Hydrologic Characterization of Multiple Seam Underground and Surface Mining in Northern Appalachia

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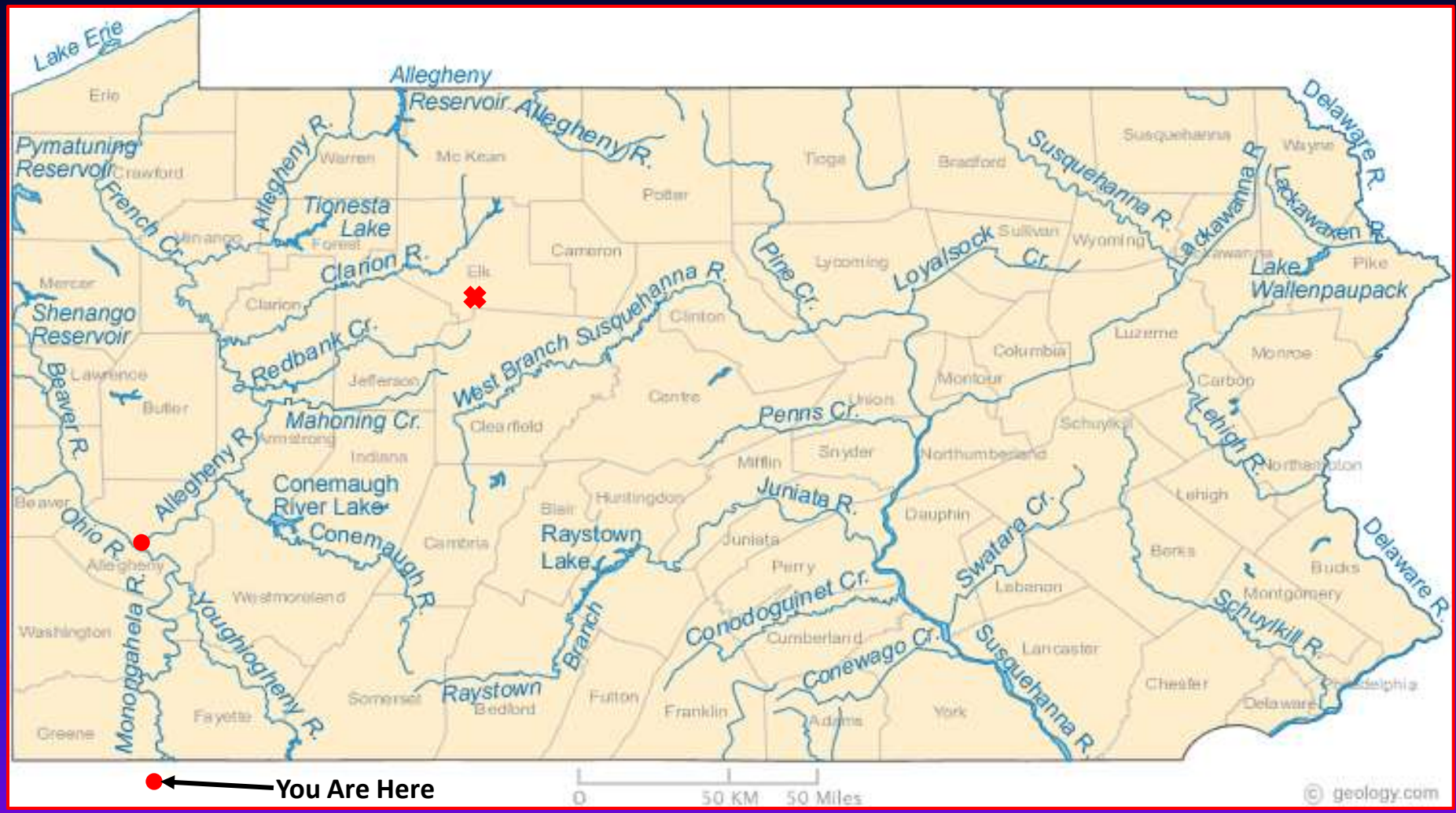
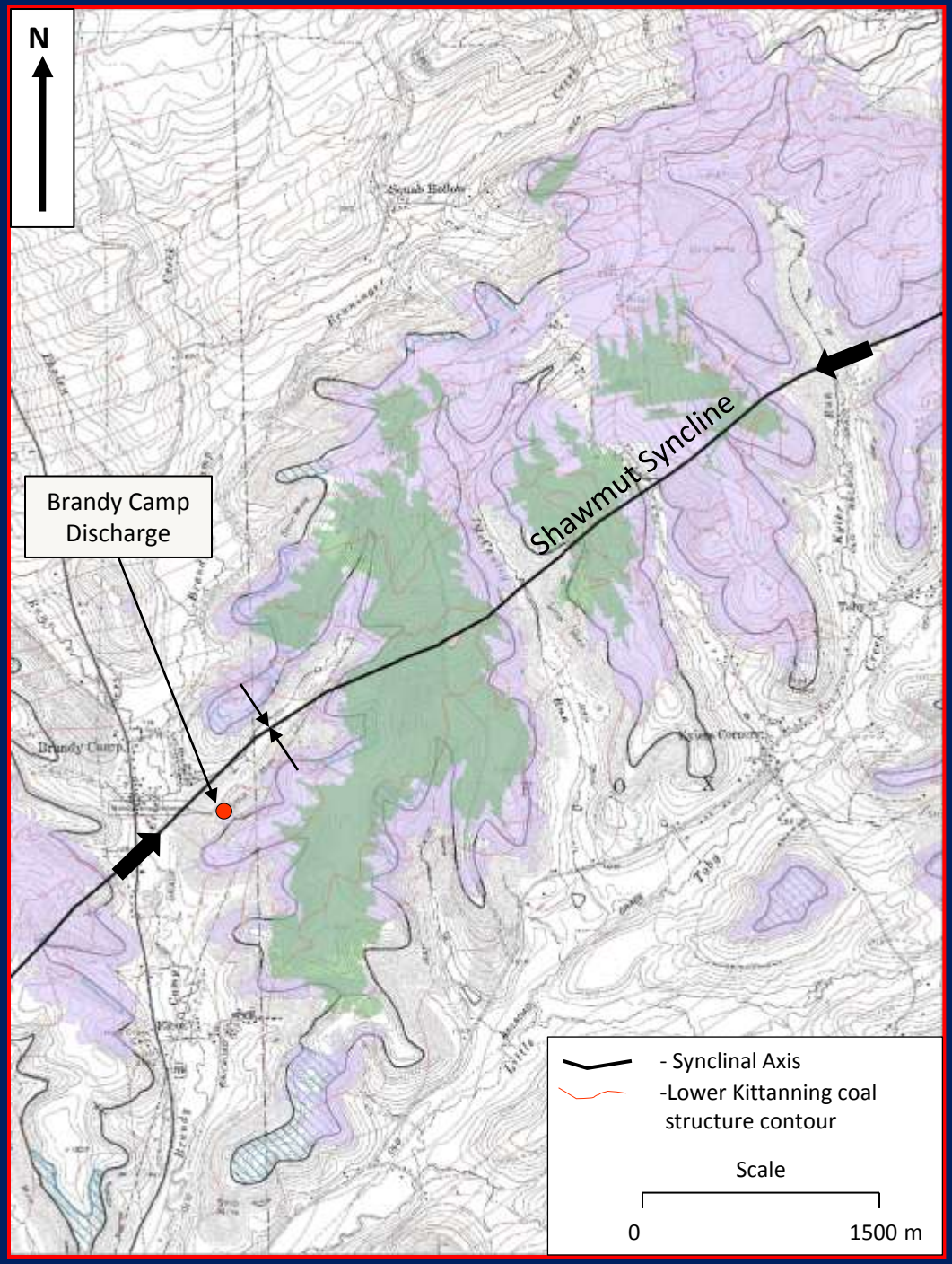
Background

- Abandoned mine complex of two vertically stacked above drainage underground mines.
- Deep mines have been abandoned for several decades.
- On top of the deep mines there are significant areas of more recent surface mining.
- One main discharge point for all of the mines (Brandy Camp discharge) for which a treatment plant was constructed.

Major Tasks

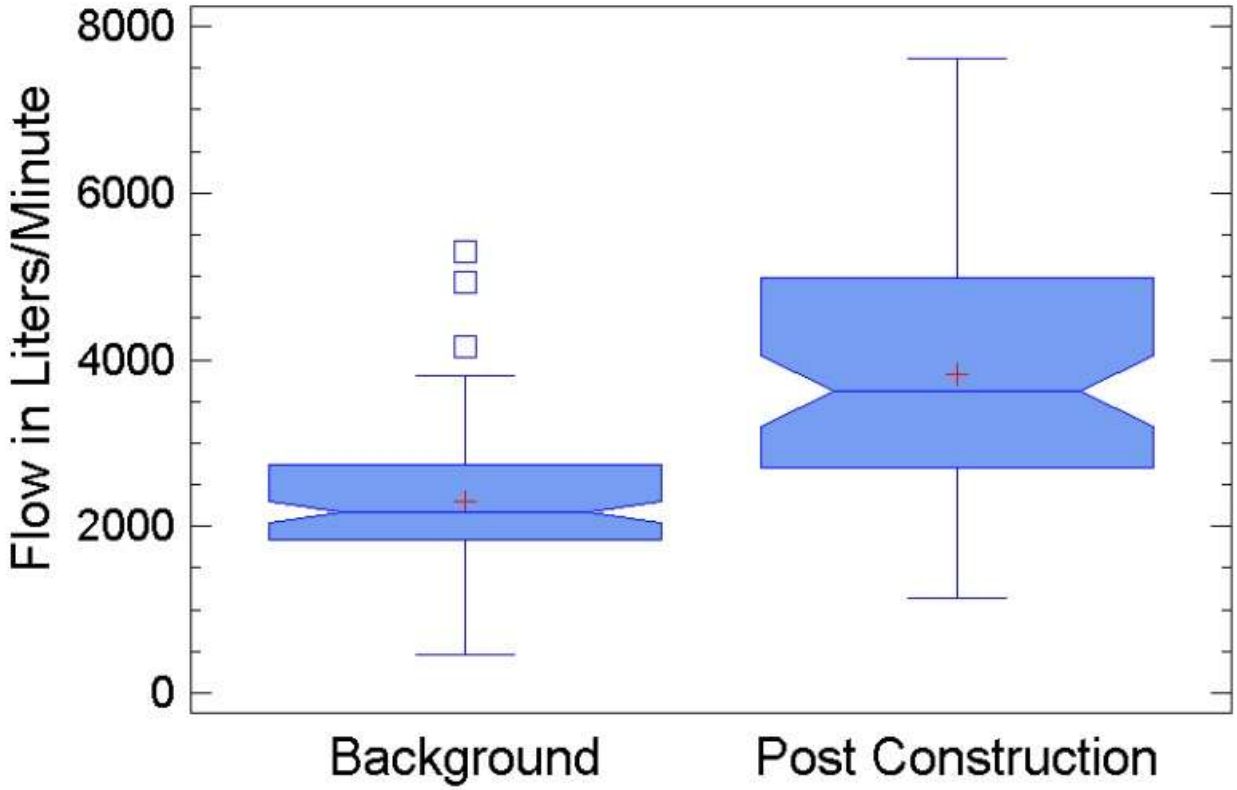
- The discharge rate nearly doubled by the time the treatment plant was completed.
- Characterize the integral hydrologic regime of the stacked underground and surface mines.
- Determine the potential to dispose of the iron hydroxide sludge back into the underground mines.
- Determine the cause of a flushing event that occurred in 2008 and recommend ways to prevent future occurrences.


Lake Erie
Allegheny Reservoir
Allegheny R.
Pymatuning Reservoir
French Cr.
Tionesta Lake
Clarion R.
Shenango Reservoir
Redbank Cr.
West Branch Susquehanna R.
Pine Cr.
Loyalsock Cr.
Susquehanna R.
Lackawanna R.
Lackawaxen R.
Delaware R.
Lake Wallenpaupack
Beaver R.
Mahoning Cr.
Penns Cr.
Lehigh R.
Ohio R.
Conemaugh River Lake
Conemaugh R.
Juniata R.
Raystown Lake
Swatara Cr.
Conodoguinet Cr.
Conewago Cr.
Schuylkill R.
Monongahela R.
Youghiogheny R.
Raystown Branch
Erie
Crawford
Warren
Mc Kean
Potter
Tioga
Bradford
Susquehanna
Wayne
Pike
Mercer
Venango
Forest
Clarion
Elk
Cameron
Lycoming
Sullivan
Wyoming
Lawrence
Butler
Jefferson
Clinton
Centre
Columbia
Luzerne
Monroe
Carbon
Armstrong
Indiana
Clearfield
Union
Snyder
Northumberland
Schuylkill
Northampton
Lehigh
Beaver
Allegheny
Blair
Huntingdon
Mifflin
Juniata
Dauphin
Cambria
Perry
Berks
Bucks
Montgomery
Lebanon
Westmoreland
Washington
Cumberland
Lancaster
Chester
Delaware
Philadelphia
Somerset
Bedford
Fulton
Franklin
Adams
York
Fayette
Greene
You Are Here
0
50 KM
50 Miles
© geology.com



Amethyst = Lower Kittanning deep mine (Elbon)
Lt Green = Middle Kittanning deep mine (Shawmut)

Discharge Rate Increase



What Could Cause the Flow Increase?

- Changes in the flow measurement location
- Incorrect flow measurements pre- and/or post-plant construction
- Surface mining activities have changed the mine recharge characteristics
- Precipitation/climatic conditions changed
- Other anthropogenic activities

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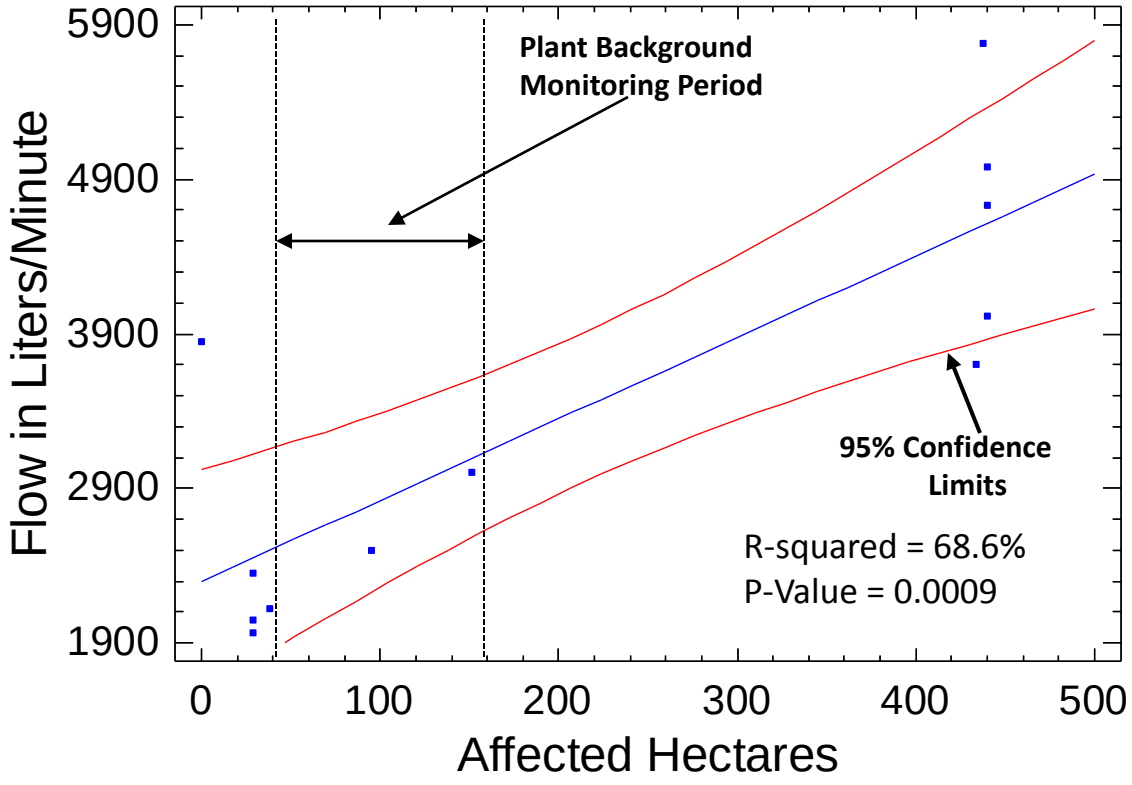
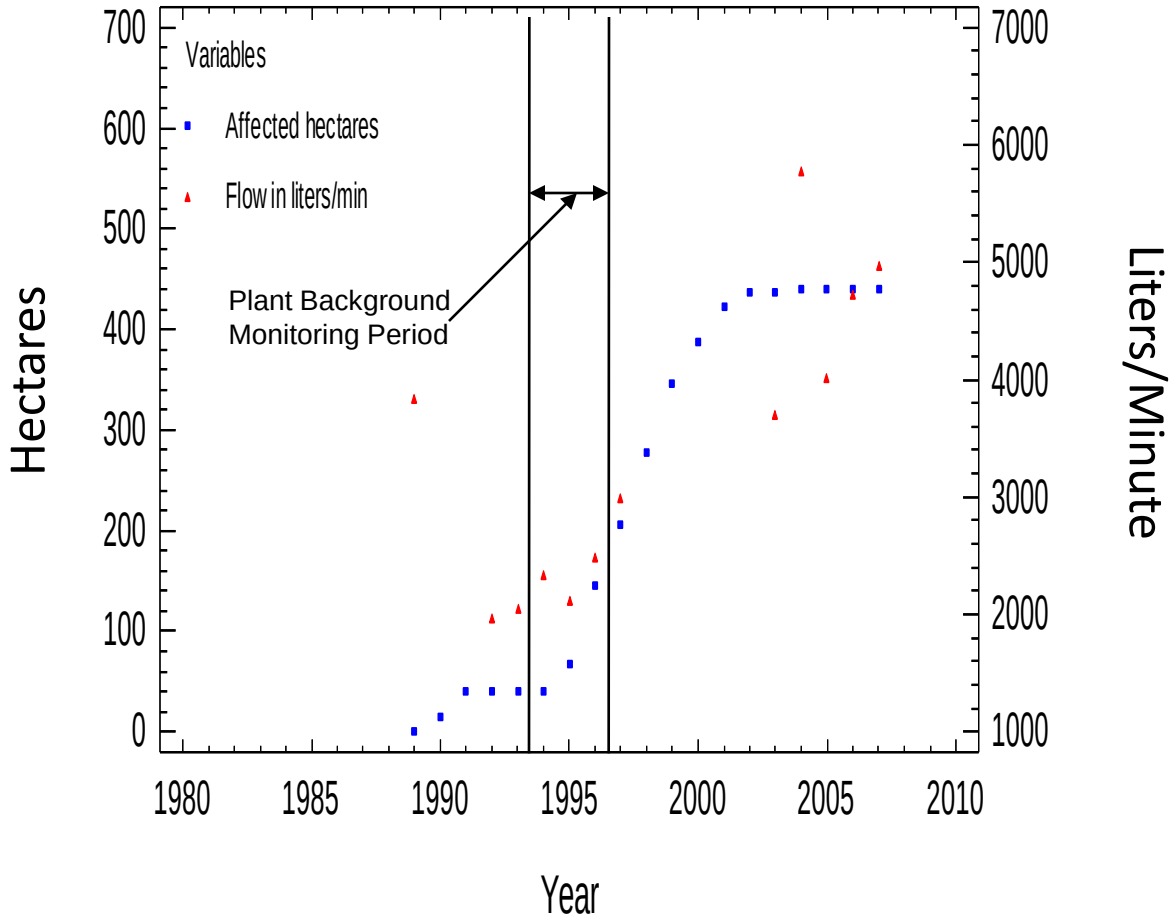
Mean Discharge Rate vs. Affected Area




Variables
Affected hectares
Flow in liters/min
Plant Background
Monitoring Period
Hectares
Liters/Minute
Year
0
100
200
300
400
500
600
700
1000
2000
3000
4000
5000
6000
7000
1980
1985
1990
1995
2000
2005
2010

Mining Changes to Site Conditions

- Loss of forest cover
- Revegetate with mainly grasses and later trees
- Water handling during mining
- Removal of E & S controls
- Restoration of soil structure over time
- Increased permeability and porosity of spoil to accept and hold ground water

Approximately 85% of the recharge area was surface mined and reclaimed

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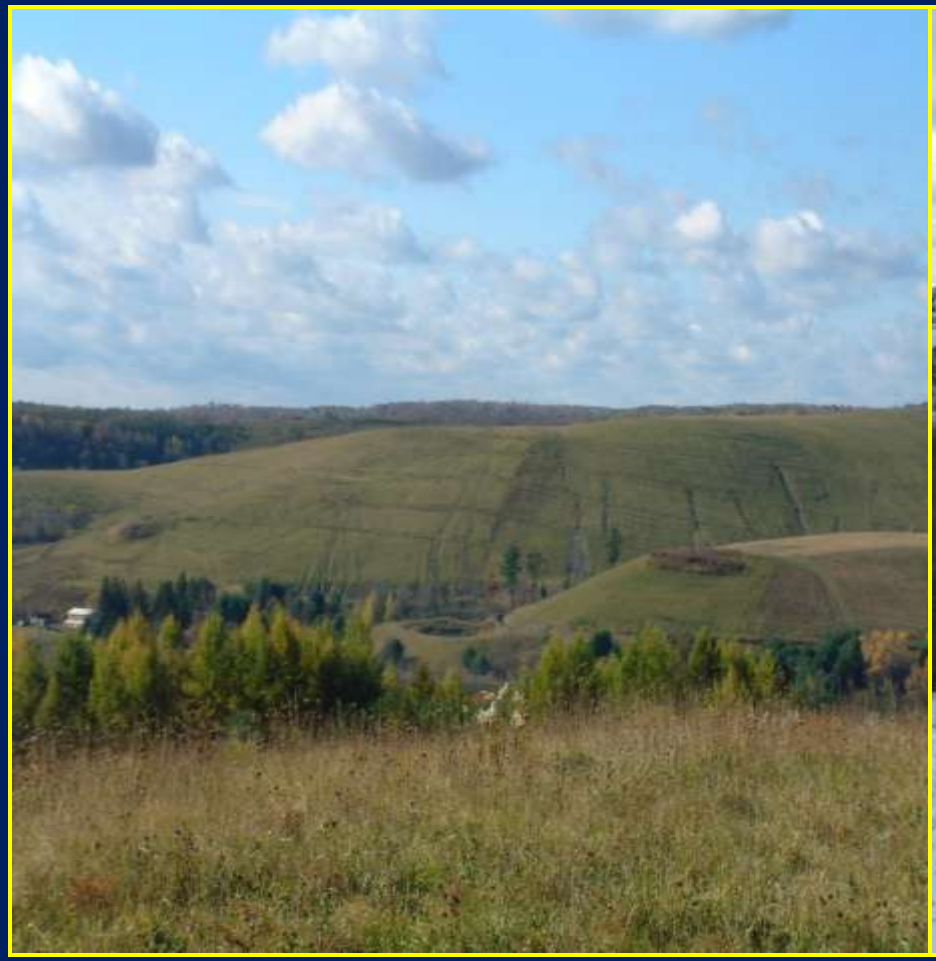

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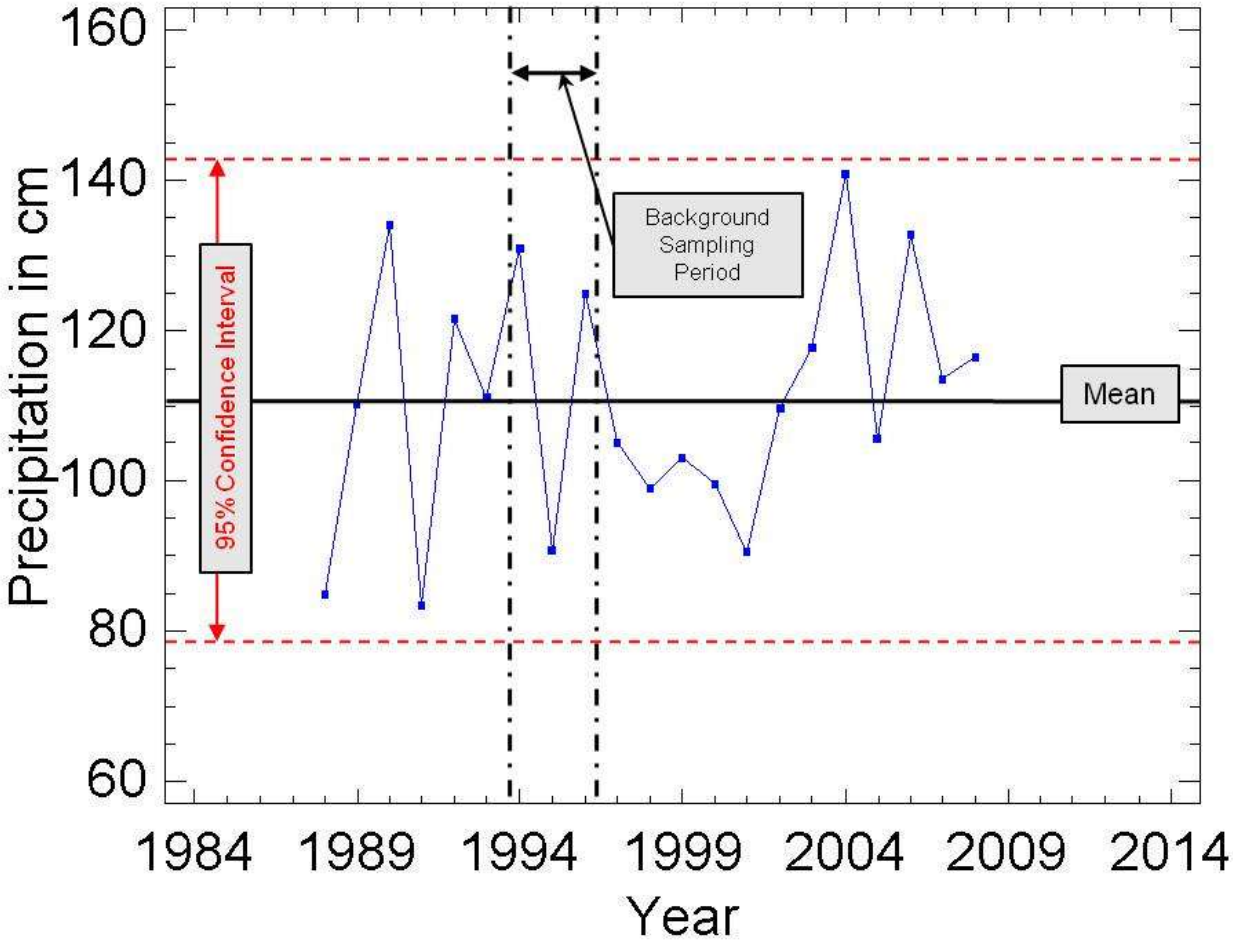
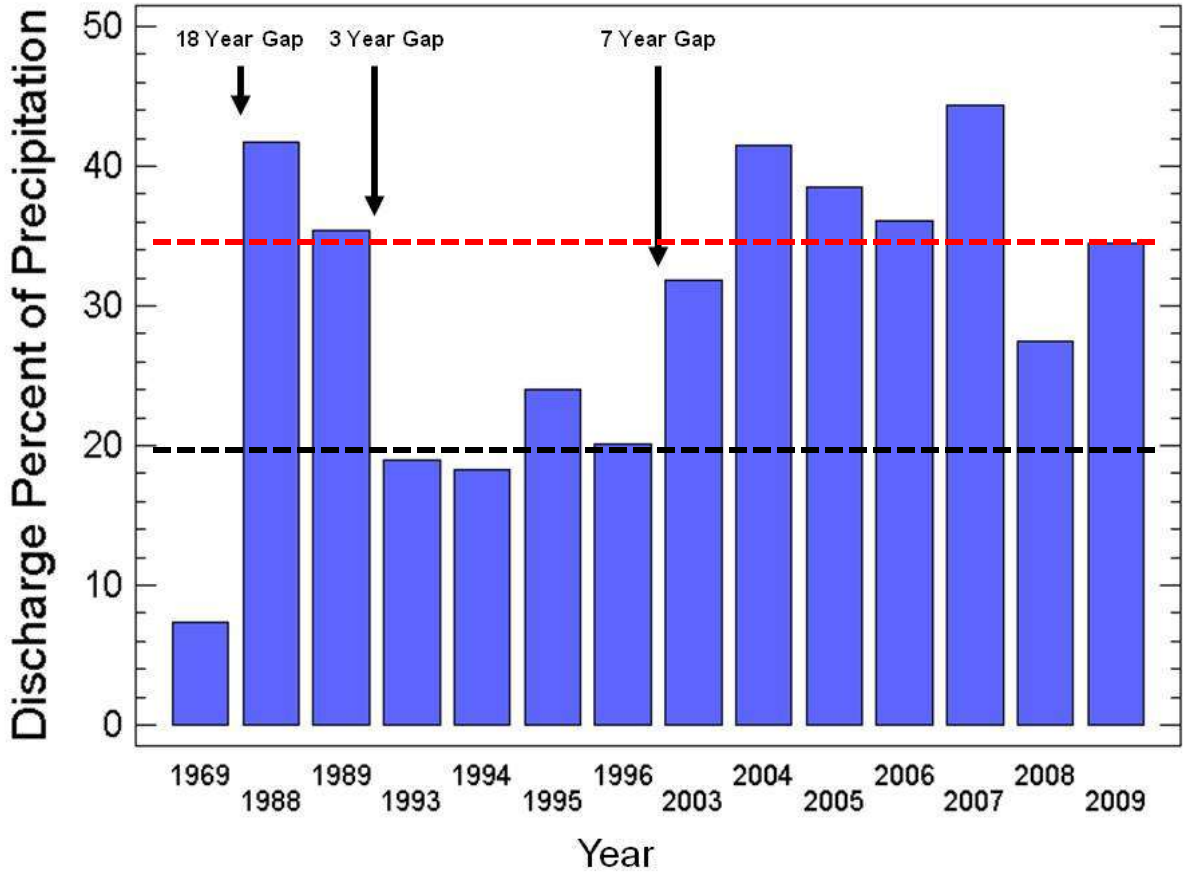
Precipitation

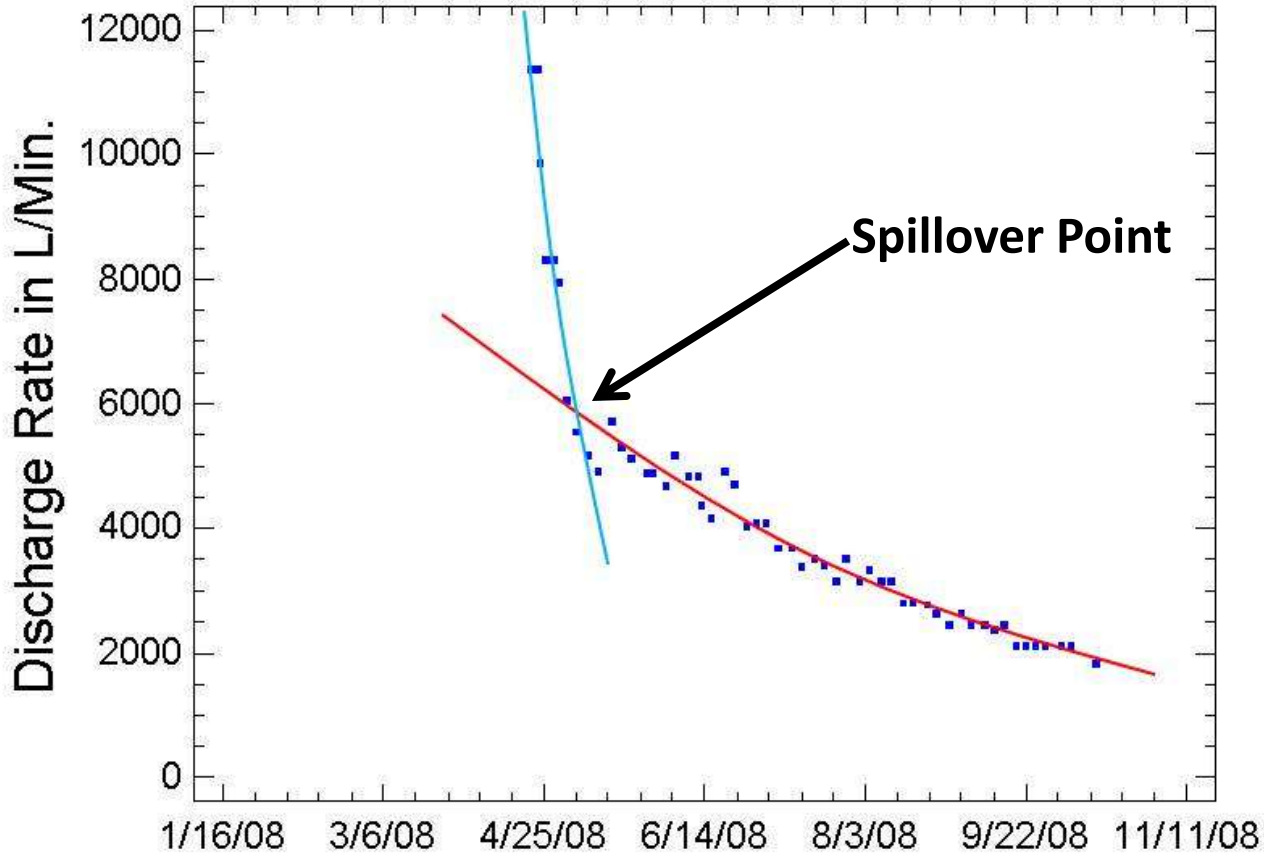
- The discharge rate clearly tied to antecedent precipitation.
- Precipitation during the background sampling and subsequently was well within the normal range.
- The discharge percentage of precipitation increased markedly since the large scale surface mining and reclamation has occurred.

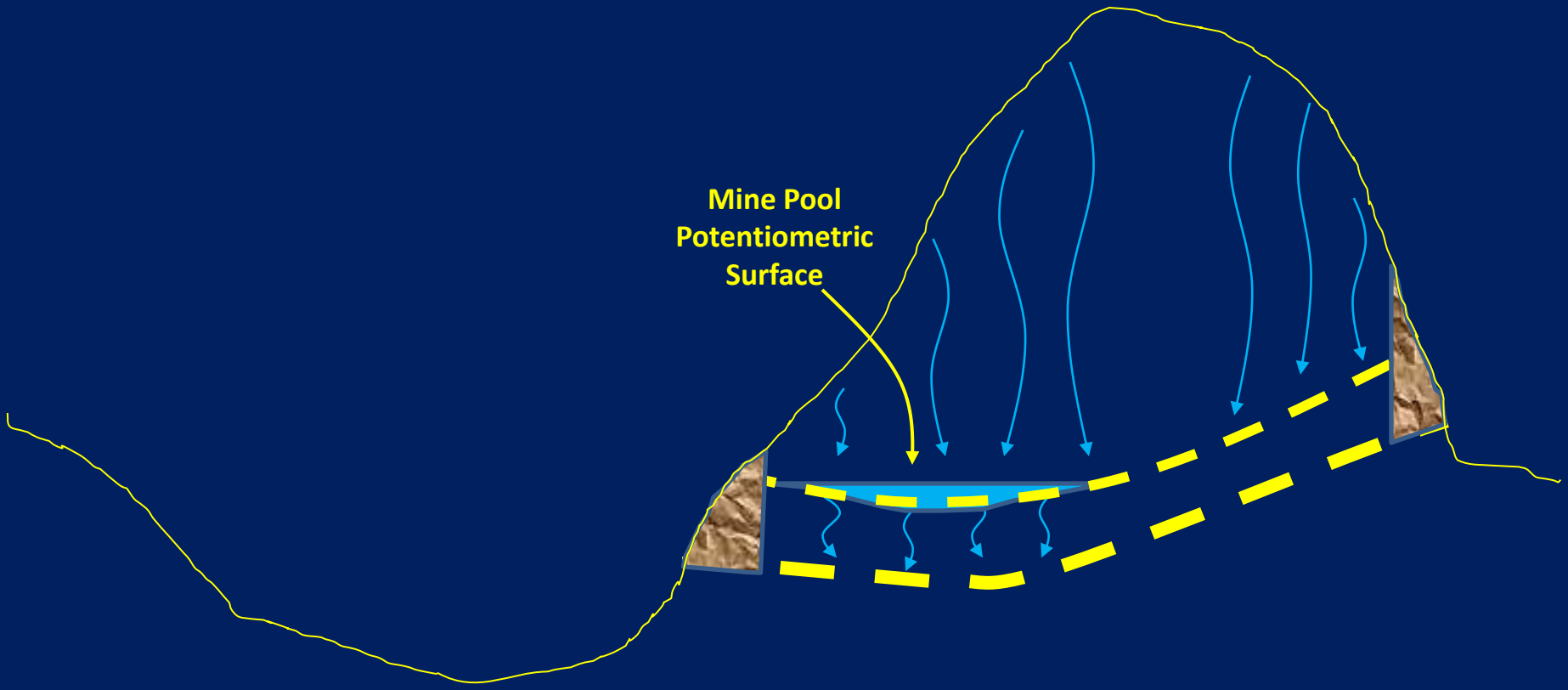

160
140
120
100
80
60
Precipitation in cm
95% Confidence Interval
Background Sampling Period
Mean
1984
1989
1994
1999
2004
2009
2014
Year

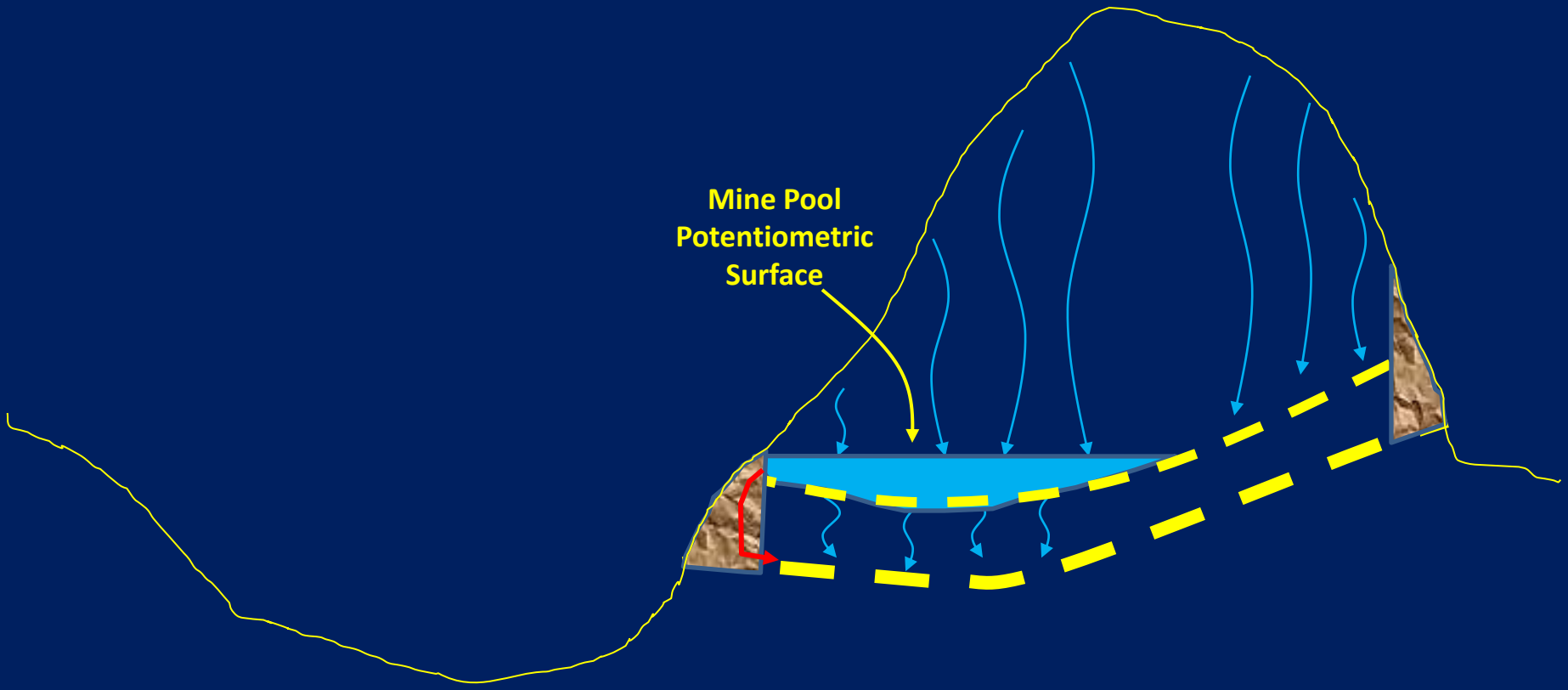

Discharge Percent of Precipitation
50
40
30
20
10
0
18 Year Gap
3 Year Gap
7 Year Gap
1969
1988
1989
1993
1994
1995
1996
2003
2004
2005
2006
2007
2008
2009
Year

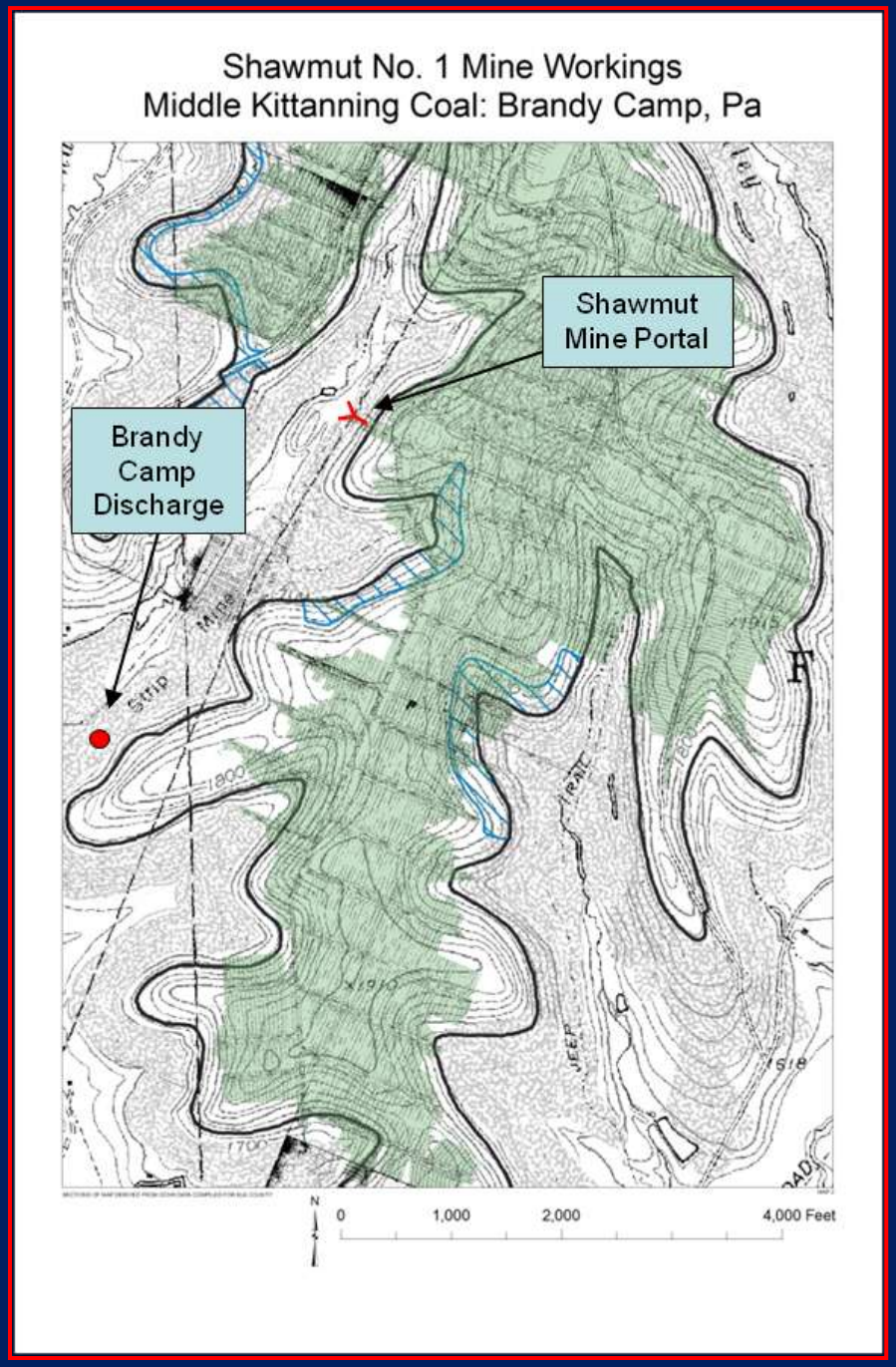
Spring of 2008 Flushing Event

- Between March 15 and April 5, 2008 the discharge increased from 4,000 L/min (1,000 gpm) to greater than 11,350 L/min (3,000 gpm).
- Concentrations of metals, acidity and sulfate likewise increased.
- Melting of a thick snowpack with more than 13.5 cm (5.3 inches) of rain.
- A distinct break in the slope of the regression hydrograph indicated a significant change in the recharge rate and flow into the lower mine.


Discharge Rate in L/Min.
12000
10000
8000
6000
4000
2000
0
1/16/08
3/6/08
4/25/08
6/14/08
8/3/08
9/22/08
11/11/08
Spillover Point


Mine Pool
Potentiometric
Surface


Mine Pool
Potentiometric
Surface

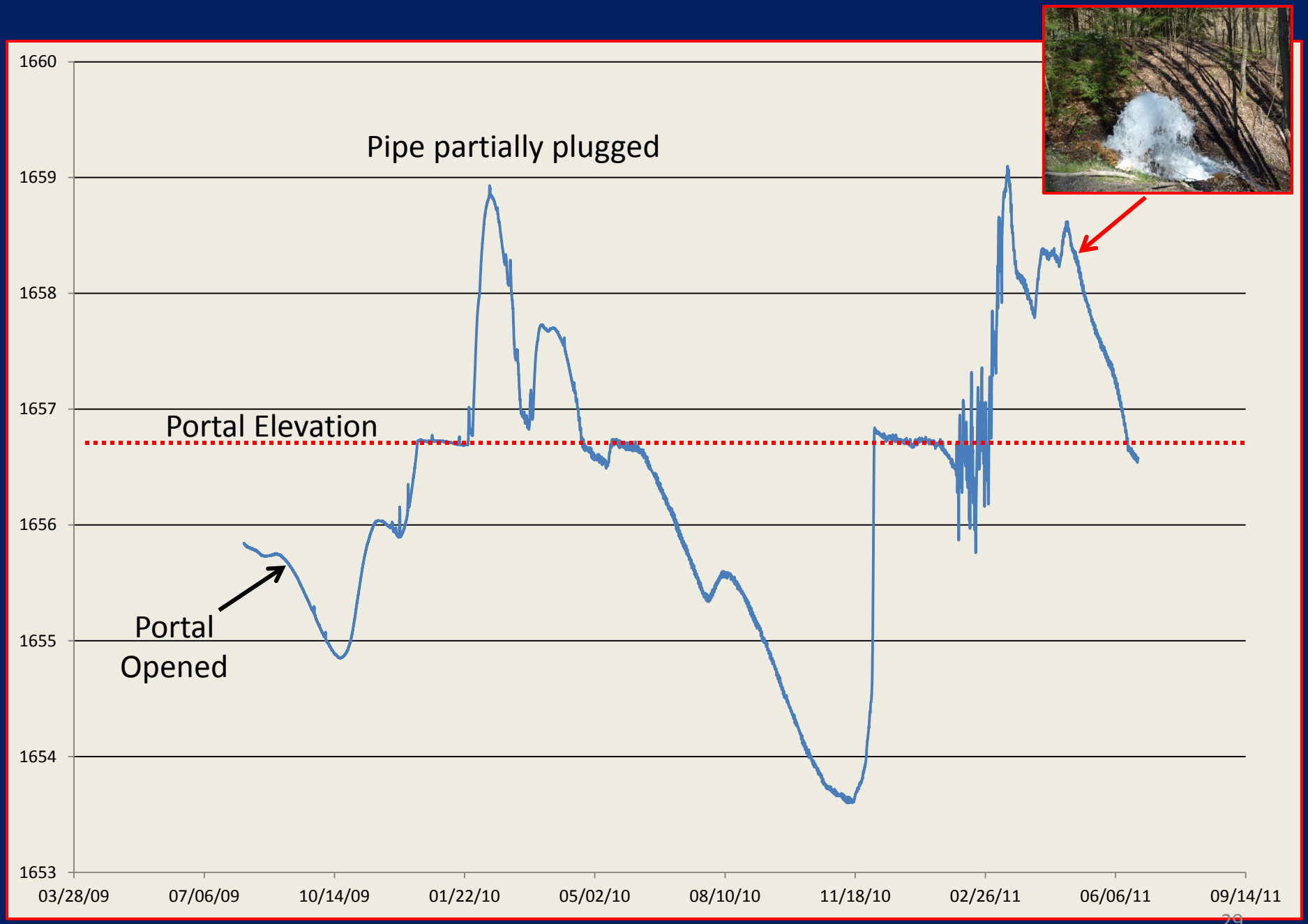


By opening up an old sealed portal we determined that a portion of the mine pool could decanted off and an upper limit to the pool level could be achieved by creating an overflow outlet.

Sept 14, 2009


October 21, 2009


May 2011


Pipe partially plugged
Portal Elevation
Portal
Opened
1660
1659
1658
1657
1656
1655
1654
1653
03/28/09
07/06/09
10/14/09
01/22/10
05/02/10
08/10/10
11/18/10
02/26/11
06/06/11
09/14/11

Disposal of the Iron Hydroxide Sludge by Injection

Additional Information

- Vertical hydraulic conductivity was calculated for the interburden between the mines (1.0×10^{-7} m/s) which supports the perched mine pool.
- The water quality of the MK is less likely to redissolve the iron. The pH averages 5.9.
- Mains and other entries are open enough to permit sufficient storage for a long time. Average opening was 1.9 meters.
- Water levels in monitoring wells indicate that there is one pool, so the works are openly connected.

Mid-July 2010 sludge injection test

- 2.8 million liters (740,000 gallons) of iron hydroxide sludge was injected into the MK mine over a three day period.
- The iron sludge averaged 2.43% solids.
- No change in the mine pool level was observed.
- No increase in the iron concentration at the discharge was noted.


Liquid Waste Handling
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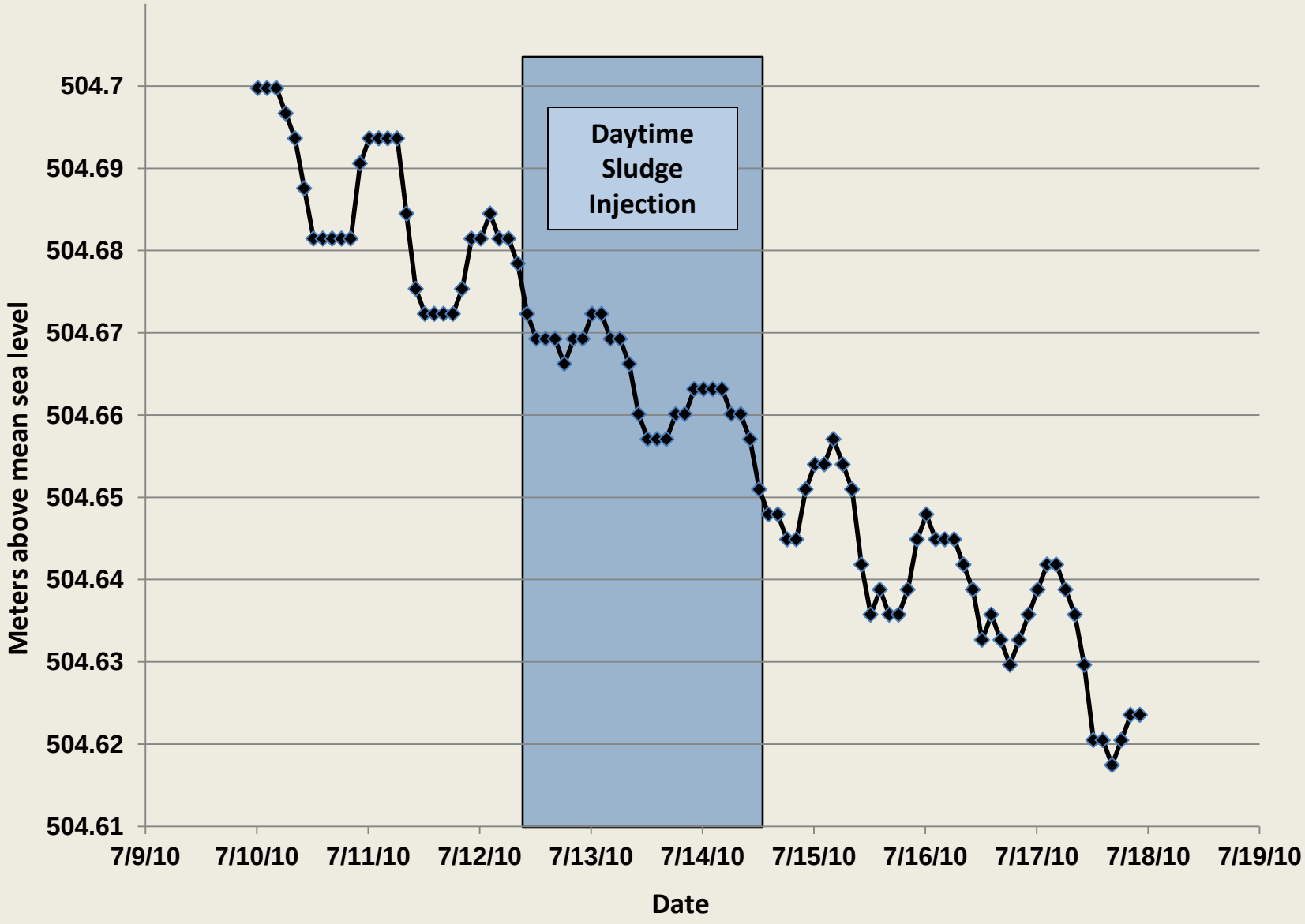
Commercial


Daytime
Sludge
Injection
Meters above mean sea level
504.7
504.69
504.68
504.67
504.66
504.65
504.64
504.63
504.62
504.61
7/9/10
7/10/10
7/11/10
7/12/10
7/13/10
7/14/10
7/15/10
7/16/10
7/17/10
7/18/10
7/19/10
Date

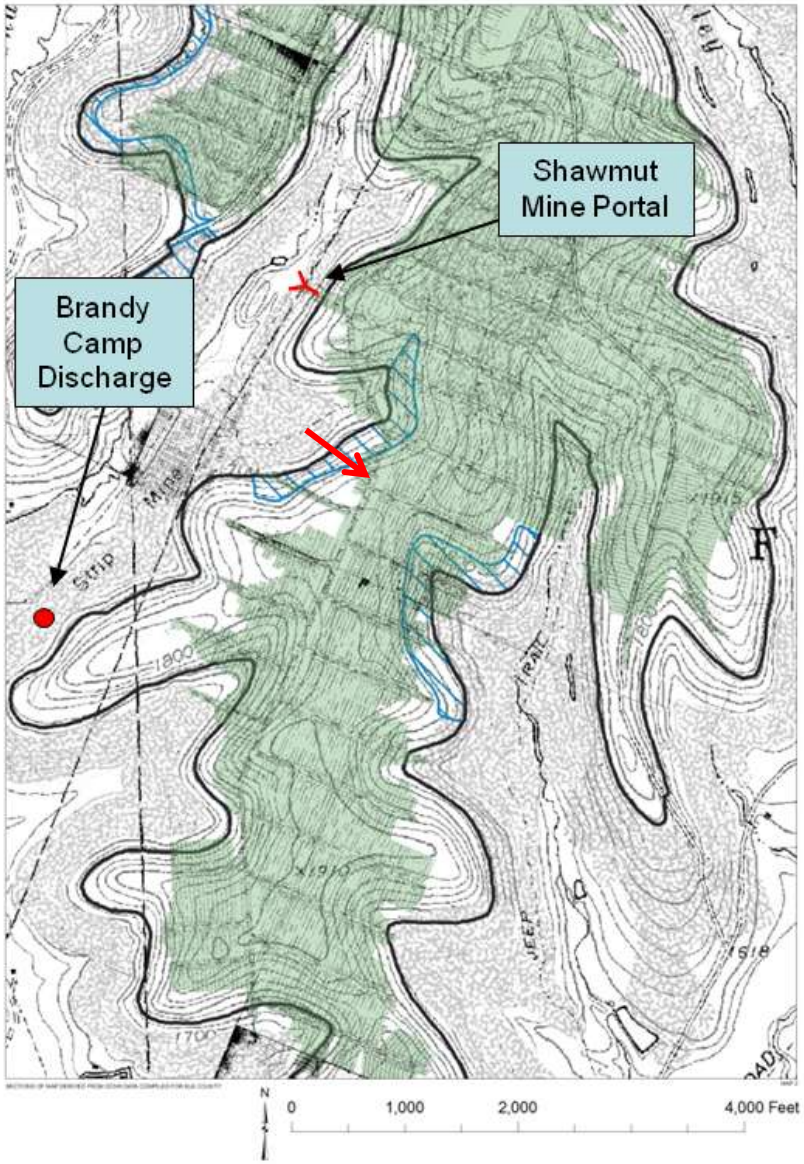
Study Results

- Increased discharge rate of the underground mines was mainly due to surface mining activities.
- The increase averaged 1.2 L/min per hectare (0.78 gpm per acre).
- The relatively low hydraulic conductivity of the clay-rich interburden created a unusual perched mine pool in the MK mine.
- Opening of the portal partially siphoned off excess mine water and helps hold the pool level down.
- The openness, water quality and perched nature of the MK mine, make it a feasible sludge injection site.

Recommendations

- Reforestation of the surface mines ASAP.
- Plant high water-use trees (e.g., white pine).
- Begin injection of the iron hydroxide sludge in to the MK mine.
- Determine if horizontal drilling could be used to drain off most of the rest of the mine pool to prevent this water from being degraded prior to entering the LK mine.

Shawmut No. 1 Mine Workings
Middle Kittanning Coal: Brandy Camp, Pa



That's All Folks!