Middle Branch Passive Treatment System Rehabilitation Project

Funded by Growing Greener

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For Trout Unlimited and the Kettle Creek Watershed Association

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Executive Summary
The Middle Branch passive treatment system was constructed in 2000 to treat two acidic discharges that impair Middle Branch of Twomile Run in western Clinton County, PA. The discharges are highly acidic in nature and are characterized by high metals concentrations. The system consists of two vertical flow ponds with compost (VFPs) arranged in parallel followed by a settling pond, an aerobic wetland and two manganese removal beds (arranged in parallel). Within one year, one VFP (identified as SAPS 1B) began to show signs of deteriorating performance. By December 2002 both VFPs were discharging acidic water. In September 2003 funding was secured to conduct an investigation and rehabilitate the treatment system. An investigation of the system contents was conducted in June of 2004 revealing several short circuiting problems in the VFPs. Chemical analysis of system performance by Dr. Art Rose indicated that the system was still producing alkalinity but was severely overloaded.

The rehabilitation took place in two phases and was completed in June of 2007. The first phase involved installation of a collection system to capture and divert water away from the overloaded treatment system. Preliminary monitoring indicates that flows at the R2 discharge were reduced by 60-70%. The second phase involved reconstructing the existing system with operational improvements. As of June 30, 2007, the system was refilling with water and is expected to discharge some time in August, depending on precipitation.

Introduction and Background

This project involves the rehabilitation of a passive AMD treatment system located on Middle Branch in the Twomile Run watershed (Clinton County). The system was constructed in 2000 by the PA DEP Bureau of Abandoned Mine Reclamation (BAMR) to treat two highly contaminated flows from an abandoned mine complex. The treatment involved two vertical flow ponds (VFP), a settling pond, a constructed wetland, and two oxic limestone beds. The VFPs contained limestone aggregate and organic substrate and were intended to neutralize acidity, generate alkalinity, and remove aluminum (Al) and some iron (Fe). The settling pond and wetland were intended to remove residual Fe. The oxic limestone beds were intended to remove manganese (Mn). The parallel beds were intended to test whether inoculation with microbes was necessary to achieve Mn removal. The layout is shown on Map 4.

The treatment system was initially effective, but its effluent declined in quality during the second and third years. In 2004, an "autopsy" of the VFPs and oxic limestone beds occurred. As a result of this investigation and a follow-up evaluation of the system's design criteria and the measured AMD loading, a rehabilitation plan was developed. The plan included two tasks: 1) the diversion of a portion of the AMD away from the system so that overloaded conditions would be decreased, and 2) the reconstruction of the existing system. A local contractor (Smith Lumber) with experience in the Twomile Run watershed was contracted to implement the modifications. The work was completed in June 2007. This is the final report of the project.

Treatment System: Design and Autopsy

The original VFPs consisted of 3 feet of limestone aggregate overlain with 2 feet of organic substrate (spent mushroom compost). An underdrain installed at the bottom of the aggregate caused water to flow vertically down through the organic substrate and limestone. The underdrains of both VFPs discharged to a common oxidation/settling pond (sampling ID Sedpond) that discharged to a single small aerobic wetland (sampling ID wetland). The discharge from the wetland was split evenly between the two oxic limestone beds (sampling IDs PYRINNOC and PYRN). One of the beds (PYRINNOC) was inoculated with Mn-removing microbes cultured by Allegheny Mineral Abatement. The second bed was not inoculated.

Based on consistently poor effluent water quality, an "autopsy" of the system was conducted to determine the cause of the poor effluent water quality. This autopsy was not part of this project. On June 15, 2004, portions of the VFPs and oxic limestone beds were excavated and the substrates examined and sampled. This autopsy revealed that limestone in the VFPs was coated with solids, but the aggregate was still porous. Photo 4 shows an excavator digging into the limestone of one of the SAPs. Photo 5 shows a close-up of the condition of that limestone after excavation.

Limestone in the oxic limestone beds was found to be plugged within the top 12-18 inches of the surface (Photo 6). Below this depth, the limestone was uncoated and appeared to be in good condition.

Several design flaws were noted during this autopsy, most of which served to promote short-circuiting. For example, cleanout pipes within the SAP ponds allowed water flowing along the outside of these pipes to enter the underdrain system without contacting appreciable amounts of organic substrate or limestone. Additionally, the rock aprons placed at the outfalls of the influent pipes extended through the compost layer providing a direct flow path to the limestone without contacting the compost. A halo of iron stained limestone was observed at both influent locations confirming that short-circuiting had taken place. While contributing to poor performance, these physical problems were not considered adequate to explain the apparent rapid decline in system performance.

With no clear physical cause of failure evident from the autopsy, an evaluation of the design criteria was conducted. Table 1 compares the design loadings to observed loadings. It appears that the discharges were well characterized based on the average conditions. However, the erratic nature of the R2 discharge is apparent in the observed maximum loads of September 28, 2003. On this date, the R2 discharge was flowing 182 gpm and R1 was flowing 22.5 gpm. Acidity and metal loadings were 3 times higher than the design conditions.

Table 1. Comparison of Design and Observed Discharge Characteristics. The maximum flow occurred on September 28, 2003

	Design	Observed average	Observed Maximum
Flow (gpm)	50	55	205
pH	3.0	2.9	2.9
Net Acidity Load (ppd)	450	359	1370
Total Iron Load (ppd)	9	8	31
Aluminum Load (ppd)	45	42	148
Manganese Load (ppd)	12	9	32

The VFPs appear to have been designed with optimistic expectations for acidity removal. Assuming the loadings shown in Table 1 and the combined VFP surface area of 1,240 m^2, then the design acidity loading was 165 grams of acidity per square meter of VFP per day (g m^{-2} day^{-1}). The actual acidity loadings averaged 132 g m^{-2} day^{-1}. Studies of acidity removal and alkalinity generation by VFPs indicate that properly constructed systems generate alkalinity at a rate of 30-50 g m^{-2} day^{-1} (Rose 2006; Hedin Environmental, unpublished data). The Middle Branch VFPs removed acidity (or generated alkalinity) at an average rate of 56 g m^{-2} day^{-1}. Their performance was not sub-standard. However because of the regular occurrence of very high acidity loadings, the final effluents of the VFPs were not alkaline.

From an effluent water quality perspective SAP 1B declined abruptly in performance by January of 2002, just one year after the system came online. SAP 1A maintained alkaline effluent until December 18, 2002, almost exactly one year longer than SAP 1B. Figure 1 shows the net acidity of both SAP 1A and SAP 1B over time.

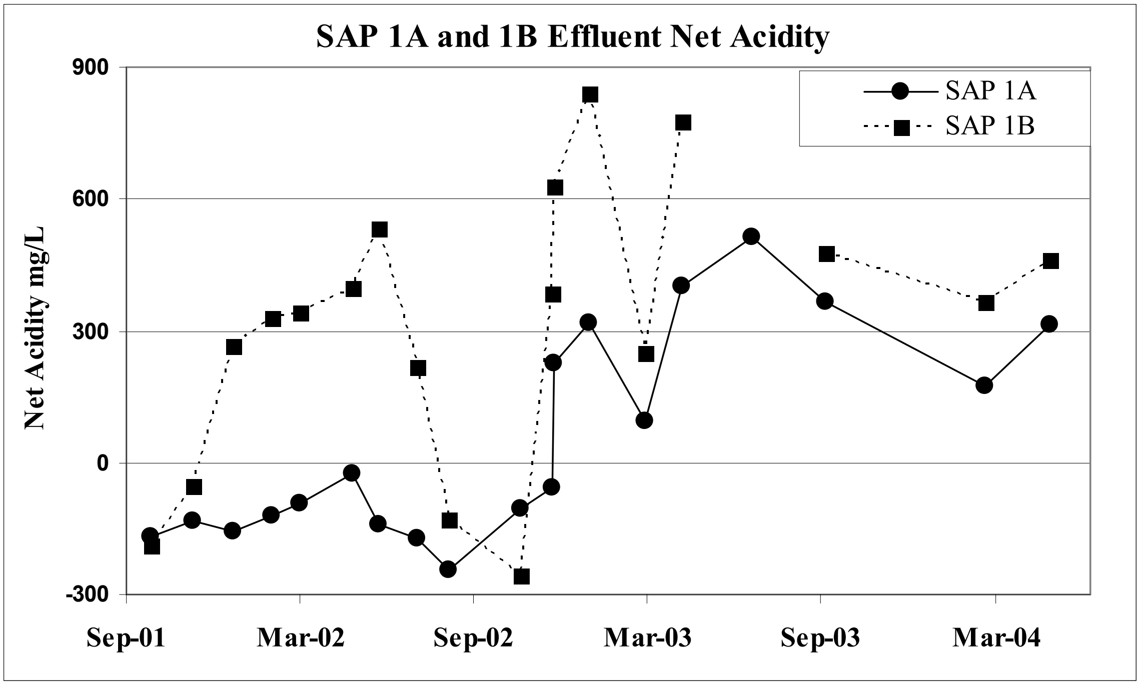

Figure 1. SAP 1A and 1B effluent net acidity over time. SAP 1A produced alkaline effluent one year longer than SAP 1B.

On December 17, 2002 both SAP 1A and 1B were flushed. Up to this point, SAP 1A was producing net alkaline effluent. Every sample collected after this point was net acidic. The reason for this reversal is unclear. It is possible that one of the valves connecting the two SAP ponds was opened during the flushing allowing more flow from the R2 discharge to enter SAP 1A.

Another way of assessing treatment system performance is through the calculation of areal loading. In this method the influent data are used to calculate the number of grams of acidity put into each square meter of SAP pond each day. Then the effluent data are used to calculate how many grams of alkalinity is produced per square meter per day. Using this method it is apparent that the system never really failed because the alkalinity generation by the VFPs on most days was close to the 40 g $m^{-2}d^{-1}$ rate expected from these systems. Figure 2 shows the acidity loading rate and alkalinity generation rate for SAP 1A and 1B combined.

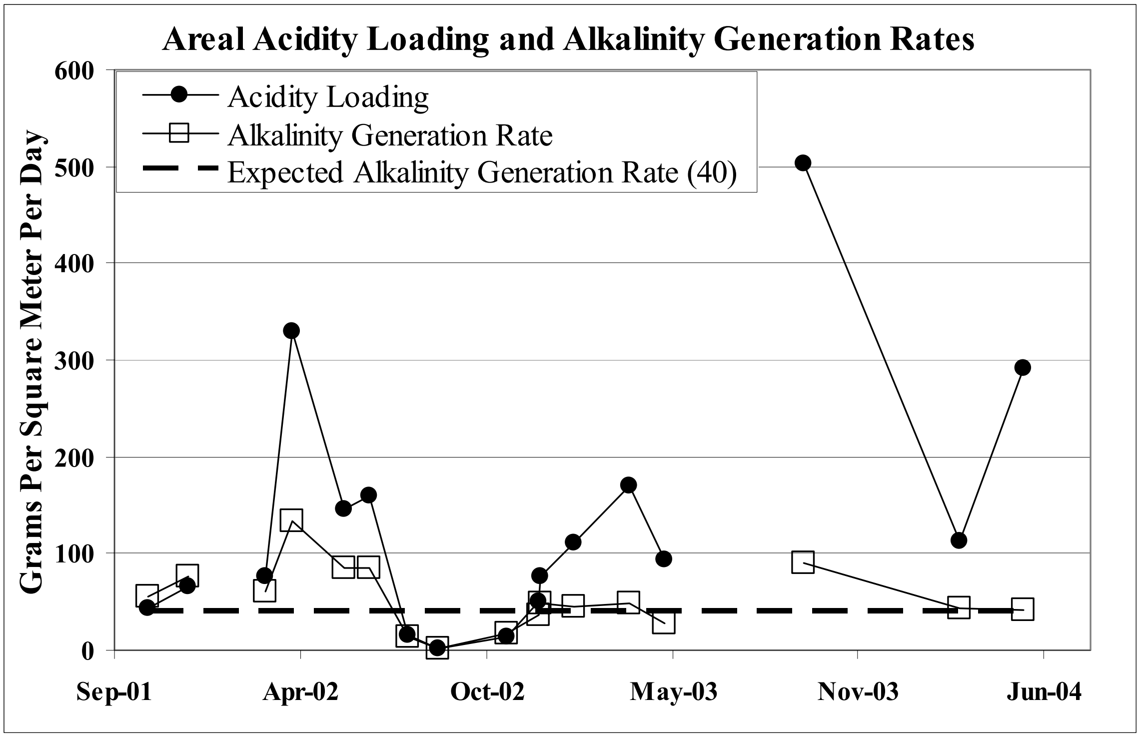

Figure 2. Comparison of total system influent loading and combined alkalinity generation rates of SAP 1A and 1B. The expected rate of alkalinity generation is also shown. The alkalinity generation rate was within the range of expected performance even in May of 2004 well after the system was declared to have "failed".

The overloaded situation is clearly illustrated in Figure 2. The average influent loading was three times the expected treatment capacity. The loading during several high flow events was 8 – 12 times more than the treatment capacity.

Rehabilitation Plan

The autopsy and loading analysis indicated that the system's reactive substrates were degraded by regular overloading with acidity and metals. A plan was developed to: 1) decrease loading to the system, and 2) rehabilitate the existing system so that it would effectively treat the lower loading.

Task 1: Collection and Diversion of the R2 discharge

The treatment system receives two discharges identified as R1 and R2. Both emanate from a complex of deep mines and unreclaimed or poorly reclaimed surface mines that straddles the watershed divide between Huling Branch and Middle Branch (Map 1). Most of the flow from this 96 acre complex flows to the Huling Branch watershed because the dip of the coal seam favors flow in that direction. AMD flowing into the Huling Branch watershed has been monitored for several years. The AMD is severe and the flows are erratic, responding quickly to precipitation events. The R2 discharge also has extreme chemistry and erratic flows.

The overloaded conditions at the Middle Branch passive system are largely due to the variable nature of the R2 discharge. In contrast, the R1 discharge has more stable flow and chemistry. Table 2 shows the characteristics of the discharges. The data and site observations suggest that the R2 discharge is fed through shallow subsurface flow paths while the R1 discharge is connected to a larger, deeper aquifer.

Table 2. R1and R2 Discharge Characteristics.

R1	Max	Min	Avg
Flow, gpm	24	3	14
Acidity, mg/L	795	98	420
Fe, mg/L	21	1	8
Al, mg/L	105	9	54
Mn, mg/L	24	4	15

R2	Max	Min	Avg
Flow	182	0	45
Acidity	1,128	362	737
Fe	38	6	21
Al	147	12	87
Mn	31	9	20

Unlike the R1 discharge whose source is unclear, the R2 discharge appeared to emanate from an abandoned deep mine drift entry (Map 2). The deep mine (identified in the Twomile Run Watershed AMD Remediation Master Plan as the “Area 7 Eastern Deep Mine”) has an area of approximately 28 acres. Surface mining on the updip side of the mine intercepted the mine workings and were abandoned with no reclamation. As a result, a 37 acre closed depression in the unreclaimed spoils drains to the intercepted deep mine workings. Additionally, the dip of the coal directs some flow on the pitfloor of the surface mine into the deep mine. In this way the deep mine serves as a conduit for large quantities of AMD. Over the years subsidence has obstructed the drift entry eliminating the primary outlet for water from the mine and forcing the AMD into the shallow subsurface where it emerges as the R2 discharge 80 feet in elevation below the coal outcrop.

R2 Discharge Collection

In September of 2007 the abandoned drift entry into the Area 7 Eastern Deep Mine was opened and a collection system was installed. During the excavation it was found that the mine was inundated with 6-8 feet of water. This water was released gradually over the course of a week to allow installation of the collection system. Once opened the mine roof was found to be in poor condition. The 4-5 foot thick Columbiana Shale had fallen into the mine leaving a hard sandstone roof well above the top of the timbers. The Columbiana shale is a high-sulfur unit and the conditions in the mine were ideal for pyrite oxidation and acid generation. Photos 1 and 2 show the excavated mine entry and poor roof conditions.

Two 6 inch Schedule 40 perforated pipes were placed as far into the mine as could safely be reached. The two pipes were then joined into a solid 6” Schedule 40 pipe. A clay plug was installed around the solid portion of the pipe and sandstone aggregate placed over the perforated pipe. Photo 3 shows the outlet pipe before it was extended into the Huling Branch watershed. Geotextile was placed over the aggregate before backfilling.

The 6 inch solid pipe was then extended 1,090 feet to an existing kill zone in the Huling Branch watershed (Photo 4). The initial plan called for 700 feet of pipe. However, the landowner (DCNR) requested that the outfall enter an existing killzone to prevent the creation of a new killzone. As a result, the pipe was extended and the outfall given the sampling identification of Huling F (Map 3). This keeps with existing collection system naming system that includes Huling Collection Systems A through E.

The diversion of the AMD caused a substantial decrease in the flow of the R2 discharge. Figure 3 shows flow rates in the three weeks following the project's initiation. The R2 flow rate decreased immediately after the installation of the collection system. The flow of R1 did not change during this period. Figure 3 shows the response of the R2 discharge to dewatering of the deep mine.

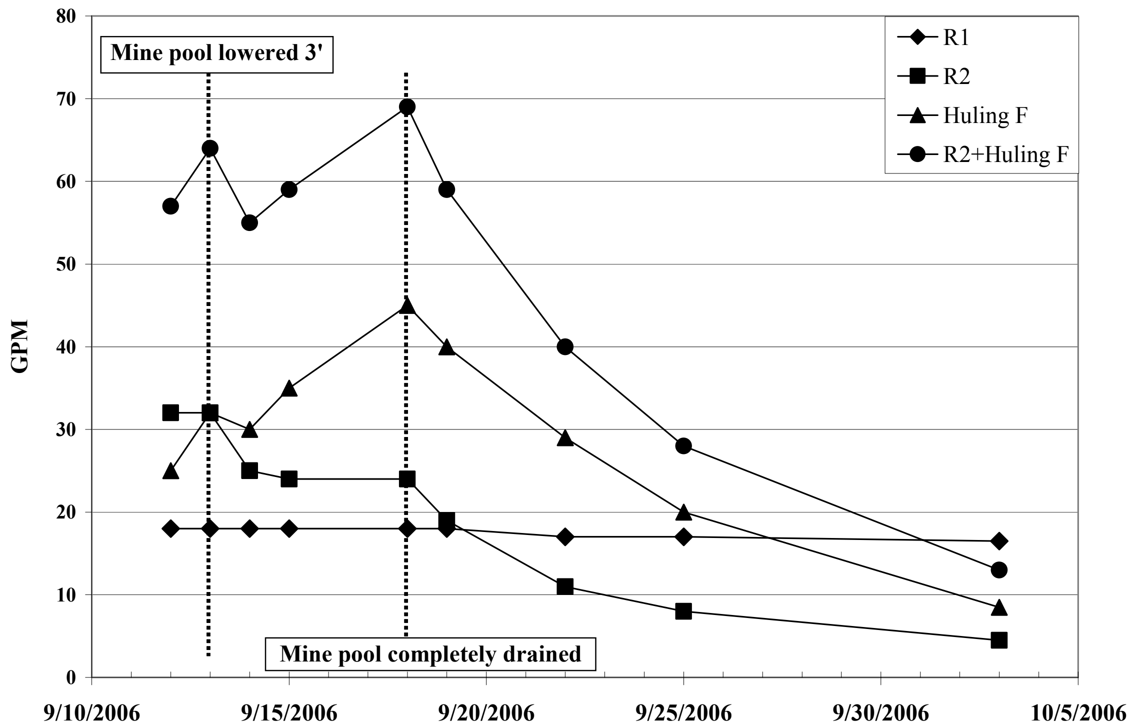

Figure 3. Relationship of flow between the Huling F collection system and the R1 and R2 discharges. Flows at R2 responded immediately to collection

Since installation, the Huling F collection system has discharged 2-3 times more flow than the R2 discharge. Despite above normal precipitation in October and early November, the R2 discharge had a maximum observed flow rate of 45 gpm on November 14, 2007. In the past, similar precipitation conditions would have resulted in flows exceeding 100 gpm. The total flow from R2 and Huling F on this date was 113 gpm. It is likely that this approximates the R2 discharge flow without collection. The installation of the collection system has successfully diverted high flows and loadings away from the treatment system.

In addition to reducing the amount of AMD that flowed into the Middle Branch Passive Treatment System, the diversion of the collected water into Huling Branch also moved the discharge 3,700 ft. downstream. Even if the collection system effluent is left untreated, 3,700 ft. of stream has been improved by the installation of the collection system itself.

Task 2: Treatment System Rehabilitation

The installation of the Huling F collection system reduced the loading to the treatment system considerably, but the loading still exceeded the capacity of the existing system. Task 2 involved improvements to the existing VFPs to increase its treatment capacity through the conversion of the two manganese removal beds to VFPs. This essentially doubled treatment capacity. The modifications are shown in detail in the As-Built Plans dated June 2007. A schematic view of these improvements is shown in Map 5 and described below.

A summary of the system improvements are as follows:

- Replace contents of upper VFPs
  - 600 tons AASHTO #1 limestone each
  - Existing compost reused and amended with 240 tons of AASHTO #10 limestone
- Eliminate short circuiting issues observed in upper VFPs during the system Autopsy.
  - Remove cleanout pipes that created large voids through the compost layer.
  - Shorten rock aprons at raw influents so that they do not extend through compost layer.
- Improve flow management.
  - Limit flow entering system from R2 discharge to ~25 gpm. High flow bypass goes to existing surface water diversion ditch.
  - Bypass R2 flow around upper VFPs to mix with treated R1 flow in settling pond.
  - Provide option for directing flow from R2 into upper VFPs.
    - Re-used existing valve to provide this option
- Increase system treatment capacity by expanding the manganese removal beds and converting them to vertical flow ponds.
  - Existing limestone cleaned and reused.
  - New compost added and amended with 200 tons of AASHTO #10 limestone.

MAP 5 shows the new layout of the system.

Treatment System Construction Notes

Fouled limestone was removed from the system during the week of October 30, 2006. The stone was removed by DCNR personnel and used to improve the driving surface of a nearby forestry road. Much of the limestone in the VFPs was removed (Photo 7) and approximately 8-12 inches of the limestone in the manganese beds was removed (Photo 8).

Construction equipment was mobilized to the site on May 23. Underdrain plumbing in the VFPs was repaired and limestone placement began soon thereafter. Photo 9 shows limestone being placed in the upper VFPs. Two existing valves connecting the VFPs were removed as the new configuration makes them unnecessary. One of the two valves was placed on the high flow bypass pipe from the R2 discharge to allow water to be diverted into the VFPs if desired. Photo 10 shows the completed VFPs.

During excavation into the limestone of the Mn removal beds, considerable amounts of metals precipitates were encountered (Photo 11). The amount of solids was much more than what was observed during the system autopsy in 2004. The system was thought to have been off line since the autopsy so the bed was assumed to be in a similar condition. This assumption was incorrect. To prevent plugging problems, the limestone was washed as it was handled using a 4" pump that sprayed water from the settling pond onto the limestone. Washing the stone seemed to effectively remove solids as shown in Photo 12.

The final thickness of limestone in the Mn removal bed VFPs is approximately 3' (Photo 13). One foot of limestone amended compost was placed on top of the limestone layer (Photo 14).

A small flow of groundwater enters the base of the Mn beds. The water was not discovered until after the limestone handling was completed. As a result the quality is not known due to the fact that the water flows through limestone before reaching the outfall pipe. The total flow into both beds was 0.75 gpm.

System Performance

As of the writing of this final report, no discharge from the rehabilitated Middle Branch system has occurred. The system rehabilitation occurred during dry weather that has persisted. The R2 discharge has been dry since mid May and flows from R1 have been less than 5 gpm since the system went online. At the current flow rates, the system will not discharge until late September to early October 2007.

Summary and Conclusions

The Middle Branch passive treatment system exhibited declining effluent water quality a year after its installation. Investigations revealed that the primary cause was overloading with acidity and metals. In order to make the system effective and provide treatment necessary to restore the water quality in Middle Branch, it was necessary to lessen the contaminant loading and rehabilitate the system. Contaminant loading was decreased by collecting flow from an abandoned deep mine entry and diverting it to Huling Branch, an adjacent stream that is already highly polluted with severe AMD. As a result of the diversion, large precipitation-related spikes in flow and contaminant loadings appear to have been removed. The treatment system was rehabilitated to increase its ability to effectively treat the remaining AMD. Two existing VFPs were rehabilitated by replacing the limestone aggregate, organic substrate and a portion of the underdrain plumbing. Two oxic limestone beds that were intended for Mn removal were reconstructed into a single VFP. The renovations have brought the treatment system's alkalinity generating capacity in line with the expected long-term acidity loadings. The result should be a good quality final effluent and considerable improvement to Middle Branch.