THE TANOMA PASSIVE MINE DRAINAGE TREATMENT PROJECT

Eric E. Cavazza, PE and Richard L. Beam, PG
Pennsylvania Department of Environmental Protection
Bureau of Abandoned Mine Reclamation
Cambria District Office
286 Industrial Park Road
Ebensburg, PA 15931-4119

ABSTRACT

Mine Drainage from the defunct Clearfield Bituminous Coal Corporation's underground mines has impaired the upper Crooked Creek watershed in Indiana County, Pennsylvania. The mines form an interconnected and partially inundated complex, covering 4,500 acres. The primary mine drainage outlet, known locally as the 'Tanoma Borehole' has discharged continuously since mining completion in the 1950s, averaging 2,500 gpm (3.6 mgd), and degrading Crooked Creek for several miles.

In 1995, at the request of the Crooked Creek Watershed Association, the Pennsylvania Department of Environmental Protection, Bureau of Abandoned Mine Reclamation, PA-DEP-BAMR, decided to address the Tanoma borehole discharge. BAMR established a monitoring program and initialized water sampling, stream bioassessments, and a hydrogeologic study to evaluate the potential for relocating the discharge to a suitable site for passive treatment. Critical to this evaluation was the protection of an aquifer located above the mine and used for domestic consumption. The relationship of mine discharge volume to in-stream iron concentration was evaluated to determine an effective design sizing criteria.

A two-phase construction approach was undertaken, with new cased and grouted boreholes installed in the first phase. After evaluating the new boreholes, phase two treatment system construction and sealing of the original boreholes occurred. An overflow borehole was left open for monitoring and for mine pool discharge in the event that system capacity was exceeded.

Since full-scale treatment of the mine discharge began in June of 2001, the passive treatment system has removed an average of ~70% of the total iron and converted over 90% of the ferrous or dissolved iron to ferric iron while experiencing flows up to ~3,000 gpm. An important result of system operation to date is that the in-stream iron concentration has consistently been lower than 1.5 mg/L which is the State's regulatory limit and which was one of the design goals for the project. This period includes the historically worst months (the summer and fall months) for water quality impacts. Stream surveys are showing that water quality is rapidly improving and the density and diversity of aquatic life is recovering.

INTRODUCTION

The Tanoma Borehole reclamation project was truly an innovative project that embodies the 21st century approach to watershed restoration by engaging the public and forging partnerships to achieve the greatest environmental benefit. Through the cooperation of a number of federal, state, and local government agencies working hand-in-hand with environmental groups and the general public, 3.5 miles of the upper Crooked Creek have been restored. This restoration has allowed for the re-establishment of indigenous aquatic life. Fish and macroinvertebrates have already begun to return to reclaim this waterway, once polluted by mine drainage. This project is significant because it demonstrated that a discharge, once thought to be untreatable due to its outfall location, could be relocated and successfully treated at a remote location. This was accomplished while carefully considering and mitigating for any potential negative impacts associated with the relocation, including impacts on local residents. The Tanoma passive mine drainage treatment system has functioned well since being put into service late in 2000.

MINING AND ABANDONED MINE PROBLEM HISTORY

The site is located within the headwaters of Crooked Creek in Rayne Township, approximately 9 miles northeast of Indiana PA. The village of Tanoma is immediately downstream of the mine discharges. Figure 1 depicts the location of the other known discharge points for the Tanoma Complex as well as the location of the treatment facility. Boreholes B3 and B6 were not included for treatment consideration because the mine water discharging at these points is non-pollutional.

Pennsylvanian Period, Allegheny Series lithologies exist within the project area. The Lower Freeport Coal Seam outcrops east of the project area along Two-Lick Creek and also to the north along Rayne Run. Lithologies dip toward west-southwest (2%) in accordance with the regional geologic structure. The most prominent structural feature is the Dixonville Syncline. The axis of the syncline bisects the project area trending in a northeast southwest direction. The trough of the syncline passes beneath the village of Tanoma and is also proximal to the location of the Tanoma Borehole (C7). In the vicinity of Boreholes C7, C6, and MP-1 the Lower Freeport coal is approximately 100 to 110 feet beneath the surface.

The Clearfield Bituminous Coal Corporation operated a number of Lower Freeport seam underground mines in the upper Crooked Creek Watershed. Three of these mines, the Barr Slope Mine, the Clymer No. 1 Mine, and the Clymer No. 3 Mine contributed to the development of the Tanoma mine drainage discharges. The Barr Slope Mine opened around 1900, the Clymer No. 1 Mine opened in the 1910s and the Clymer No. 3 opened in the 1930s. The three mines operated in the Lower Freeport or "D" coal seam and are extensively interconnected such that they can be considered as a single abandoned underground mine complex. The mines closed in 1962, 1952 and 1956 respectively. The three mines all had two slope-type entries, with the Barr Slope entries located near the Village of Dixonville, the Clymer No. 1 entries located at the Village of Sample Run and the Clymer No. 3 entries located at the Village of Weimer. The complex covers an area of over 4,500 acres, and the average coal seam thickness was 42 inches. A large underground mine pool developed in the Clymer No. 1 and Clymer No. 3 mines following abandonment. Due to the down dip advance of the mining, the complex is approximately 50% inundated. The mine pool has been calculated to contain roughly two billion gallons of water.

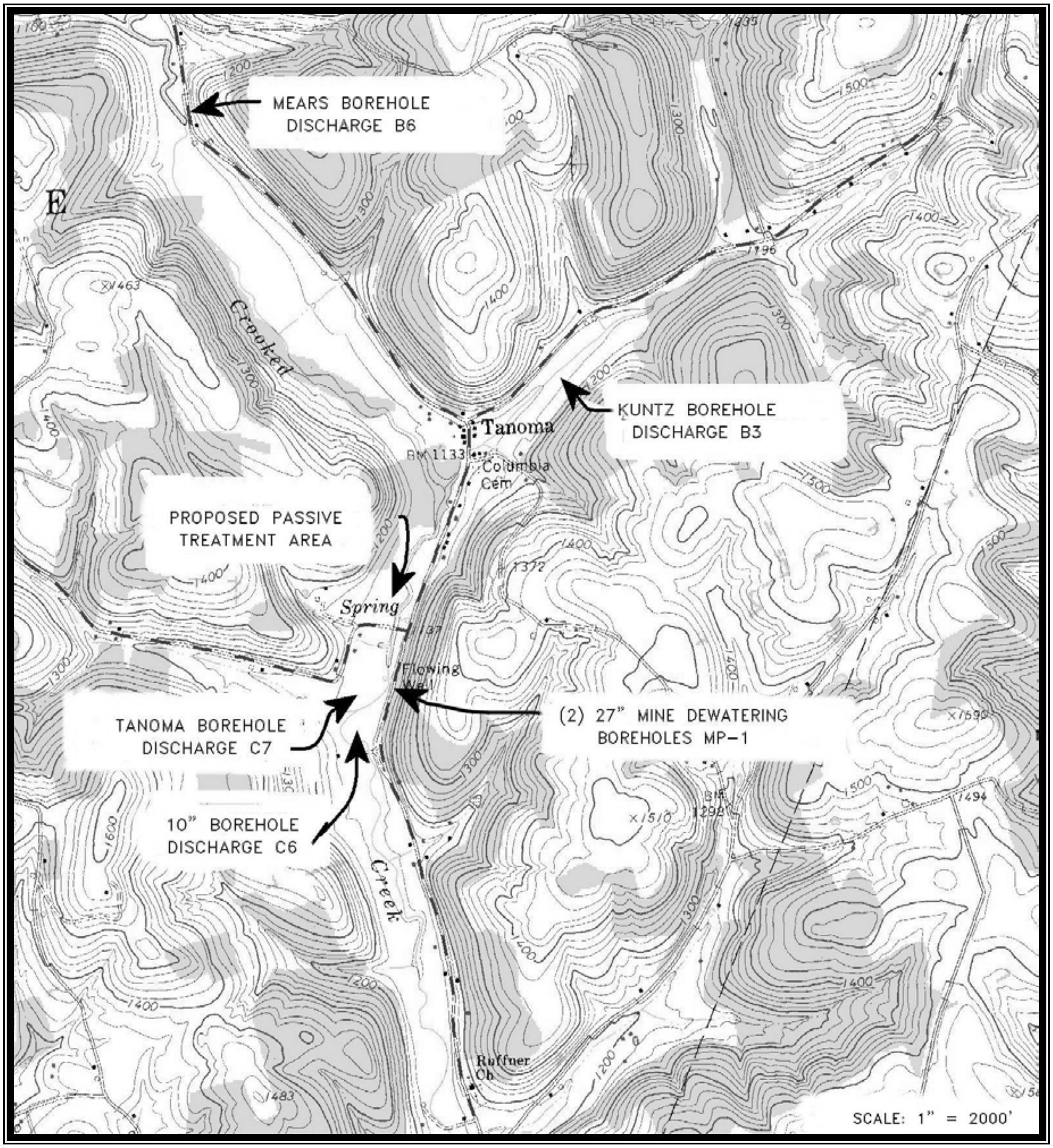

Figure 1 - Location of Boreholes and Treatment Area *(From Clymer 7.5' U.S.G.S. Quadrangle)*

The most prominent outlet of mine drainage from the complex was a twelve-inch discharge borehole known locally as the 'Tanoma Borehole' or the C-7 borehole. The borehole was located within the Crooked Creek stream channel just upstream of the Village of Tanoma. The borehole had discharged continuously since shortly after mining operations at the two mines ceased in the 1950s. The discharge averaged 2,500 gallons per minute (3.6 million gallons per day) and contained significant dissolved iron (~20 mg/L) and some free acidity (~10 mg/L) that significantly degraded the water quality within Crooked Creek for several miles below the discharge point.

Located near the Tanoma Borehole were several other boreholes which discharge mine water periodically. One of these is known as the C-6 borehole and consists of a 10-inch vertical borehole. Between boreholes C-6 and C-7, and located on the opposite bank from the boreholes, are two 27-inch overflow boreholes known as the MP-1 boreholes. Figure 1 shows the location of the various discharge boreholes. The MP-1 boreholes are capped with steel grating and discharge seasonally when the mine pool rises due to spring rains and winter snow melts. The MP-1 boreholes served as dewatering boreholes when the mines were operating. Water in the mines was pumped to a sump area at this location and then pumped to the surface through the MP-1 boreholes and discharged directly into Crooked Creek. Several other boreholes, openings, and man-ways into these two Clymer mines are known to exist, but no significantly degraded mine drainage discharges have been documented.

Following closure of the mines, discharge water quality from the Tanoma Borehole has improved. Table 1 summarizes historical changes in mine pool water quality at this site. The discharge is now consistently alkaline (120 mg/L). The concentration of iron has also decreased slightly to approximately 15 mg/L. However, the volume of the discharge in relation to the normal base flow of Crooked Creek has resulted in significant iron precipitation that covers the stream bottom coloring it orange for several miles below the discharge during periods of low stream flow. Stream monitoring completed during 1996 and 1997 showed that the Tanoma Borehole discharge accounted for an average of 42% and a peak of 83% of the total stream flow within Crooked Creek. This sheer volume of contaminated mine water results in significant adverse impacts on the water quality and the associated density and diversity of aquatic life in Crooked Creek for several miles downstream of the discharge.

The Lower Kittanning Coal seam (B Seam) is located approximately 150 feet below the Lower Freeport Coal and has been, and continues to be, mined in the general area. Several abandoned underground operations exist within and adjacent to the project area. These operations were developed in a manner similar to the Lower Freeport operations. Entries were driven westward (down-dip) from the Two-Lick Creek watershed into the Crooked Creek watershed. The Tanoma Mining Company currently has an active Lower Kittanning operation underlying the majority of the project area. Surface facilities, including the portals, preparation plant, coal refuse disposal area and mine drainage treatment facilities are located approximately 2 miles north of Tanoma along Rayne Run. Significant portions of the Lower Freeport Tanoma Complex, including the majority of the mine pool, overlie this active operation. Coal removal was initiated in 1983 and continued up until the fall of 2001. Mine maps indicate that first mining (50% coal removal) has occurred in areas directly underneath the Lower Freeport mine pool during the mid to late 1990's. First-mined areas underlying the pool are completed and have been sealed. No retreat mining occurred.

PROJECT BACKGROUND

In 1995, the Crooked Creek Watershed Association approached the PA-DEP-BAMR with a request to consider abatement of the Tanoma discharges under the newly established AMD 10% Set-Aside Program. A detailed monitoring and evaluation program was established for the site since no detailed monitoring or analysis of the mine pool and discharges had been completed since the early 1970s.

Table 1 - Water Quality Summary - Borehole Discharges

	Tanoma Borehole C7			**10-inch Borehole C6**			**Mears Borehole B6**			**Kuntz Borehole B3**		
	1970-79	1980-89	1990-96	1970-79	1980-89	1990-96	1970-79	1980-89	1990-96	1970-79	1980-89	1990-96
Min. Flow	1044	no data	283	no data	no data	no data	80	no data	15	no data	no data	75
Median Flow	2154	no data	301	no data	no data	no data	240	no data	60	no data	no data	75
Max. Flow	4722	no data	3000	no data	no data	no data	300	no data	79	no data	no data	75
No. of samples (n)	19	0	10	0	0	1	11	0	9	0	0	1
Min. pH	5.5	5.9	6.1	5.6	no data	6.6	5.8	6	6.04	5.7	no data	6.4
Median pH	6.4	6.4	6.47	6.3	no data	6.6	6.35	6.41	6.58	6.3	no data	6.4
Max. pH	6.65	7.17	7.15	6.5	no data	6.6	6.9	7.3	7.16	6.9	no data	6.4
No. of samples (n)	57	55	17	10	0	1	16	55	17	8	0	1
Min. Net Alkalinity	-120	60	34	-111	no data	162	29	30	144	11	no data	142
Med. Net Alkalinity	100	120	133	-28	no data	162	68	90	172	49	no data	142
Max. Net Alkalinity	155	175	180	99	no data	162	115	170	222	101	no data	142
No. of samples (n)	53	55	17	8	0	1	12	55	18	5	0	1
Min. Iron	0.24	2.8	0.44	0.36	no data	13.9	0.04	0.01	0.03	0.1	no data	0.77
Median Iron	10.7	7	11.4	27.4	no data	13.9	0.17	0.04	0.045	0.565	no data	0.77
Max. Iron	40	19.5	22.4	45.5	no data	13.9	2.4	3.6	0.32	1.58	no data	0.77
No. of samples (n)	57	55	17	10	0	1	16	55	18	8	0	1
Min. Manganese	no data	0	0.08	no data	no data	0.84	no data	0	0.03	no data	no data	0.41
Med. Manganese	no data	1.1	0.86	no data	no data	0.84	no data	0.1	0.06	no data	no data	0.41
Max. Manganese	no data	2.5	1.03	no data	no data	0.84	no data	0.3	0.42	no data	no data	0.41
No. of samples (n)	0	52	17	0	0	1	0	52	18	0	0	1
Min. Sulfate	300	270	113	520	no data	353	91	100	306	23	no data	210
Med. Sulfate	565	450	367	880	no data	353	326	250	520	267.5	no data	210
Max. Sulfate	1850	590	556	1200	no data	353	380	390	688	390	no data	210
No. of samples (n)	56	55	17	10	0	1	15	55	17	8	0	1

Note: Flow is expressed in gallons per minute (gpm) , all other parameters are concentrations in milligrams per Liter (mg/L)

From May 1996 through April 1997, all of the mine pool discharge points were extensively sampled and monitored. The total combined flow of the discharges (from the C-6, C-7 and MP-1 boreholes) ranged from a low of 1,174 gpm in August 1996 to a peak of 5,397 gpm in December 1996. The average flow was just over 2,500 gpm. The total iron concentration ranged from a low of 7.9 mg/L to a peak of 22. 4 mg/L. The discharges were determined to be contributing an average of 233 lbs/day of iron to Crooked Creek. The in-stream iron concentration downstream of the boreholes ranged from 1.23 mg/L to 7.81 mg/L. In all but two sampling events, the acceptable in-stream standard for iron (1.5 mg/l) was exceeded. Table 2 summarizes the pre-design monitoring of the discharges, stream flow, and the in-stream iron concentration.

Macroinvertebrate surveys of Crooked Creek were conducted by BAMR staff in the fall of 1994 and in the early summer of 1996. Both surveys indicated good diversity and density of macroinvertebrates upstream of the Tanoma Borehole. The 1994 survey found very good diversity and large numbers of insects upstream of the discharges. Immediately below, there was a drastic reduction in both the number of taxa and total insects, with partial recovery found at a station located approximately 2.5 miles below the discharges. The 1996 survey, which utilized the EPA's Rapid Bioassessment Procedures (RBP-III), discovered similar findings with 40 insects representing 11 taxa upstream, 17 insects representing seven taxa immediately below the discharges, and 35 insects representing 10 taxa approximately 1.5 miles downstream. While the upstream samples in both surveys had good representation by the more pollution intolerant ephemeroptera/plecoptera/trichoptera taxa (mayflies/stoneflies/cadisflies), these taxa were almost non-existent immediately below the discharge, and only trichoptera were represented further downstream. Fish habitat has also been negatively impacted by the mine drainage discharges. The Ken Sink Chapter of Trout Unlimited reported that the instream iron concentration exceeded the limits for trout stocking. Trout have been historically stocked in Crooked Creek upstream of the Tanoma Borehole, but not below.

Table 2 – Pre-Design Monitoring of Discharge Flow Rate and Total Stream Flow.

Date Sampled	Upstream Station Flow (gpm)	Downstream Station Flow (gpm)	Unnamed Tributary Flow (gpm)	Calculated Flow for Mine Drainage Discharges (gpm)	% of Total Stream Flow Due to Discharges	Downstream Fe Concentration (mg/l)
5/30/1996	3199	5768	105	2464	42.72	3.00
7/2/1996	1760	3473	0	1713	49.32	4.19
7/30/1996	1631	3187	105	1451	45.53	4.05
8/15/1996	217	1418	27	1174	82.79	7.81
9/25/1996	5513	7409	4	1892	25.54	2.92
11/20/1996	4946	8591	240	3405	39.63	2.76
12/5/1996	12370	18739	972	5397	28.80	1.65
1/30/1997	12586	16527	764	3177	19.22	1.50
2/21/1997	19837	23254	1380	2037	8.76	1.23
3/25/1997	3588	7050	306	3156	44.77	2.74
4/24/1997	2601	4786	185	2000	41.79	3.03

PROJECT IMPLEMENTATION CHALLENGES

Several challenges were quickly evident soon after the monitoring and evaluation program got underway. First, the sheer volume of the discharges (1,174 to 5,397 gpm) was going to make treatment with passive mine drainage technology very difficult. To construct treatment ponds with any significant detention time, many acres of land would be needed. Second, the location of the discharges was a problem. The Tanoma Borehole (C-7) discharged directly into Crooked Creek at stream level. The 27-inch overflow boreholes (MP-1) as well as the C-6 borehole were also located close to the stream in an area with little land available for construction of a passive treatment system. Third, the active Lower Kittanning underground mining operation underlies a significant portion of the abandoned Lower Freeport workings, including essentially the entire flooded portion. Careful planning and coordination with the active Lower Kittanning underground mine operation was necessary. Finally, many homes in the area relied on private wells for their water supply, and manipulation of the mine pool would require careful analysis to ensure protection of these aquifers.

An extensive hydrogeologic study of the area was initiated in late 1996. All available mapping and historical mining information was compiled and evaluated. Site surveys were conducted. A comprehensive water quality and quanity monitoring program, including stream and discharge gaging, was conducted on a monthly basis. Several coordination and data exchange meetings occurred with the active underground mine operator, Tanoma Mining Company. The objective of the study was to evaluate the potential for relocating the primary discharge point of the mine pool to a point downstream where sufficient land was available for construction of a passive treatment system.

A critical element of this evaluation also included the protection of the aquifer located well above the mine that was being used for domestic water supplies. The Village of Tanoma and all nearby residences rely upon individual water supply systems. No public water supply system exists within the immediate vicinity. Springs and wells provide water for domestic use. Hydrologic information indicated that many of the wells produce inferior quality water with elevated metal concentrations. A number of wells have been developed in close proximity to the mine pool and are undoubtedly hydrologicaly connected to some degree. Clearly any significant change to the mine pool elevation has the potential to impact these wells. The study concluded that it would be technically feasible to relocate the discharges approximately 1,000 feet downstream to an abandoned 10-acre pasture for construction of the passive treatment system. The selected location would afford the construction of new boreholes into the mine complex and would provide the required artesian discharge into the treatment system without significantly changing the mine pool elevation. Figure 3 illustrates the acceptable range of mine pool elevations that the selected site needed to be capable of maintaining. An elevation of 1131 was chosen as the invert elevation for the new discharge boreholes.

A two-phase construction approach was selected. The first phase would be to drill new boreholes at the proposed treatment location with valves for control of the discharge. The new wells would be carefully constructed by casing and grouting the boreholes down to the elevation of the mine. This would ensure protection of the upper aquifer that was heavily relied upon by local residents as a source for their domestic water wells. Survey control and detailed mine mapping of the abandoned mine workings were provided by the active underground mine operator, Tanoma Mining Company. This aided the Department's efforts in precisely locating the new boreholes and resulted in encountering mine voids in all holes that were drilled. Once the wells were constructed and demonstrated to adequately redirect the discharges of the mine pool, the second phase of the project could be undertaken.

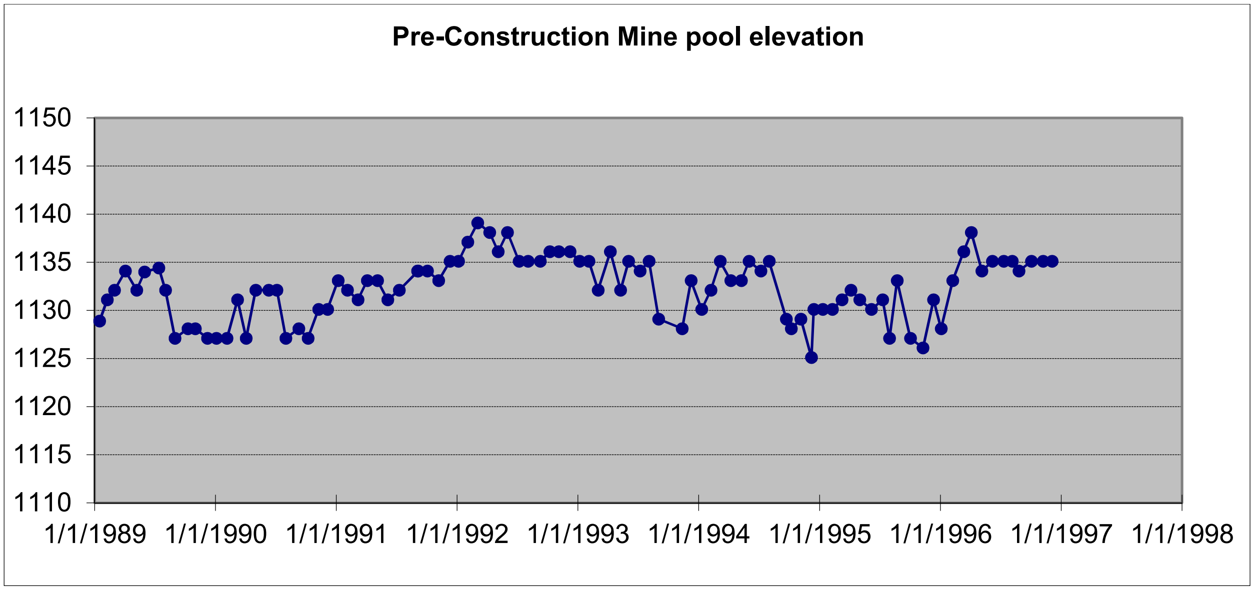

Figure 3 - Mine Pool Monitoring Data Collected Prior to Construction

The second phase included construction of passive mine drainage treatment facilities at the downstream site, opening of the valves on the new wells to redirect the mine pool discharge to the newly constructed treatment system, and finally, the sealing of the Tanoma Borehole (C-7) and the C-6 borehole. The 27-inch overflow boreholes (MP-1) would be left open to provide for monitoring of the mine pool and for mine pool discharge in the event that the pool would rise that high in the future.

A significant observation during the study involved the relationship of the volume of the mine drainage discharges to the in-stream iron concentration as measured downstream of the borehole locations. This relationship is illustrated in Figure 4. The periods when the discharge volume was the highest (winter and spring), the in-stream iron concentration was the lowest due to the normally high base flow in the stream. During the drier summer and fall months, the discharge volume dropped off, but the in-stream iron concentration rose to levels (> 1.5 mg/L total Fe) intolerable for most aquatic life. This was the result of low stream base flow relative to the mine drainage discharge volume. This relationship was key in determining the design criteria that would be used for the development of the final project plan.

Other design challenges developed at the newly selected treatment area. First, the property owner was unwilling to allow the construction of a treatment system on his property without compensation. The owner was willing, however, to sell the property to the Department or any other conservation group for the purpose of constructing the treatment system.

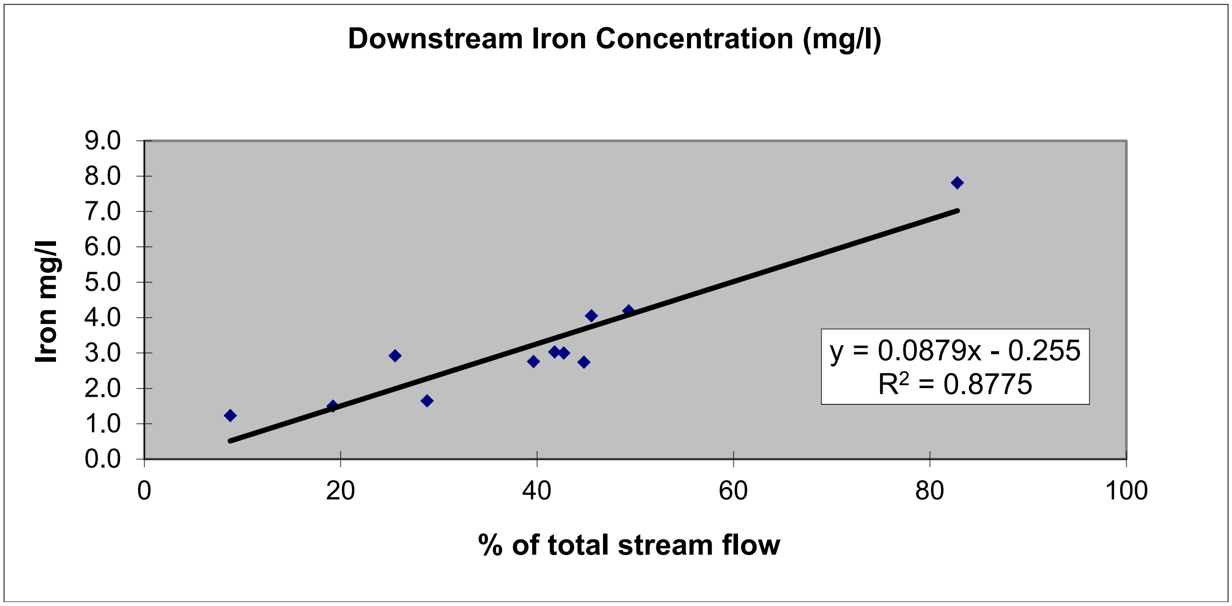

FIGURE 4 – Relationship of mine drainage discharge flow rate as a percentage of the total stream flow to the in-stream iron concentration.

The site also had a private water line and two gas well gathering lines that bisected the site. Coordination with the gas companies and water line owner needed to be completed such that these facilities would remain functional and accessible following construction of the treatment system.

PROJECT DESIGN APPROACH

Analysis of the mine drainage discharges consistently indicated that the mine water was net alkaline with a moderate to high concentration of dissolved iron. From a passive mine drainage treatment perspective, this is the easiest mine water to treat. The engineering difficulties at this site involved the complete relocation of the discharges and the need to treat from between 1.5 to 8.0 million gallons per day (MGD) of mine water. Even at the downstream location selected for treatment, less than 10 acres of land was available for construction of the system.

Using the inverse relationship of discharge flow rate to in-stream iron concentration discussed in the previous section, a decision was made to select a maximum design flow rate which would maintain a constant in-stream iron concentration of 1.5 mg/L or less. The hydrogeologic study determined that this equated to a maximum flow rate of 2,500 gpm or 3.6 MGD. A decision was also made to target the maximum iron concentration observed during the pre-design discharge monitoring of 22.4 mg/L.

The design of the passive treatment system was completed using the above design criteria. Due to the limitations of the proposed project site, including topography, utility lines, and proximity to the stream, a passive treatment system consisting of an approximate one acre settling pond followed by two multi-chambered aerobic wetlands was laid out. The system was designed to allow for the rapid aeration of the mine water and for the necessary detention to allow for the oxidation, hydrolysis and precipitation of the iron sludge. The two wetland treatment cells total approximately 7.5 acres. Analysis of the on-site soils for engineering properties indicated that the material would be ideal for construction of the earthen pond embankments.

CONSTRUCTION SUMMARY

The relocation of the Tanoma discharges to the proposed downstream treatment area began with drilling of three new six-inch diameter wells in the summer of 1998. The wells were cased and pressure grouted down through the upper aquifer that was being used for several nearby residential water wells. A detailed groundwater monitoring program documented the pre and post construction conditions of the adjacent private water supplies. Pump tests of the new wells confirmed the hydrologic connection to the Tanoma mine pool. Monitoring of all nearby water supplies determined that they would not be impacted by the relocation of the deep mine discharge.

After the successful installation of the new discharge wells, the PA-DEP-BAMR began negotiations with the property owner for the subdivision and purchase of the property required for treatment. Approximately 10.1 acres was subdivided from a larger tract and sold to the Southern Alleghenies Conservancy (SAC), a local environmental stewardship group that agreed to take ownership of the property. The PA-DEP-BAMR funded this property acquisition with funds from the AMD 10% Set-Aside Program. The survey for the subdivision was completed in October 1999, and the sale of the property was finalized in the spring of 2000.

While the property was being secured, final design for the project including permitting, development of detailed plans and specifications, and the obtaining of construction easements from the gas companies, water line owner and SAC were being finalized. The project was let, and construction on the passive treatment system began on June 4, 2000. The contractor was Casselman Enterprises of Somerset, PA. Once the treatment facilities (settling pond and two aerobic wetlands) were constructed, a portion of the mine water was redirected from the new discharge boreholes via pipes with flow control valves into the newly completed treatment system. Finally, the Tanoma Borehole (C-7) and the C-6 borehole were permanently sealed thus beginning the restoration of a 3.5 mile reach of Crooked Creek. A final inspection for the project was held on December 8, 2000. The final project costs are as follows: installation of new discharge boreholes - $19,783.50; property acquisition cost - $38,000; sealing abandoned Tanoma boreholes - $7,535; and construction of the passive treatment system - $351,367.31. Figure 5 shows an aerial view of the completed project in October of 2000.

POST CONSTRUCTION MONITORING AND STREAM RESTORATION RESULTS

Flow into the completed treatment system was limited to approximately 200 gpm for the first six to eight months of operation to allow for the wetland plants to acclimate and to get established. On June 8, 2001, the valves controlling the influent were opened completely, allowing the full volume of the discharges to enter the treatment system. Figure 5 shows the inlet wells and the settling pond during January 2001. Since full-scale treatment began, the treatment system has experienced flows ranging from 77 gpm in December 2001 to 3,003 gpm in May 2002. Flows were lower than expected through the fall of 2001 and early winter of 2002 due to a general drought condition over much of Pennsylvania. The drought has since ended, and the influent flow rate has been at or above the expected flow rate since February of 2002. The influent mine discharge has averaged 11.6 mg/L of iron, and the treatment system has removed an average of 68% of the total iron and converted 93% of the ferrous, or dissolved iron, to ferric iron. The treatment system has, on average, removed 2,689 lbs/month of iron, and has removed over 16 tons of iron since full-scale treatment began in June of 2001. Table 3 is a summary of the treatment performance of the Tanoma passive mine drainage treatment system.

FIGURE 5 – Aerial view of the completed Tanoma Mine Drainage Treatment System.

The most important result of the treatment system operation to date is that the in-stream iron concentration, as measured downstream of the effluent, has consistently been lower than 1.5 mg/L since full-scale operation of the system began in June 2001. This period includes the historically worst months (the summer and fall months) for water quality impacts from the Tanoma discharges. The highest measured in-stream iron concentration was 1.33 mg/L in May of 2002 and the lowest measured in-stream iron concentration was 0.158 mg/L in October of 2001. The target concentration selected during project planning and design was an in-stream iron concentration not to exceed 1.5 mg/L. Table 3 also shows a summary of the downstream monitoring of the total iron concentration.

Domestic water wells in the vicinity of the project have been monitored periodically since the completion of the project. The relocation and treatment of the Tanoma discharges has not had any negative impact on the quantity or quality of the water supplies.

TABLE 3 – Summary of flow and water quality monitoring at the treatment system to date.

MONTH	Influent Flow Rate (gpm)	Influent Total Fe (mg/L)	Effluent Total Fe (mg/L)	Downstream Total Fe (mg/L)	Total Fe Removal Rate (%)	Total Fe Removed (lbs/day)	Total Fe Removed (lbs/Month)	Total Influent Fe (lbs/Month)	Influent Ferrous Fe (mg/L)	Effluent Ferrous Fe (mg/L)
PRE-DESIGN	**1174 - 5397**	**7.9 - 22.4**	**n/a**	**1.50 - 7.81**	**n/a**	**n/a**	**n/a**	**--**	**--**	**n/a**
Jun-01	1792	12.5	1.47	0.750	88.2	237.6	7,127.5	8,077.4	12.50	0.28
Jul-01	1190	9.0	2.68	0.581	70.3	90.7	2,811.3	3,999.6	9.00	0.65
Aug-01	522	12.0	1.27	0.832	89.4	67.3	2,087.1	2,334.1	12.00	0.47
Sep-01	302	12.5	0.91	0.223	92.7	42.1	1,262.2	1,361.3	12.50	0.26
Oct-01	149	13.6	0.43	0.158	96.8	23.6	731.2	755.1	13.60	0.04
Nov-01	107	11.9	0.40	0.199	96.6	14.8	443.7	459.2	11.90	0.14
Dec-01	77	14.4	0.48	0.180	96.7	12.9	399.4	413.2	14.40	0.16
Jan-02	709	12.9	0.42	0.300	96.7	106.3	3,294.7	3,405.6	12.90	0.21
Feb-02	969	12.4	2.99	0.720	75.9	109.6	3,068.9	4,044.0	12.40	0.05
Mar-02	1702	9.7	4.95	1.170	49.0	97.2	2,720.9	5,556.4	9.70	2.91
Apr-02	3003	8.5	5.23	1.190	38.6	118.8	3,325.2	8,611.1	8.50	2.61
May-02	2724	9.43	3.98	1.330	57.8	178.4	4,996.5	8,645.3	9.43	1.33
Jun-02	2,029	6.89	3.79	1.080	45.0	75.6	2,116.9	4,705.0	6.20	0.56
Medians	**969**	**12.00**	**1.47**	**0.720**	**88.2**	**90.7**	**2,720.9**	**3,999.6**	**12.00**	**0.28**
Total pounds of iron (Fe) removed since full-scale treatment was initiated.							**34,385.5**			

The MP-1 boreholes have also been monitored since full-scale treatment began in early June 2001. Above normal precipitation during the spring of 2002 has resulted in discharges of untreated mine drainage from the MP-1 boreholes. In spite of this, instream iron concentration has remained below the target level of 1.5 mg/l. Surveys of the stream are showing that the water quality in the upper Crooked Creek is rapidly improving and the density and diversity of aquatic life is already recovering. Several species of fish have been observed in areas where the stream was nearly devoid of life only a short time ago. The stream bottom no longer has the brilliant orange coloration associated with the iron precipitates that smothered the life of many of the streams bottom dwellers. A macroinvertebrate survey of the stream was completed in late October 2001. The results are very positive and extremely encouraging. Upstream of the treatment system, 107 insects were collected representing 14 different taxa. Downstream of the treatment system 100 insects were collected representing 14 taxa. Thirty-three of the downstream insects collected belong to the pollution intolerant taxa of mayflies/cadisflies/ stoneflies, which shows a dramatic improvement compaired to the pre-construction sampling.

CONCLUSIONS

In conclusion, the Tanoma Borehole reclamation project and the documented restoration of 3.5 miles of the upper Crooked Creek watershed is a unique example of successful abandoned mine reclamation and creative problem solving that lead to the elimination of impacts from abandoned mines and resulted in a dramatic improvement to the environment. The project demonstrated that a discharge that was previously considered to be untreatable could be successfully relocated and treated while protecting and maintaining the quality of an uncontaminated groundwater aquifer. The project also demonstrated that an in-stream target concentration for contaminants could allow for less than 100% of the discharge to be treated. The project analysis and reclamation techniques used in the Tanoma South reclamation project can be duplicated at other mine drainage discharge sites once thought to be untreatable. Upper Crooked Creek, for the first time in nearly 100 years, has been restored to near pre-mining water quality and now supports fish and other aquatic life.

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