



ALKALINE IRON STAINING **A TREATMENT ALTERNATIVE?**

By Tiff Hilton-Ben Faulkner-Jamie McPeck

Alkaline iron water is easily treated but can be expensive and a PITA depending upon the type of treatment used. Some of the current treatment alternatives are as follows.

Sodium Hydroxide (Raising pH)



Malestrom Oxidizer (Physical Oxidation)



Hydrogen Peroxide (Chemical Oxidation)



Staining (Transition of Fe+2 to Fe+3)



The Journey Begins

My Iron Staining Journey actually began in 1981 and continues today. The information obtained over the 44 years centered around 3 down dip drift mines in the Pocahontas 6 seam, 1 up dip drift mine in the Pocahontas 6 seam, and an alkaline iron discharge associated with an under-drain from a refuse area. Interestingly enough, the four drift mines offered up an important “Revelation” in addition to the utilization of staining as a treatment alternative. More about the “Revelation” later.

Mine No.50-Down Dip P6 Drift



Mine No.59-Down Dip P6 Drift



Mine No.62-Down Dip P6 Drift



Pocahontas Mine-Up Dip P6 Drift



Mine No.50-Down Dip P6 Drift

Mine

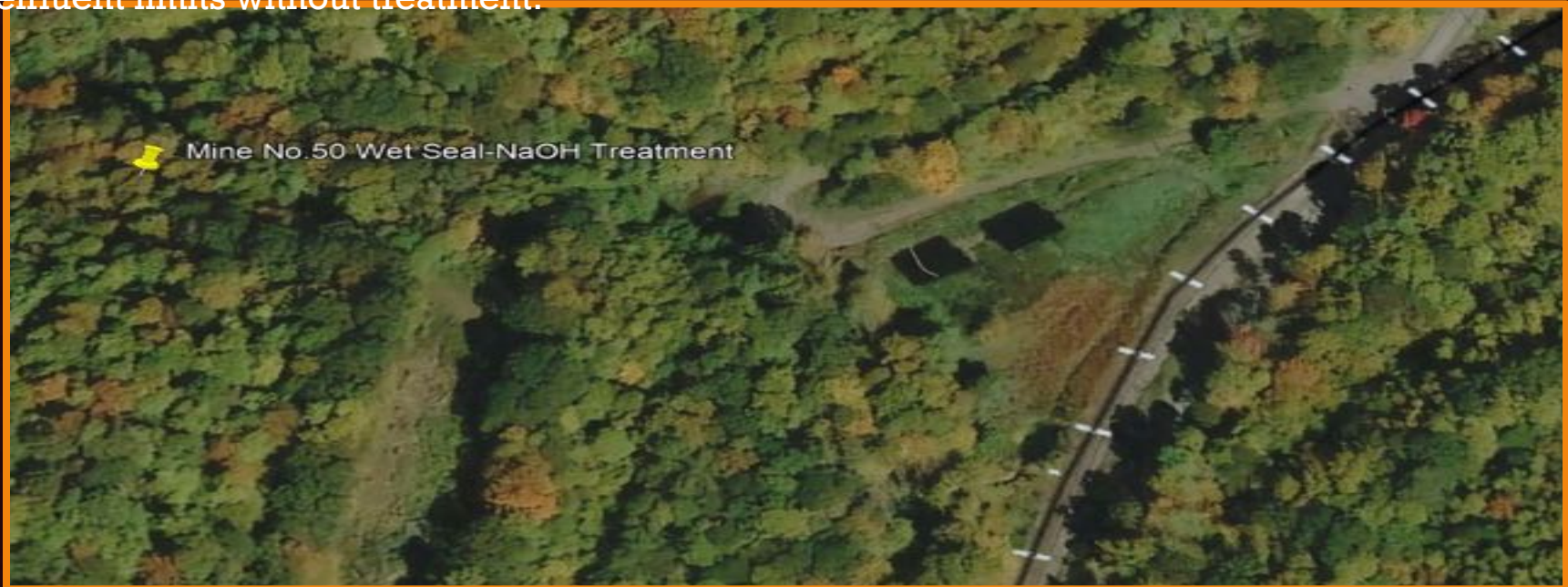
In 1978, I left a very profitable Coal Company in Buchanan County, Virginia, to go a very non-profitable Coal Company in Anjean West Virginia by the name of Leckie Smokeless Coal Company. Leckie Smokeless had been started by W.H. Leckie (from Scotland) in 1919 and if you were wondering how Anjean got its name-he named it after his wife and daughter. By 1978, the company had changed ownership and the glory days of coal were in the past. Remaining were two, (what we in the profession call) “dog-holes” (awful underground mines) and one surface mine. To give you an example of how awful; Mine No.50 had 26 pumps in the mine. This was a small mine and it was amazing that you could find enough room to set 26 pumps. However, and this is the part you won’t believe and I promise it is the truth. Remember that this was a down dip mine from the entrance of the mine to the back of the mine. The 26 pumps were connected to a couple of discharge lines to take the water outside. Without me telling you, where did the discharge lines end on the surface? That’s right, at the entrance to the mine and the water was simply running back into the mine. Obviously, it required 26 pumps to keep the water circulating (LOL). I turned to the guy who I came up from Virginia with and he looked at me—and it was obvious what we were both thinking—Oh Sh_t, what have we done? Anyway—47 years later I am still there and catch myself saying, Oh S_it, what have I done. On the other hand, I have learned a great deal about water and in basic survival. Mine 50 was eventually reclaimed but had a wet seal that discharged alkaline iron water that stained the adjacent un-named tributary. Sediment ditches were constructed and the water was treated with 20% sodium hydroxide. What always puzzled me until a few years later was the fact that **we never had any alkaline iron water while the mine was active and pumping was ongoing.**

This last statement should give you a clue about the “Revelation” I spoke of earlier.

Around 2009, I was doing water related consulting work for the WVDEP, Special Reclamation Division and I recommended that a flume be constructed to take advantage of the staining properties of this type of water. After all, it did a dandy job staining the un-named tributary, why not use that to our advantage and minimize the treatment cost? As it turned out, it eliminated the treatment cost entirely.

Mine No.50-Down Dip P6 Drift Mine

Special Reclamation Continued
“What the heck?” and constructed a grouted flume and two polishing ponds as illustrated below. The polishing ponds themselves testify to the success of staining (no orange color). This system worked for 15 years at which time the water met iron effluent limits without treatment.



Mine No.50 is also the place where I began to understand that the staining occurs during the transition from Fe^{+2} to Fe^{+3} . Once totally oxidized the remaining solid Fe^{+3} would settle but not stain. To know how to control the rate of oxidation (Fe^{+2} to Fe^{+3}) for maximizing staining, eludes me to this day.



Mine No.59-Down Dip P6 Drift

Mine

In 1981, we opened Mine No.59 in the Pocahontas No.6 seam about 1.5 miles upstream of Mine No.50 adjacent to Big Clear Creek in Greenbrier County. An all down-dip mine as with Mine No.50, we put this in as a “Show Mine”, complete with pine trees along the highwall, a trout pond next to the entrance portal, and an underground so well kept that finding a gum wrapper on the ground triggered a major investigation for the guilty party. This along with the productivity, landed the mine on the cover of Coal Age Magazine in 1985.



Mine No.59-Down Dip P6 Drift Mine

Continued

In 1985 we left Mine No.59 to open up Mine No.62, another all down-dip Pocahontas 6 seam drift mine. As Mine No.59 filled up and began to run out the drifts (before sealing), we immediately began treating for alkaline iron. This was despite the fact that **while the mine was active, no treatment was necessary**. Starting to sound like a broken record? Wait until we get to Mine No.62. All 3 of these initial mines were put in where the drifts were the highest points in elevation in accordance with the regulatory policy of putting all drift mines in down-dip. I once heard someone at a conference say that doing this would eliminate the oxygen and no bad water would be produced. I guess they forgot to tell the mines that. The "Revelation" is picking up steam. Stay tuned. Well, we mined No.62 (next chapter in the story) and when completed, went back to Mine No.59 to try and reach some additional reserves that we didn't get on the first go around. We had been treating the water from the 59 drifts with 20% sodium hydroxide and set up a 600 gallon per minute pump to dewater the mine. After we dewatered the mine, **we did not treat any water while the mine was active**. Pumped plenty of water but didn't have to treat any. Once mining was complete, the company moved to a new mine in the Firecreek seam after in



Mine No.59-Down Dip P6 Drift Mine

Continued

As you already suspect, the mine filled back up with water and treatment was required. Leckie Smokeless was purchased in or around 1997 by Royal Scot Minerals and ultimately filed for bankruptcy a few years later. Special Reclamation assumed control of treatment and installed an AquaFix water wheel treatment system. Jumping ahead to present day, they decided to put in an iron staining bed along with a wetland and additional polishing ponds and the system is performing as expected.



Mine No.59-Down Dip P6 Drift Mine

Continued

BEFORE: AquaFix Water
Wheel



AFTER: Staining Bed/Wetland/Polishing
Pond



Mine No.62-Down-Dip P6 Drift

Mine

In 1985, we opened Mine No.62 in the Pocahontas No.6 seam about 2 miles up Brown Creek, a tributary of Big Clear Creek. As with the other 2 mines, water treatment began after operations were completed and wet seals were installed. After alkaline iron water began to discharge from the seals, chemical treatment was required or so I thought at the time. Consequently, I began treatment by raising the pH up with anhydrous ammonia and applying coagulant and flocculents to quickly settle out the iron. Below, you can see a series of sediment cells that collected the sludge after treatment. Another PITA relative to sludge disposal.



Mine No.62-Down Dip P6 Drift Mine

Continued

During this time of chemical treatment, I ran across a lady by the name of Jo Davison (The Bug Lady) who had some success at utilizing bacteria to remove iron from water. Getting to know her introduced me to new four letter words that I didn't even know existed. A very colorful individual to say the least but dedicated. She couldn't have been more than 5' tall and said she spent 25 year studying bacteria in the Okefenokee swamp in Florida. She gathered up 125 different bacteria that consisted of floaters swimmers, and sinkers. She even had a few prolific bacteria shipped in from Sweden for obvious reasons (LOL). However, before she would put the bacteria in the water, she had me ship in several tons of Zeolite from out West to eliminate residual ammonia from the ponds. That was my introduction to Zeolite as a Cation exchange material. Years later I would conduct research with Zeolite using Acid Mine Drainage (an amazing reusable material that takes out manganese, iron, aluminum, hydrogen ions (acid), and a number of other metals. I learned that chicken farmers spread it on the chicken coop floors to adsorb the ammonia to keep from scalding the chicken's feet. Why? Turns out that chicken feet are a big export item to China for consumption. So, I put the Zeolite in the sediment cells and removed the ammonia and she introduced the bacteria into the cells by using impregnated activated carbon. She then had me add some hay bales as a carbon source and install wooden baffles to force sub-surface flow. Needless to say, as seen below, results were 1



Mine No.62-Down Dip P6 Drift Mine

Continued

Sorry to get off topic, but sometimes there is a story within a story and this is it. Added to this story is Mike Daily. He helped me with the other 10 treatment sites across the property. He was self-taught (a genius) and spent his evenings reading Mother Earth News. Mike volunteered that the reason the process was not working the way it was supposed to was because the bugs were hungry. He said they needed phosphorous, potassium, and nitrogen (Mother Earth News). Well, where would you find this at a coal mine? He went to our hydroseeder and got two bags of fertilizer and poured them in the entrance channel of the first sediment cell. Within 24 hours, the water went from looking like

THIS



TO THIS



Effluent limits were met and treatment from that point on was two bags of fertilizer once a month. Like Mike said, “The Bugs were hungry”.

Mine No.62-Down Dip P6 Drift Mine-The Rest of the Story

Continued

As Mine No.62 was part of the same bankruptcy as Mines No.50 and No.59, Special Reclamation reclaimed the site in 2004 and whoever did the design on the drainage system must have partially recognized the possible benefits from using staining to help treat the water.

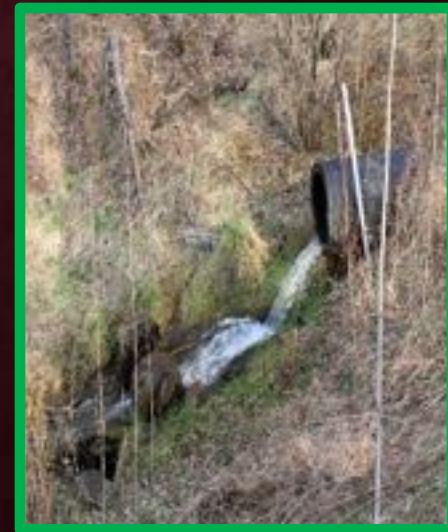


You can see a very long ditch in the shape of a loop which the designer forced the water to flow through. The easiest way to get the water to the sediment cells was without the loop by taking it directly to the entrance channel to the cells. Staining must have played a role in his/her thoughts.

Mine No.62-Down Dip P6 Drift Mine

Continued

Staining continues to remove iron after 21 years. See below.



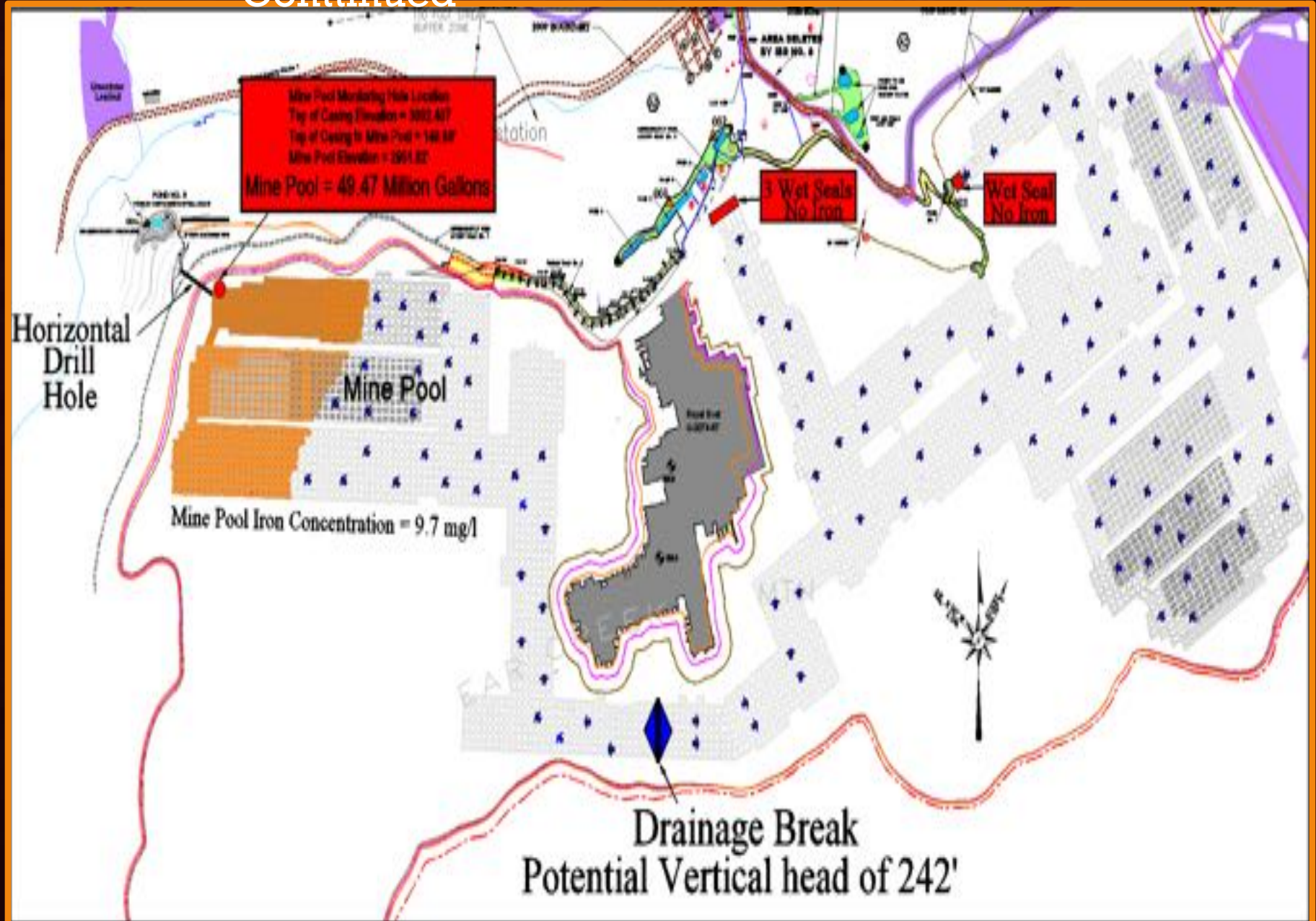
Pocahontas Mine-"The

Revelation"

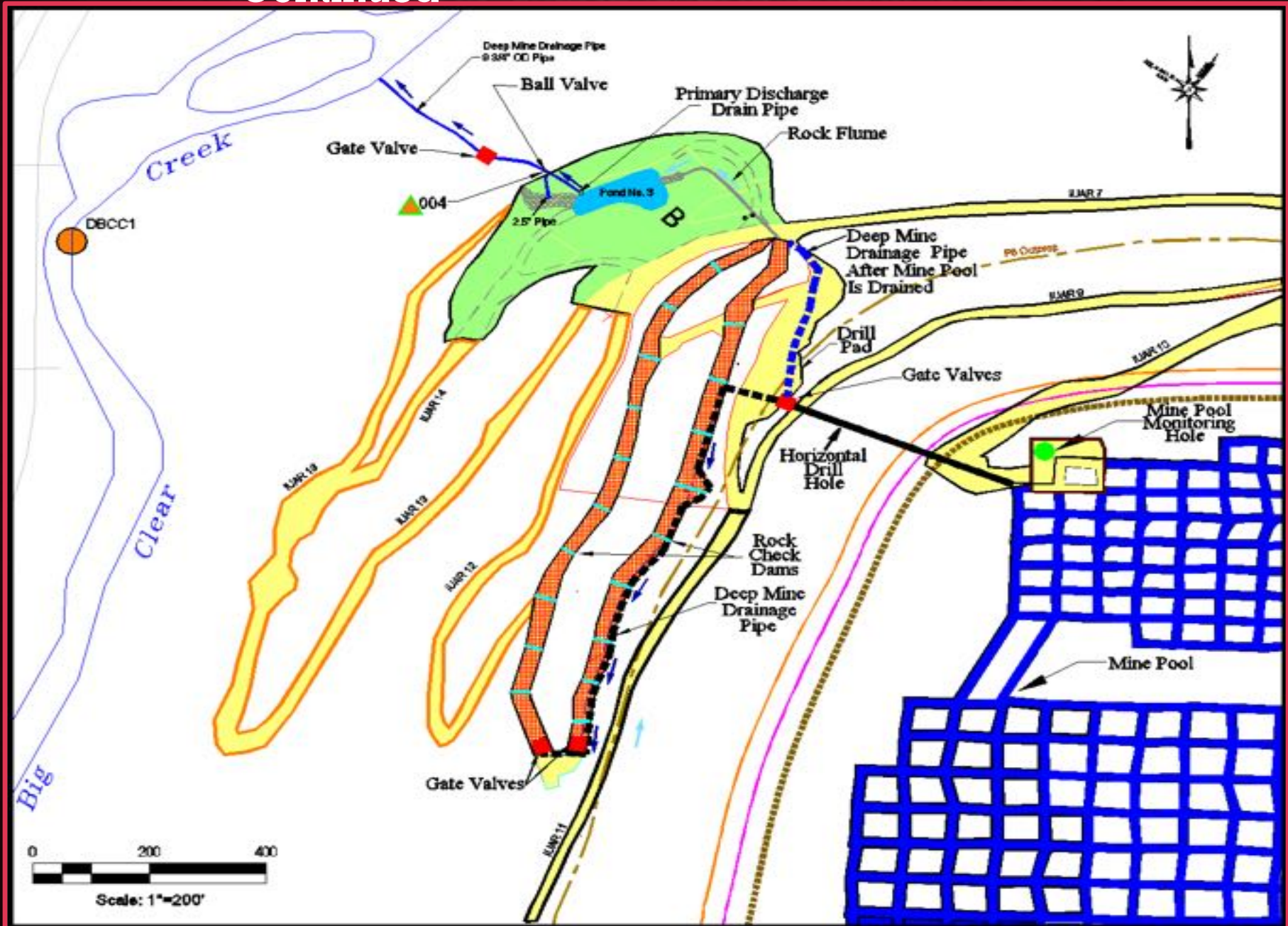
The Pocahontas Mine is a 6 seam and was purposely permitted for up-dip mining based on the three previous down dip mines permitted in the 1970's/1980's that produced alkaline iron water, that are still being treated for such present day and because a previous adjacent Pocahontas mine was put in up-dip without producing any residual alkaline iron water. All water discharging East of the Drainage Break in the Pocahontas Mine (see the following illustration) is alkaline but low in iron and meets iron related effluent limits. The water West of the Drainage Break became impounded and if like the 3 down dip mines, should contain approximately 10 mg/l of alkaline ferrous iron water if the evolving theory on up-dip versus down-dip was proven true. If this could be verified, it would eliminate the possibility of a change in the geology that might be the reason for the absence of alkaline iron water east of the drainage break. Consequently, a plan was developed to drill a horizontal hole into the lowest elevation in the impounded water in order to drain the existing pool of 50,000,000 gallons of water. Besides water quality, the pool would be drained in order to complete the required PUMA (Post Underground Mine Assessment) in moving forward to get the permit released. Failure to drain the pool and the fact that the ultimate vertical head of the mine could reach 242', which could be problematic relative to getting the permit released

The next consideration was if the water turned out to contain iron, how would it be treated as the mine Pool was drained. The first method of treatment considered was the use of sodium hydroxide (chemical treatment) to help chemically oxidize the dissolved ferrous iron to the solid ferric iron which would induce precipitation (settling of the iron in a pond). This, in fact is how many sites with this type of water are treated. The problem with using sodium hydroxide or a chemical/physical oxidizer is the cost of the chemical/process and the cost to remove the sludge created from the iron settling in the treatment pond. Also, chemicals such as sodium hydroxide increases the conductivity and osmotic pressure post treatment, which could potentially affect the quality of the Macroinvertebrate communities downstream. Because of achieved success with other Iron Staining projects, a decision was made to do the same here, only on a larger scale. Plans were to

Pocahontas Mine- "The Revelation" Continued



Pocahontas Mine-"The Revelation" Continued



Pocahontas Mine-"The Revelation"

Continued

To minimize the surface disturbance for the Iron Staining Bed (ISB) construction, two existing skid roads previously used by timber operators were utilized. The two roads were then lined with 6" of stone and rock barriers 12" high were installed across the beds every 100'.



Pocahontas Mine-"The Revelation" Continued

The rock barriers were meant to help distribute the flow evenly across the beds to maximize contact time for staining to take place.

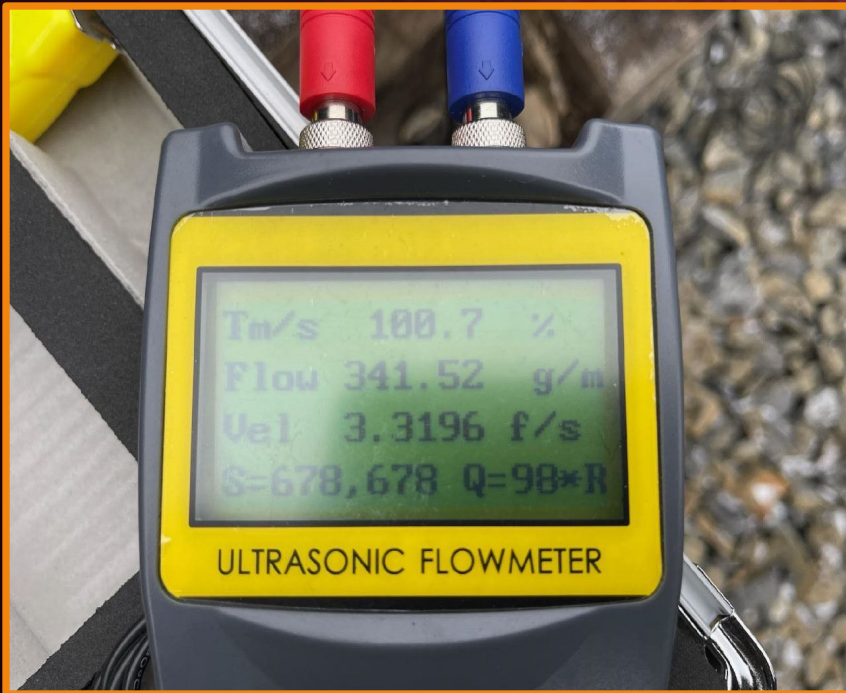


Pocahontas Mine-"The Revelation"

Continued

Concurrent with construction of the beds, pipes and valves were installed to carry the Alkaline Iron water from the Horizontal Drill hole to each bed. The water could be evenly split or one bed could be operated individually in case the other needed some maintenance or other related work. An ultrasonic flow meter measured 342 gallons per minute when the valves were opened for the first time on October 25, 2023. When water entered the beds, it took less than an hour to reach the other ends before proceeding to the polishing pond. The water entering the beds had a ferrous iron concentration of 9.7 mg/l. The permitted discharge limit is 0.93 mg/l. by the time the water reached the end of the beds, Bed No.1 had a Total Iron of 0.1 mg/l and a Dissolved Iron of 0.04 mg/l. Bed No.2 had a Total Iron of 0.08 mg/l and a Dissolved iron of 0.03 mg/l. Needless to say, the beds far exceeded our expectations as iron removal was near instantaneous and complete from the very first time the flow reached the end of the beds to the last day the beds were in use. All in all, over 60,000,000 gallons of water was processed through the beds. As a matter of general interest, we intermittently ran the entire flow through each bed alone and got the same results.

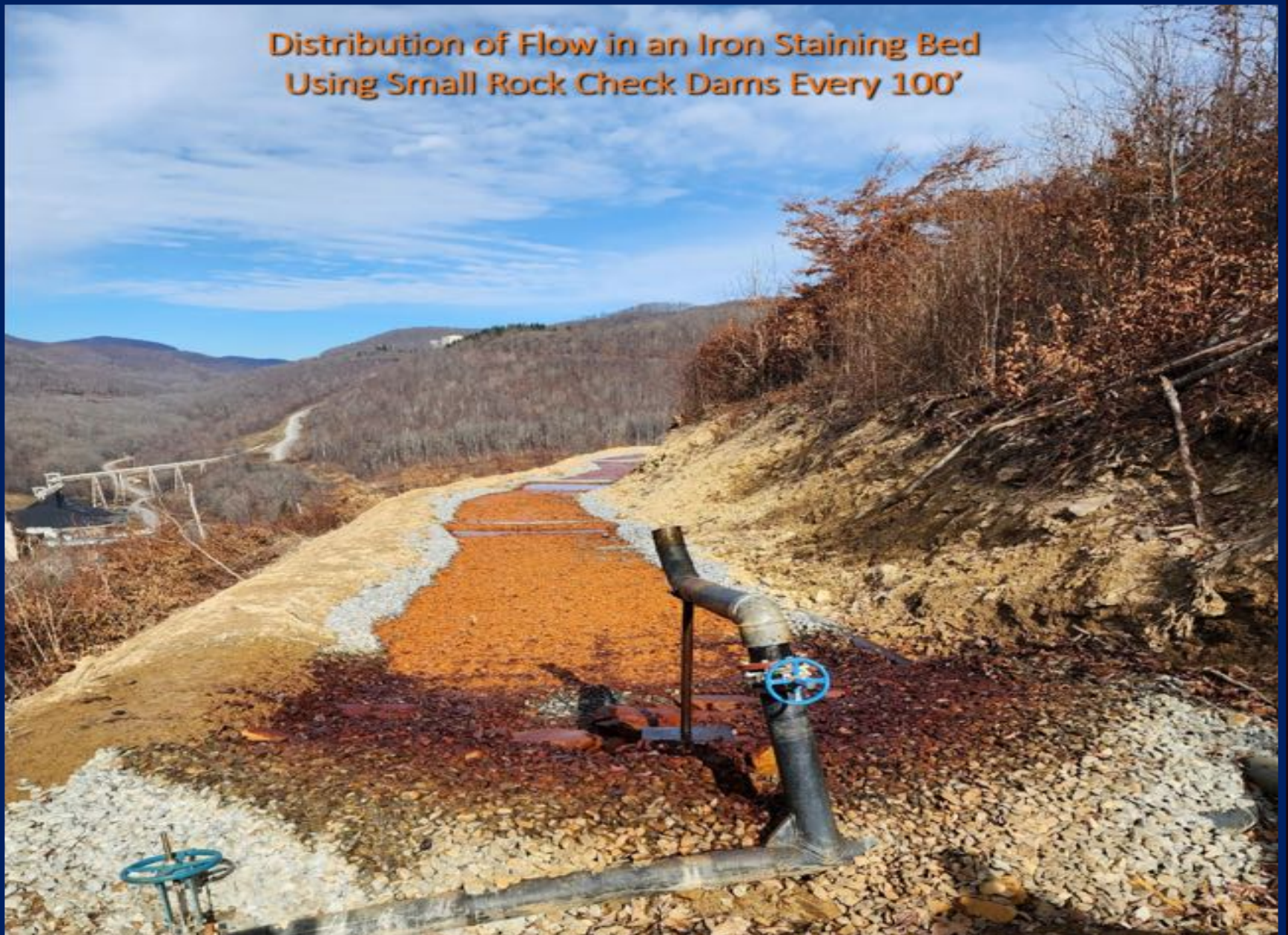
No.2 (Lower Staining Bed)



Pocahontas Mine-"The Revelation" Continued

No.1 (Upper Staining Bed)

Distribution of Flow in an Iron Staining Bed
Using Small Rock Check Dams Every 100'



Pocahontas Mine-FINALLY- "The Revelation"



Impounded water in the western part of the Pocahontas Mine was **“9.70 mg/l”**
Upon draining the impounded water, free flowing water since 6/2024 **“0.31 mg/l”**

Down Dip or Up Dip? That is indeed the Question.

The No.1 Iron Staining Bed averaged discharging a Total Iron of 0.11 mg/l & Dissolved Iron of 0.038 mg/l

The No.2 Iron Staining Bed averaged discharging a Total Iron of 0.059 mg/l & Dissolved Iron of 0.023 mg/l

Summary Comments and Conclusions Concerning the Mine Pool Project

- Free flowing water in the eastern up-dip portion of the mine was absent of iron.
- Impounded water in the Western down-dip portion of the mine contained 9.7 mg/l of Ferrous Iron.
- Due to the vertical head of the mine pool, flow was measured to be 342 gallons per minute through the horizontal drill hole.
- Upon draining the mine pool, flows currently average 30-50 gallons per minute based on the amount of precipitation and associated infiltration.
- Fluctuation in flow is monitored by rain gauge data to try and determine the lag time between precipitation and infiltration.
- As stated previously, the Iron concentration of the water draining through the horizontal drill hole is now between 0.25 mg/l and 0.35 mg/l.
- All in all, over 60,000,000 gallons passed through the ISB's before it was directed straight to the polishing/discharge pond.
- It is extremely significant that no chemicals whatsoever were used to remove the iron and that all water flow was gravity driven (no pumping).
- As the iron in the beds is inert and stable, no further disposal is required. The soil on either side of the beds will be rolled over the beds and seeded for final reclamation.
- Because of the Passive nature of this type treatment, the ISB's produced water containing lower dissolved solids, a lower conductivity, and a lower osmotic pressure.
- Use of the ISB's instead of conventional chemical treatment saved over \$ 100,000 and