



Iron Mountain Mine Superfund Site Long Term O&M Challenges

August 12-14, 2014

James Sickles, U.S. EPA Region 9



National Conference on Mining-Influenced Waters:
Approaches for Characterization, Source Control and Treatment
Albuquerque, New Mexico

Iron Mountain Mine Site

- Site Setting
- Mining Impacts
- Geologic Setting
- Mining Chronology
- Mining Processes
- Site Remedial Components
- O&M Challenges
- Issues and the Future

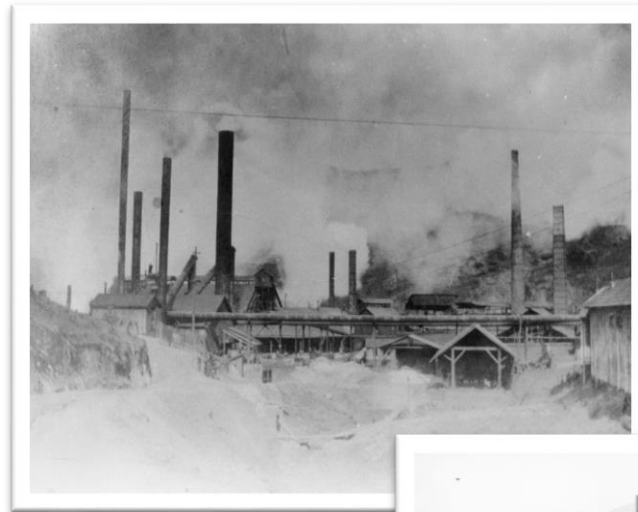
Site Setting

- Located 9 miles northwest of Redding, CA
- Consists of more than a dozen sulfide mines
- Covers approximately 4,400 acres, with over 2,500 feet of relief
- Mines produced silver, copper, zinc and pyrite

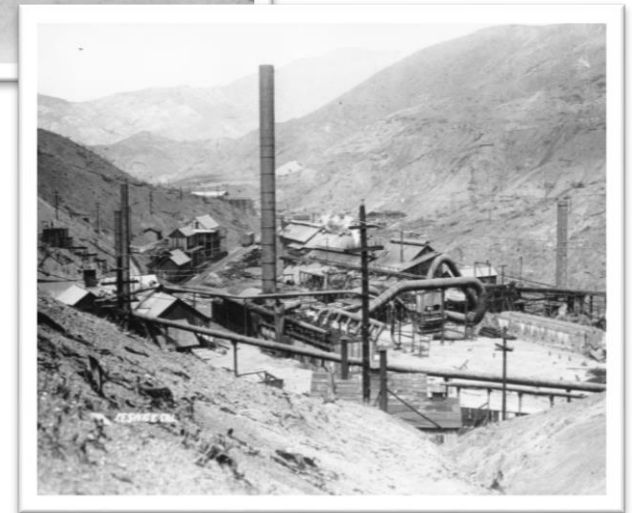


Mining Impacts

- Fish kills in the Sacramento River
- Open-air heap roasting and smelters stripped the land of vegetation for over 100 square miles along lower Spring Creek
- Acid mine water seeping into the Sacramento River, created sediment deposits in Keswick Reservoir
- Drinking water source for the city of Redding is the Sacramento River downstream



Keswick Smelter
Operations
1895 - 1907



Mining Impacts



- Mining influenced waters (MIW) with pH as low as -3.6 found in Richmond Mine workings
- 10,000 pounds of iron, 650 pounds of copper, and 1,800 pounds of zinc were discharged per day prior to remediation
- AMD entering Keswick Reservoir precipitated more than 200,000 cubic yards of metal rich sediment into the Spring Creek Arm



Geologic Setting

- Complex of nearly pure sulfide (massive sulfide deposit) and several small massive sulfide deposits
- Several zones of disseminated sulfides and a gossan (a weathered zone of iron and heavy metals, aka “Iron Mountain”)
- Country rock is rhyolite, low porosity with jointing and faulting

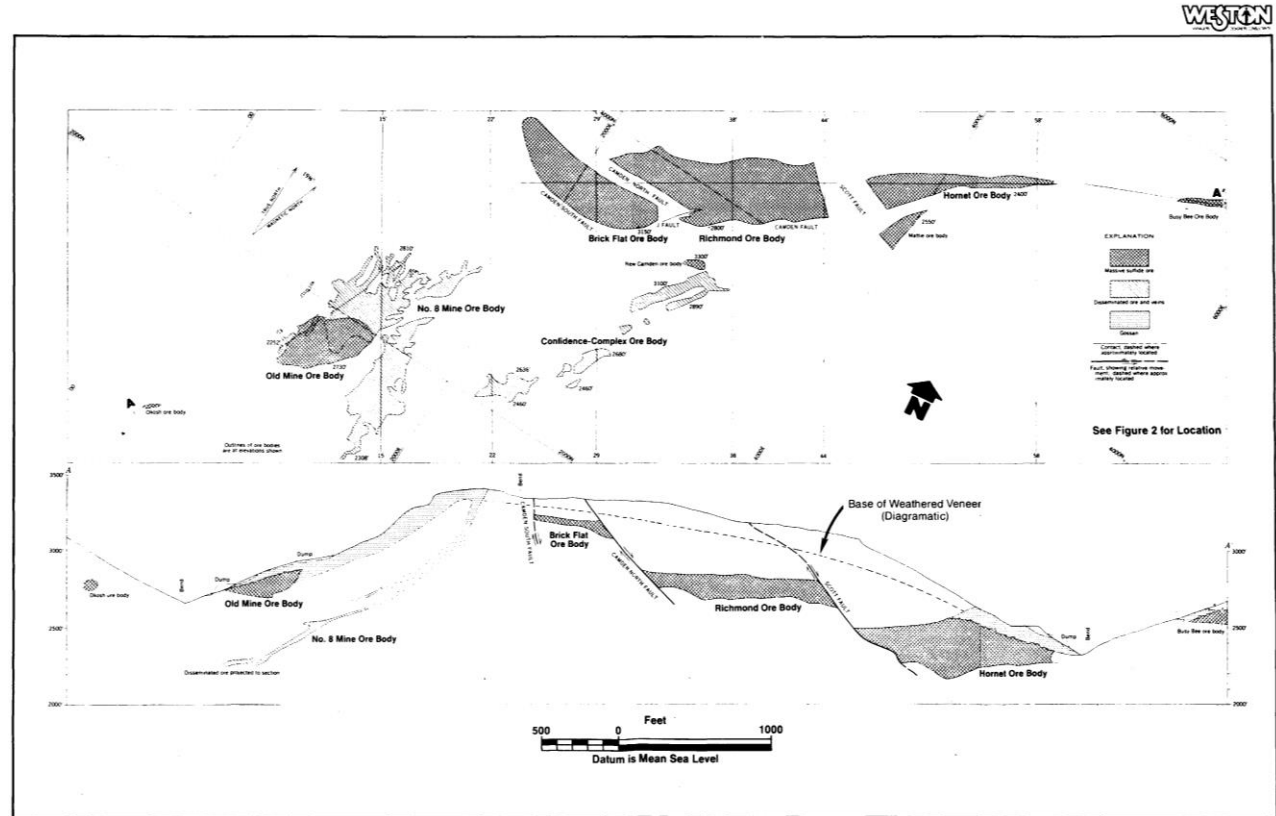
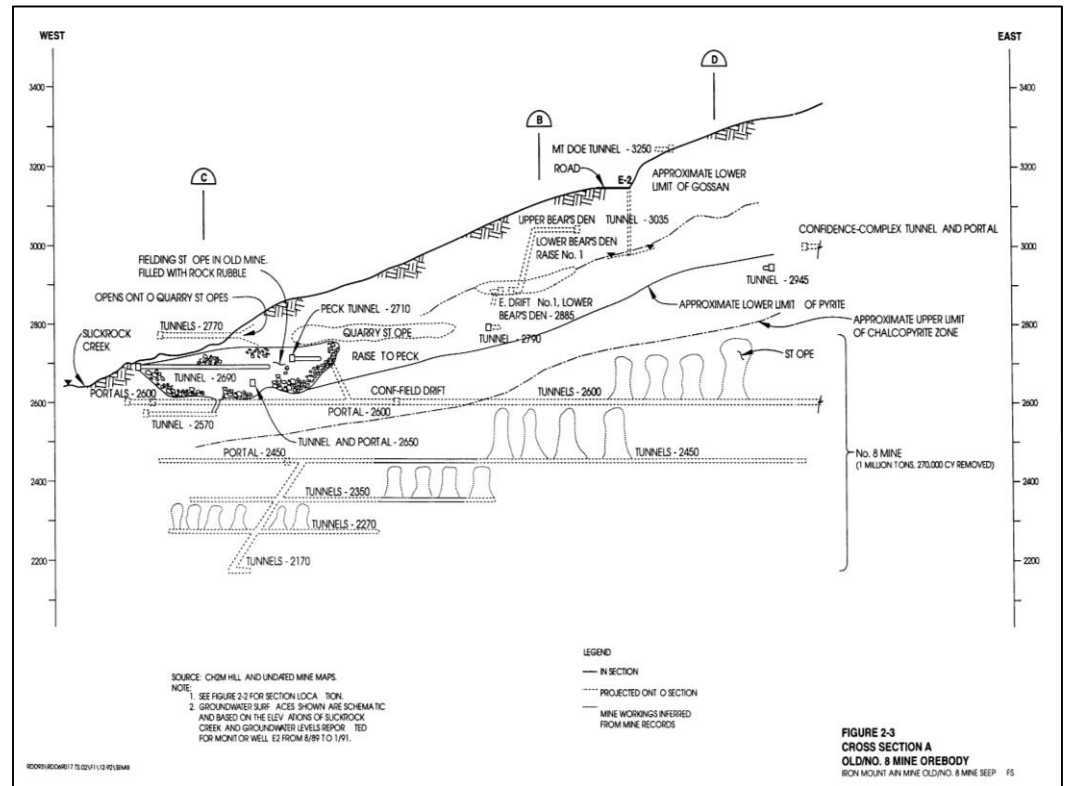


FIGURE 3 MAP AND SECTION OF ORE BODIES AT IRON MOUNTAIN (MODIFIED FROM KINKEL AND OTHERS, 1956)

Mining Chronology

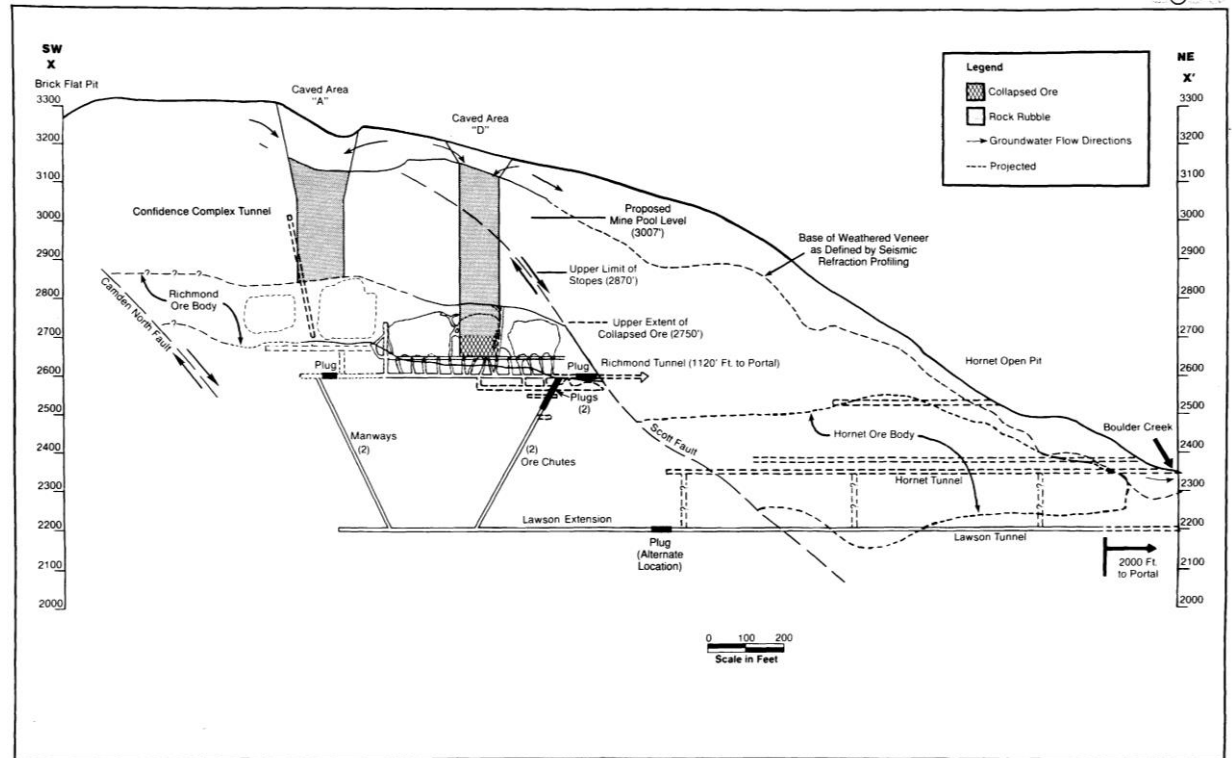
- Underground mining on south flank starting in 1880s
- In the first quarter of the 20th century was the largest copper producer in California and the sixth largest in the U.S.
- Underground mining on north flank started in 1907
- Brick Flat Pit mined by open pit method starting in 1920s
- Mining ended in 1962 with copper recovery by cementation plants in the 1970s



Typical Mine Workings on South Flank

Mining Processes

- Mining used: 1) Stopping and block caving; 2) Room and pillar; 3) Side-hill; and 4) open pit at the surface
- Collapse of workings fractured overlying rock 400 feet to the surface
- Pathways opened for air and water flow
- Massive sulfides in the unsaturated zone and can oxidize and induce convective air flow



Typical Mine Workings on North Flank with Collapse Features

FIGURE 12 CROSS SECTION OF THE RICHMOND AND HORNET ORE BODIES (COMPILED FROM UNPUBLISHED IMM DATA; LOCATION SHOWN BY FIGURE 4)

Site Remedial Components



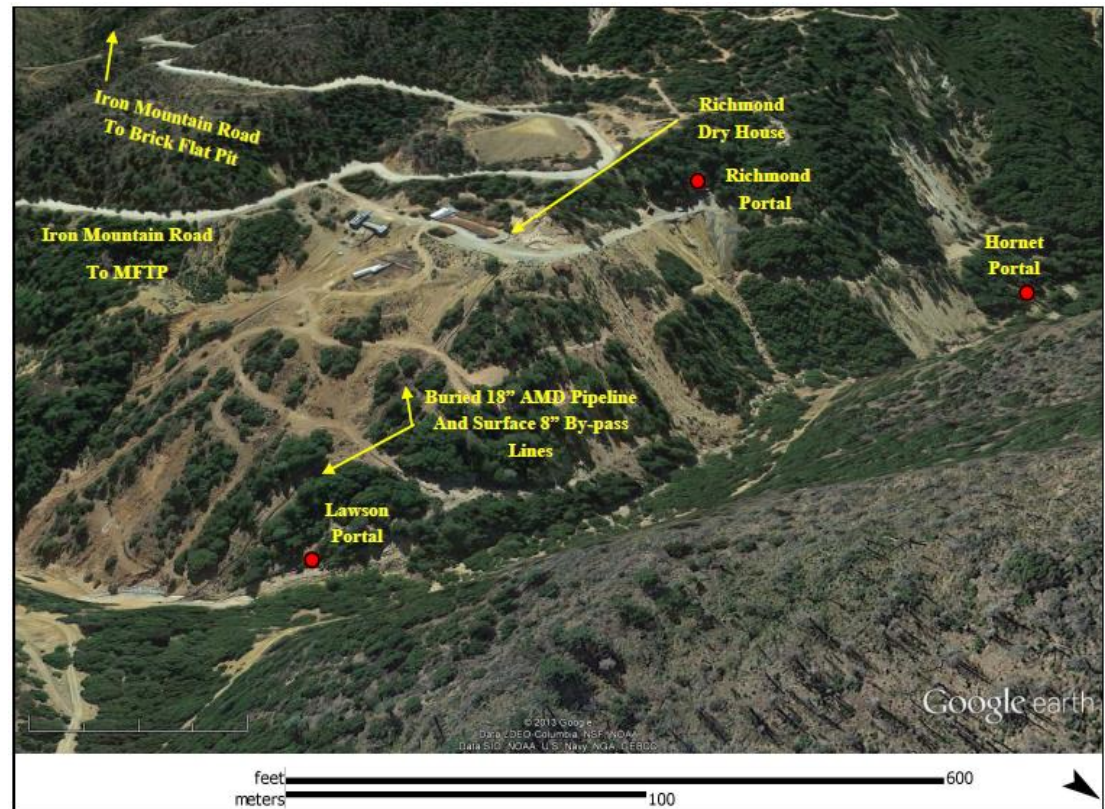
Site Remedial Components:

1. MIW collection systems – sumps, subsurface drains in the Richmond and Lawson adits, extraction wells, surface water retention reservoir and surface water controls;
2. Conveyance systems – HDPE pipelines to Minnesota Flats Treatment Plant;
3. Clean water diversion systems – tunnels and pipelines;
4. Mine waste disposal facilities – Brick Flat Pit, waste rock cells, and a confined disposal facility for dredged material from Keswick Reservoir; and
5. MIW treatment plant – lime neutralization/high density sludge (HDS) facility at Minnesota Flats.

MIW Collection Systems

Major AMD Sources

- Richmond and Lawson Adits – pH ranges 0.8 to 2.6 – flow rates up to 1,400 gpm in winter storms
- Old/No. 8 extraction wells – pH ranges 2.5 to 2.8 – flow rates up to 175 gpm
- Slickrock Creek Retention Reservoir – pH ranges 2.8 to 3.0 – flow up to 3,250 gpm



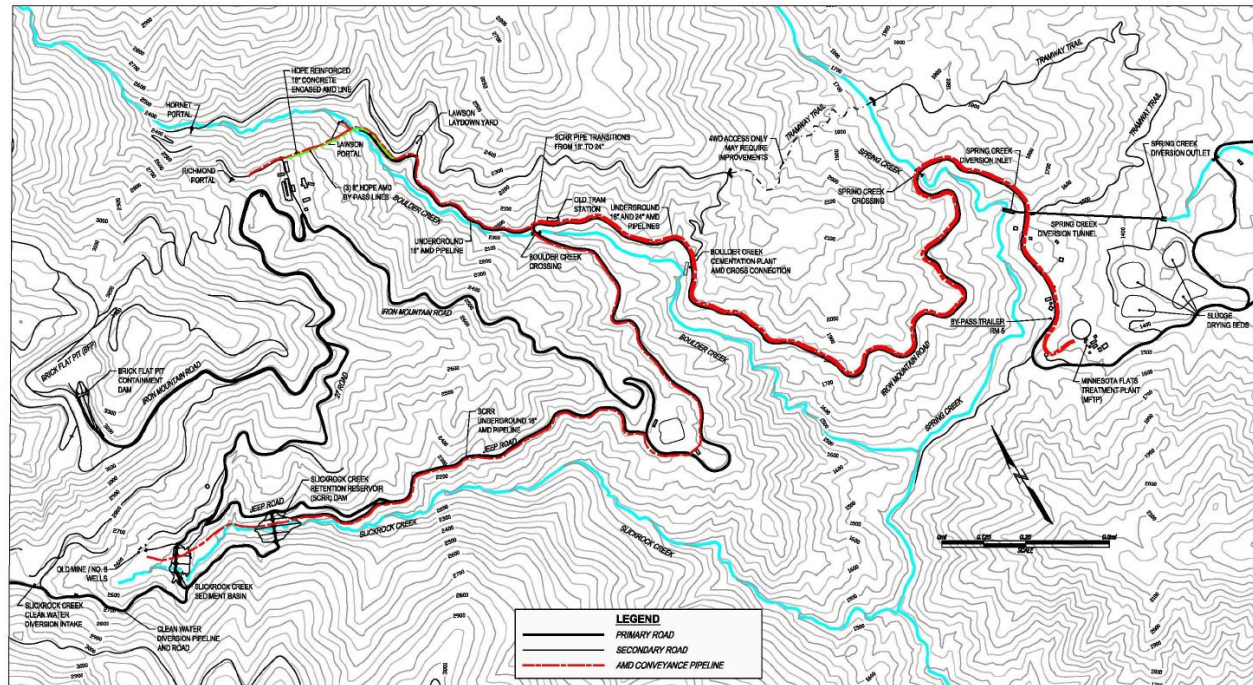
Conveyance Systems and Clean Water Diversions

MIW Pipelines

- Over 28,000 feet of 12 to 24 inch HDPE piping carrying AMD by gravity flow from the major sources on the north and south flanks to treatment Plant

Clean Water Diversions

- Slickrock Creek Clean Water Diversion which routes clean water around tailings and waste rock in Slickrock Creek drainage
- 2) the Upper Spring Creek Diversion which routes clean water from upper Spring Creek and empties into Flat Creek



Note:
See map on [Rip and Runs 7.11 and 7.12](#) for alternate access roads.

Base Topo From Aerial
Photogrammetry: 04/14/1994

MIW Treatment Plant

Minnesota Flats Treatment Plant

- Lime neutralization/high density sludge plant – design capacity of 6,500 gpm (53.5 million gals per day)
- 280 foot diameter thickener tank – Plant generates approximately 20,000 cubic yards of HDS per year that is placed in Brick Flat Pit
- The plant has a 1 million gallon AMD emergency storage tank that can handle 2 weeks of flow in the summer and less than a day in large winter storms



O&M Challenges at Iron Mountain Mine

1. Mineral precipitates in the MIW pipelines due to microbial $Fe(II)$ oxidation occurs over short timeframes, results in loss of up to 40% of pipe capacity and air vent spills
2. Deterioration of polyurethane liner in Upper Spring Creek Diversion, due to steep elevation drop and excessive flow velocities
3. Significant loss of leachate from HDS stored in the lined Brick Flat Pit landfill due to potential leakage into open fractures in pit wall and/or into underlying mine workings
4. Deterioration of concrete plugged ore chutes in the Richmond Mine

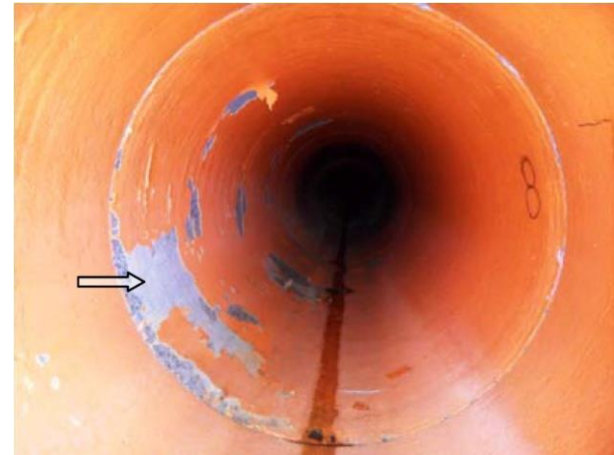
O&M Challenge – Formation of Pipe Scale

- Pipe scale formed by varying pH in MIW due to microbial oxidation of $Fe(II)$ in piping scale, as has been shown by USGS research, which will be discussed in the next presentation
- Precipitation of scale occurs in short time frame, reduces up to 40% of pipe capacity causing blockage and releases through air vents
- Traditional cleaning methods problematic due to HDPE piping and burial of piping distorting pipe shape



O&M Challenge – Deterioration of Liner in Upper Spring Creek Diversion

- Diversion is 1,200 feet long unlined concrete arch tunnel and reinforced concrete pipe
- Diversion system drops 280 feet in elevation from upper Spring Creek to Flat Creek – designed to convey 800 cubic feet per second (cfs)
- Flow velocities at 800 cfs range from 15 feet per second (fps) to 70 fps. Usual design flow is 15 fps
- High flow velocities in winter storms result in abrasion-erosion and cavitation with loss of cement up to 1 ¼ inch and lining failures of up to 40%



Liner Failure in Pipe



Erosion of Concrete Approximately 1" Deep

O&M Challenge – Brick Flat Pit Landfill

Leachate Leakage

- Brick Flat Pit was first lined in 1989 and designed to place waste materials from site. It was expanded in 1993-1994
- Currently estimated to cover 44 acres and contain 494,000 cubic yards of sludge with a depth of 80 feet
- At the current fill rate of 20 to 25,000 cubic yards per year; a third phase of the containment dam will be needed to allow another 150 years of use



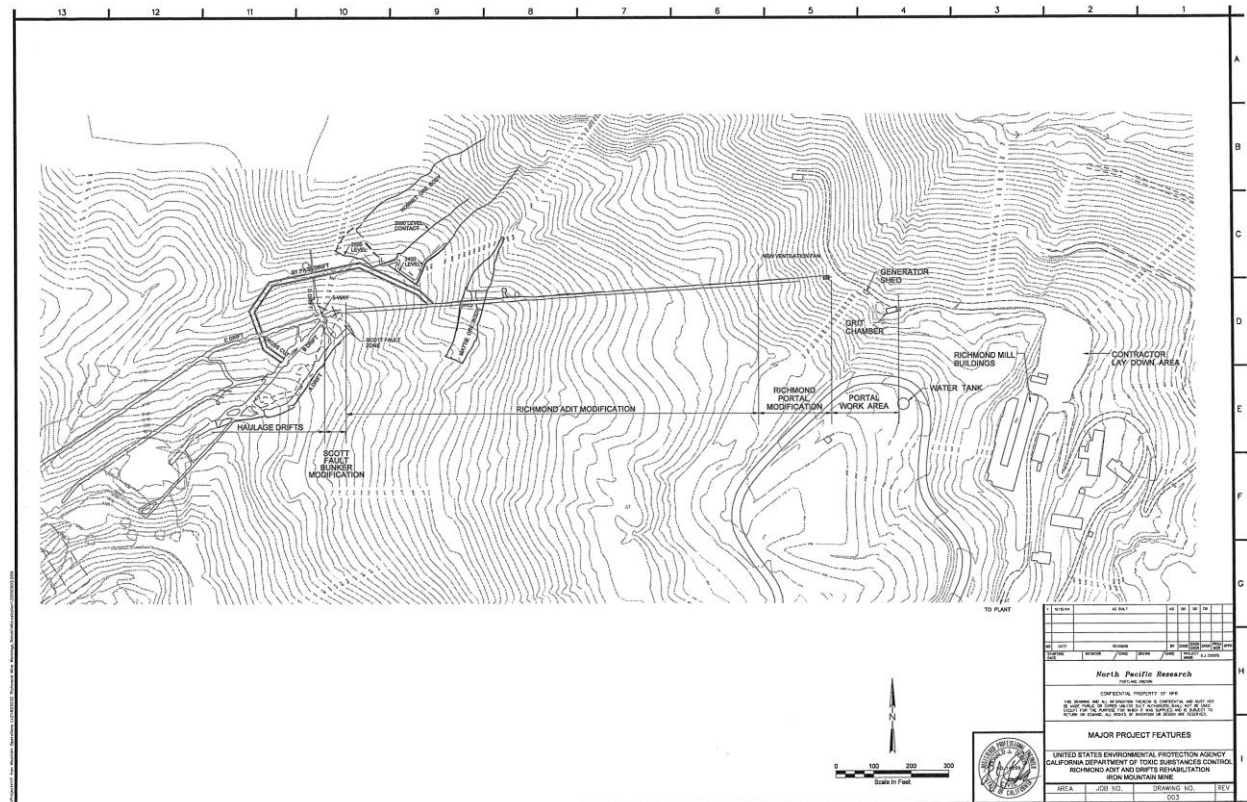
O&M Challenge – Brick Flat Pit Leachate Leakage

- Filtrate flow in 2004 dropped from up to 100 gpm discharge to a trickle during winter operations
- Summer 2004 tracer study and investigation have not been able to trace leakage – assumed to be leaking through fractured rock in unlined side walls of pit
- Investigation into loss of filtrate being evaluated to determine path of leakage and how to address in needed



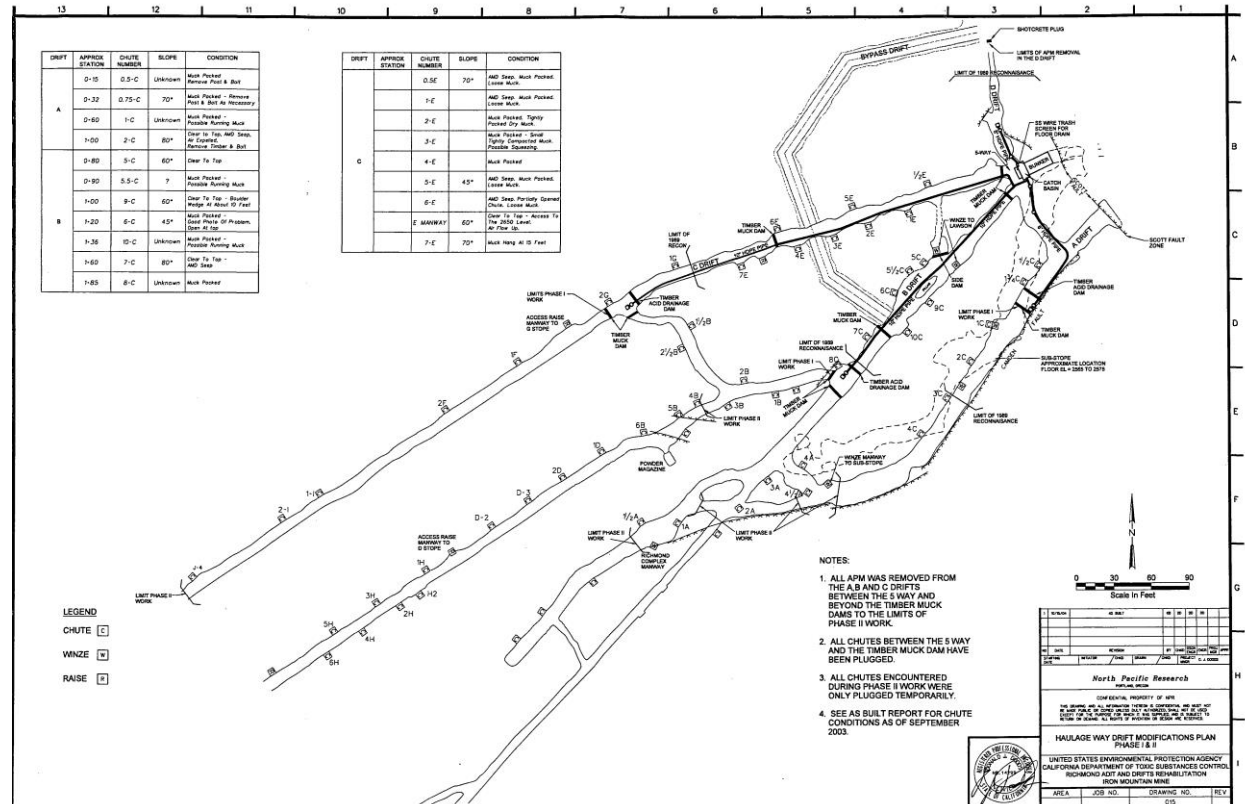
O&M Challenge – Richmond Adit Chute Plugs

- Rehabilitated in 1989-90 and again in 2001-2003 creating configuration of the “5-way” catch basin (sump) where four haulage drifts intersect 1,400 feet inside mountain
- The “5-way” catch basin captures AMD from AMD dams in the A Drift, B Drift, and C Drift
- 18 inch pipeline extends from the “5 way” to a grit chamber outside the portal with a 6,000 to 7,000 gpm capacity
- Typical AMD pH ranges from 0.6 to 1.4 (lower pH in the stopes above)



O&M Challenge – Richmond Adit Chute Plugs

- Timber and stainless steel AMD dams, 4 to 5 feet high, with AMD intakes constructed in A, B, and C drifts downstream from muck timber dams
- Muck is waste rock, mine debris and fine-grained, silty, and pyritic material with “quick” characteristics (sudden impacts causes the material become liquid) found throughout the workings
- 22 ore chutes from overlying stopes were plugged with concrete and shotcrete due to past surges of up to 3,000 gals of extremely acidic MIW and mine debris



O&M Challenge – Richmond Adit Chute Plugs

- Drifts A,B, and C are flat at the 2,600 level with multiple chutes, raises and manways – ore chutes extend upward from the drifts to an access level at 2650. Ore mined above at the 2700 level were dumped through the chutes to the haulage adit
- Five major levels occur in the Richmond above the drifts up to the 3000 level – Larger stopes were rectangular and 60 to 150 feet on a side and 60 to 200 feet high with 40 to 80 foot unsupported spans.
- Ore chutes were packed with sulfide muck and clayey waste, others with large rocks suspended in the chute – some with pooled AMD or wet muck at up to 100 degrees

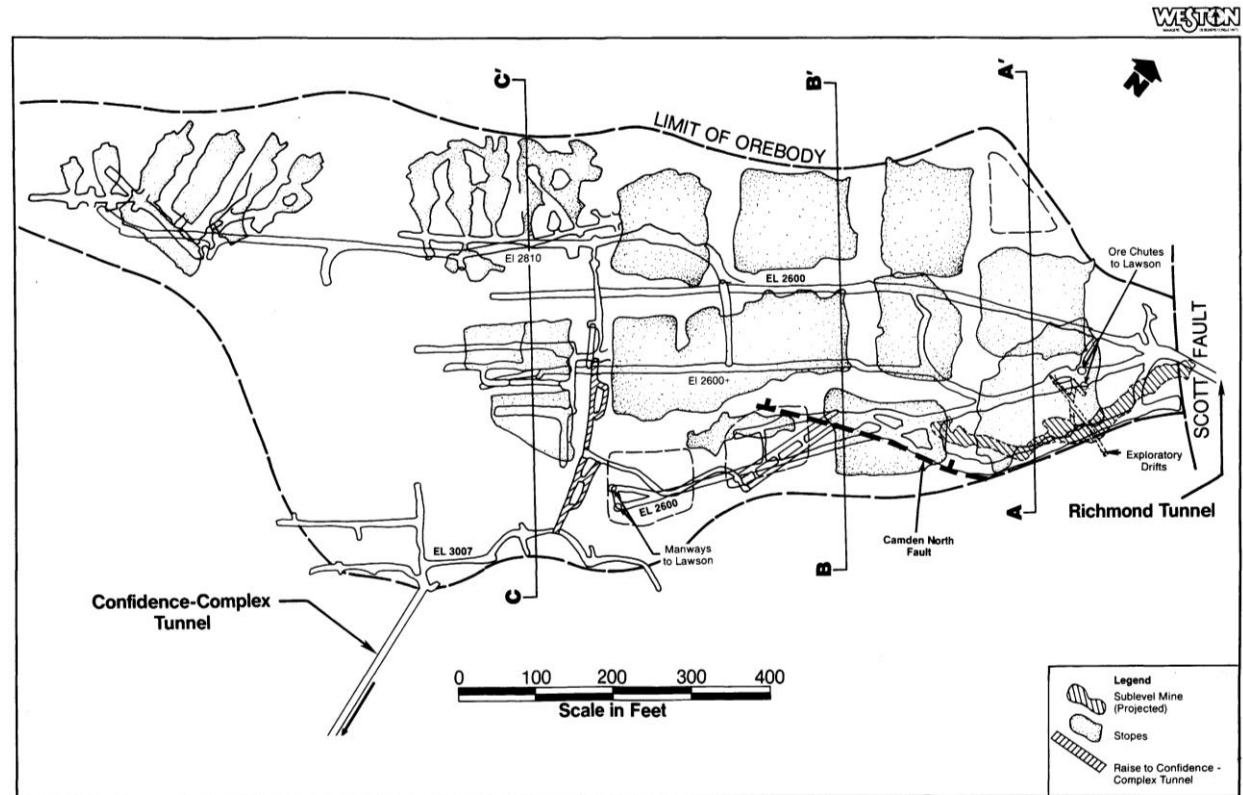
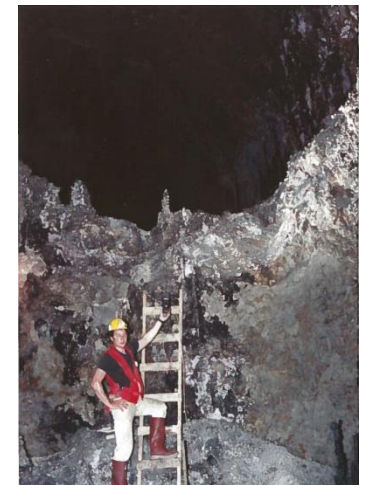


FIGURE 8A PLAN OF HAULAGeways AND STOPES OF THE RICHMOND MINE (COMPILED FROM UNPUBLISHED IMM DATA)

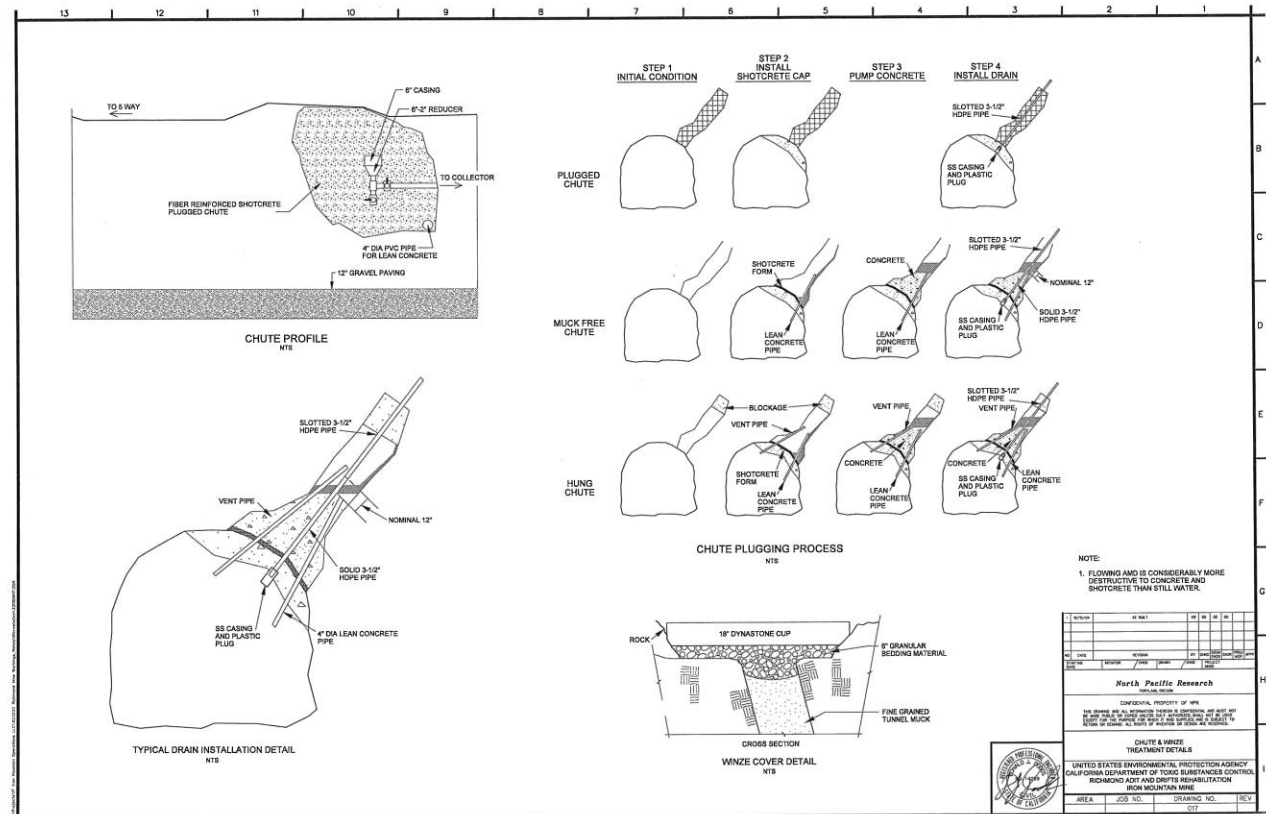
O&M Challenge – Richmond Adit Chute Plugs

- The 2650 level entered in 1990 and 1991 to evaluate conditions and compare historical mine mapping with actual conditions
- Re-entry encountered extreme heat – greater than 120 degrees due to exothermic reactions of bacterially driven oxidation of massive pyrites
- AMD did not appear to be pooled at the bottom of the stopes except at isolated locations
- AMD pH was measured as low as -3.6 along with abundant crystallization of acid sulfate salts



O&M Challenge – Richmond Adit Chute Plugs

- Due to a 800 gallon AMD surge with 50 cubic yards of mine debris during the winter 2003-2004, it was decided to plug the ore chutes for worker safety and to control potential surges
- Three types to be plugged – 1) those plugged with muck, 2) those with hung up material in the chute and 3) those which were muck free
- Chutes were covered with a shotcrete cap and a hole drilled through the cap and concrete pumped into the chute above – a slotted 3 ½ inch HDPE pipe was installed through the concrete plug



O&M Challenge – Richmond Adit Chute Plugs

- Inspected annually – usually in the summer to avoid wet winter conditions
- As of the 2013 inspection all ore chutes are considered to be dangerous and to be avoided. Shotcrete on walls and ceilings of drifts is spalling and to be avoided
- A drift has two leaking chute plugs, B drift has seven leaking chute plugs, C drift has nine leaking chute plugs, one of which is leaking at greater than 5 gpm



O&M Challenge – Richmond Adit Chute Plugs

- Study to evaluate a subset of previously treated chutes that were plugged with concrete and those not treated but plugged with cemented mine muck
- Techniques to be used
 - surfacial evaluation of concrete and rock
 - non-destructive testing using hammer sounding, impulse response, impact echo and rebound hammer
 - ultrasonic pulse velocity to measure stress and shear wave velocities
 - petrographic analysis of concrete and materials
- Re-enter 2650 level to compare existing conditions with 1990 reconnaissance
- Compile a 3-D map of the mine workings to better evaluate orientations of mine workings and ore chute configurations

Issues and the Future

- **Current O&M Issues consists of:**
 - 1)Mineral Scale
 - 2)Liner Failure in Upper Spring Creek Diversion
 - 3)Brick Flat Pit Landfill Leakage
 - 4)Richmond Adit Ore Chute Plugs Deterioration
- O&M conducted by Iron Mountain Operations under contract to AIG Insurance until 2030
- **Future O&M Issues**
- EPA is responsible for O&M in 2030 – will receive \$514 million to pay for all future O&M in perpetuity
- 1,800 to 3,200 years of acid generating potential remaining
- Future evaluation of new remedial technologies and potential metals recovery from AMD and mine wastes

Questions?



Sunset at Iron Mountain Mine