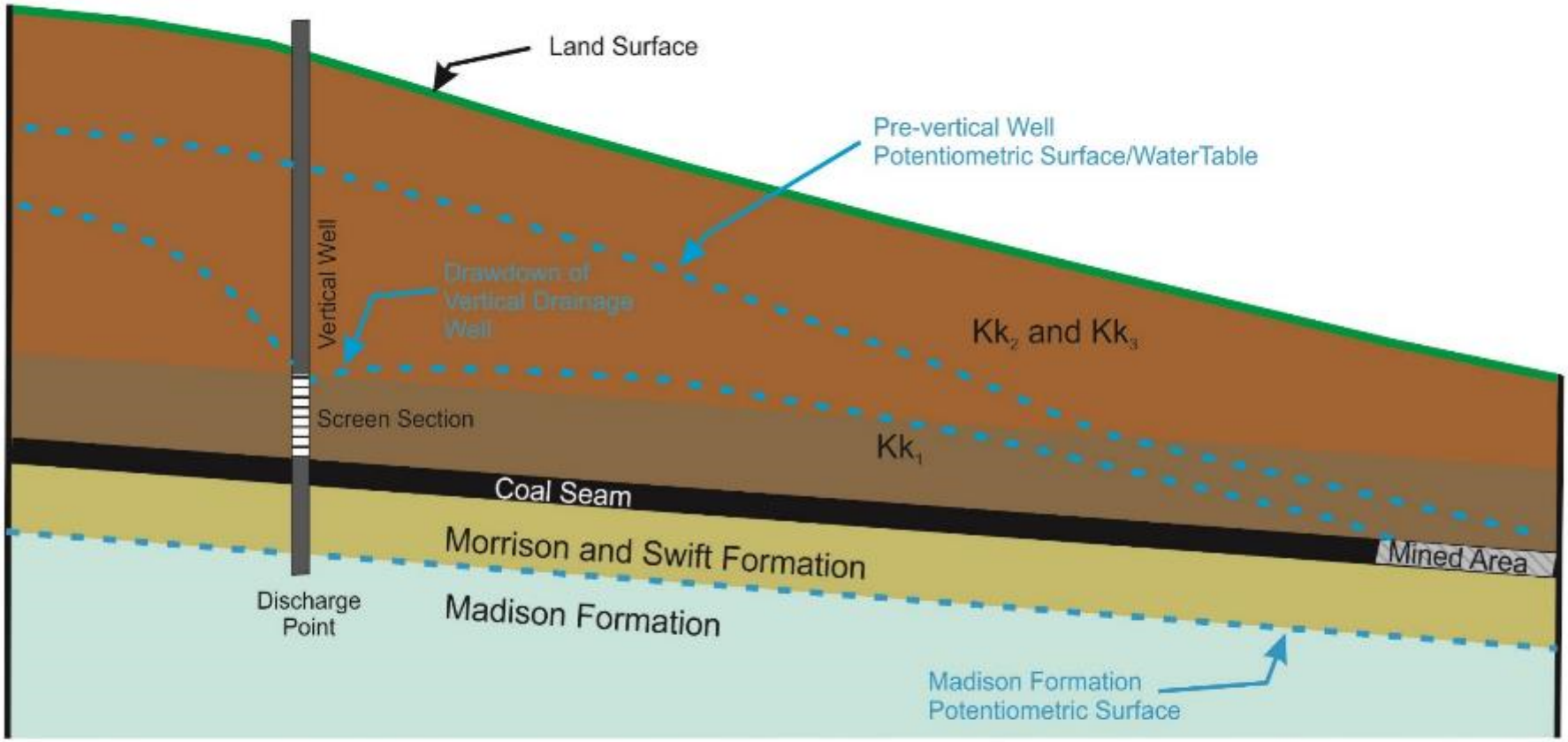

Conceptual Cross Section for
Vertical Well Design

Not to Scale
Prepared By: R. Svingen
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File: SandCoulee_Concept_XSection20180223.cdr

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Kk-Kootenai Formation Stratigraphic Units

Source Control Feasibility Evaluation

* 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.

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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

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Adit Discharge

* 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.

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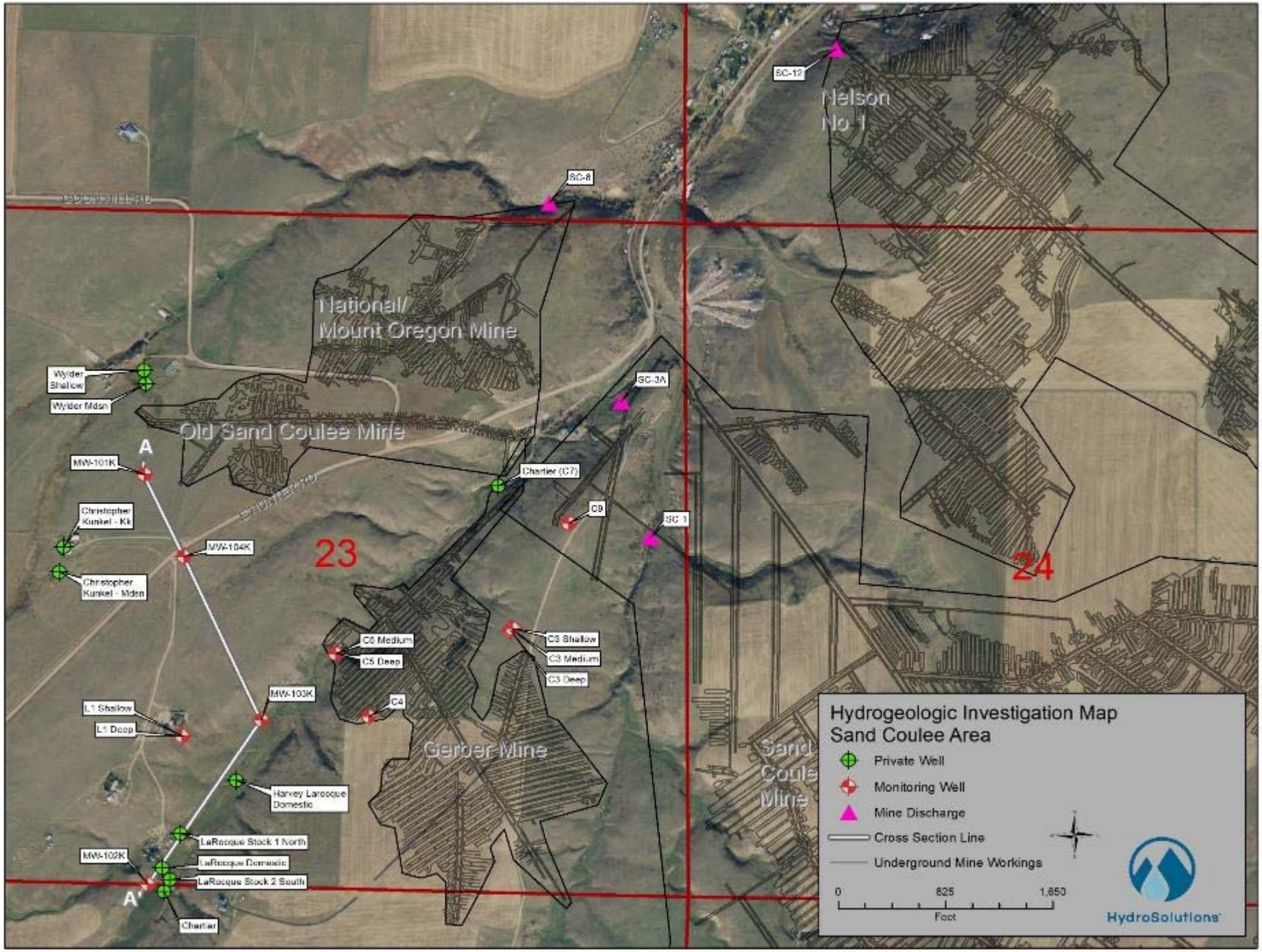
SC-12
Nelson
No. 1
SC-8
National/
Mount Oregon Mine
Wylder
Shallow
Wylder Mdsn
SC-3A
Old Sand Coulee Mine
A
MW-101K
Chartier (C7)
C9
SC-1
Christopher
Kunkel - Kk
MW-104K
23
24
Christopher
Kunkel - Mdsn
C5 Medium
C5 Deep
C3 Shallow
C3 Medium
C3 Deep
MW-103K
C4
L1 Shallow
L1 Deep
Gerber Mine
Sand
Coule
Mine
Harvey Larocque
Domestic
LaRocque Stock 1 North
MW-102K
LaRocque Domestic
LaRocque Stock 2 South
A'
Chartier
Hydrogeologic Investigation Map
Sand Coulee Area
Private Well
Monitoring Well
Mine Discharge
Cross Section Line
Underground Mine Workings
0
825
1,650
Feet
HydroSolutions

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.

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Nelson Drain SC-12

Nelson Drain SC-12

Kate's Coulee SC-8

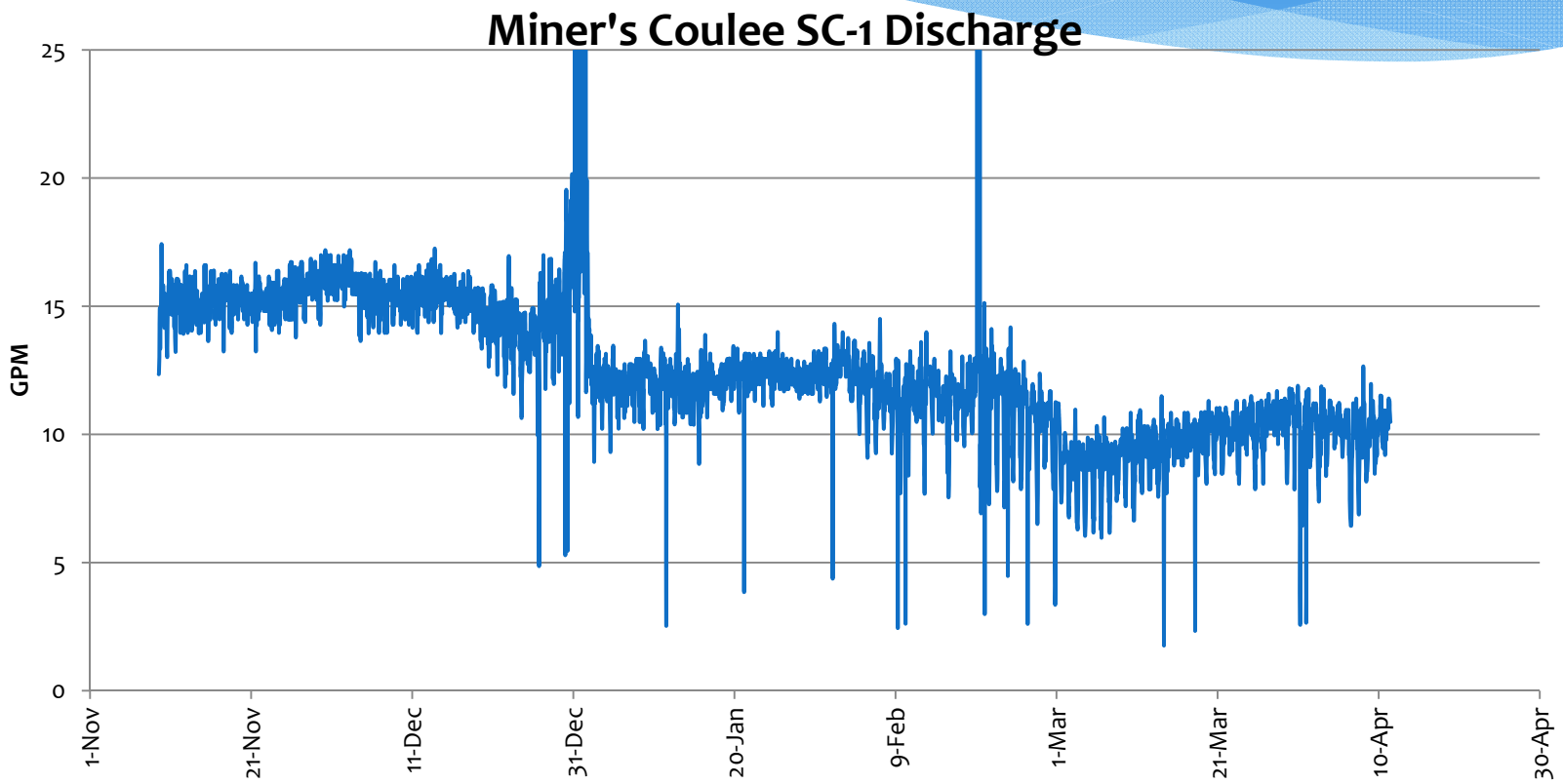

SC-3A


Miner's Coulee SC-1

Non-contact Stage Measurement

Winter Operation

Adit Discharge Measurements



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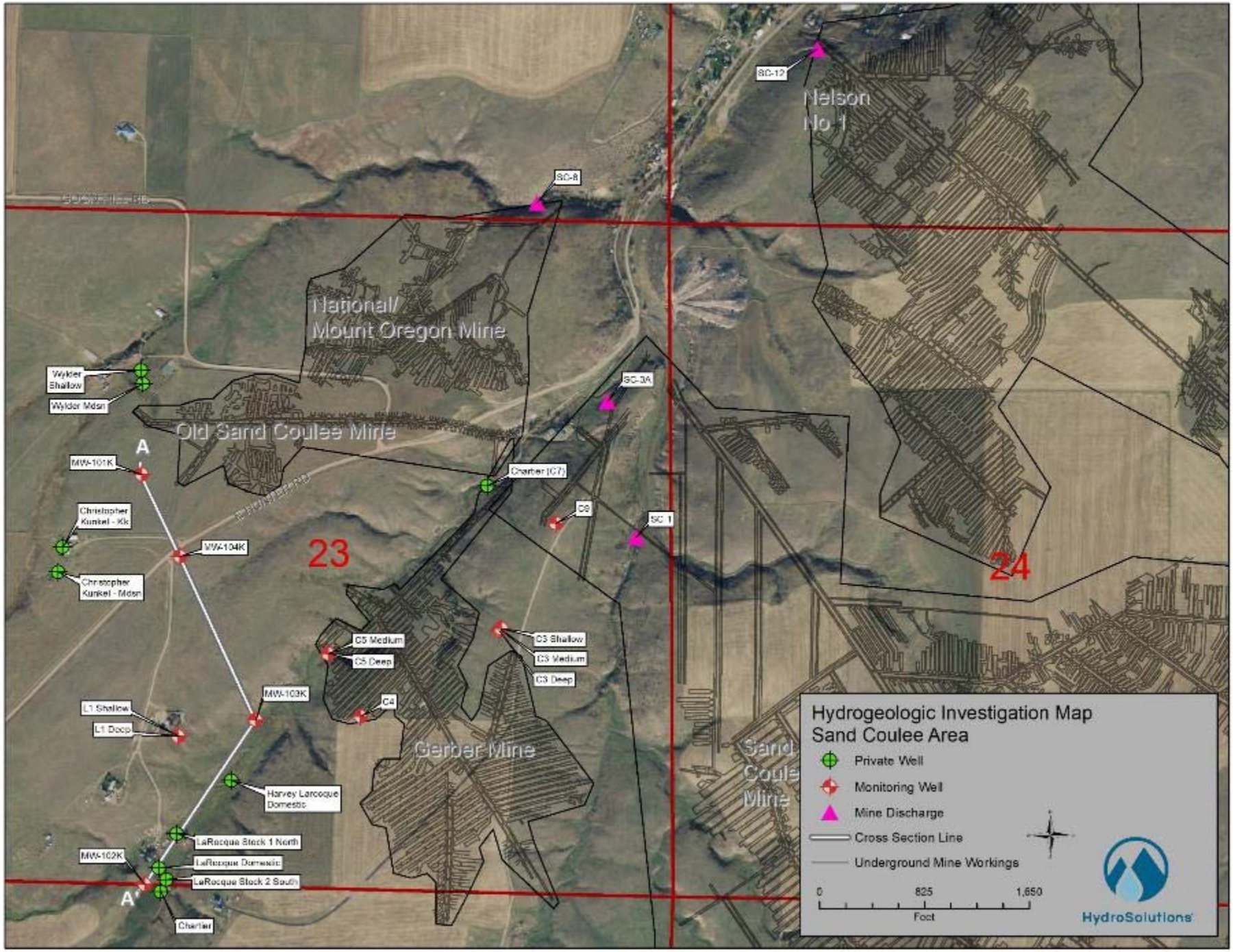
Private Well Inventory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C8
SC 1
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Kunkel - Kk
MW-104K
Christopher
Kunkel - Mdsn
23
24
C5 Medium
C5 Deep
C3 Shallow
C3 Medium
C3 Deep
MW-103K
C4
L1 Shallow
L1 Deep
Gerber Mine
Sand
Coule
Mine
Harvey Larocque
Domestic
LaRocque Stock 1 North
MW-102K
LaRocque Domestic
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Hydrogeologic Investigation Map
Sand Coulee Area
Private Well
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Mine Discharge
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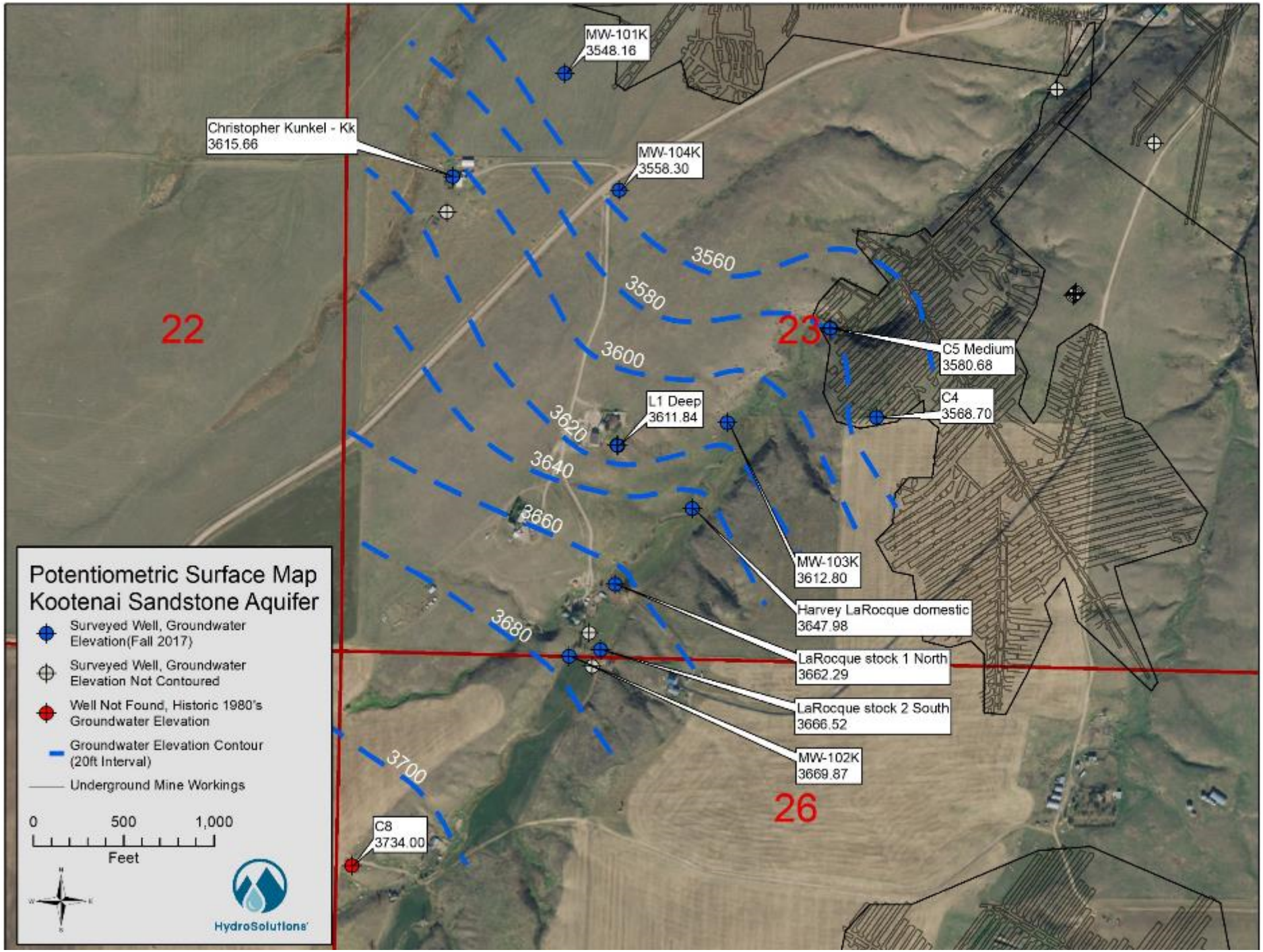
MW-101K
3548.16
Christopher Kunkel - Kk
3615.66
MW-104K
3558.30
3560
3580
3600
3620
3640
3660
3680
3700
22
23
26
C5 Medium
3580.68
C4
3568.70
L1 Deep
3611.84
MW-103K
3612.80
Harvey LaRocque domestic
3647.98
LaRocque stock 1 North
3662.29
LaRocque stock 2 South
3666.52
MW-102K
3669.87
C8
3734.00
Potentiometric 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)
Underground Mine Workings
0
500
1,000
Feet
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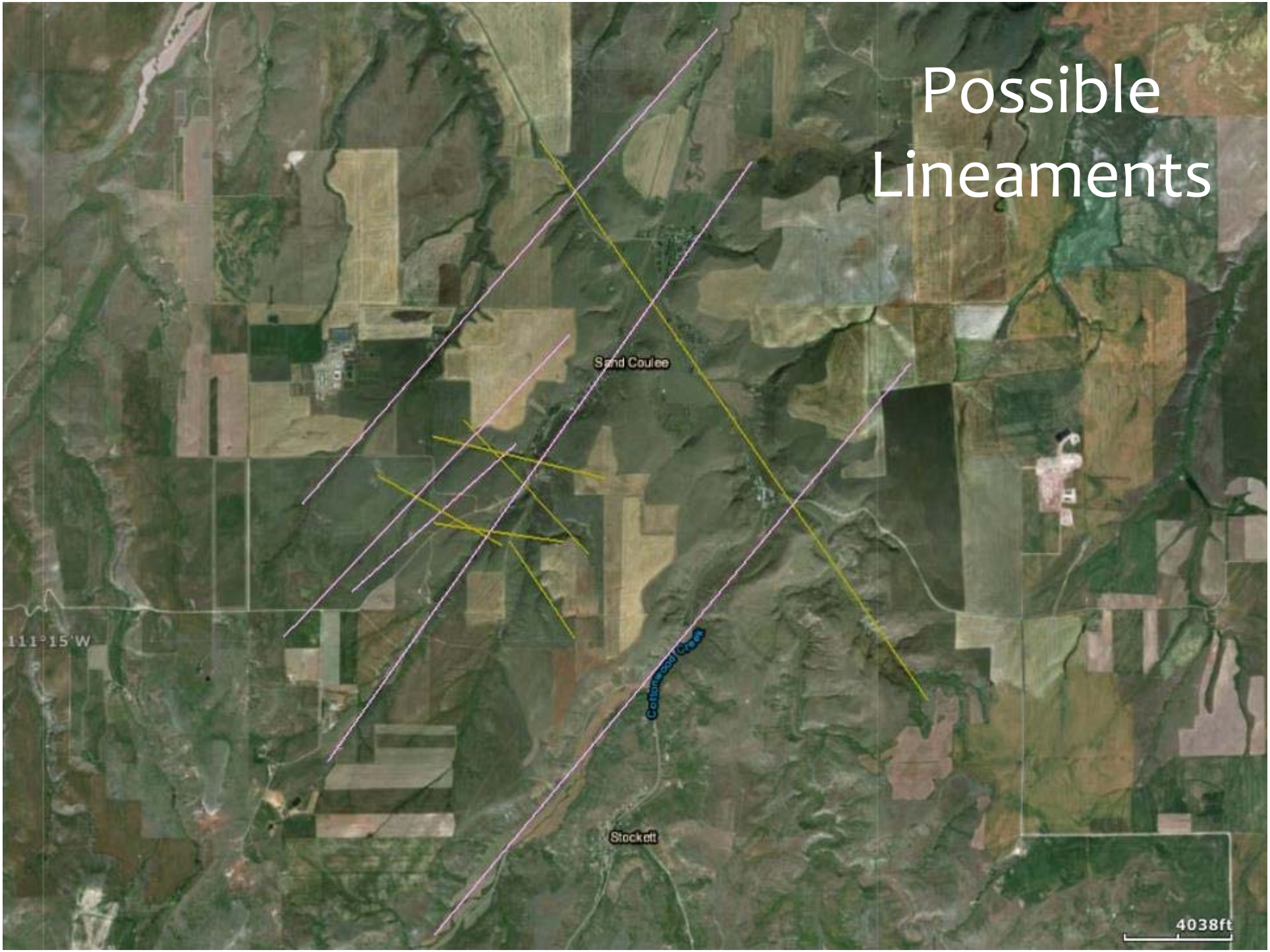
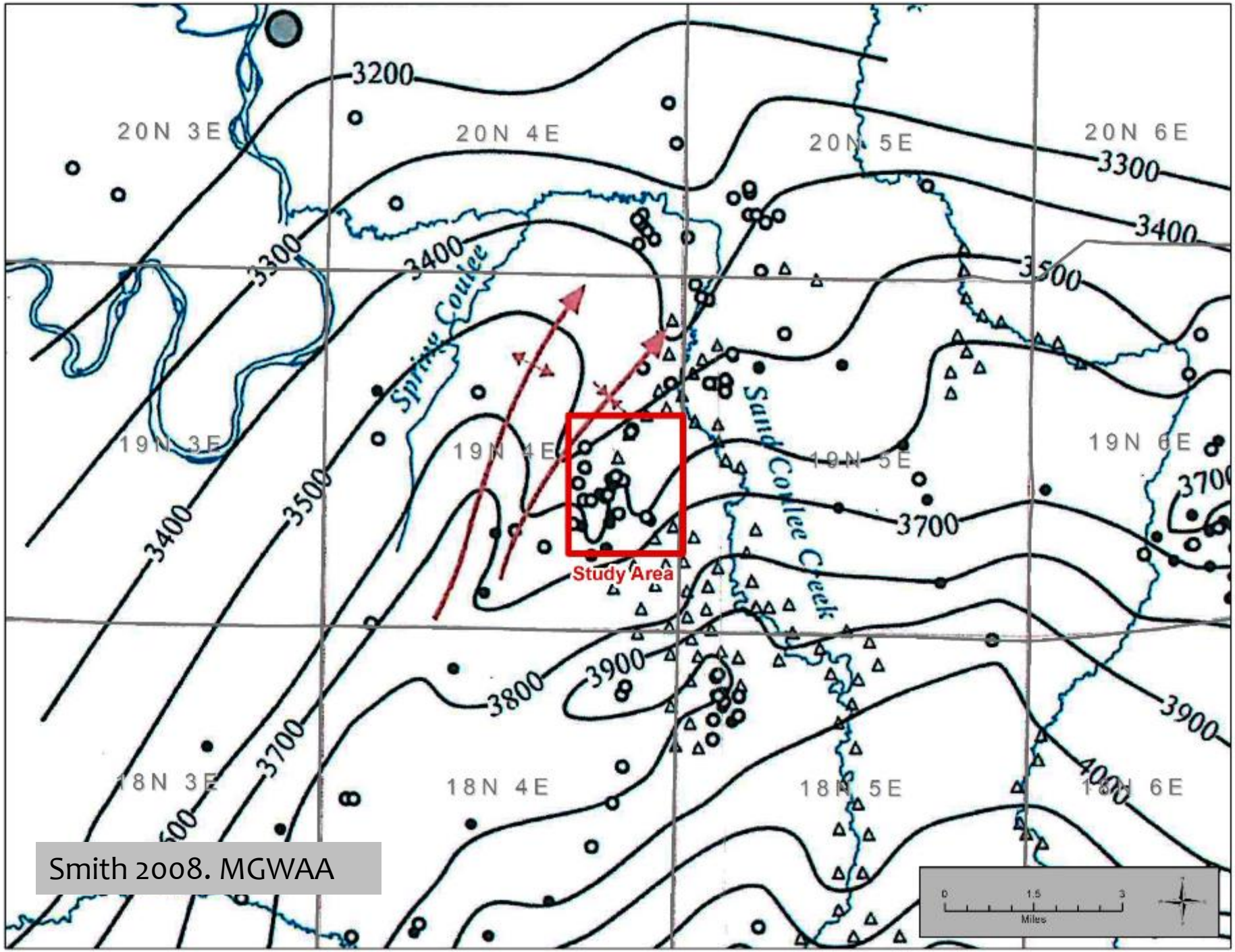

Possible Lineaments
Sand Coulee
Stockett
111°15'W
4038ft

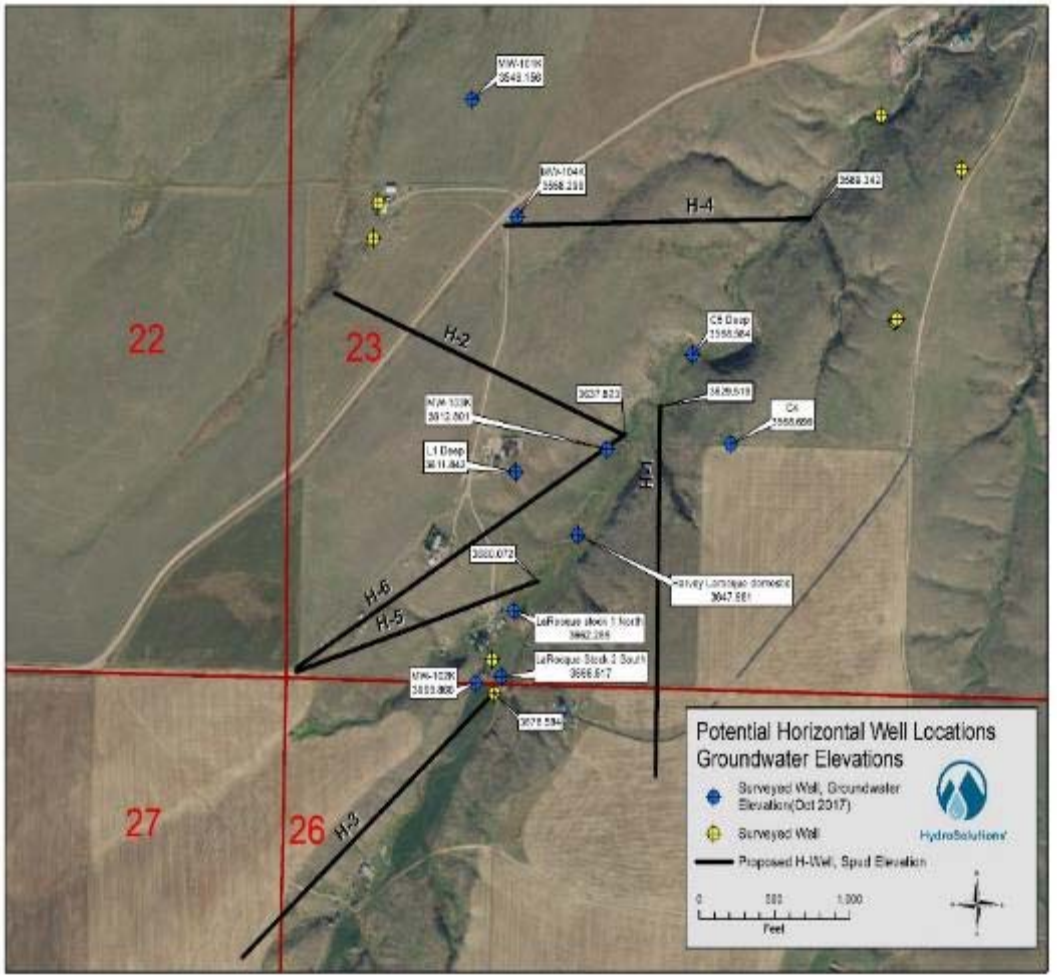


Smith 2008. MGWAA

Horizontal Well Locations

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

* H-3, H-5, H-6



Pilot Vertical Interception Well

* 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 Kk_1 aquifer directly to the Madison aquifer would be less expensive than a horizontal well.

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Madison Limestone

* 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.

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Vertical Drainage Well Locations

* Given the surface elevations found within the drainages and the head encountered in Kk_1, 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

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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.

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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

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Thank you

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