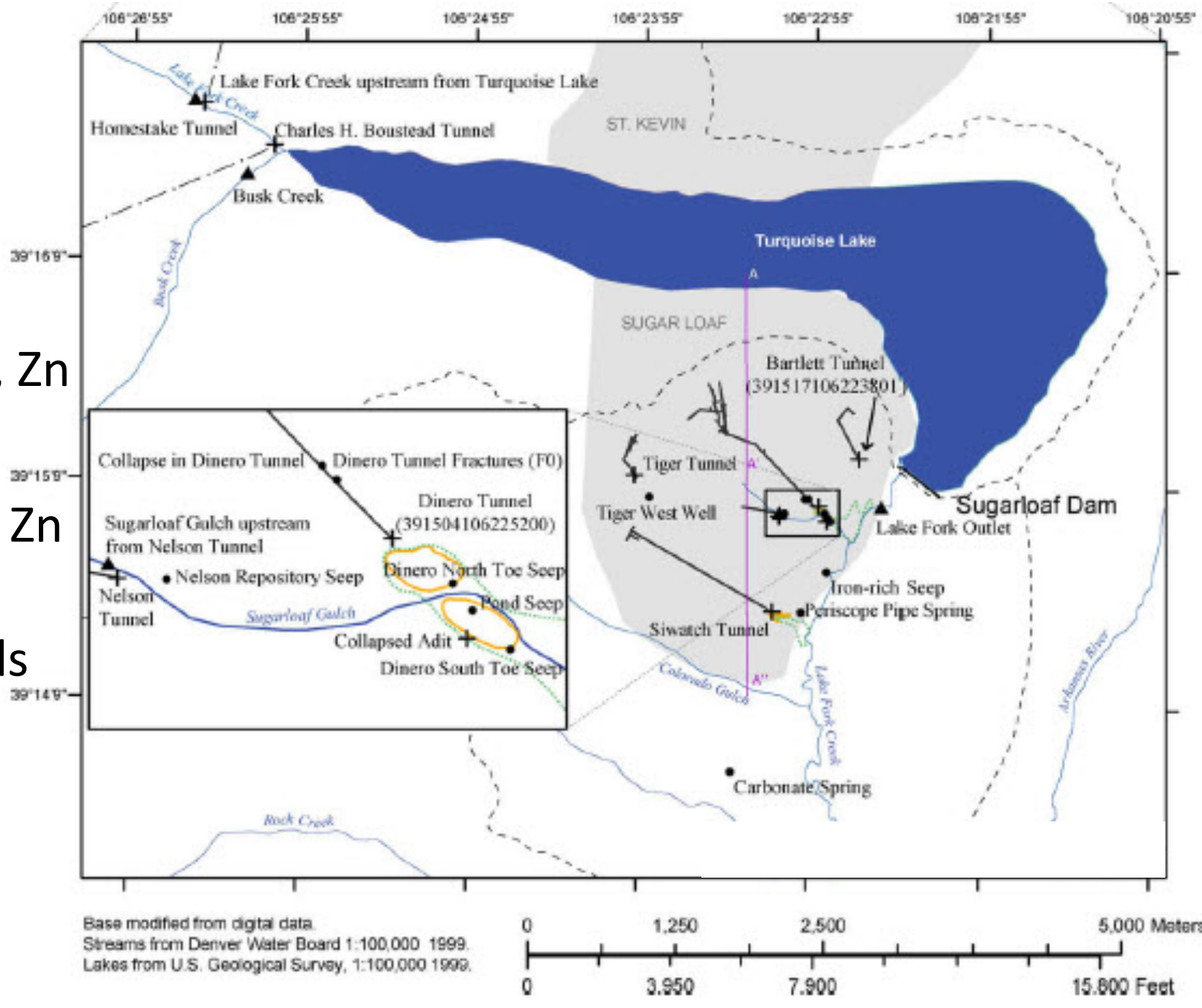
Bulkhead Case Studies

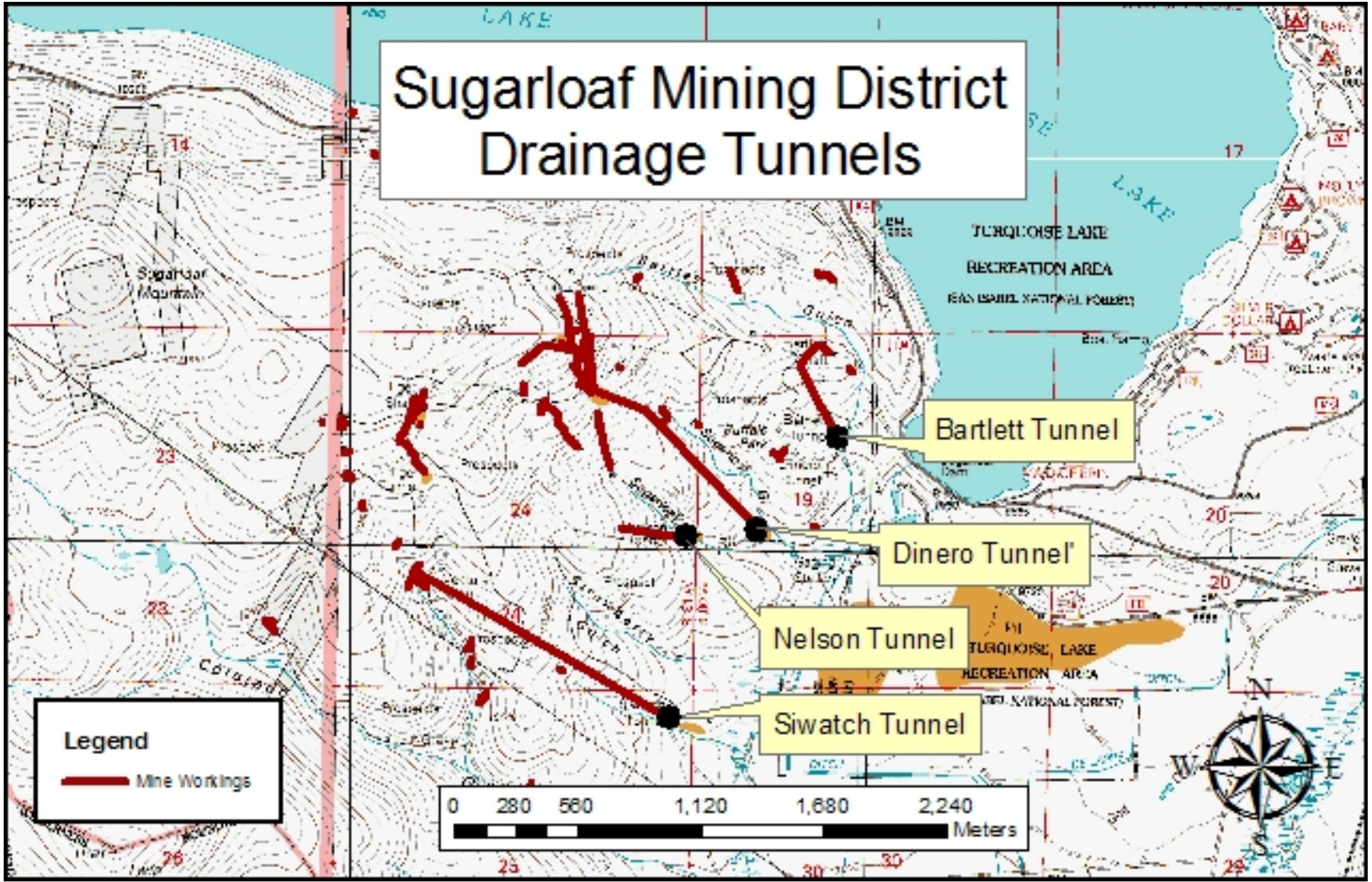
- Dinero Tunnel Bulkhead, Lake County, Colorado.
  - Installed 2009
- Pennsylvania Mine Bulkheads, Summit County, Colorado.
  - Multiple bulkheads installed 2014, 2015 and 2016

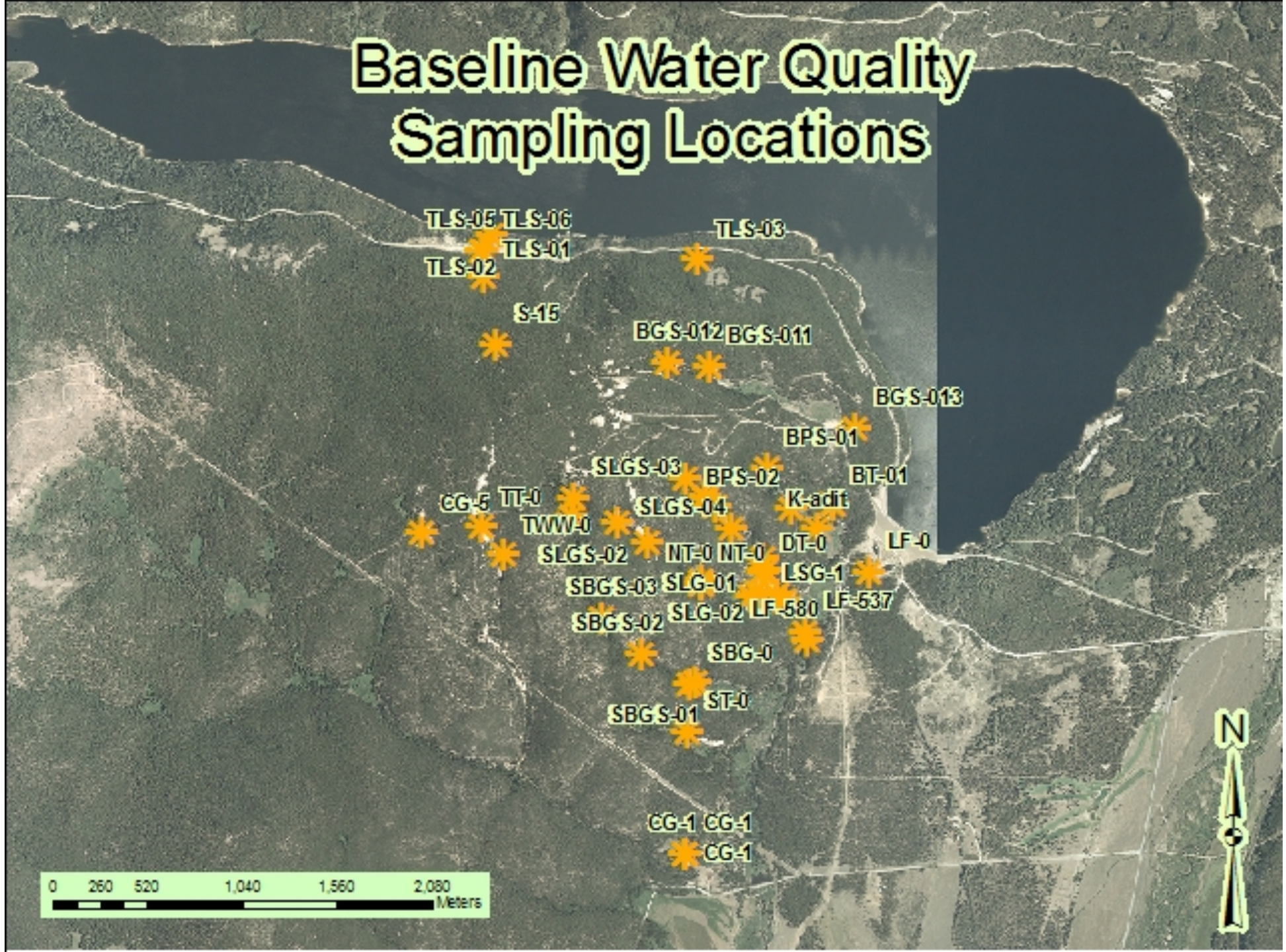
Dinero Tunnel, Lake County, Colorado

Setting

- Sugarloaf Mining District
- 1880s to 1920s Ag, Au, Pb, Zn
- Granitic formation
- Dinero Area ~75% Mn and Zn loading at low flow
- Numerous drainage tunnels within district




Sugarloaf Mining District
Drainage Tunnels
Bartlett Tunnel
Dinero Tunnel
Nelson Tunnel
Siwatch Tunnel
Legend
Mine Workings
0 280 560 1,120 1,680 2,240
Meters
N
W
E
S
TURQUOISE LAKE
RECREATION AREA
Sugarloaf Mountain

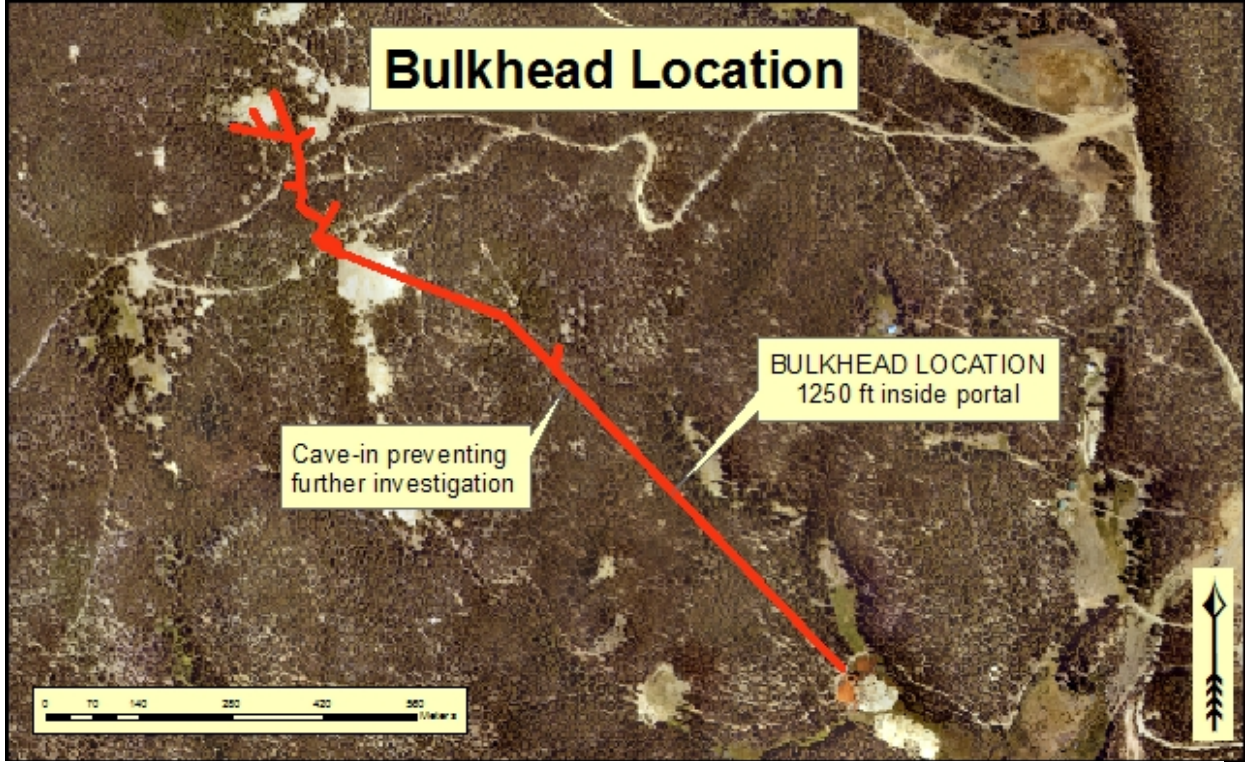

Baseline Water Quality
Sampling Locations
TLS-05
TLS-06
TLS-01
TLS-02
TLS-03
S-15
BGS-012
BGS-011
BGS-013
BPS-01
SLGS-03
BPS-02
BT-01
CG-5
TT-0
SLGS-04
K-adit
TWW-0
DT-0
LF-0
SLGS-02
NT-0
NT-0
LSG-1
SBGS-03
SLG-01
LF-537
SLG-02
LF-580
SBGS-02
SBG-0
ST-0
SBGS-01
CG-1
CG-1
CG-1
0
260
520
1,040
1,560
2,080
Meters
N

Tunnel Conditions

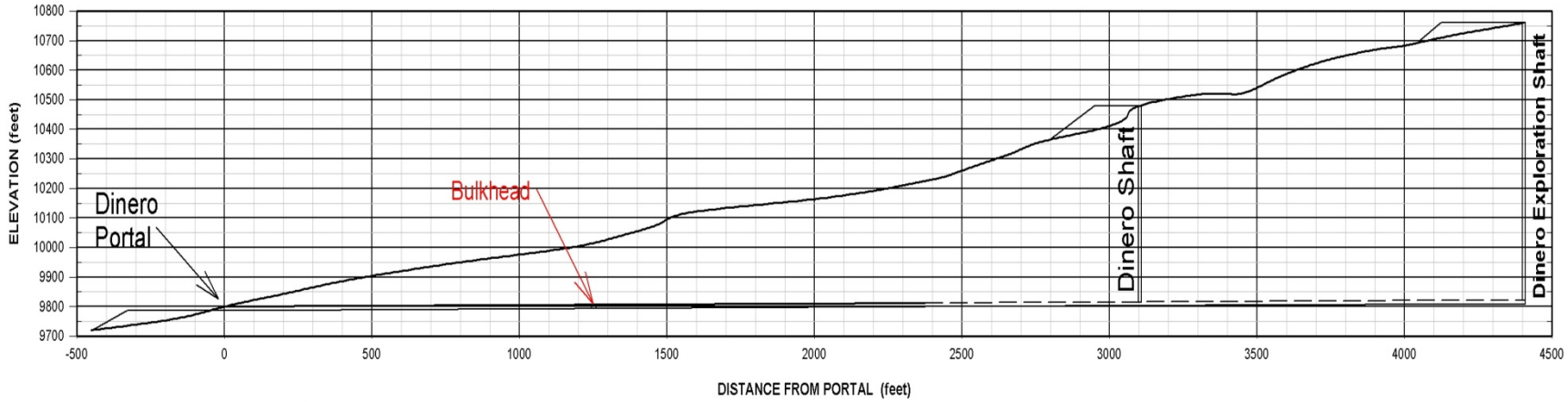
- Evidence of past blowouts were found inside the tunnel
- Underground evaluation of the tunnel was completed in 2005
- Extensive underground rehab required
- 121 gpm max measured flow

Proposed Bulkhead

- 1250’ from portal
- 15’ thick of reinforced concrete
- Parallel plug
- 680’ design head



CROSS SECTION OVER DINERO TUNNEL



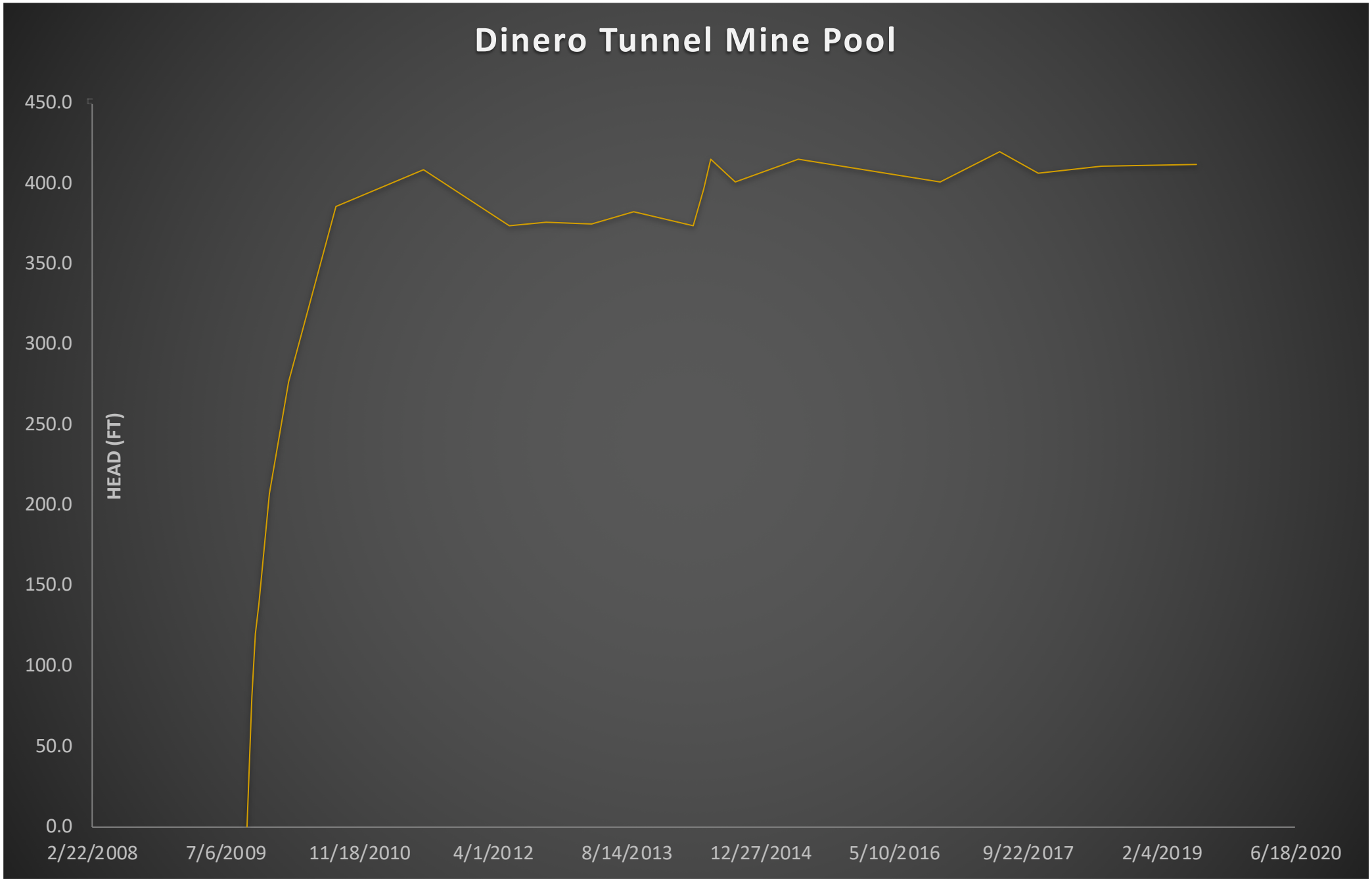
NOTES: 1) Assumed tunnel grade of 0.5%.
2) Tunnel roof line dashed where tunnel is off section of initial tunnel direction.
3) Elevations from USGS topographic mapping.

Figure 4. Dinero Tunnel Cross Section

Why choose a bulkhead at this site?

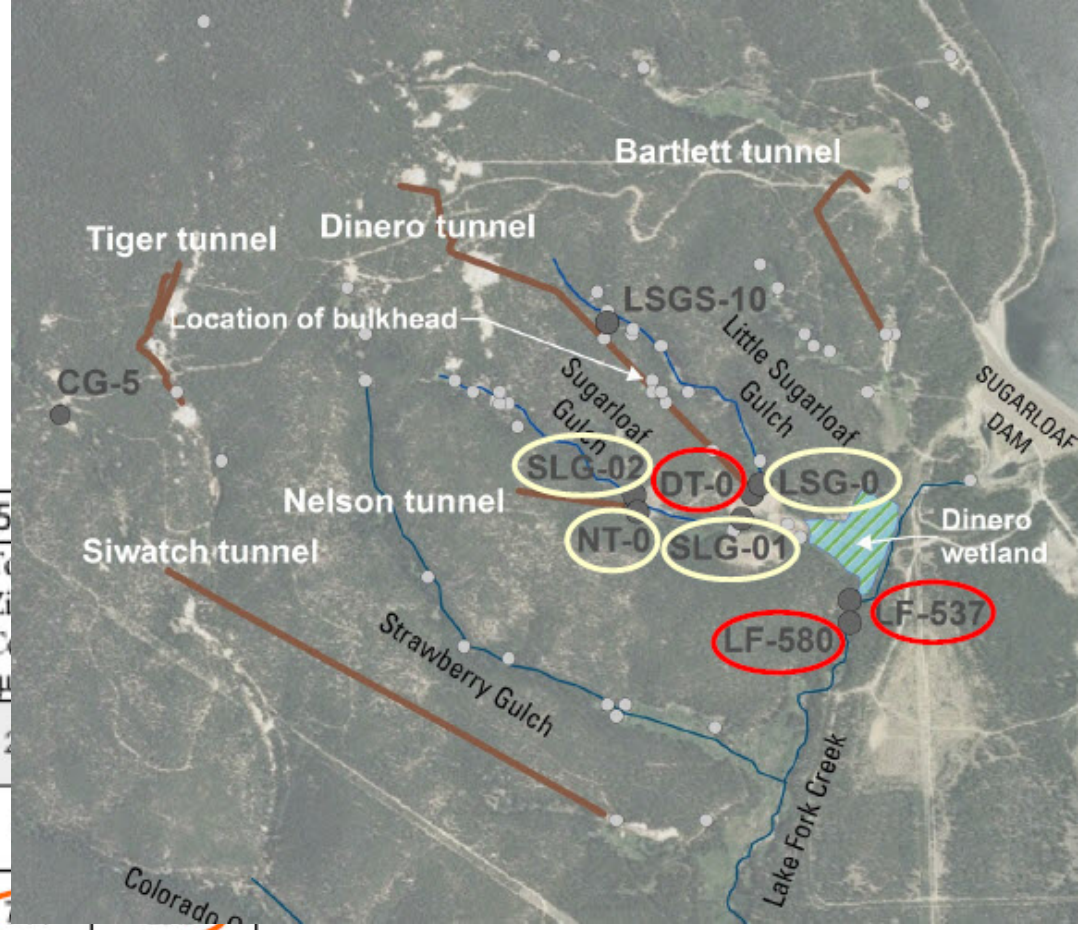
- Cost effective flow control.
- Alternative to water treatment.
- Limited mine working connectivity.
- Cross cut tunnel scenario.
- Opportunity to reduce oxygen interaction with sulfides.

Bulkhead Construction


Dinero Tunnel Mine Pool
HEAD (FT)
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
2/22/2008
7/6/2009
11/18/2010
4/1/2012
8/14/2013
12/27/2014
5/10/2016
9/22/2017
2/4/2019
6/18/2020

Post Bulkhead Data

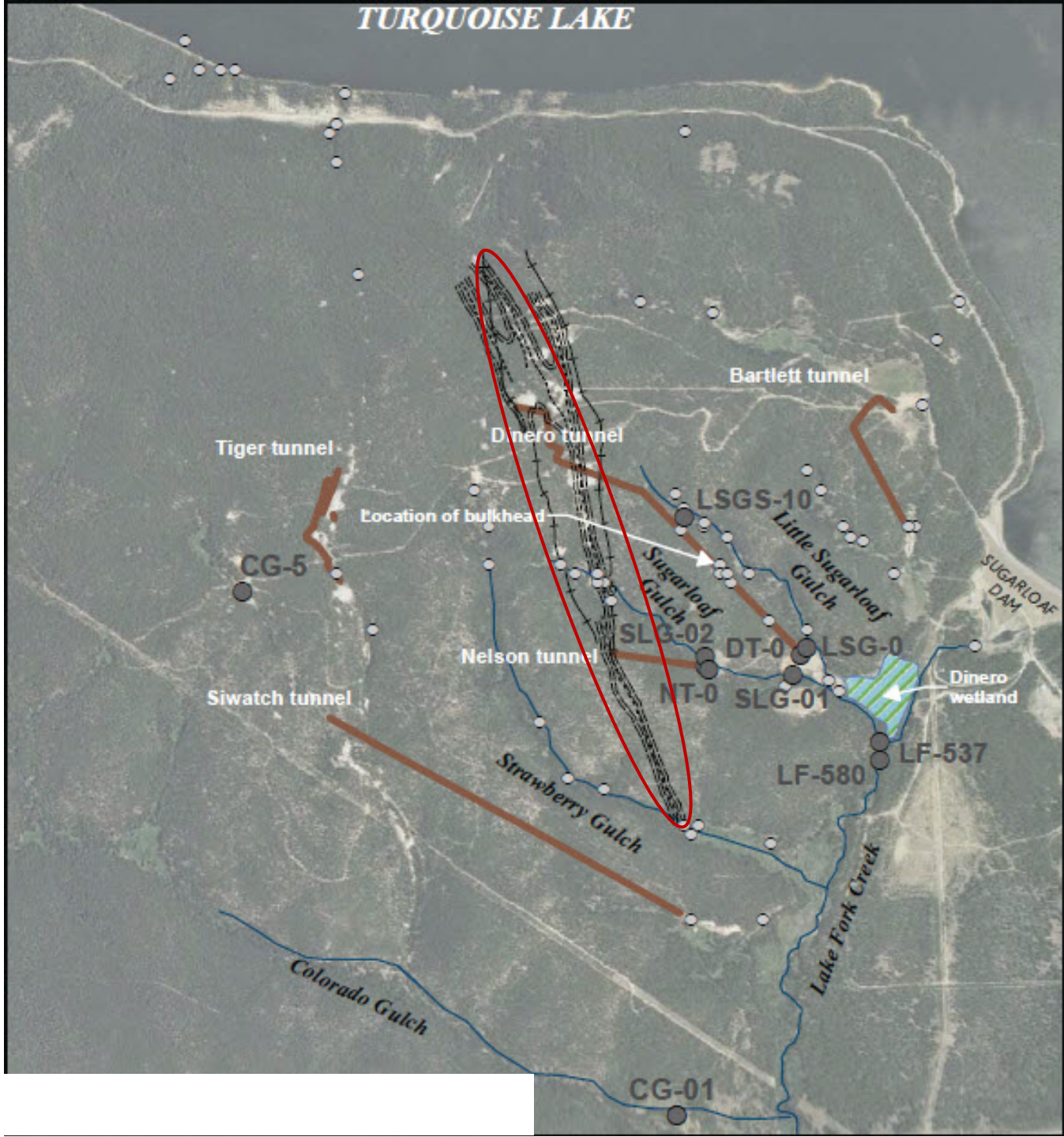
	Dinero Tunnel				LF-537				LF-5			
	Disch (ft^3/s)	pH (SU)	Total Zinc Conc. (µg/L)	Total Zinc Load (kg/day)	Disch (ft^3/s)	pH (SU)	Total Zinc Conc. (µg/L)	Total Zinc Load (kg/day)	Disch (ft^3/s)	pH (SU)	To Zi C (µ	
June '06	0.26	5.2	19,200	12.2	0.069	3.7	9,790	1.65	14.4	7.0		
June '10	0.018	6.7	3,230	0.14	0.14	4.5	1,890	0.63	8.3	7.0		
June '11	0.045	6.7	4,520	0.50	0.61	4.5	4,170	6.1	17.2	6.5		
May '12	0.029	6.5	5,100	0.38	0.021	4.7	4,320	0.22	17.1	7.2	25	1.09
Oct. '06	0.17	6.3	10,100	4.34	0.097	4.2	6,820	1.61	19.4	6.9	61	2.92
Sept '10	0.02	6.4	4,700	0.24	0.002	4.9	2,520	0.010	2.97	6.4	70	0.52
Sept '11	0.04	6.2	6,050	0.58	0.03	4.5	1,720	0.12	2.99	6.6	49	0.37
Sept '12	0.029	6.9	5,390	0.38	0.018	4.4	1,300	0.06	17.3	7.5	34	1.69

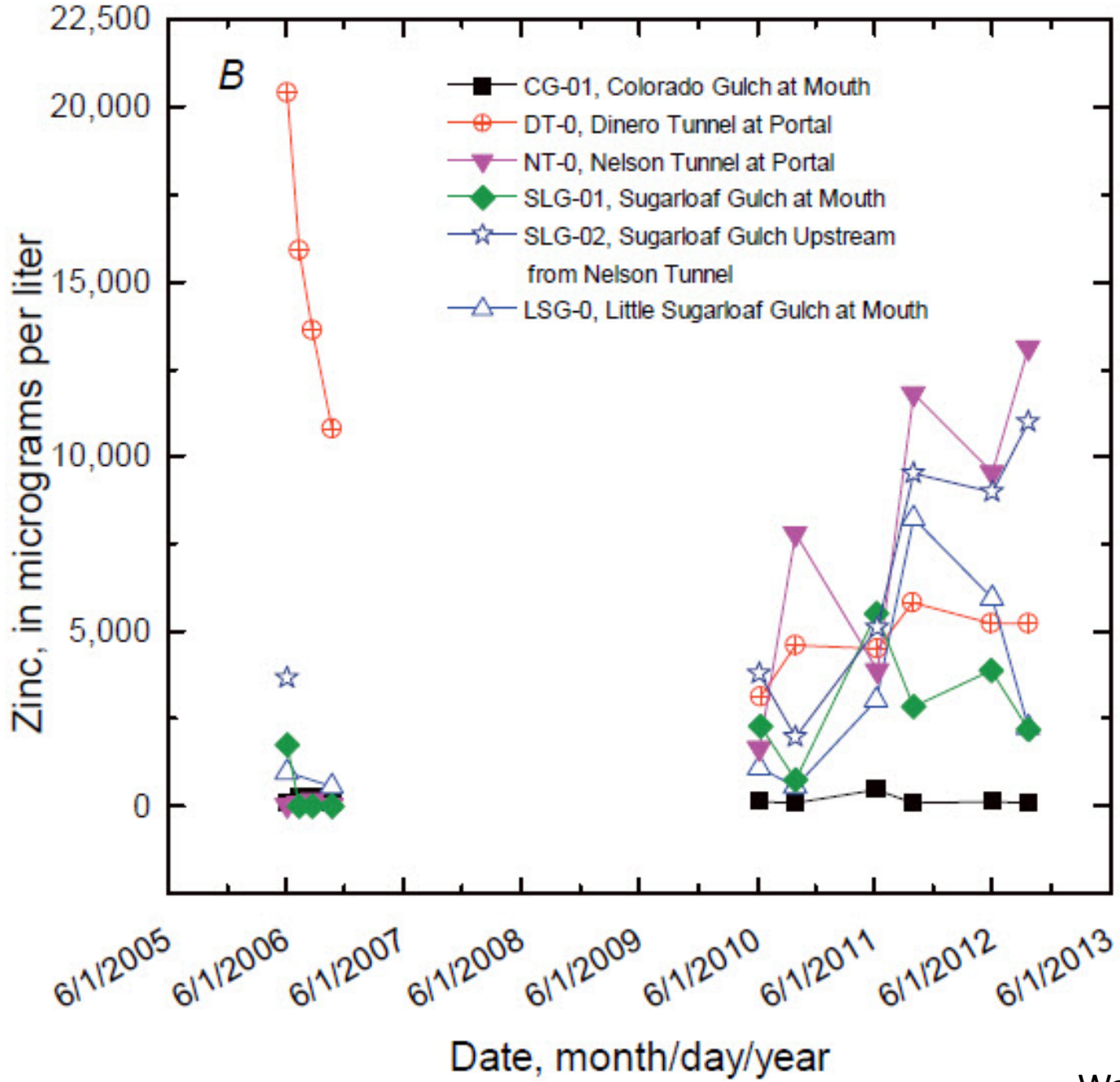


Walton-Day, Mills, USGS, MIW, 2014


Nelson Tunnel, 12 July 2006
USGS


Nelson Tunnel, 24 July 2013
USGS


TURQUOISE LAKE
Bartlett tunnel
Dinero tunnel
Tiger tunnel
Location of bulkhead
LSGS-10
Little Sugarloaf Gulch
Sugarloaf Gulch
SUGARLOAF DAM
CG-5
SLG-02
DT-0
LSG-0
Nelson tunnel
NT-0
SLG-01
Dinero wetland
Siwatch tunnel
LF-537
LF-580
Strawberry Gulch
Lake Fork Creek
Colorado Gulch
CG-01



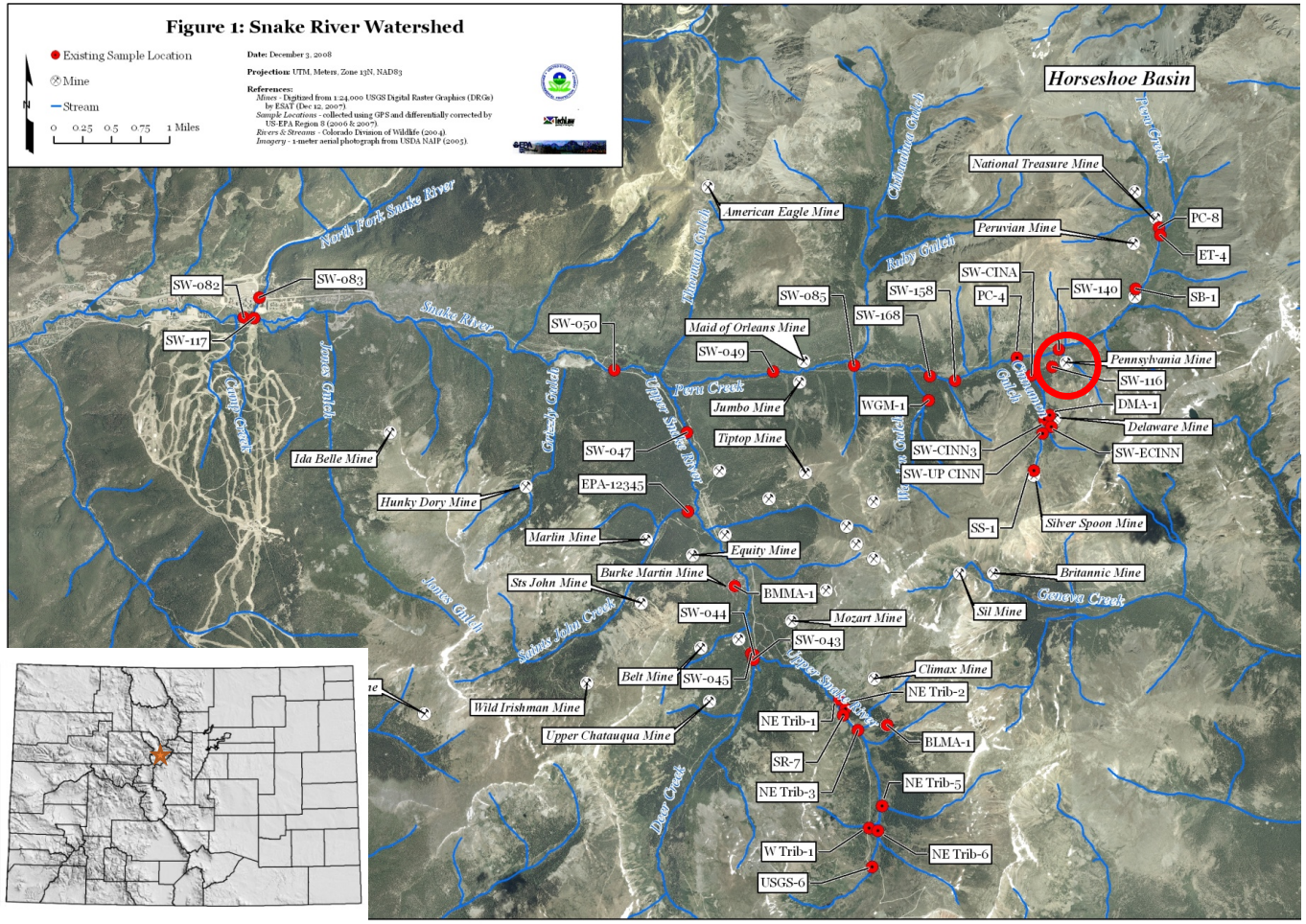
Walton-Day, etal., IMWA, 2013

Dinero Bulkhead Results

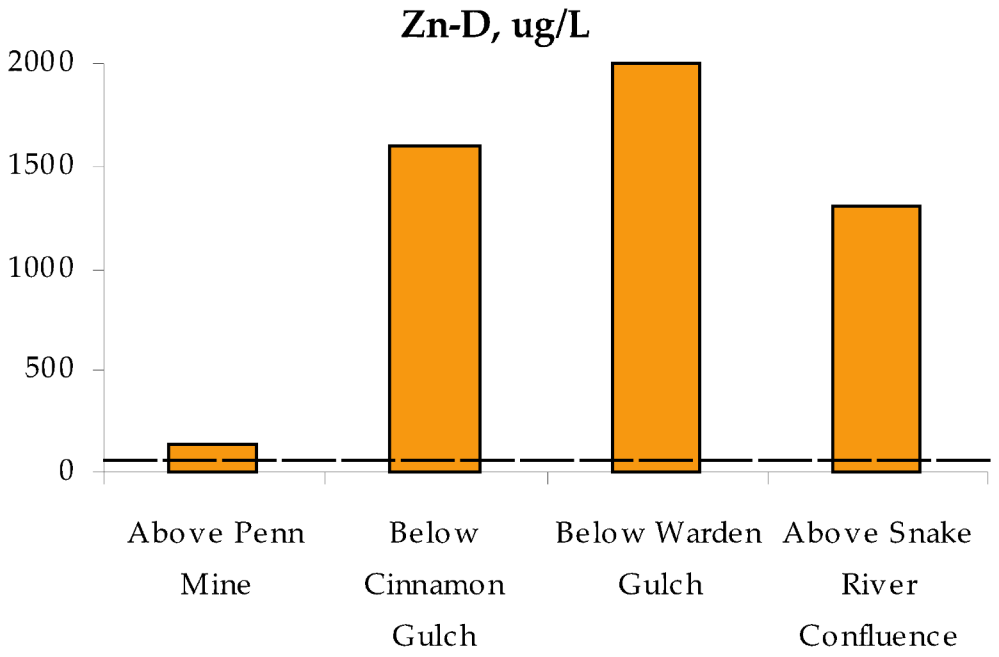
- Eliminated portal blowout or surge events.
- Reduced discharge from the portal.
- Reduced downstream loading of most metals.
- Increased flow at the Nelson Tunnel.
- Increased loading in Sugarloaf Gulch.
- Long term impacts still unknown.

Pennsylvania Mine, Summit County, Colorado

Setting

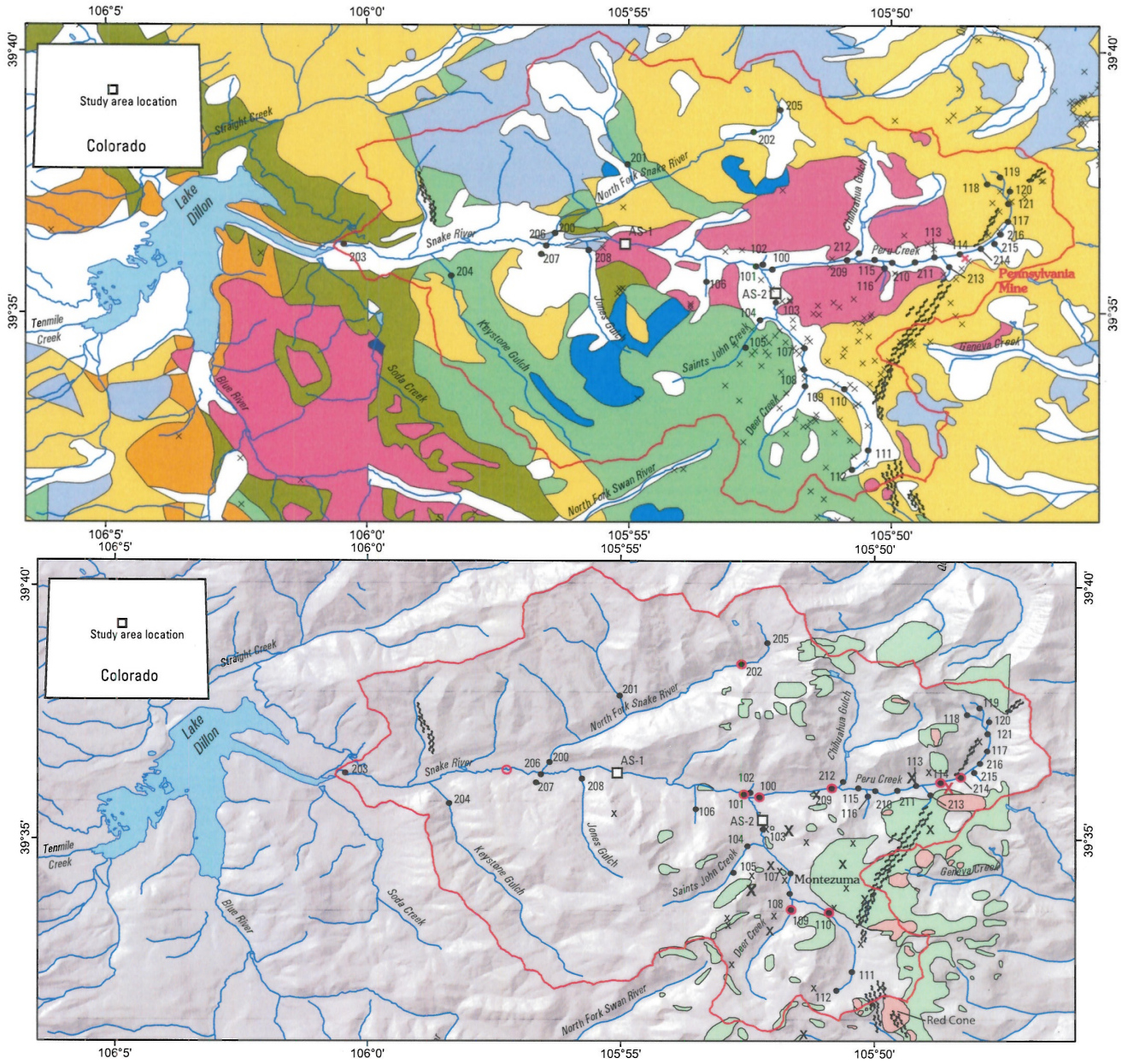


- Located in Upper reaches of Peru Creek, a tributary to the Snake River.
- Pennsylvania Mine - single largest manmade metals contributor to the Snake River (~40,000lbs Zn/yr).

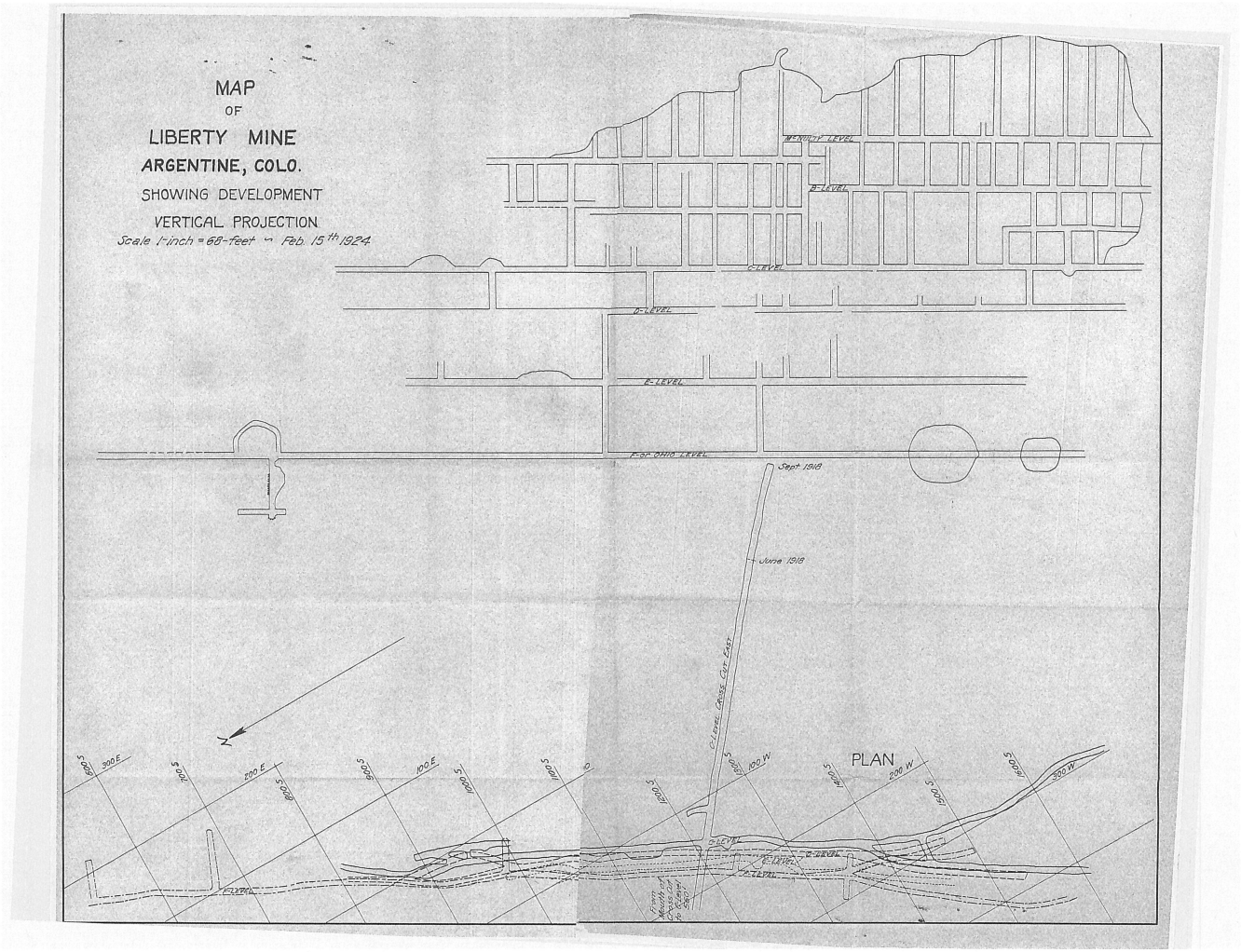


Geology

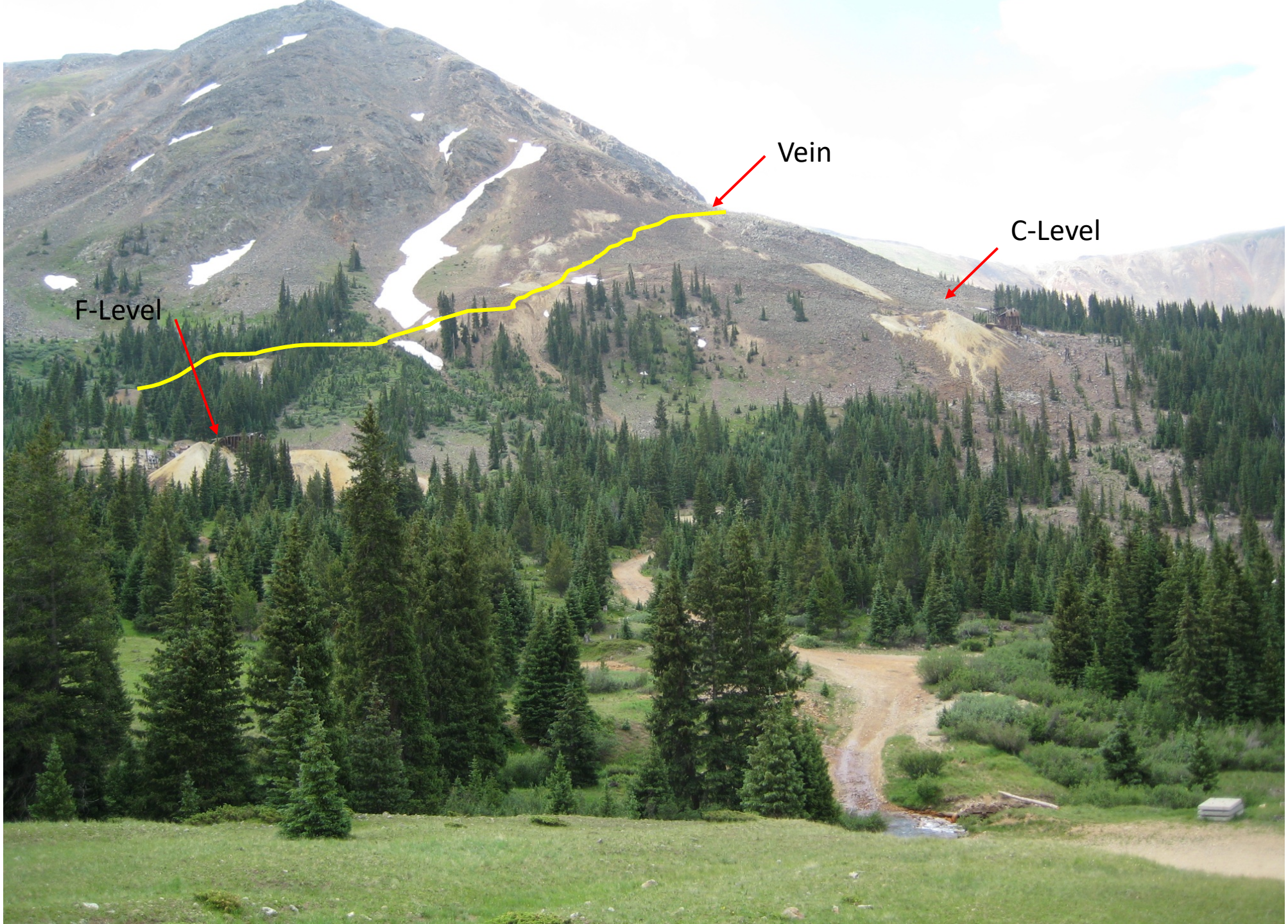
- Geology dominated by Montezuma Stock.
- Majority of mining along stock margins.
- Significant hydrothermal alteration throughout Peru Creek and Snake River watersheds.



History

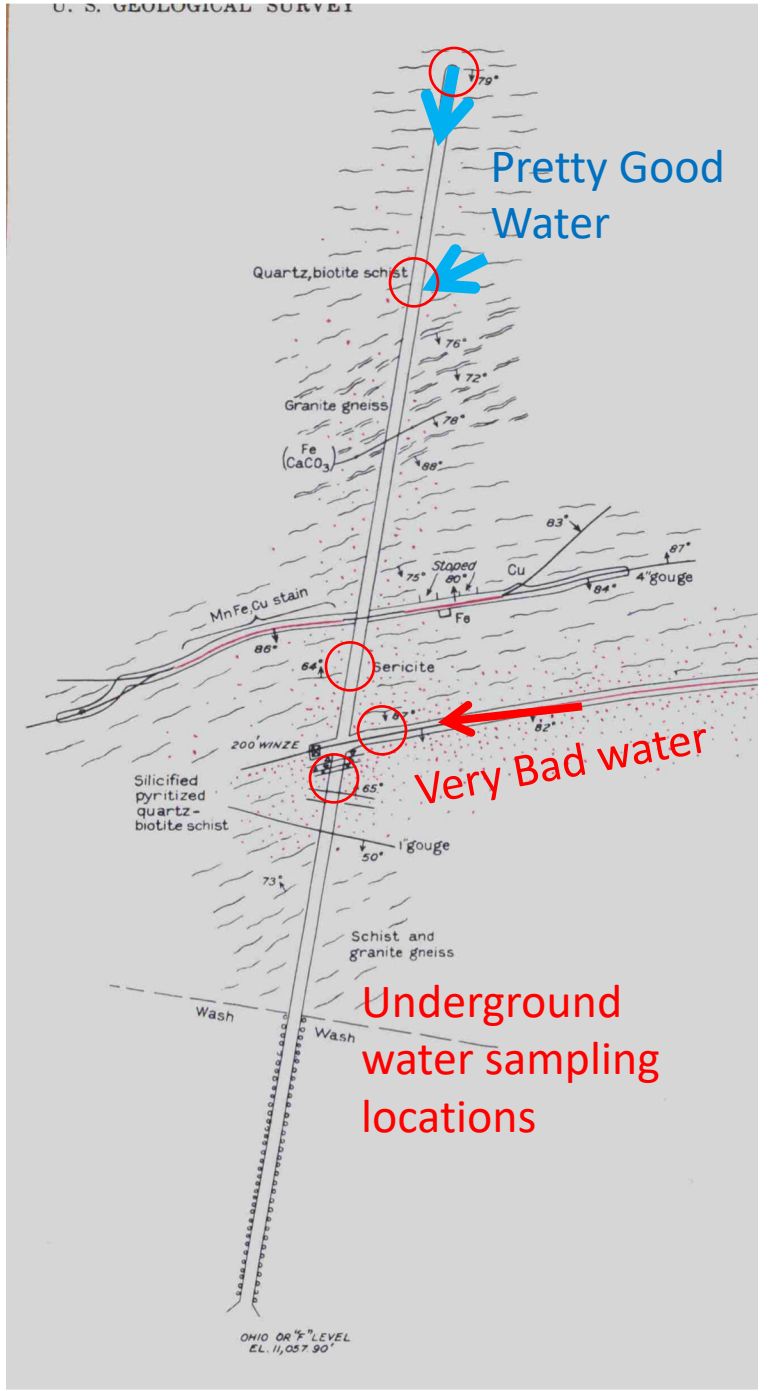


- Vein originally discovered in 1879.
- Mined for gold and silver through 1950's.
- Six main levels, A – F.
- Production:
  - > 3,500 ounces gold
  - > 895,000 ounces silver
- All portals into mine workings are collapsed.


Vein
C-Level
F-Level

Portal and Underground Rehab

Underground Characterization

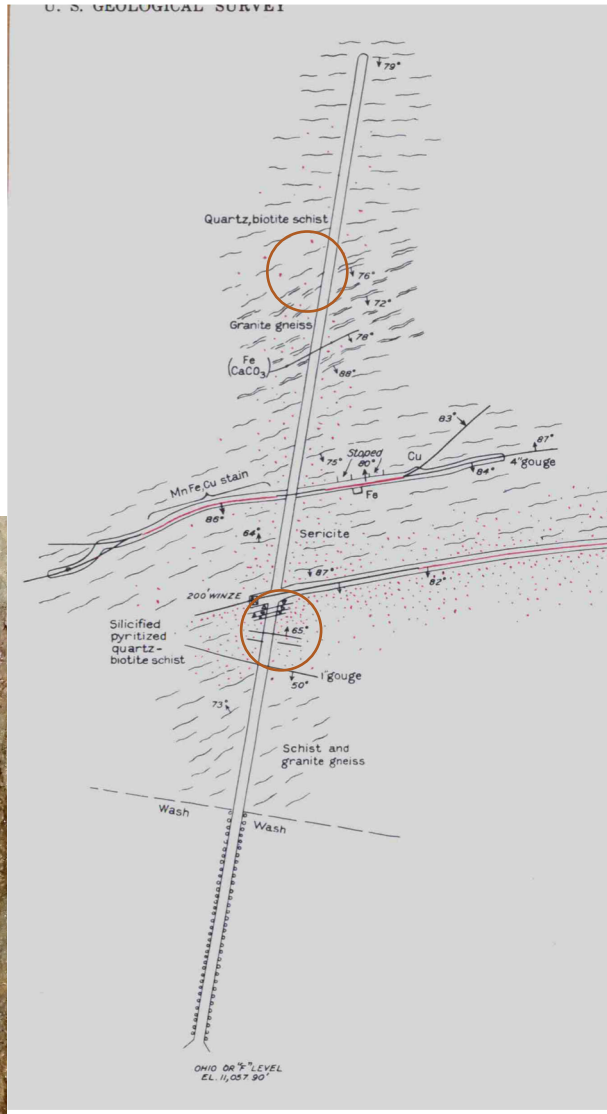


Why choose a bulkhead at this site?

- Cost effective flow control.
- Alternative to water treatment.
- Limited mine working connectivity.
- Cross cut tunnel scenario.
- Opportunity to reduce oxygen interaction with sulfides.

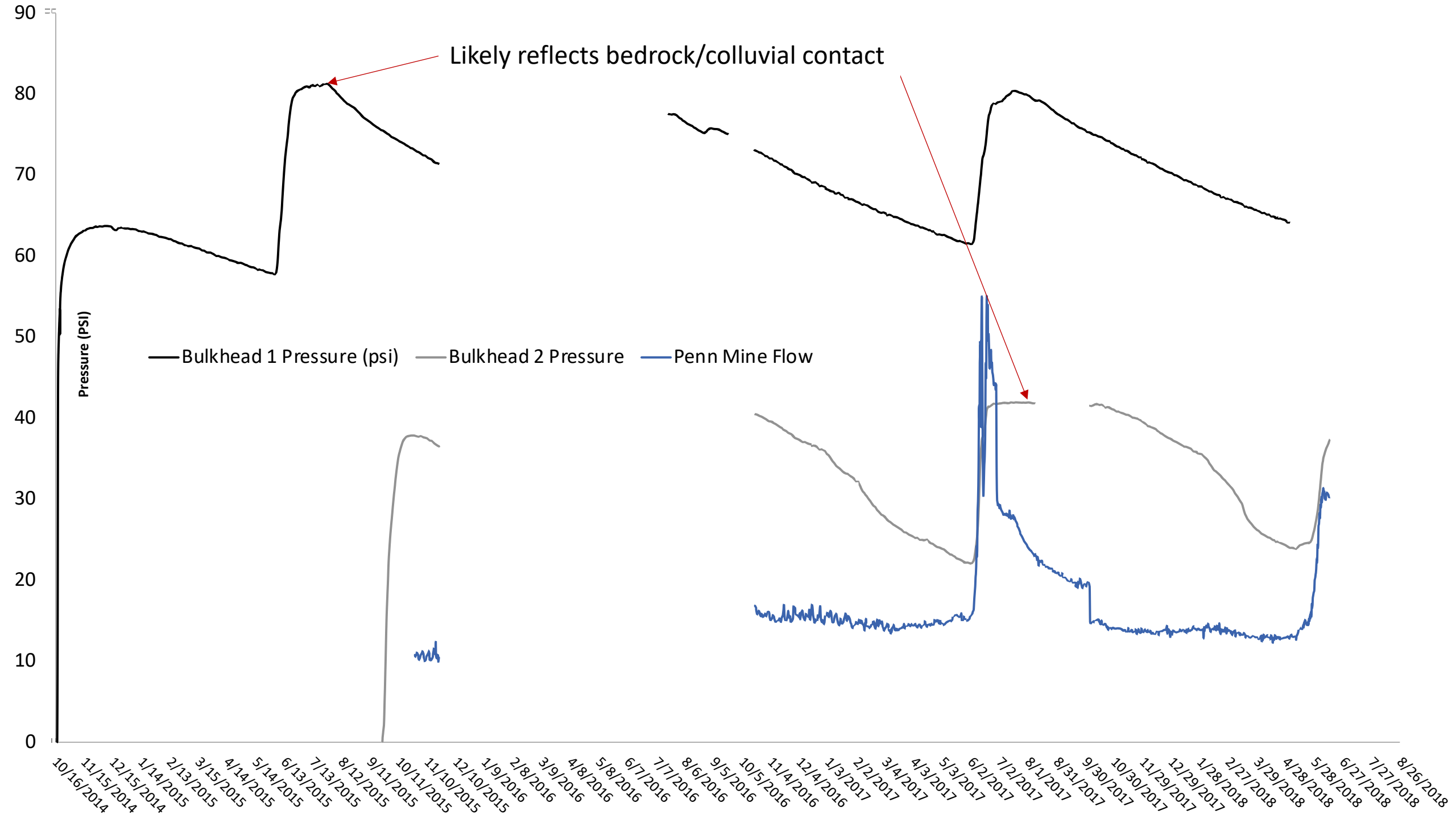
Bulkheads

- 2 bulkheads in series
- Bulkhead 1 (2014): $268,062
  - 475’ from portal
  - 1000’ design head
  - 18.5’ thick reinforced concrete
  - Parallel plug
- Bulkhead 2 (2015): $233,016
  - 275’ from portal
  - 500’ design head
  - 19’ thick reinforced concrete
  - Parallel plug



Bulkhead 1 Construction

Bulkhead 2 Construction


Likely reflects bedrock/colluvial contact
Pressure (PSI)
Bulkhead 1 Pressure (psi)
Bulkhead 2 Pressure
Penn Mine Flow
90
80
70
60
50
40
30
20
10
0
10/16/2014
11/15/2014
12/15/2014
1/14/2015
2/13/2015
3/15/2015
4/14/2015
5/14/2015
6/13/2015
7/13/2015
8/12/2015
9/11/2015
10/11/2015
11/10/2015
12/10/2015
1/9/2016
2/8/2016
3/9/2016
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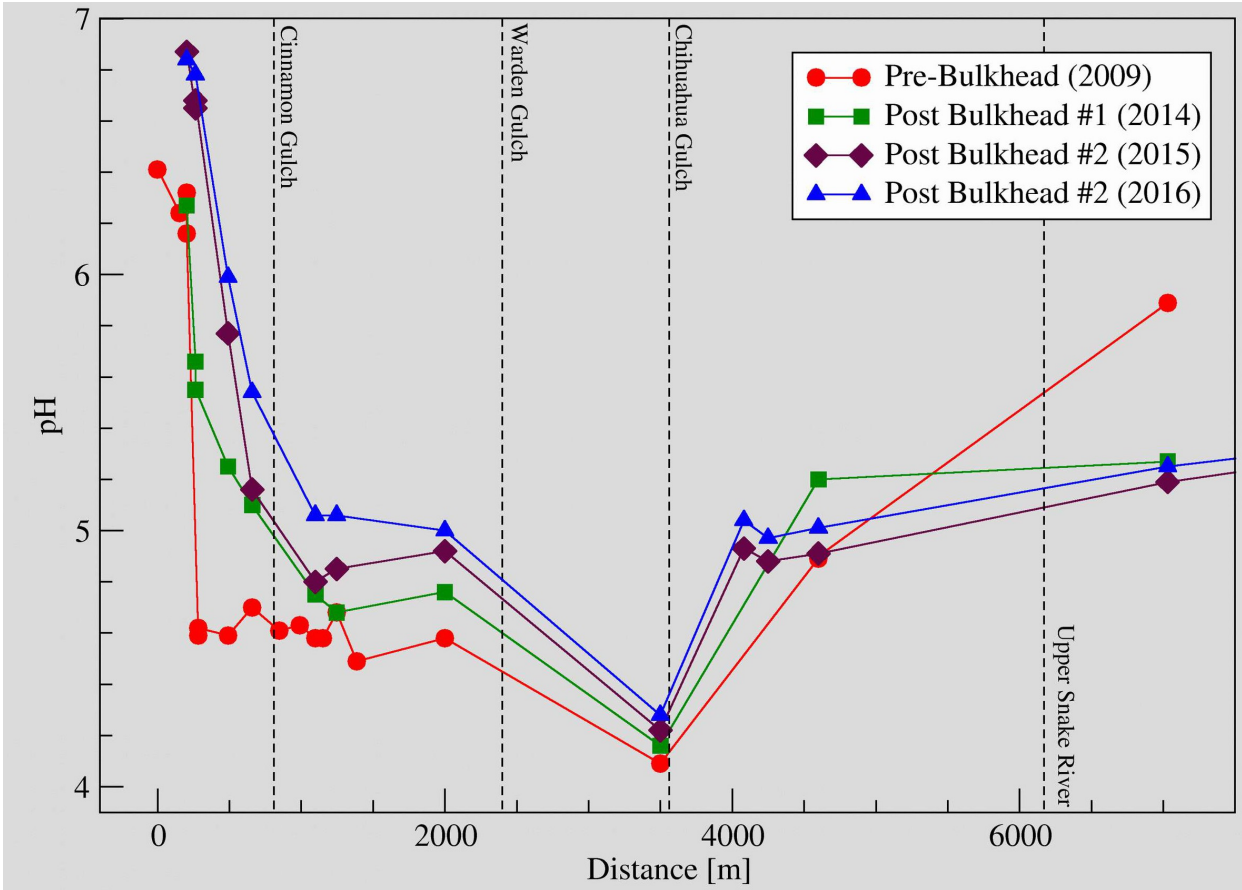
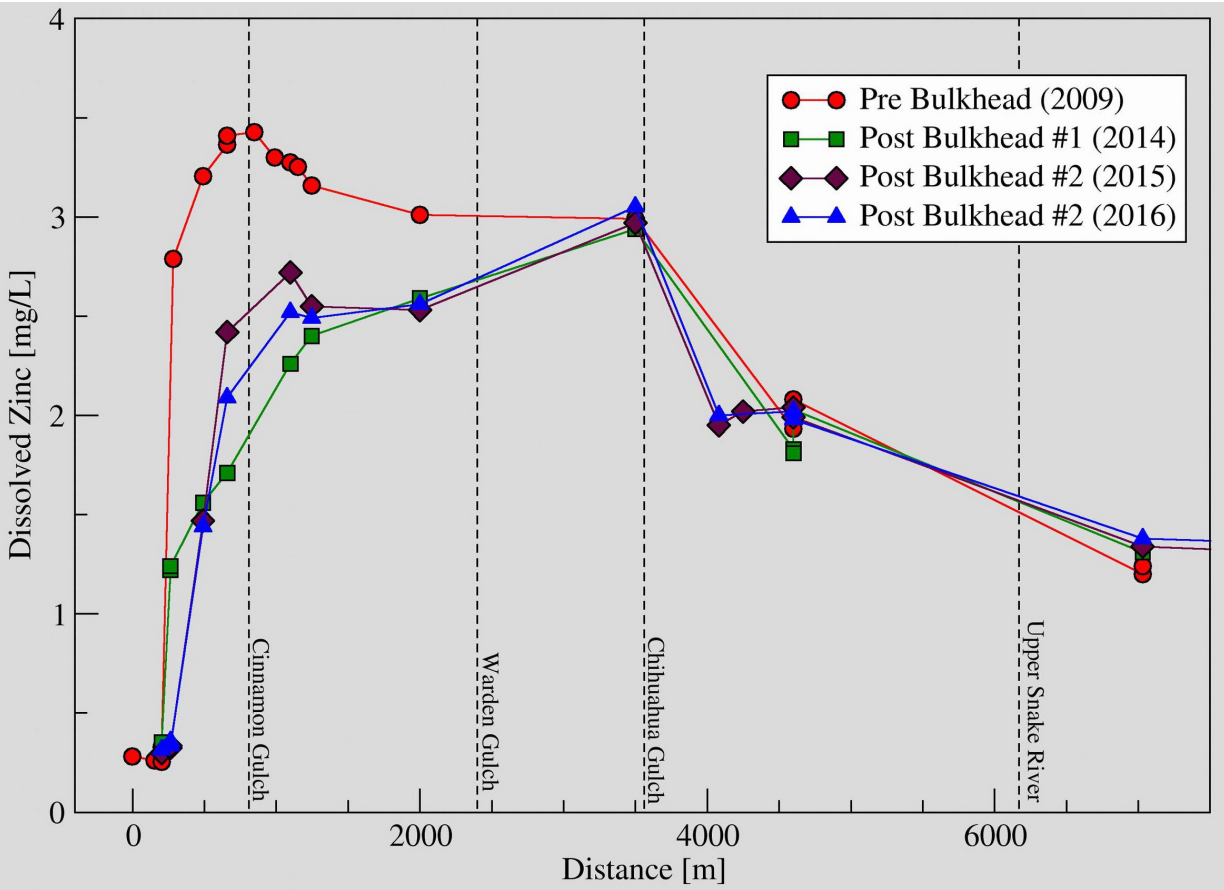
5/8/2016
6/7/2016
7/7/2016
8/6/2016
9/5/2016
10/5/2016
11/4/2016
12/4/2016
1/3/2017
2/2/2017
3/4/2017
4/3/2017
5/3/2017
6/2/2017
7/2/2017
8/1/2017
8/31/2017
9/30/2017
10/30/2017
11/29/2017
12/29/2017
1/28/2018
2/27/2018
3/29/2018
4/28/2018
5/28/2018
6/27/2018
7/27/2018
8/26/2018

Bulkhead Results – pH and Zn





Data compiled and provided by Runkel, USGS

Effect of Penn Mine Bulkheads

- % Load reduction compared to 2009 baseline, downstream in Peru Creek.
- Small improvements after first bulkhead (2014).
- Larger improvements following second bulkhead.

	Al	Cd	Cu	Fe	Mn	Pb	Zn
2014	-83%	-16%	5%	-76%	-24%	10%	-21%
2015	-14%	37%	50%	76%	22%	51%	29%
2016	-10%	38%	57%	83%	35%	66%	33%

Data compiled and provided by Runkel, USGS

Penn Mine Bulkhead Results

- Eliminated portal blowout or surge events.
- Reduced surface discharge from the mine portal.
- Reduced downstream loading of most metals.
- Reduced long term O&M.
- Increased flow in spring above mine portal.
- Long term impacts still unfolding.