Evaluation of the Dober Mine Synergetic Acid Water Treatment System

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10 March 2005

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Cite as: Johnson, Allan M., Kent Premo, David Tiller, and Bette Premo. 2005. Evaluation of the Dober Mine Synergetic Acid Water Treatment System. White Water Associates, Inc., 10 March 2005. 32 pages, plus Appendices for Figures (8 total) and Photographs (18 total).

Aerial photography courtesy of James Bond, Iron River Watershed Manager,
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INTRODUCTION

In late October of 2004, PolyOne Corporation of Cleveland, Ohio, authorized White Water Associates, Inc., to proceed with a series of field and laboratory evaluations of the Dober mine acid water treatment system which has been operating since 1987 near Iron River, Michigan. The main purpose of the study was to check on the key operating functions of the Dober mine synergetic acid water treatment system in an effort to discover the reason or reasons for the occasional lower than permitted pH levels of the outfall water from the pond system in response to an order by the Michigan Department of Environmental Quality (MDEQ).

The synergetic pond system operates by diverting a controlled quantity of Iron River water into the Dober mine pit where it mixes with and neutralizes upwelling acid mine water. This neutralization in turn causes the precipitation of iron, a major component of the acid water. The insoluble hydrated iron hydroxide, commonly known as “yellow boy” begins to settle in the Dober pit and continues settling through a series of downstream ponds before a much clearer effluent is returned to the Iron River.

This study, begun in late October 2004, was designed to evaluate the key portions of the Dober mine synergetic acid mine water treatment system through field observations and measurements plus selected laboratory analysis of water samples collected in the field, namely:

1. The nature of the acid water remaining within the mine complex.
2. The inflow rate and neutralizing capacity of the diverted Iron River water.
3. The condition of the Dober mine pit where mixing and neutralization of acid water occurs and where iron hydroxide precipitation begins.
4. The effectiveness of the downstream ponds in receiving and retaining precipitated iron compounds.
5. The current overall flow regime within the mine complex and pond system as determined from water level measurements.
6. Changes in the system that have occurred over the years as determined by comparisons of current water data to earlier water level measurements.

This report provides background information on the Dober and associated mines of the complex. It draws heavily on the reports of the extensive research performed at Michigan Technological University in the 1970s and 1980s from which evolved an understanding of the hydrology of the mine complex. The report also describes the work done from late October 2004 through February 2005 to address the six critical items listed above and offers specific recommendations to improve the effectiveness of the synergetic pond treatment system.

HISTORICAL BACKGROUND

The Dober mine is located west of the City of Stambaugh and south of the City of Iron River, Michigan, in the Iron River Valley. It is part of an interconnected complex of mines also made up of the Hiawatha and Isabella mines. The Dober mine and the smaller Isabella mine are on the east side of the Iron River and are connected with the larger and deeper Hiawatha mine (Figure 1, 2). These three mines were initially separate but were later combined into a single operation. Direct shipping iron ore was extracted from the Riverton Iron Formation from depths as great as 2500 feet from within a complexly folded and faulted synclinal structure (Figure 3).

Direct shipping ore was mined from the Riverton Iron formation at the Dober-Hiawatha-Isabella mine complex. This formation is underlain by the Dunn Creek slate, the upper part of which is the pyrite-rich Wauseca member. When exposed to air and water, the fine grained and porous pyrite would rapidly oxidize to form iron sulfate and sulfuric acid. Although the mine complex was not particularly wet, acid waters were pumped from the mine into the Iron River. The Iron River rapidly neutralized this acid causing the former soluble iron to become an insoluble iron hydroxide precipitate. This in turn turned the waters into a yellowish brown color, commonly called yellow boy. As many other mines operating in the Iron River District also produced acid waters and the economy was almost totally supported by iron ore mining, the discolored river waters were mostly accepted in the earlier days. When the mine complex closed, the flow of acid waters into the river stopped, as did the yellow boy formation.

The Hiawatha was the last mine of the complex to operate. Production there ceased in 1966 and the mine was allowed to flood. Of course all the mines of the complex flooded as the workings of the three mines had been interconnected by stopes, cross cuts and drifts. Six years later, in the fall of 1972, water was noticed in the bottom of the Dober mine pit. Over a period of 45 days it rose 100 feet. Residents were quite surprised to see the Dober and Isabella mine pits flood as they had been dry for as long as anyone could remember, in fact, since the mines were opened in the late1800s.

The rising acid waters were of more than just idle curiosity. The main sewage line feeding the nearby Stambaugh Sewage Treatment Plant passed immediately west of the Dober mine pit. When the acid waters reached the level of the sewage line it entered corroded sections of the cast iron pipe and flowed into the plant, disrupting the bacteriological sewage digester. This problem was temporarily solved by inserting a smaller diameter plastic pipe inside the sewage line and by lowering the acid water about two feet by dredging a ditch from the Dober mine pit to the Iron River (Van Alstine, 1973).

This action diverted the acid directly into the Iron River, resulting in the seemingly intractable problem of persistent acid water drainage and billowing plumes of yellow boy forming in the Iron River at the Dober discharge ditch. This insoluble iron hydroxide hydrate discolored the Iron River from Stambaugh, past the downstream Iron County communities of Caspian and Gaastra to the state line with Wisconsin where the roiled waters entered the Brule River some seven miles to the south. This occurrence soon involved the State of Wisconsin and the Nicolet National Forest. Pressure from these groups caused the State of Michigan to provide funding to study these problems in 1974.

Mine studies funding came to the former Institute of Mineral Research of Michigan Technological University through the Geological Survey Division of the Michigan Department of Natural Resources. Dr. Allan Johnson, a young research engineer at IMR with degrees in geological engineering and geology, was given the responsibility of overseeing the acid mine water drainage study plus issues related to mine subsidence. These studies resulted in a series of reports which initially addressed and quantified the dual problems (Johnson and Frantti, 1976; Cregger, 1977; Johnson and Frantti, 1978). Supplemental funding to follow up on the recommendations of the initial reports led to several proposed plans for addressing the acid drainage problem at the Dober mine, first by pumping (Johnson, 1979) and lastly with a synergetic acid water pond treatment system (Johnson, Hockings and MacDonald, 1984), the subject of this report.

Reviewing all options, it was recognized that the acid water from the Dober pit was readily neutralized by the Iron River and that the iron was converted to an insoluble precipitate. It was reasoned that if this could be done away from the river a possible solution was at hand. Of the three options for neutralizing acid waters—a high pH laundry discharged at Caspian, Stambaugh Sewage Treatment plant water discharge near the Dober mine, and Iron River water—the latter was eventually selected for pilot scale field testing. Further development of this idea was to use the Dober mine open pit as a mixing chamber for neutralization and a series of natural pond areas south of the Dober mine as settling ponds for further treatment of the effluent from the Dober pond to promote settling of the insoluble iron precipitates before returning a neutralized and largely iron-free effluent to the Iron River.

THE DOBER MINE SYNERGETIC ACID TREATMENT SYSTEM

Previous research on the Dober-Hiawatha-Isabella mine complex provided much of the basic knowledge needed for this project, including:

1. Chemical composition of acid water flowing from the Dober pit.
2. Range of acid water flow rates over the year and an average flow rate.
3. The presence of a fresh/acid water interface within the mine complex that changed with time.
4. The volume of voids within the mine complex from mine maps and ore production records as a check.
5. An understanding of the complex chemistry of ferrous to ferric iron oxidation and the formation and hydration of yellow boy.
6. Knowledge that additional acid was not being generated within the flooded mine due to oxygen depletion.
7. Elevated water levels in the western portion of the mine complex from less dense fresh waters being balanced by dense acid water in the Dober mine shafts.
8. A working hydrological model of the mine complex developed from an assimilation of the above data.

The research plan was divided into five phases. First, laboratory bench scale tests would be performed. Second, scaled-up pilot tests would follow in the field near the Dober mine with the selected neutralizing water (Iron River water). Third, a field assessment phase would examine the effectiveness of the Dober pit and the several downstream pond areas in the old Iron River channel on the east side of the river as settling ponds. Fourth, a preliminary engineering design phase would be concerned with the mixing system in the Dober pit based on the lab and field data. Fifth, a final report would be prepared describing the research and its findings and giving specific recommendations for the synergetic acid water treatment system.

In lab tests, river water showed nearly complete precipitation of iron at a mixing ratio of 1:27 in 3 days time at 2°C and in one day at 10°C. The pH gradually increased with time from about 7 to 8. Likewise in the field pilot-scale tests run at the Stambaugh Sewage Treatment Plant for a period of 36 days utilizing a four tank, 10,000 gallon system, optimum results in terms of neutralization and precipitation were obtained with a 25:1 mixing ratio of river to acid water and 5 days settling time. Aeration in the field tests significantly enhanced metal precipitation.

The synergetic pond system plan proposed a diversion structure in the Iron River be utilized to raise the water level sufficiently to divert controlled amounts of water into the Dober mine pit via a large diameter pipe. Here mixing and neutralization of the acid water would take place causing the yellow boy to form and begin to precipitate and settle out in the Dober pit. This neutralized water with the finer suspended particles of precipitate would flow out of the pit and into a series of stepped ponds where further precipitation and settling would occur. Weirs were planned that would control the level of each pond to promote aeration of the pond waters and provide additional retention time for settling to take place. From the last pond, a much cleaner effluent would be returned to the Iron River.

The ponds already existed in the former channel of the Iron River which had been moved westerly away from the Dober mine in the 1890s following the disastrous flooding of the Mansfield mine in east Iron County. This happened in 1893 when the Michigamme River poured into the failed timber shaft located next to the river, killing 27 miners.

The synergy of the system would be achieved in a number of ways. A first synergy is the gravity flow of water through the system, as no electric power would be needed to pump water. A second synergy is the use of preexisting basins for neutralization of the acid water and settling of the yellow boy precipitate—the Dober mine pit and shallow ponds in the former Iron River drainage immediately south of the Dober mine. A third synergy comes from the nature of chemical reactions leading to precipitation of dissolved iron in the acid water. Although the river water would dilute the acid and lessen the concentration of dissolved iron in proportion to the mixing ratio of river to acid water, the elevated pH accompanied by the oxidation of the dissolved iron to insoluble ferric iron would further reduce the iron by a factor of nearly 10 times that of dilution alone.

The favorable attributes of the synergetic pond system for treating acid mine water from the Dober mine combined with persistent efforts by individuals of the local Acid Mine Water Clean-Up Committee, Michigan Technological University (MTU), the Michigan Department of Natural Resources (MDNR), the Natural Resources Commission, Trout Unlimited, the

Outdoor Clubs of Iron County, and others finally paid dividends. In August of 1985, then Governor Blanchard came to Iron River to present an Act 307 (Michigan's Superfund) check for $140,000 for the pond system design and construction. The firm of McNamee, Porter and Seeley did the engineering design, and Hebert Construction Company was one of the contractors. By late 1988, the system was installed and operating.

The main elements proposed in the preliminary engineering plan prepared by MTU were adhered to in terms of river water diversion, mixing in the Dober mine pit and the downstream settling ponds with one exception: weirs were not put in place between the ponds.

It was expected that the system would function as designed as long as the proper amount of mixing water was provided. What was unknown at the time was how rapidly the iron hydroxide hydrate precipitate would build up and whether removal would be needed at some point in the future.

The Dober mine synergetic pond system has been operating for a little over 16 years since its construction. For the most part, the system has performed well. To date, over 300,000 tons of iron have been precipitated from acid waters issuing from the Dober mine that otherwise would have gone into the Iron River. It is apparent that some problems were encountered during this period. High water levels in the spring sometimes flooded the Dober mine pit and pond system which made its functioning questionable until water levels dropped to normal.

Also, occasionally the pH of the outflow waters would drop below that established for the discharge permit, which has been set at pH 6.5. This happened in June 1992, after the system had been in operation for approximately 3.5 years. At that time I was asked to come to Iron River by Steve Casey of the then MDNR (now, MDEQ) to seek my input on what might have caused the low pH and what might be done to correct the situation. On 29 June 1992, a pH measurement of the pond outfall was 5.74 and a great deal of suspended iron hydroxide floc was coming over the outfall weir. Also the water levels in the Dober pit and pond system were very high but obviously had been much higher from the yellow boy rings (high water marks) on trees growing around the pit and ponds.

Steve told me that the pond system had been shut down without the MDNR being informed. Apparently this had been done at the time of construction on the Museum Road culvert below the Dober mine pit. Based on my knowledge of the hydrology of the mine complex, I believe that when the river water flow to the Dober mine pit was cut off, suspended iron hydroxide in the pit settled and temporarily sealed the channel way for acid water to enter the pit. This, in turn, caused recharging waters to rise in the Hiawatha mine to the west possibly until the head was great enough to break through the seal in the Dober pit, sending a surge of acid water into the pit and pond system. I don't know how long the water had been shut down, but it is quite likely that the seal broke when the weir was opened to let river water in. The mixing system at depth in the pit creates a brisk current near the pit bottom which may have aided the rupturing of the seal. The buildup of water in the Hiawatha mine would have forced very high volumes of acid water through the mine complex and caused unusually high flows through the Dober pit and pond system, so that mixing ratios were much too low to neutralize all the acid. Perhaps the river water had not been turned on when the seal broke, resulting in an even larger slug of acid water passing through the pond system untreated.

Several times I became aware that beaver dams downstream of the pond system on the Iron River have raised the water several feet or more in the pond system and the Dober pit which would in turn raise water levels in the Hiawatha mine complex and retard the inflow of neutralizing water into the Dober pit. These conditions also set the stage for subsequent heavy flows of acid water which the system has difficulty handling, resulting in incomplete treatment of the acid water and negative impacts to the Iron River.

Concluding these personal comments, I am very pleased when I am brought in to help solve problems arising with the Dober mine acid water treatment system. After all, a significant part of my professional career has been devoted to developing an in-depth understanding of the hydrology of the Dober mine and acid mine water prevention and treatment systems. Being able to work on this challenging, seemingly intractable problem with some effectiveness has been highly rewarding professionally in terms of self satisfaction. I am sure that most of my co-investigators have the same rewarding feelings.

FIELD AND LABORATORY INVESTIGATIONS

Beginning in late fall of 2004, White Water Associates undertook a project involving specific field evaluations and laboratory analyses directed toward improving the functioning of the synergetic Dober mine acid water treatment system. The specific tasks are as follows:

1. reestablish the water level measurements across the mine complex
2. perform deep sampling of the Hiawatha No. 2 shaft
3. profile and sample the Dober mine pit
4. investigate the pond system and determine its effectiveness
5. check and measure flow at the inflow and outflow weirs

Each of the items listed above are described in the following sections.

Water Levels Measurements

Water level measurements have been taken in the mine complex at four locations, three from within the Hiawatha mine on the west elevated side of the Iron River and one at the Dober mine in the Dober pit on the east side of the river in the river valley. The Hiawatha mine measurements are identified as CDH 2-45 (churn drill hole 2-45), Hiawatha mine shaft No. 1, and Hiawatha mine shaft No. 2. The fourth measurement was taken at the flooded Dober mine situated at a lower elevation east of the Iron River in the valley flood plain. These locations are shown in Figures 2 and 5.

Water level measurements in the pond system were taken at three stations within the pond system beginning at the Dober mine pit, and then downstream at a steel stake at the end of a levee that separates two ponds near the center of the pond layout east of the Iron River. The last measurement was taken at the outfall weir of the lowest pond where the water drops into a short channel which flows a short distance west into the Iron River. Locations of these points are shown in Figures 5 and 7.

For this study, a single water level measurement was also taken within the concrete weir box located near the water diversion structure on the Iron River. This reading was accomplished by unlocking the metal cover and measuring the distance to the water from the southwest corner of the aluminum metal border which is fastened to the concrete. This location is shown in Figures 5 and 8.

In order to provide a common datum, a precision level survey was contracted for this study. The survey consisted of eleven control points including all of the reference points listed above. The survey was tied into a USGS elevation bench mark in Stambaugh, Michigan near the Stambaugh High School which is northeast of the Dober mine above the Iron River valley. These stations are listed and some are shown on Figure 5. They have been surveyed to within the nearest 0.01 foot by the closed level survey.

Water level readings were taken at all of the above stations on 23 November 2004 and have been converted to the USGS datum for comparison purposes. The results are shown in the following table (Table 1).

Table 1. Water Levels Within the Dober Mine Complex and Pond System on 23 November 2004.

Hiawatha Mine	***Elevation (feet)***
Hiawatha #2 shaft	1460.27
Hiawatha #1 shaft	1460.04
CDH 2-45	1460.21
Dober Mine and Ponds	***Elevation (feet)***
Intake Weir on Iron River	1459.41
Dober mine pit	1459.22
Settling Pond steel stake	1458.98
Settling Pond outfall	1457.85

It can be seen from data in Table 1 that water levels in the Hiawatha mine range in elevation from 1460.04 feet to 1460.27 feet and average 1460.18 feet elevation. These elevations represent the greatest height of waters within the mine complex. Because the

Hiawatha mine is situated on higher ground than the Dober mine and has thick overburden cover, it also receives groundwater inflow from the overburden which is the driving force for the acid water flowing from the Dober mine, situated at a lower elevation across the Iron River to the east.

The water level in the Dober mine pit on 23 November 2004 was 1459.22 feet. The elevation of the intake weir water was 1459.41, or 0.19 feet above the Dober pit surface.

The mixed river and acid mine waters flow southward from the Dober mine pit into natural settling ponds in the former Iron River channel. A series of four ponds make up the settling pond complex. One of the water level measuring points selected for this study is the north concrete pier of the outfall weir. On 23 November 2004, the water exiting the lower pond was 0.96 feet below this pier (1457.85 feet). A second point near the center of the pond system was established by driving a steel stake in the flow channel just east of the long berm that juts easterly into the ponds system (Figure 5). On 23 November 2004, the water level was 1.77 feet below the steel stake (1458.98 feet). On that day the total drop through the settling ponds from the Dober mine pit to the outfall was 1.37 feet.

In the mid 1970s, the head on the Hiawatha mine waters was 6 feet above the acid water in the Dober mine pit. This 6-foot differential was proven to be due to differences in density of the columns of water in the two mine complexes (Johnson, 1979). A U-tube concept was used to explain this difference where one leg containing a denser liquid caused the less dense liquid in the other leg to rise higher when at equilibrium. This hypothesis was supported by deep mine sampling of the waters and pycnometer measurement of the denser acid water in the Dober leg of the “U-Tube”. One must keep in mind that there was no inflow of river water into the Dober pit then as there is now.

Presently the head difference between the Dober mine pit and the Hiawatha mine is less than one foot (0.96 feet). This present smaller difference in head shows that the acid water in the Dober mine leg of the U-tube is much closer in density to the recharging ground waters replacing acid water in the Hiawatha leg. This is evidence that much acid has been flushed from the mine complex and is largely replaced by less mineralized water after 30 years; i.e., compared to 1975 conditions.

Deep Sampling of Hiawatha No. 2 Shaft

Earlier work on deep sampling of the Hiawatha mine was done at the Hiawatha No. 2 shaft in the summer of 1976 for the initial mine subsidence and acid water study (Johnson and Frantti, 1978). At that time, the fresh water/acid water interface was found to lie at a depth between 525 to 550 feet below the surface water level in the shaft or between 563 and 588 feet below the shaft's concrete cap.

Fortunately for this study, the mine shaft sampling device was still available, although some effort was needed to retrieve it from storage and to put it in working condition. This was done and on 3 November 2004, Johnson and Tiller brought the unit to the Hiawatha No. 2 shaft and set it up to take deep samples.

Although the Hiawatha No. 2 shaft is 2357 feet deep, it was determined that 1200 feet would be the maximum depth sampled. The shallower depth was selected because a Kemmerer sampler had been lost in 1976 when samples at depths greater than 1200 feet were attempted. In was learned last fall when the deep sampling was being done at the Hiawatha No. 2 shaft, from an elderly former miner, that the shaft is lined with concrete down to the 12th level (1200 feet), and also that much mining equipment debris was left in the shaft below this level (steel cable, mine skips, etc.).

Six samples were collected from within the shaft from depths ranging from 100 to 1200 feet below the water level on 23 November 2004. Field tests were run for pH and specific conductance. Samples were returned to Amasa, Michigan to be analyzed in the White Water Associates laboratory for iron and titrated with sodium hydroxide to determine acidities and measured for ORP (oxygen/reduction potential). These data are presented in the following table (Table 2).

Table 2. Analysis of Deep Water Samples, Hiawatha No. 2 Shaft, 23 Nov. 2004

Depth (feet)	*pH (s.u.)*	*Conductivity (μmhos/cm)*	*Acidity (mg/L $CaCO_3$)*	*Iron (mg/L)*	*ORP (mv)*
100	6.63	556	66	0.19	70
500	7.16	553	12	0.19	21
750	7.22	553	13	0.54	28
1000	7.13	594	16	4.68	20
1050	6.10	5670	945	672	19
1200	5.70	6540	995	945	41

1976 analyses are presented below

100	7.2	580	100
500	6.6	2020	240
525	6.7	7000	38
550	3.8	5900	1670
600	3.7	5900	1680
1000	3.7	6200	1870
1200	4.0	6800	2080

Water to a depth of 1000 feet in the Hiawatha No. 2 shaft is seen to be of rather high quality; that is, it has elevated, near neutral pHs and moderate specific conductivities between 500 and 600 μmhos/cm. The acidities are also low (from 12 to 16 mg/L calcium carbonate) as are the total iron values, which are well below 1 mg/L (except for the 1000-foot sample at 4.68 mg/L). The redox potential of the waters diminishes with depth from a high of 70 millivolts at 100 feet to a low of 20 mv at 1000 feet.

However, at 1050 and 1200 feet the water is more acid (pHs from 5.7 to 6.1) and specific conductivity values are up ten-fold (5670 and 6540, respectively). The acidity values are also significantly higher at 945 and 995 mg/L calcium carbonate, respectively. The total dissolved iron values are very much higher at 672 and 995 mg/L Fe, respectively.

When compared to the readings obtained at similar depths within the mine shaft in 1976, 29 years ago, it is obvious that the pH, specific conductivity, and iron concentrations have improved significantly. This can be attributed to the flushing action of recharging ground waters.

It must be realized that the Hiawatha No. 2 shaft represents only a narrow vertical sampling within the mine complex. However, there are a number of interconnections between this shaft and the other shafts in the mine complex through drifts, cross cuts and mine stopes which permit water flow and mixing. This suggests that the waters in the No. 2 shaft are probably fairly representative of the Hiawatha mine to the depth of 1200 feet. It follows then, that there has been a great reduction of acid in the upper 10 levels of the Hiawatha mine over time, including a marked reduction of acid water above the 10th level.

Conditions in the Flooded Dober Mine Pit

The flooded Dober mine pit is the key element in the synergetic pond system, for it is here that rising acid mine waters mix with larger volumes of river water resulting in chemical changes causing neutralization of the acid and precipitation of iron and other dissolved metals.

The Dober mine pit exists because the first mining was done by open pit methods. Because the Dober ore body is lenticular and dips 65 degrees to the southwest the open pit could only be operated to about the 3rd level of the mine some 300 feet deep. Mining continued via shafts on both sides of the pit. Early mine maps show the Dober No. 1 vertical shaft on the north side of the pit has 10 levels to a depth of 980 feet and the inclined No. 2 shaft, southeast of the pit dips 65 degrees southwesterly to follow the dip of the ore body as far as the 9th level (Figure 4).

A mine map shows the Dober pit to extend to the 3rd level of the mine (300 feet). However, extensive caving of open stopes between levels broke through the drift pillars on the lower levels of the mine resulting in caving to at least the 10th level (1000 feet below ground). In a 1975 interview with 94-year-old former mine captain Peter Kuchan, he recalled that when the Dober mine was operating he could stand on the 10th level and see daylight above. This was possible because the footwall pillars left on some of the drifts had collapsed into open stopes below. He also said that extensive sand filling was done to stabilize the mine and to prevent mine fires from spontaneous combustion of pyritic-graphitic slate encountered on some levels in the footwall rock.

On 10 November 2004, Tiller and Johnson had plans to take depth measurements and water samples from the Dober mine pit. Using a 12-foot aluminum row boat, they put in at the Dober pit drainage channel above Museum Road. Some difficulty was experienced getting upstream into the flooded pit through the sunken and floating debris (logs and limbs from dead trees), but once accomplished it was relatively easy maneuvering the rowboat.

Prior to taking measurements and samples, a series of five NNE by SSW lines were marked using prominent locations on the easterly bank of the pit and corresponding snags of tree tops jutting above the yellow water on the southwest side of the pit. Colored flagging was used to mark snags for each of the lines. Two lines traversing the deep part of the pit perpendicular to the aforementioned lines completed the grid. A sketch map of the pond and grid was made while in the boat and the distances between the lines were later paced from the banks of the pit (Figure 6).

A portable sonar-type depth finder was used initially to profile the bottom by rowing slowly along each line. The maximum depth recorded from these measurements was 81 feet near the NNE shore of the pit. Most of the readings in the deep eastern central part of the pit were from 70 to 75 feet deep. Selected sonar depths are penned on grid lines of Figure 6 and the deeper portions of the pit are contoured.

Depth measurements with a weighted measuring line were taken at several locations to see how measured depths compared with the sonar measurements. At a sonar recorded depth of 74 feet in line with the manholes, a sounding showed a depth of 63 feet to a sludge layer that was 10 feet thick (the weight on the sounding line moved sluggishly through the sludge). On a second comparison, a sonar depth of 44 feet compared with a 46 foot sounded depth. On a third comparison, a sonar depth of 76 feet compared with a 73 foot depth with several feet of sludge near the bottom (some sludge residue came up with the sounding device). Thus the sonar depths seemed to be quite accurate when checked by sounding. This was a welcome finding, showing that sonar depths (which are easier to obtain) are fairly accurate with an apparently smooth bottom profile; i.e.; with no rapid changes in depth.

Around 1975, prior to the pond system, the Dober mine pit was sounded with a weighted line to profile the pit. At that time, the maximum vertical depth in the pit was 135 feet. Actually, it is believed that the pit was much deeper than 135 feet, because the ore body dips quite steeply at 65 degrees to the southwest and the vertical sounding line would not follow the mine openings "down dip" at that angle. It is evident now that iron hydroxide precipitates have filled in the lower levels of the pit up to the approximate depth of the mixing water header.

Six water and precipitated iron hydroxide sludge samples were collected from deeper portions of the Dober pit with a Kemmerer sampler. The samples were taken at the intersections of the center grid lines and also near the indicated locations of the mixing river water discharge points (as determined from the blueprint drawings examined at the White Water Associates offices in Amasa earlier in the morning). Several of the bottom samples contained large amounts of red brown iron hydroxide hydrate (yellow boy) precipitate. Also, several water samples were collected near the mixing river water discharge pipes. These samples, nearly sludge-free and little discolored, were believed to be mostly river water shortly after entering the Dober pit at the 70 foot depth from the HDPE headers. Here the specific conductance readings were in the mid-700s and the pHs ran from 6.56 to 6.63. Elsewhere the conductance values varied from 1200 to 1400 µmhos/cm and the pHs values varied from 6.03 to 6.23, indicating the presence of up-welling acid water.

It was observed that an apparently firm bottom was present in the vicinity of the river discharge header at the depth of approximately 70 feet. It should be kept in mind that the Dober pit was initially an open pit mine and that open stopes (mined openings) were caved to the 10th level, although significant sand filling was also done to stabilize the mine and to extinguish mine fires. Also it should be kept in mind that the Number 1 and 2 shafts are situated adjacent to the Dober pit and would be connected with stopes on the lower levels via drifts. Thus there are many paths that the upwelling acid waters can follow within the "plumbing system" of the mine to reach the surface.

It also appears that the iron hydroxide precipitate has filled much of the volume of the pit and perhaps the open stopes below. This not only reduces the volume of the Dober mine pit, and therefore retention time in the system, but may also interfere with effective mixing and neutralization of the acid water.

What was not determined from this effort was the exit location or locations of the upwelling acid mine water in the pit. It was apparent that more detailed measurements and sampling would be needed to ascertain the whereabouts of such location(s).

The purpose of the 10 November 2004 trip to the Dober Mine was to obtain data from which to profile the bottom of the Dober Mine Pit and to obtain water samples for analysis. What had not been determined then was where up-welling acid water was entering the Dober pit.

During the sonar profiling of the Dober pit on 10 November, it was noted that there was one spot in the pit where erratic readings were observed. This occurred near the southeast part of the pit above formerly open stopes in the Dober mine. The readings at this spot showed rapidly changing depths ranging from tens of feet to depths of more than 80 feet. At the time, it was believed that the sonar unit was malfunctioning. However, in retrospect, it was thought that the readings may have detected the inflow point for mine water and that the erratic readings might be representing plumes of iron hydroxide precipitate being carried up by a higher velocity current of mine water entering the pit through a small opening or series of openings. Consequently, it was deemed important to check out this possibility before winter conditions settled in and the work could not be done without great difficulty.

Late in the day on 23 November, after other tasks were completed, a 12 foot aluminum rowboat was put into the Dober mine pit for a second sounding. An attempt was made to locate the zone where erratic readings were previously observed using the sonar device. The suspect area was passed over a number of times with the sonar unit, without being able to reproduce the earlier erratic readings.

Next a water level measuring device with 200 feet of tape marked in feet was used to sound the suspect area. After several attempts, the weighted signal device at the tape's end fed freely to the limit of the tape. As the maximum depth in the pit had been determined to be about 80 feet deep earlier in the month, this seemed to indicate that an opening or channel way had been found into the mine through which mine water was believed to be entering the pit. However, when the larger diameter Kemmerer sampler was lowered in the same general area to obtain a sample of the suspected acid water we were unable to relocate this channel way. As it was near the end of the daylight period, we were unable to pursue this activity to the extent desired and had to end this quest without a satisfactory resolution. However, two bottom samples were taken from this site with the Kemmerer device. They were both dark colored precipitate-filled samples of brownish iron hydroxide hydrate, but not the anticipated upwelling clear acid mine water.

These two sludge samples described above were submitted for acidity titrations. They did yield high acidity levels of 800 and 885 mg/L calcium carbonate. Thus the samples must have been taken near the inflow of acid water before significant mixing with river water had taken place.

Perhaps more careful sounding in the Dober mine pit might be considered for a future sampling trip. Maybe the Iron River water inflow weir could be shut down for a brief while to improve the chances that the acid water inflow site can be located.

Downstream Settling Ponds

The settling ponds, four in number, are actually part of the former Iron River channel which was abandoned when a new straight channel was cut west of the Dober mine in the 1890s. As mentioned previously, this rerouting was done to move the Iron River farther away from the mine following the terrible Mansfield mine disaster.

The settling ponds are defined by several earthen berms and a former railway grade as shown in Figure 7. These ponds are part of the synergetic Dober mine acid water treatment system. They were needed to provide additional time for settling of the metal precipitates from the neutralized acid water issuing from the Dober mine pit.

The settling ponds vary in depth from about 2 to 4 feet and lie east of the present Iron River channel. The mixed acid waters flow through an unused weir structure downstream of the Dober mine pit on the north side of Museum Road. Museum Road was constructed after the pond system had been in operation for several years. It is believed that the weir by the road was disabled after the road was built to help keep the road from flooding during spring runoff. Presently the only operating weir in the pond system is the outfall weir located downstream of the 4th pond near the Iron River.

The first field trip made for this project was 27 October 2004. The plans for that day were to put a canoe into the ponds downstream from Museum Road and to paddle through the ponds taking samples, measuring pond depths and observing the effectiveness of the settling of iron and other metal precipitates in the pond system. However, the cattail growth was so thick and pervasive near Museum Road that it was not possible to put the canoe in the choked channel.

Consequently, on that day the ponds were examined on foot from the east and west boundaries and from the railway grade and constructed berms separating the ponds. It was apparent then that the mixed acid/river water flowed quite rapidly through well-defined channels in the ponds without obstruction and with a seemingly shorter than desired retention time. It also was apparent that extensive cattail growth enhanced the channeling of waters and restricted the effective settling area and volume of the ponds. It was decided then that the pond survey should be postponed until ice cover formed and the work could be done from the ice surface.

Winter Survey of the Dober Mine Settling Ponds

On 26 January 2005, Tiller and Johnson undertook the postponed survey of the four settling ponds lying south of Museum Road. The ponds were frozen over with a maximum ice thickness of 16 inches. The air temperature was about 10°F, with a high overcast in the morning, later clearing. There was about 12-16 inches of snow on the ground and a brisk north wind.

The intent of the survey was to determine the effectiveness of the pond system in retaining the iron hydroxide precipitate (yellow boy) coming from the Dober mine pit. Some of the yellow boy settles in the Dober pit and the remainder settles into a connected series of four settling ponds (Figure 7). Clearer water exits the fourth pond in a narrow channel, passes over the outfall weir, and flows into the Iron River.

The survey consisted of boring a 4 inch diameter hole through the ice with a hand auger. The ice thickness was measured and recorded. Ice chips remaining in the hole were scooped out and the depth of the water was measure with a wooden rule. Next a long clear plastic tube about two inches in diameter was pushed into the bottom sediment as far as hand pressure would allow and was extracted with the water column and soft sediment core intact. The thicknesses of the iron hydroxide sludge and lower organic sediment layer were quickly determined and this information recorded.

The survey began at the south end of the 4th pond system just upstream of the outfall weir and proceeded northerly over the other three upstream ponds. The lower two ponds had complete ice cover, in fact the 4th pond was completely frozen to the bottom, with the water flow restricted to a narrow channel at the north end of the pond. The larger 3rd pond was ice covered, but not completely frozen to the bottom. The first open water was encountered in the narrow channel between the 2nd and 3rd ponds. Here the current was strong enough so that ice did not form. On the 2nd pond, the ice was much thinner and in some places unsafe to walk on. Also, water had flooded the ice over part of the 2nd pond to a depth of from one-half to 2 inches. The 1st pond which received water from the channel coming from the Dober pit had an extensive area of open water in the main flow channel of this pond. Thicker ice was present in areas of the pond away from the channel. A total of 18 holes were bored in the four ponds and the water and sediment columns examined. These data are presented in Table 3.

Table 3. Water and Sediment Profiles of the Dober Pond System, 26 January 2005

Sample No.	*Pond No.*	*Ice thickness inches*	*Water depth inches*	*Comments*
1	4	16	0	No yellow boy precipitate, no water, ice to bottom
2	4	16	0	No yellow boy precipitate, no water, ice to bottom
3	4	16	0	No yellow boy precipitate, no water, ice to bottom
4	4	16	0	No yellow boy precipitate, no water, ice to bottom
5	3	15	45	Slight amount of yellow boy (1-2 inches)
6	3	13	48	Trace of yellow boy, mostly black organic muck
7	3	15	48	3-4 in. yel. boy, black organic mud below, current
8	2	13	48	3-5 in. yel. boy overlying black organic muck
9	2	15	25	water on ice, 6-8 in. yel. boy, blk. organic below
10	2	15	42	water on ice, 24-30 in. yellow boy sludge
11	2	15	42	20-24 in. yellow boy sludge, black organics below
12	2	15	45	8-10 inches yellow boy sludge, clear ice
13	2	15	42	12-14 inches yellow boy sludge
14	1	1	42	24 inches of yel. boy sludge, dark organics below
15	1	12	36	1-2 inches of yellow boy sludge, mostly organics
16	1	15	36	12-14 inches of yellow boy sludge, organics below
17	1	15	30	15 inches yellow boy with black organics below
18	1	15	24	10 inches yel. boy sludge, black organics below

Discussion of Results for Settling Ponds

This sampling trip was taken several days following a prolonged cold spell of below zero (Fahrenheit) weather, and the ponds had developed a very thick layer of ice. The ice cover and cold temperatures are not conducive to effective neutralization and precipitation of iron hydroxide hydrates as established in earlier laboratory work (Johnson, Hockings and MacDonald, 1982). The ice cover keeps oxygen from the system and the near freezing temperature of the water slows down all reactions. Fortunately, the flow of acid water from the Dober mine is much lower in the winter, about one half or less of the average flow rate of 65 gpm (Johnson, 1978) which perhaps makes up for the poor conditions causing slower kinetics of the reactions producing the iron hydroxide hydrate precipitate.

From Table 3 it can be seen that most of the precipitation of yellow boy takes place in Pond 1 and Pond 2. A small amount is seen to have been precipitated in Pond 3, from the sediment column data. The small Pond 4 showed no yellow boy precipitate in the sediment column. These data suggest that, even though the ponds are in places choked with cattails and that channeling of water is occurring, significant settling of iron hydroxide precipitates does occur in the pond system even in the dead of winter under very cold conditions.

With this discussion it is important to consider the synergetic system in its entirety, and not just the settling ponds. Thus, it must be realized that the neutralization and precipitation reactions take place in the Dober mine pit and that significant quantities of yellow boy are precipitated and settle there. The problem at the present time is that iron precipitate has filled the pit up to the level of the water inflow pipes and that the pit, if not already full to capacity with precipitate, is very near this condition.

Water Flow Through the Synergetic Pond Treatment System

The water flow regime through the Dober mine synergetic system consists of two distinct parts, (1) acid water flow from the Dober-Hiawatha-Isabella mine complex which surfaces at the Dober mine pit, and, (2) Iron River waters diverted into the Dober mine pit where mixing and neutralization takes place. Each system will be discussed separately.

The acid mine waters come from three flooded underground mines comprising the mine complex. The Hiawatha mine located on the west side of the Iron River is the greatest contributor of acid with the Dober mine a distant second. The Isabella mine located to the northwest of the Dober mine also contributes acid, but it was a relatively small operation with 8 levels to a depth of 800 feet. The Isabella mine open pits and underground mine workings are linked to the Dober mine by drifts on the 4th and lower levels. As mentioned, the Hiawatha mine is by far the largest contributor of acid water because it is the largest and deepest mine of the complex with extensive areas of acid forming rock encountered during its operation.

For all practical purposes the flooded mine complex does not generate any significant amount of acid. The acid was formed in the mines during and after mining, before the mine was flooded. The acid formed by the oxidation of iron sulfide in the form of abundant framboidal (porous and fine grained) pyrite present in the Wauseca member of the Dunn Creek slate formation which stratigraphically underlies the Riverton Iron formation and sometimes is enclosed within the iron ore. Sulfuric acid is produced when the pyrite is oxidized in the presence of water and air which furnishes needed oxygen. In the last 20 years it has become known that the bacterium, *Thiobacillus ferrooxidans* plays a very significant role in the formation of acid from pyrite and other iron sulfides. This chemoautotroph derives its life energy by oxidizing ferrous iron to ferric iron which greatly accelerates key reactions in the oxidation of pyrite. As ferric sulfate becomes hydrolyzed to form insoluble ferric hydroxide hydrate, or yellow boy, this results in the production of additional sulfuric acid. Moreover, ferric iron is a powerful oxidant and in acid solution directly attacks and dissolves pyrite, thus greatly accelerating acid production.

Ferrous sulfate salts crystallize from dilute sulfuric acid formed from acid mine or acid rock drainage solutions under evaporative conditions. Under dry conditions the ferrous salts lie dormant. When wetted from rainfall or inundation as in a flooding mine, they dissolve to form sulfuric acid. White ferrous sulfate salts have been observed on outcroppings of the black pyritic-graphitic slate present around the Isabella mine pit and also on the same slate material present in waste rock piles around the Dober, Isabella and Hiawatha mines.

However, once the mines are flooded, sufficient oxygen is not present in ground water to support pyrite oxidation reactions. This means that the sulfuric acid present in the flooded mine complex was generated prior to mine flooding and that as long as the mine complex remains flooded, additional acid will not form. Thus, the acid remaining in the mine complex is finite and as it mixes with recharging ground water it is expelled, and in this way the acid is slowly removed from the flooded mine.

Hydrology of the Dober-Hiawatha-Isabella Mine Complex

Extensive work in the Dober mine complex has resulted in a reasonably clear understanding of its hydrology. In short, recharging ground waters over the elevated surface of the Hiawatha mine west of the Iron River enter the mine through various openings such as shafts, raises, drill holes, and rock fractures. This inflow causes an imbalance in the flooded mine and drives waters to the surface in the Dober mine which is situated at a lower elevation in the Iron River valley to the east. The mine openings (open stopes, drifts, crosscuts, shafts, and raises) can be considered as a complex plumbing system of pipes and reservoirs. As the shallowest open connection existing between the Hiawatha and Dober mine is believed to be a crosscut on the 10th level, it has been necessary for all of the acid at higher levels in the Hiawatha mine to pass through the 10^{th} and lower levels and from there to the surface in the Dober mine. Because the structure of the ore body is synclinal, the Hiawatha and Dober mine can be considered as a big “U Tube” with the Hiawatha mine being the western leg of the tube and the Dober mine the eastern leg of the tube.

Given that acid water flows from the Dober mine in response to ground water recharge in the Hiawatha mine, it is obvious that precipitation and ground water flow over the Hiawatha mine determines the rate at which acid flows from the Dober mine. It also follows that the flow from the Dober mine represents the recharge of the Hiawatha mine. Measurements of flow were taken at the Dober mine in 1978 before the synergetic pond system was installed. A V-notched weir was installed in the ditch draining acid water from the Dober pit into the Iron River and periodic measurements were taken over the year. The flow rates ranged from a low of 30 gpm in dry periods (winter and mid summer) to a high of 150 gpm during wet periods (spring runoff and heavy rains). A reasonable estimate of the average flow was determined at that time to be 65 gpm. This 65 gpm figure has been used in the design of the synergetic pond system to calculate the desired river water to acid water ratio of 27:1.

Flow of Iron River Water Through the Synergetic Pond System

A concrete diversion structure in the Iron River raises the water level several feet so sufficient head exists for river water to flow into the Dober mine pit to mix with the acid water entering the pit at depth. The river water flows into a concrete box through a coarse screen used to keep out large debris. From there it flows over a protected weir into a 24 inch diameter plastic pipe that runs from the weir box to the Dober pit via three manhole connections. At the pit the water flows through the final manhole connection into a plastic pipe which exits at depth in the pit. Two closely spaced 45 degree connections take the water down a vertical plastic pipe 70 feet to a horizontal plastic header fitted with 8 exit ports. Six of the ports face into the pit and two, at the ends of the header, project water along the sides of the pit wall (Figure 8).

The weir is adjusted to provide a river to acid water ratio of about 27:1 in the Dober mine pit. The portion of the inflow pipe in the Dober mine pit has a configuration designed to enhance the mixing of the river and mine waters so that neutralization will readily take place to promote oxidation and hydrolysis of the iron to form an insoluble iron hydroxide hydrate precipitate. Much of the iron precipitates in the Dober mine pit and the remainder in the downstream settling ponds, allowing near-neutral pH water, largely devoid of iron, to be returned to the Iron River.

The Dober mine pit inflow weir was checked on 23 November 2004. At that time the lock was cut off the hasp on the trap door protecting the concrete weir box, because no key was available with which to gain access. The staff gauge in the weir box could not be read clearly, so the head above the weir head was measured and found to be 0.51 feet. Using the weir tables provided in the Dober pond system operations manual this value corresponded to 3.5 sec-ft. or 1570 gpm or 2.26 MGD (million gallons/day). Given that the true head upstream of the weir plate should have been slightly lower, this flow value is probably a little high. At this rate and if the average flow rate of acid water from the Dober mine is assumed to be 60 gpm, the mixing ratio of river water to acid water is 26:1. To the best of our knowledge, the weir had been operating at this setting for a considerable period of time. The weir trap door was then fitted with a new lock and a copy of the key provided to Hebert Construction Company, the weir caretaker.

Also on 23 November 2004, a commercial water velocity measuring device was utilized in taking a series of readings in the flow channels of both the inflow and the outfall weirs. These data were later used to calculate water volume flows as a check on the flows calculated from weir head readings using engineering tables for standard contracted rectangular weirs. These flow velocity readings were used in conjunction with the area of flow over each weir to calculate water flow volumes. These calculations were made in late January 2005 in preparation for this report. The results are discussed separately in the following paragraphs.

When the 23 November 2004 intake water velocity flow measurement data were worked up for the Dober mine pit river water intake weir, a discrepancy was found between the calculated flow and the flow values using the Dober mine pond system operating manual procedure. The flow volume calculated from the product of an average flow velocity and the area above the weir yielded a value of only 590 gpm. By comparison, the operations manual method (weir head compared to the flow volume in the engineering tables) showed 1580 gpm flowing over the weir. At that time, because there was such a discrepancy between these values, I believed that there must have been a problem with the measured flow velocities. In addition, I assumed that the flow volumes calculated from the Dober pond operations manual must be correct. Additional support for this belief came from the realization that the higher flow volume was close to the 27:1 ratio established in the laboratory and field studies as an ideal mixing ratio for optimum neutralization of Dober mine acid water. For if the 590 gpm figure was correct the mixing ratio of river water to acid (at 60 gpm) would be only a little more than 9:1.

Water velocities over the outfall weir of the Dober pond system outfall were measured on 23 November 2004, and these data were also worked up in late January 2005. Using the product of the outfall weir average velocity and the weir flow area, a flow rate of 410 gpm was calculated. For comparison, using the water head above the weir board and engineering flow tables for rectangular contracted weirs of the dimensions of the outfall weir, the flow volume was determined to be 447 gpm. Had a staff gauge been in place above the outfall from which a proper reading could have been taken, a slightly lower head would have resulted and the flow value from the tables would be closer to that calculated using the flow velocity readings. Thus the calculated volume from flow velocity measurements and weir flow area matched the flow rates taken from engineering tables (and the operations manual) closely.

The above results called into question the volume of river and acid water entering the Dober pond system and the water exiting, a discrepancy that needed addressing. How could the inflow rate be more than three times greater than the outflow from the pond system (1580 gpm vs. 410 to 450 gpm)? After all, outflow should roughly equal inflow. The question was, “where was all this water going”? With the assumption being that the inflow water volume was three times the outfall, the following possibilities were considered:

1. Water was seeping from the pond system through the adjacent railway grade into the Iron River.
2. Water was leaking from a break in the intake pipe between the river and Dober pit and was flowing into:
   a. The river via seepage through porous mine rock fill around the Dober mine pit.
   b. The river upstream via seepage into the nearby City of Stambaugh storm drain.
   c. The river upstream via the mine complex on the east side of the river: variously through the Isabella, Dober, Chatham and possibly other unknown connections to other mines.
3. The water from one or more of the settling ponds was flowing into the river downstream through an unknown channel or channels draining one or more of the settling ponds.

Additional time, effort, and expense were put into investigating the above possibilities, to either prove or disprove them. First, water samples were taken along the river to detect by simple measurements (temperature, pH, and specific conductivity, plus chemical analysis for sulfate) whether seepage from the pond system or from the Dober mine pit into the river could be a cause. The results were negative and there was no evidence to support either of these occurrences.

Second, mine maps were examined to determine if there were possible alternative flow routes through interconnected mines on the east side of the river. It was determined this was possible as interconnections do exist between several other mines to the north of the Dober mine. However, no mine water inflows into the Iron River had been observed upstream in the vicinity of these mines either before or after the pond system was operating.

Third, the outflow site of the Stambaugh storm drain not far upstream from the Dober mine intake weir did not have any significant flow. Thus this possibility was rejected.

Fourth, neither aerial photographs of the pond system nor personal knowledge of the pond system area supported a hypothesis for water loss from the ponds.

With the exception of the hypothesis that a loss of river water passing over the intake weir might be from a break in the buried pipe leading to the Dober mine pit, all of the above hypotheses are rejected. Inasmuch as it seems unlikely that a break in the shallowly buried line losing over one million gallons per day could remain undetected, this hypothesis is given little credence.

This leads to the conclusion that the intake weir is not and probably has not been admitting sufficient water for efficiently neutralizing acid flow from the Dober mine into the Dober pit. Laboratory and pilot scale testing prior to the system design showed that a 27:1 mixing ratio was a desired optimum to be achieved when the system was designed. Using 60 gpm as an average yearly figure for acid waters issuing from the Dober mine, the river water flow should have been 2.3 MGD. Presently the flow is roughly one third of that amount or 0.85 MGD based on 23 November 2004 data. It may actually be somewhat less than that as the maximum flow calculated for the outfall weir the same day was approximately 0.75 MGD. However, these calculations do not take into account any losses from the pond system from seepage, transpiration, evaporation, or others.

From available evidence, the reason for the above discrepancy is not the fault of the engineering tables from which the flow rate values have been taken. The problem appears to be that the intake weir does not match the weir style necessary to apply the table values. The intake weir although contracted, does not flow with a nappe and is not sharp crested which could well account for the discrepancy in flow being one-third of the desired flow rate. From all appearances this has been a problem since the system has been in operation. This would explain why discharge waters from the pond system are occasionally below the 6.5 pH limit set in the permit. It is remarkable that the system has performed as well as it has since its inception despite this deficit.

This condition of a greatly reduced inflow of mixing water is presently not as serious as it must have been when the Dober pond system was first installed (assuming the condition existed then). At that time the acid water coming from the mine complex into the Dober pit was much more concentrated than now. The acidity of acid water flowing from the Dober mine in 1983 was 3000 mg/L calcium carbonate. In 2004, the acidity value of deep samples (below 1000 feet) in the Hiawatha No. 2 shaft were slightly less than 1000 mg/L (945 and 995 mg/L) as were bottom samples from the Dober pit. With acidity levels on the order of one-third former concentrations, all else being equal, the mixing water ratio could be reduced by the same factor. Thus, using these data, it appears that the current mixing ratio of 9:1 may be nearly correct for the current acidity level of the Dober mine acid waters.

A second mitigating factor for winter operation of the Dober pond system is the reduced flow of acid water from the mine complex during the winter. Earlier work established that acid water flows were much lower during the coldest winter months due to reduced groundwater recharge of the Hiawatha mine. However, this effect is offset to some degree by less favorable conditions for precipitation of iron in the settling ponds. Cold temperatures slow chemical reactions and ice cover inhibits oxygen exchange from air to water, both retarding iron hydroxide formation.

RECOMMENDATIONS

Following are a list of specific recommendations for consideration regarding improving the operation and public image of the Synergetic Dober Mine Acid Treatment Pond System.

1. The inflow weir should be recalibrated so that the readings reflect the correct amount of water entering the Dober mine pit for a variety of settings. The weir settings should be increased to determine the maximum flow possible over the weir. At the same time these experiments are in progress, the outflow over the outfall weir should be monitored and recorded. Samples from the outfall weir should be run for pH, acidity, specific conductivity, temperature, and dissolved and total iron to test the effectiveness of increasing the amount of mixing water on iron removal. Also a staff gauge should be put in place to simplify accurate readings at the outfall weir.

2. As it appears that the Dober mine pit is full of iron hydroxide precipitate, its functioning and that of the lower pond system should be carefully monitored over the next year. It may be necessary to remove enough of the accumulated iron hydroxide to permit the mixing system to function properly. This means a disposal site needs to be identified for the iron hydroxide. Perhaps some could be disposed of in the caved area of the open Chatham mine which would serve the purpose of making this mine safer. In 1992 there was a fatality in this mine when a teenager drowned in a flooded stope underground. Also as large amounts of iron hydroxide have filled the Dober mine pit, perhaps some testing should be done to see if it may have sufficient commercial value to pay for its extraction.

3. A high gated chain link fence should be constructed on the east side of the Dober mine pit with a locked gate to permit access for monitoring purposes. This is a dangerous site where vehicles can and do park very close to the deepest part of the flooded Dober mine pit where it is about 80 feet deep. Also, this would protect the delicate mixing water system which is suspended close to the near vertical east edge of the mine pit. The fence should completely stop suspected dumping of trash into the pit, which undoubtedly has been done in the past. It is possible that dumping has caused damage to the mixing system HDPE pipes in the past. If damage has been done, it would be difficult to determine because of extremely limited visibility of the clouded Dober pit waters loaded with suspended yellow brown iron hydroxide floc.

Warning signs should be prominently posted and proper authorities notified to regularly inspect the area (Iron County Mine Inspector, and city/county/state police).

4. The inflow water to the Dober mine pit should be temporarily shut down to permit an inspection of the mixing chamber pipes to ascertain that they are undamaged and functioning properly. Perhaps a remote TV camera could be used to inspect the pipe system from inside the pipe.

5. Consideration should be given to installing a weir structure in the narrows between the second and third settling ponds south of the Dober mine. A weir would have several benefits. Increased settling of iron hydroxide precipitate would take place in ponds 1 and 2, as only surface waters would flow over the weir. The present channel flow would be restrained, increasing retention time in the pond system with the resultant improvement of water quality below the outfall weir into the Iron River. With sufficient drop over the weir, additional aeration of pond waters would occur, enhancing precipitation of iron hydroxide and other metals (aluminum, manganese) in the last two ponds and resulting in a cleaner effluent flowing into the Iron River.

6. Water level measurements using the recently reestablished stations should be taken quarterly to help assure that the system is working effectively and to provide warnings of any blockages or other unseen conditions in the mine complex that may cause problems in the synergetic system's operation.

7. The steel plate holding the locking cover over CDH 2-45 should be fastened securely to its concrete base to make the 10-inch drilled hole safe for any who might be attracted to this site. The mine water lies 60 feet below the concrete plug in the churn drill hole and is at least 300 feet deep. The steel plate was at one time secure, but is now loose. Warning signs should be prominently posted and the Iron County Mine Inspector should be aware of the site and include in future inspections.

8. A local reliable individual, knowledgeable of the functioning of the synergetic acid water treatment pond system should be engaged to undertake the recommended measurements, including those required under the NPDES permit by the MDEQ. Such a person is in the best position to recognize any malfunctioning of the system, including tampering and vandalism, and to take or recommend needed action. This person should be instructed to keep good records in permanent form that would be suitable for any legal purposes to oversee and protect the property and avert any

potential liability. Also, the numerical data should be reviewed and interpreted by an expert familiar with the Dober mine complex. This could be achieved by using the current White Water Associates, Inc. team.

9. A useful public relations effort would be to install several walking trail-type informational signs so the interested public and school groups could become aware of the practical scientific approach toward resolving a seemingly intractable acid drainage problem that now protects the environment in a simple, elegant way. This would provide another attraction for the Apple Blossom Trail running adjacent to the Dober and Isabella mines and the pond system in the former Iron River channel.

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APPENDIX A
Figures

APPENDIX CONTENTS:

Figure 1. Location of the Dober Mine Complex in Iron County, Michigan, Within the Region and County, and Relative to Adjacent Property (Quarter Sections)

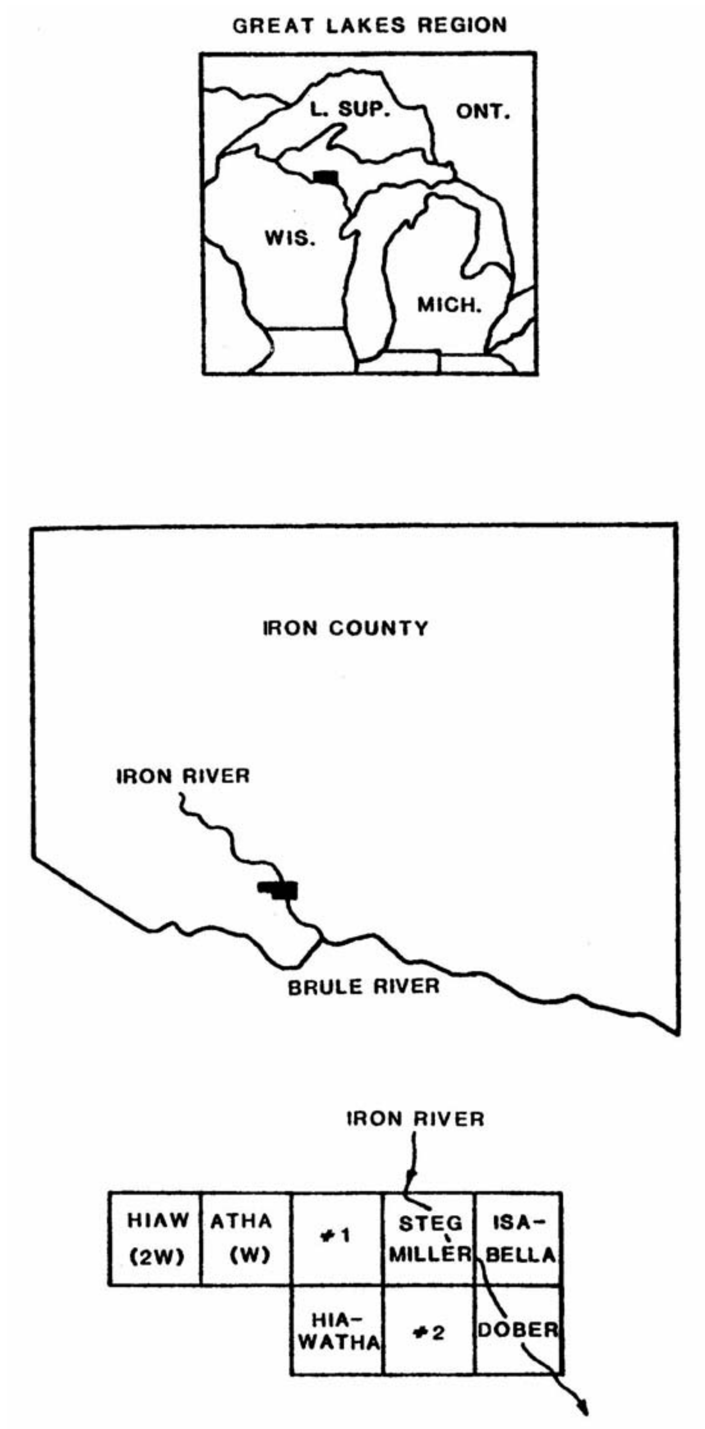


Figure 2. Surface Plan Map of the Dober Mine Complex

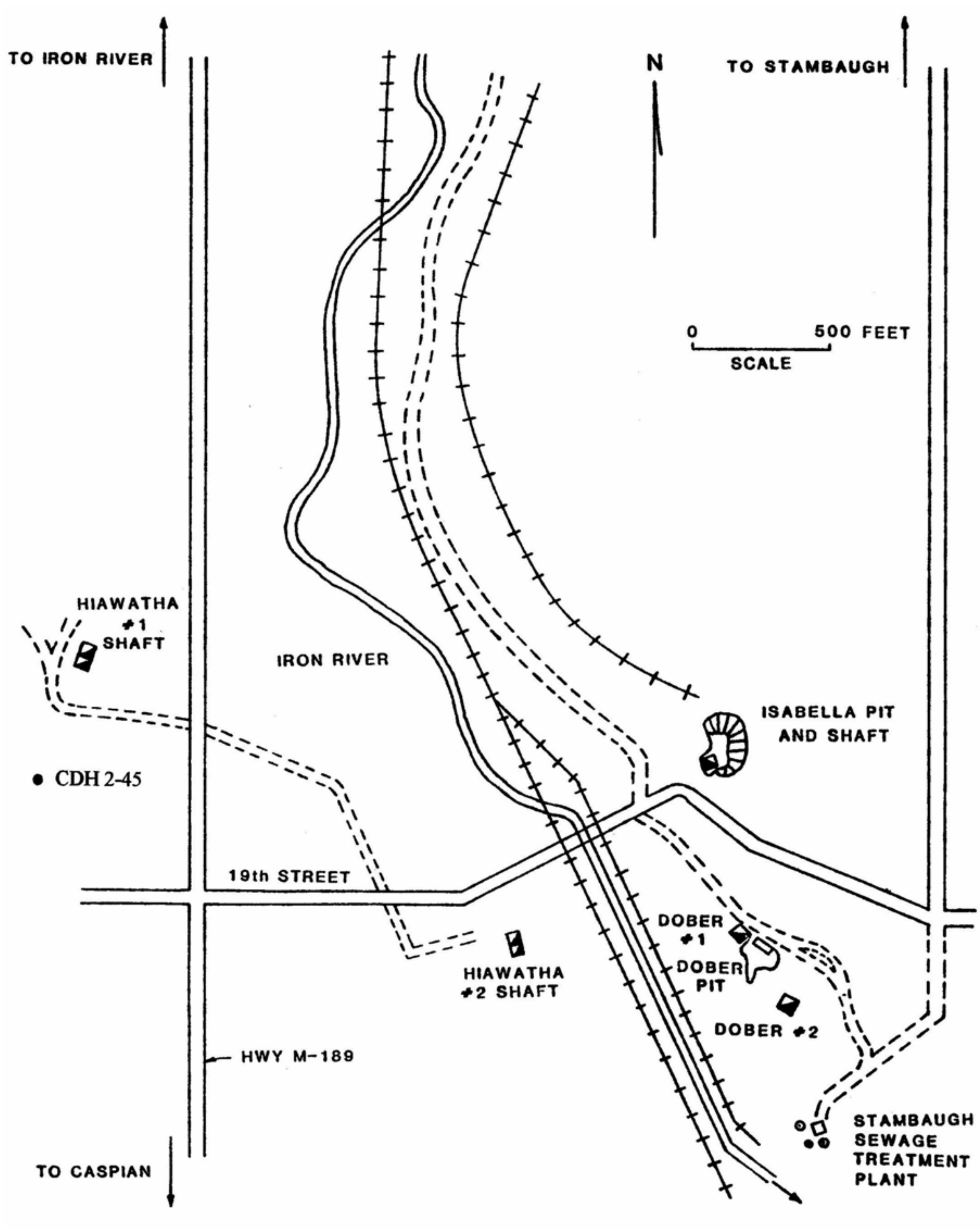


Figure 3. Isometric Diagram of Part of the Hiawatha and Dober Mines (from Dutton, 1969)

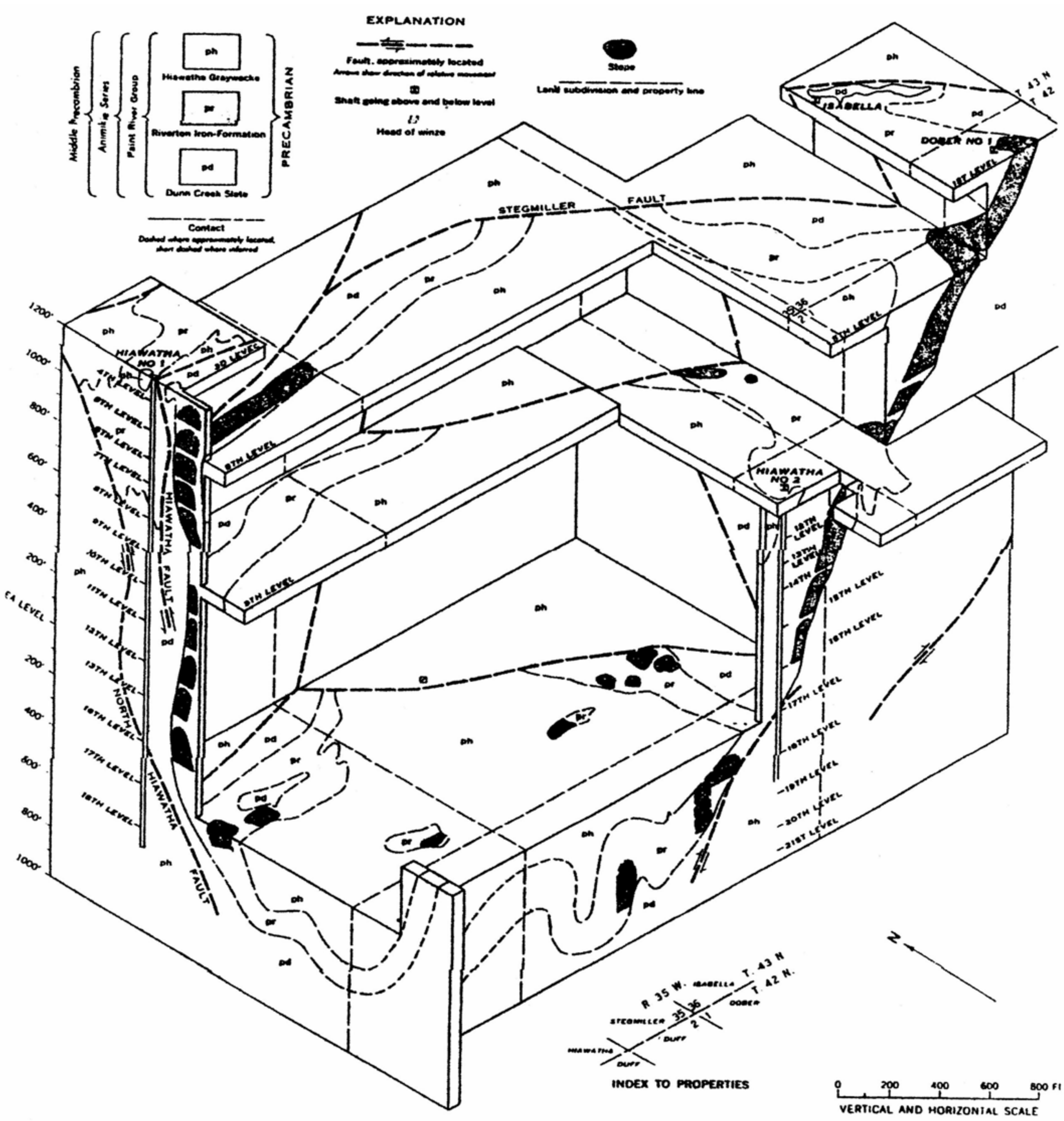


Figure 4. Schematic Representation of Acid Water Flow from the Dober Mine Complex

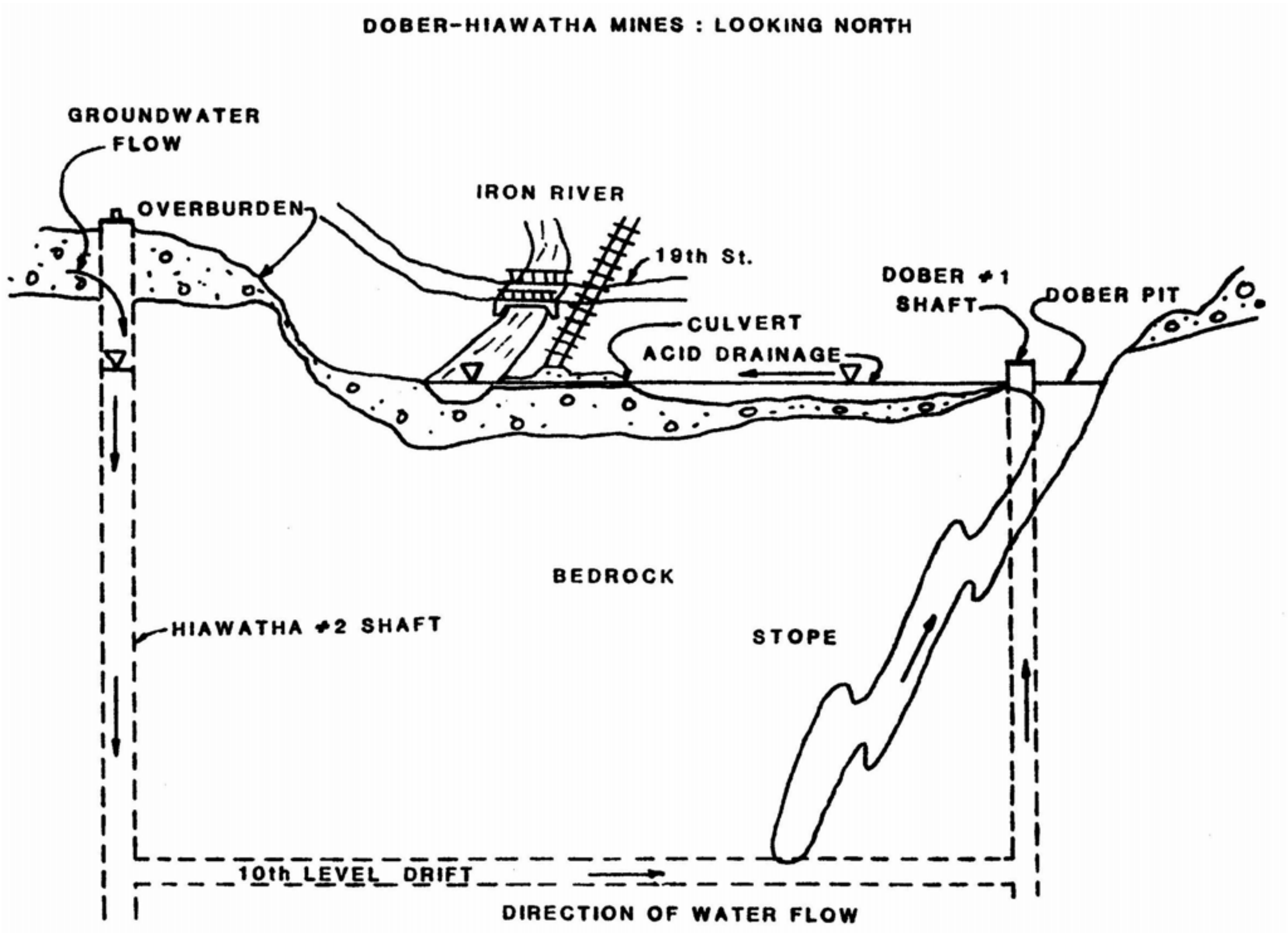


Figure 5. Location of Ponds and Other Features near the Dober Mine

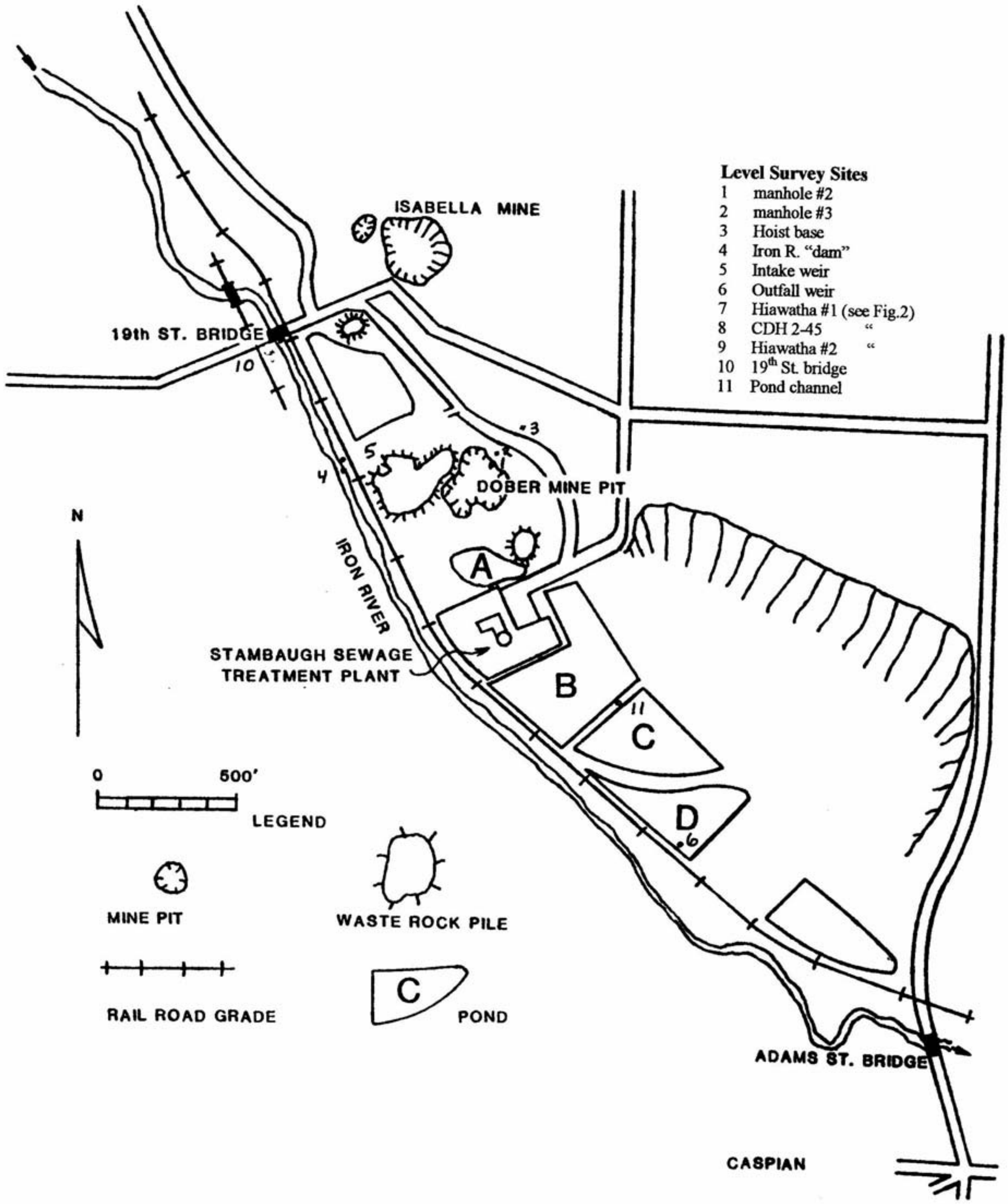


Figure 6. Depth Profile of Dober Mine Pit Conducted on 10 November 2005

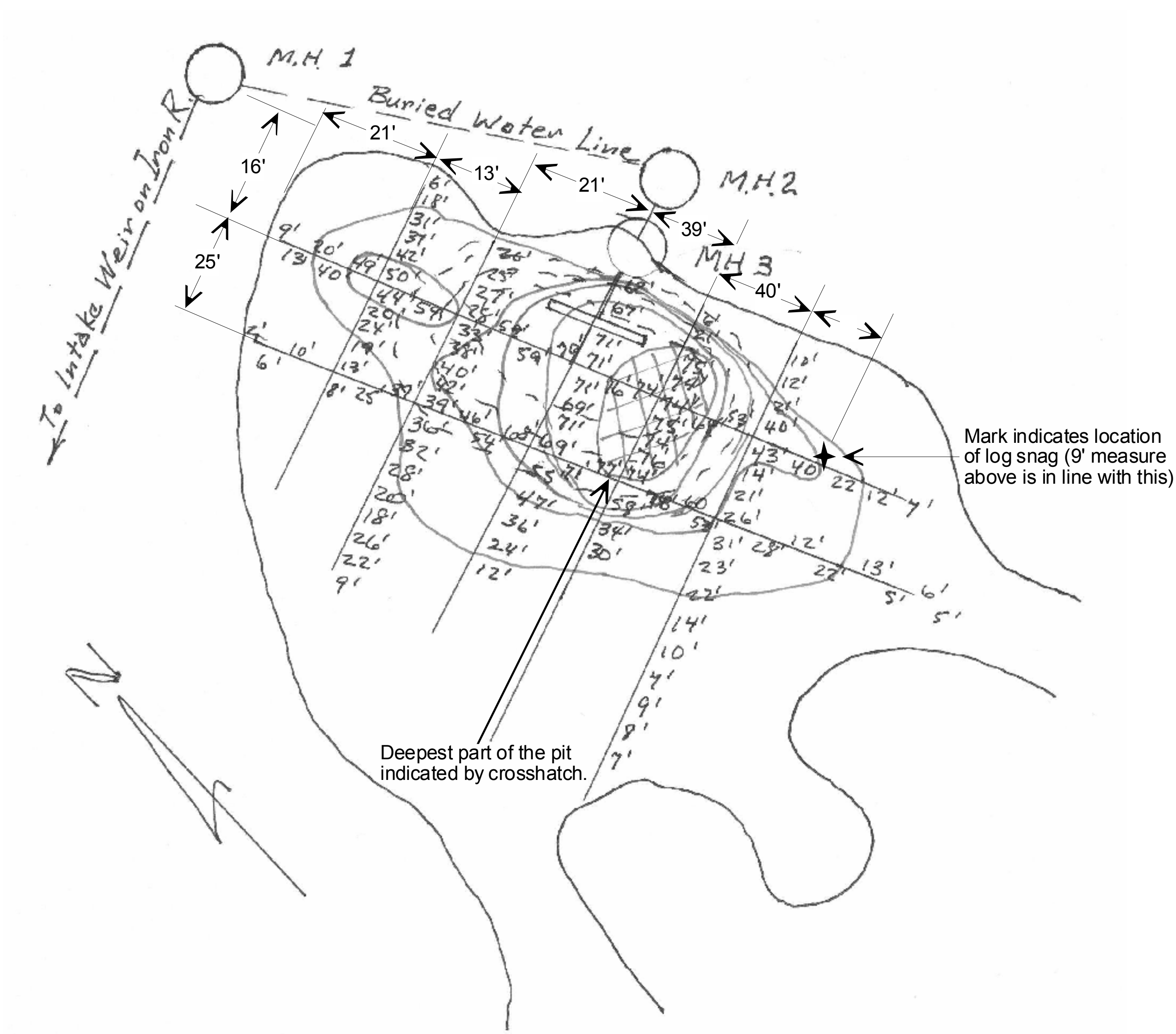
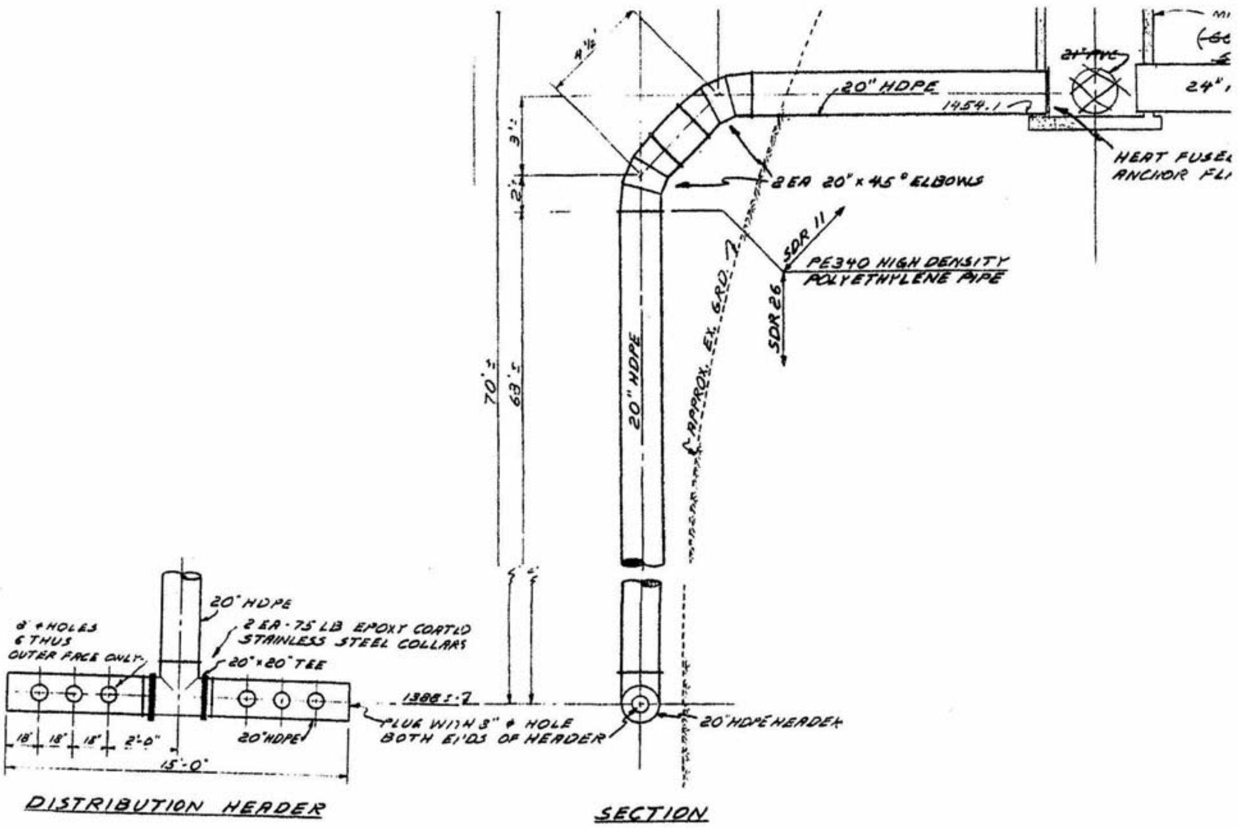


Figure 7. Aerial Photo View of Dober Mine Settling Ponds with Ice Auger Locations

Figure 8. Dober Mine Pit Inflow Water Mixing Pipe System



APPENDIX B
Photographs

APPENDIX CONTENTS:

Photo 1 (top left). Tiller taking water level reading at Hiawatha #1 pipe shaft, 22 October 2004

Photo 2 (top right). Manhole #2 (foreground) and #3 (in Dober pit), looking westerly, 26 October 2004

Photo 3 (middle right). Looking east along Apple Blossom Walking Trail, Dober mine waste rock pile to left and Iron River on the right, 27 October 2004

Photo 4 (bottom right).Dober Mine Synergetic Acid Water Treatment System outfall weir, 27 October 2004

Photo 5 (top left). Apple Blossom walking trail near Dober Mine Synergetic Acid Water Treatment System intake weir, 27 October 2004

Photo 6 (top right). Retrieving a 1200 foot deep acid water sample from the Hiawatha mine No. 2 shaft (Kemmerer sampler), 3 November 2004

Photo 7 (bottom left). Johnson with deep water sampler, Hiawatha #2 shaft, 3 November 2004

Photo 8 (bottom right). Tiller removing old lock at CDH 2-45 Hiawatha #1 mine, 3 November 2004

Photo 9 (top left). Tiller at intake weir by Iron River diversion structure, 3 November 2004

Photo 10 (middle right). Tiller entering Dober mine pit from dead snag clogged outflow channel, 10 November 2004

Photo 11 (bottom left). Johnson with Kemmerer rig on Dober mine pond, 10 November 2004

Photo 12 (top right). Johnson with sonar unit on Dober mine pit, 10 November 2004

Photo 13 (middle right). Tiller with yellow boy sample taken from 75 foot depth in Dober mine pit, 23 November 2004

Photo 14 (bottom left). Tiller taking sonar depth readings over deepest part of the Dober mine pit, Stambaugh, MI (about 75 feet deep), 23 November 2004

Photo 15 (top left). Tiller with bottom sample of Dober mine settling pond #1, 26 January 2005

Photo 16 (top right). Tiller on 10 inches of ice sampling Dober mine settling pond #1, 26 January 2005

Photo 17 (bottom left). Tiller drawing up yellow boy sediment sample from Dober mine settling pond #1, 26 January 2005

Photo 18 (bottom right). Tiller holding sediment tube with yellow boy sample, pond #1, Dober Mine Synergetic Acid Water Treatment System, 26 January 2005

APPENDIX C
Laboratory And Survey Reports

APPENDIX CONTENTS:

WHITE WATER ASSOCIATES, INC.

Cover Page

All analyses performed according to EPA Methods (EPA-600/4-79/020, March 1983 or SW-846, Third Edition). Sample chain-of-custody form(s) attached.

Client: PolyOne Corp. **WWA Job #:** 21251

Project:	Dober Project - H-2	**Sample Matrix:**	Water
Date Received:	11/3/2004	**Date Reported:**	4/4/2005

Sample Number	Client Sample ID	Date Sampled
21251-001	H-2 100'	11/03/04
21251-002	H-2 500'	11/03/04
21251-003	H-2 750'	11/03/04
21251-004	H-2 1000'	11/03/04
21251-005	H-2 1050'	11/03/04
21251-006	H-2 1200'	11/03/04

Comments (if any):

Key to Laboratory Flags:

B: The analyte was found in the associated blank as well as in the sample.
J: The analyte was positively identified, the quantitation is an estimation.
M: A matrix effect was present.
Q: Batch QC data associated with samples does not meet stated objectives.
U: The analyte was analyzed for, but not detected. The associated numerical value is at or below the MDL.

I certify that the data contained in this Final Report has been generated and reviewed in accordance with approved methods and White Water Associates Standard Operating Procedures. Exceptions, if any, are discussed in the accompanying sample narrative. Release of this Final Report is authorized by White Water Associates management, as is verified by the following signature.

Approved By: ______________________________

Bette J. Premo

Electronically signed by Bette J. Premo

WHITE WATER ASSOCIATES, INC.

Client: PolyOne Corp. **WWA Job #:** 21251

Project: Dober Project - H-2 **Sample Matrix:** Water
Date Received: 11/3/2004 **Date Reported:** 4/4/2005

Trace Metals - Total

Sample / Client Sample ID	Result	Units	Date	Method	MDL	MQL
21251-001 / H-2 100'						
Iron (t)	0.19	mg/L	11/23/2004	6010B	0.01	0.1
21251-002 / H-2 500'						
Iron (t)	0.19	mg/L	11/23/2004	6010B	0.01	0.1
21251-003 / H-2 750'						
Iron (t)	0.54	mg/L	11/23/2004	7380	0.01	0.1
21251-004 / H-2 1000'						
Iron (t)	4.68	mg/L	11/23/2004	7380	0.01	0.1
21251-005 / H-2 1050'						
Iron (t)	672.2	mg/L	11/23/2004	7380	0.25	0.25
21251-006 / H-2 1200'						
Iron (t)	944.9	mg/L	11/23/2004	7380	0.25	0.25

ND = Not Detected, MDL = Method Detection Limit, MQL = Method Quantitation Limit,
ppm = mg/l (liquid) or mg/kg (solid), ppb = ug/l (liquid) or ug/kg (solid)

WHITE WATER ASSOCIATES, INC.

Client: PolyOne Corp. **WWA Job #:** 21251

Project:	Dober Project - H-2	**Sample Matrix:**	Water
Date Received:	11/3/2004	**Date Reported:**	4/4/2005

General Chemistry, Demands and Physical Data

Sample / Client Sample ID	Result	Units	Date	Method	MDL	MQL
21251-001 / H-2 100'						
Acidity	66	mg/l	11/5/2004	SM2310B	1	5
ORP	70	mV	11/3/2004	2580B	1	22
21251-002 / H-2 500'						
Acidity	12	mg/l	11/5/2004	SM2310B	1	5
ORP	21	mV	11/3/2004	2580B	1	22
21251-003 / H-2 750'						
Acidity	13	mg/l	11/5/2004	SM2310B	1	5
ORP	28	mV	11/3/2004	2580B	1	22
21251-004 / H-2 1000'						
Acidity	16	mg/l	11/5/2004	SM2310B	1	5
ORP	20	mV	11/3/2004	2580B	1	22
21251-005 / H-2 1050'						
Acidity	945	mg/l	11/5/2004	SM2310B	1	5
ORP	19	mV	11/3/2004	2580B	1	22
21251-006 / H-2 1200'						
Acidity	995	mg/l	11/5/2004	SM2310B	1	5
ORP	41	mV	11/3/2004	2580B	1	22

ND = Not Detected, MDL = Method Detection Limit, MQL = Method Quantitation Limit,
ppm = mg/l (liquid) or mg/kg (solid), ppb = ug/l (liquid) or ug/kg (solid)

White Water Associates, Inc.
429 River Lane, P.O. Box 27
Amasa, Michigan 49903
Phone (906) 822-7373, Fax -7977

CHAIN-OF-CUSTODY RECORD AND ANALYSIS REQUEST

J.O.# 21251

CLIENT NAME Polyone Corp

ADDRESS

PHONE #

SAMPLER'S SIGNATURE D.Tiller

ANALYSIS TYPE REQUESTED *

SAMPLE LOCATION	SAMPLE I.D.#	TIME	DATE	SAMPLE TYPE: GRAB	SAMPLE TYPE: COMPOSITE	SAMPLE TYPE: MATRIX	NO. OF CONTAINERS	Ferrous Iron	Total Iron	Acidity	ORP				REMARKS
H-2 100'	001		11/3/04	X			1	✓	✓	✓	✓				
H-2 500'	002						1	✓	✓	✓	✓				
H-2 750'	003						1	✓	✓	✓	✓				
H-2 1000'	004						1	✓	✓	✓	✓				
H-2 1050'	005						1	✓	✓	✓	✓				
H-2 1200'	006						1	✓	✓	✓	✓				
															note: unable to
															do ferrous iron at this time

RELINQUISHED BY	DATE	TIME	RECEIVED BY	RELINQUISHED BY	DATE	TIME	RECEIVED BY
D.Tiller	11/3/04	1600					

RELINQUISHED BY	DATE	TIME	RECEIVED BY LABORATORY	DATE	TIME	REMARKS:
			[illegible]	11/3/04	1600	

Customer retain pink; send white and yellow with samples. Original (white) will be returned with report.

WHITE WATER ASSOCIATES, INC.

Cover Page

All analyses performed according to EPA Methods (EPA-600/4-79/020, March 1983 or SW-846, Third Edition). Sample chain-of-custody form(s) attached.

Client: PolyOne Corp. **WWA Job #:** 21274

Project:	Dober Project	**Sample Matrix:**	Water
Date Received:	11/10/2004	**Date Reported:**	4/4/2005

Sample Number	Client Sample ID	Date Sampled
21274-001	#1	11/10/04
21274-002	#2	11/10/04
21274-003	#3	11/10/04
21274-004	#4	11/10/04
21274-005	#5	11/10/04
21274-006	#6	11/10/04

Comments (if any):

Key to Laboratory Flags:

B: The analyte was found in the associated blank as well as in the sample.
J: The analyte was positively identified, the quantitation is an estimation.
M: A matrix effect was present.
Q: Batch QC data associated with samples does not meet stated objectives.
U: The analyte was analyzed for, but not detected. The associated numerical value is at or below the MDL.

I certify that the data contained in this Final Report has been generated and reviewed in accordance with approved methods and White Water Associates Standard Operating Procedures. Exceptions, if any, are discussed in the accompanying sample narrative. Release of this Final Report is authorized by White Water Associates management, as is verified by the following signature.

Approved By: ______________________

Bette J. Premo

Electronically signed by Bette J. Premo

WHITE WATER ASSOCIATES, INC.

Client: PolyOne Corp. **WWA Job #:** 21274

Project: Dober Project **Sample Matrix:** Water
Date Received: 11/10/2004 **Date Reported:** 4/4/2005

General Chemistry, Demands and Physical Data

Sample / Client Sample ID	Result	Units	Date	Method	MDL	MQL
21274-001 / #1						
Acidity	1060	mg/l	11/11/2004	SM2310B	1	5
ORP	12	mV	11/11/2004	2580B	1	22
21274-002 / #2						
Acidity	21	mg/l	11/11/2004	SM2310B	1	5
ORP	19	mV	11/11/2004	2580B	1	22
21274-003 / #3						
Acidity	940	mg/l	11/11/2004	SM2310B	1	5
ORP	15	mV	11/11/2004	2580B	1	22
21274-004 / #4						
Acidity	515	mg/l	11/11/2004	SM2310B	1	5
ORP	9	mV	11/11/2004	2580B	1	22
21274-005 / #5						
Acidity	27	mg/l	11/11/2004	SM2310B	1	5
ORP	3	mV	11/11/2004	2580B	1	22
21274-006 / #6						
Acidity	17	mg/l	11/11/2004	SM2310B	1	5
ORP	1	mV	11/11/2004	2580B	1	22

ND = Not Detected, MDL = Method Detection Limit, MQL = Method Quantitation Limit,
ppm = mg/l (liquid) or mg/kg (solid), ppb = ug/l (liquid) or ug/kg (solid)

CHAIN-OF-CUSTODY RECORD AND ANALYSIS REQUEST

White Water Associates, Inc.
429 River Lane, P.O. Box 27
Amasa, Michigan 49903
Phone (906) 822-7373, Fax -7977

J.O.# 21274

SAMPLER'S SIGNATURE: D. Tiller

CLIENT NAME: PolyOne Corp

ADDRESS: Dober Project

PHONE #

SAMPLE LOCATION	SAMPLE I.D.#	TIME	DATE	GRAB	COMPOSITE	MATRIX	NO. OF CONTAINERS	Acidity	ORP						REMARKS
#1	001		11/10/04					✓	✓						
#2	002		11/10/04					✓	✓						
#3	003		11/10/04					✓	✓						
#4	004		11/10/04					✓	✓						
#5	005		11/10/04					✓	✓						
#6	006		11/10/04					✓	✓						

RELINQUISHED BY	DATE	TIME	RECEIVED BY	RELINQUISHED BY	DATE	TIME	RECEIVED BY
D. Tiller	11/10/04	2000					

RELINQUISHED BY	DATE	TIME	RECEIVED BY LABORATORY	DATE	TIME	REMARKS:
			[signature]	11/10/04	2000	

Customer retain pink; send white and yellow with samples. Original (white) will be returned with report.

ANALYTICAL REPORT

WHITE WATER ASSOCIATES, INC.

Cover Page

All analyses performed according to EPA Methods (EPA-600/4-79/020, March 1983 or SW-846, Third Edition). Sample chain-of-custody form(s) attached.

Client: PolyOne Corp. **WWA Job #:** 21327

Project:	Dober Project	**Sample Matrix:**	Sludge
Date Received:	11/24/2004	**Date Reported:**	4/4/2005

Sample Number	Client Sample ID	Date Sampled
21327-001	Bottom Sludge #1	11/23/04
21327-002	Bottom Sludge #2	11/23/04

Comments (if any):

Key to Laboratory Flags:

B: The analyte was found in the associated blank as well as in the sample.
J: The analyte was positively identified, the quantitation is an estimation.
M: A matrix effect was present.
Q: Batch QC data associated with samples does not meet stated objectives.
U: The analyte was analyzed for, but not detected. The associated numerical value is at or below the MDL.

I certify that the data contained in this Final Report has been generated and reviewed in accordance with approved methods and White Water Associates Standard Operating Procedures. Exceptions, if any, are discussed in the accompanying sample narrative. Release of this Final Report is authorized by White Water Associates management, as is verified by the following signature.

Approved By: ______________________

Bette J. Premo

Electronically signed by Bette J. Premo

WHITE WATER ASSOCIATES, INC.

Client: PolyOne Corp. **WWA Job #:** 21327

Project:	Dober Project	**Sample Matrix:**	Sludge
Date Received:	11/24/2004	**Date Reported:**	4/4/2005

General Chemistry, Demands and Physical Data

Sample / Client Sample ID	Result	Units	Date	Method	MDL	MQL
21327-001 / Bottom Sludge #1						
Acidity	800	mg/l	11/24/2004	SM2310B	1	5
ORP	16	mV	11/24/2004	2580B	1	22
21327-002 / Bottom Sludge #2						
Acidity	885	mg/l	11/24/2004	SM2310B	1	5
ORP	21	mV	11/24/2004	2580B	1	22

ND = Not Detected, MDL = Method Detection Limit, MQL = Method Quantitation Limit,
ppm = mg/l (liquid) or mg/kg (solid), ppb = ug/l (liquid) or ug/kg (solid)

White Water Associates, Inc.
429 River Lane, P.O. Box 27
Amasa, Michigan 49903
Phone (906) 822-7373, Fax -7977

CHAIN-OF-CUSTODY RECORD AND ANALYSIS REQUEST

J.O.# 21327

SAMPLER'S SIGNATURE: D. Tiller

CLIENT NAME: PolyOne

ADDRESS:

PHONE #:

SAMPLE LOCATION	SAMPLE I.D.#	TIME	DATE	SAMPLE TYPE: GRAB	SAMPLE TYPE: COMPOSITE	SAMPLE TYPE: MATRIX	NO. OF CONTAINERS	Acidity	ORP						REMARKS:
Bottom Sludge	001		11/23/04	✓			1	✓	✓						
Bottom Sludge	002		11/23/04	✓			1	✓	✓						

RELINQUISHED BY	DATE	TIME	RECEIVED BY	RELINQUISHED BY	DATE	TIME	RECEIVED BY
D. Tiller	11/24/04	0800					

RELINQUISHED BY	DATE	TIME	RECEIVED BY LABORATORY	DATE	TIME	REMARKS:
			[illegible signature]	11/24/04	0800	

Customer retain pink; send white and yellow with samples. Original (white) will be returned with report.

NIIGAANNII SURVEYING COMPANY
P.O. Box 175, 500 Harrison Ave
Crystal Falls, MI 49920
906-874-3344
niigaani@up.net

March 23, 2005

Bette J. Premo, PH.D.
White Water Associates, Inc.
429 River Ln
Amasa, MI 49903

Re: Change in original Dober Mine elevation survey

Dear Bette:

After our conversation in regards to Al Johnson's concerns that site 4 & 5 elevations being switched I examined my notes and have concluded that this may very well be the case. The Manhole at weir (4) and Concrete Dam (5) were originally located with the use of a handheld Garmin GPS unit with an accuracy of 50 feet or better. Given the close proximity of the two sites and the considerable snow cover these two sites could have easily gotten mixed up. Here are the revised elevations:

1. Upper manhole at pit = 1466.50 ft.
2. Lower manhole at pit = 1463.32 ft.
3. Concrete foundation = 1469.92 ft.
4. Manhole at weir – southwest corner = 1465.34 ft.
5. Concrete dam = 1461.84 ft.
6. Outfall = 1458.81 ft.
7. Hiawatha West 189 – southwest corner = 1524.56 ft.
8. Churn hole = 1522.31 ft.
9. Hiawatha (Raymond Iron & Metal) = 1502.00 ft.
10. 19th Street Bridge = 1470.27 ft.
11. Metal stake in ponded area = 1460.75 ft.

NGS designation R 124 (PID - RL0295) benchmark was closed upon using a Sokkia auto level C3 model. The benchmark used is a vertical second order and elevation is referenced to NAVD 88.

This elevation survey closed within the allowable error of a 3rd order survey. A copy of the field notes is provided with this letter.

Thank you for providing Niigaanii Surveying Co. with this opportunity to serve you.

Sincerely,

Christie Otchingwanigan

Christie Otchingwanigan, MI PS 47968

DOBER MINE

STA	BS +	HI	FS −	ADJ ELEV	ELEV
	10.48				GPS ELEV - DON'T USE
R124	9.45	1631.86		1622.37	1622.41
	8.42				
	5.61		2.23		
TP1	4.55	1635.12	1.29		1630.57
	3.49		0.35		
	3.37		5.98		
TP2	2.93	1633.10	4.95		1630.17
	2.48		3.93		
	~~3.37~~				
~~TP3~~	~~2.93~~	~~1633.10~~			
	~~2.48~~				
	1.66		9.03		
TP3	1.21	1625.79	8.52		1624.58
	0.75		8.02		

100 Light Snow

1-03-05
C. OTCHING. ⊼
J. BUTLER ∅

SN#
Sokkia C3 383163

50

NGS DESIGNATION R-124
PID - RL0295

NOTE - ELEV OF ~~122~~ 1622.41 WAS GPS ELEVATION AND IS NOT TO BE USED. SHOULD HAVE USED NAVD 88 ELEVATION = ~~1637~~ 1622.37

*ALL ELEVATIONS IN FIELD BOOK NEED TO BE LOWERED RELATIVE TO THIS DIFFERENCE. *

STA	BS +	HI	FS −		ELEV
	1.38		12.79		
TP4	0.97	1614.70	12.06		1613.73
	0.56		11.33		
	0.95		10.59		1604.53
TP5	0.56	1605.09	10.17		
	0.19		9.75		
	0.59		11.21		
TP6	0.18	1594.52	10.75		1594.34
	—		10.28		
	1.02 ~~1.01~~		10.08		
TP7	~~0.57~~ 0.58	1585.43	9.68		1584.84
	0.16		9.29		
	0.85		11.01		
TP8	0.46 ~~0.07~~ ~~0.11~~	1575.32	10.57		1574.86
			10.12		

STA	BS +	HI	FS −		ELEV
	1.14		10.25		
TP9	0.79	1566.29	9.82		1565.50
	0.43		9.40		
	1.12		10.42		
TP10	0.74	1557.03	10.00		1556.29
	0.36		9.57		
	1.24		10.83		
TP11	0.88	1547.54	10.37		1546.66
	0.52		9.91		
	1.29		10.30		
TP12	0.93	1538.57	9.90		1537.64
	0.57		9.50		
	1.18		10.78		
TP13	0.83	1529.06	10.34		1528.23
	0.47		9.89		

STA	BS +	HI	FS −	ELEV
	1.30		9.27	
TD14	0.56	1520.79	8.83	1520.23
	—		8.38	
	4.56		8.20	
TP15	3.75	1517.11	7.43	1513.36
	2.93		6.66	
	6.82		5.04	
TP16	6.09	1519.15	4.05	1513.06
	5.36		3.06	
	1.55		4.59	
TP17 $\boxed{TBM1}$	0.79	1516.46	3.48	1515.67
	—		2.37	
	0.81		14.59	
TP18	0.50	1503.05	13.91	1502.55
	0.19		13.23	

1503.05

(54)

STA	BS +	HI	FS		ELEV
	2.04		9.07		
TP 19	1.53	1495.91	8.47		1494.38
	1.01		8.27		
	2.62 ~~3.62~~		8.82		~~1489.70~~
TP 20	2.13	1489.83	8.21		1487.70
	1.63		7.59		
	1.23	1482.19	8.91		
TP 21	0.82	~~1481.78~~	8.46		1481.37
	0.41		8.01		
	1.50		10.33		
TP 22	0.93	1473.42	9.70		1472.49
	0.37		9.07		
	1.11 ~~1.10~~		3.86		
10. BRIDGE	0.90	1471.22	5.15		$\boxed{1470.32}$
+ a T.P.	0.60		3.37 2.34		

8.5 billable hours for 1-3-05

* THIS ELEVATION IS ONE OF THREE ELEVATION USED TO FIND MEAN ELEVATION, WHICH is the final ELEV. for BRIDGE. = $\boxed{1470.31}$ — DON'T USE

ADJUSTED - FINAL ELEV $\boxed{1470.27}$

1471.22

~~STA~~ STA	BS+	HI	FS−	ELEV
	6.12		7.57	
TP23	5.39 ~~7.66~~ ~~4.84~~	1469.80	4.81	1464.41
			6.05	
5 CONC. DAM ~~TP24~~			5.22	DON'T USE
			4.42	~~1465.38~~
			3.62	
			8.85	DON'T USE
4			7.92 ~~6.49~~ ~~7.30~~	~~1461.88~~
	6.99		4.92	
TP24	6.31	1472.11	4.00	1465.80
	5.64		3.07	
	8.73		8.26	
TP25	7.99	1472.56	7.54 ~~7.55~~	1464.57
	7.24		6.82	

10°F Calm sunny

1-04-05
D. Otching
J. Butler

55

#5 CONCRETE DAM $\boxed{1465.34}$ FINAL ADJ. ELEV.

#4 MAN HOLE AT WEIR - SOUTHWEST CORNER

$\boxed{1461.84}$ FINAL ADJ. ELEV.

NOTE! ACCORDING TO Al Johnson of MTU the two sites are mixed up!

3-23-05

CJE

1472.56

STA	BS +	HI	FS −	ELEV
			2.81	DON'T USE
3. Conc. Fond.			2.60	~~1469.96~~
			2.39	
~~UPPER MANHOLE~~			6.14	DON'T USE
UPPER 1. MANHOLE			6.02	~~1466.54~~
			5.89	
LOWER ~~UPPER~~			9.38	DON'T USE
2. MANHOLE			9.20	~~1463.36~~
			9.01	
	5.38		2.21	
TP26	4.74	1475.80	1.50	1471.06
	4.10		0.79	
	2.82		11.62	
			10.85	
TP27	1.89	1466.84	~~10.09~~	1464.95
	0.96		10.09	

50

#3. CONCRETE FOUNDATION $\boxed{1469.92}$ FINAL ADJ. ELEV

#1 UPPER MANHOLE $\boxed{1466.50}$ FINAL ADJ. ELEV.

#2 LOWER MANHOLE $\boxed{1463.32}$ FINAL ADJ. ELEV.

1466.84

STA	BS +	HI	FS −		ELEV.
	8.28		2.82		
TP28	7.53	1472.29	2.08		1464.76
	6.78		1.33		
	1.13		4.00		
TP29	0.39	1469.69	2.99		1469.30
			1.97		
			~~1.13~~		
~~TP30~~			~~0.39~~		
	4.79		8.36		
TP30	3.74	1465.85	7.58		1462.11
	2.69		6.80		
	5.84		4.71		
TP31	5.31	1467.13	4.03		1461.82
	4.78		3.36		

1467.13

STA	BS +	HI	FS −	ELEV
			4.78	DON'T USE
metal 11. STAKE pond	←//→		4.34	$\boxed{1460.79}$
			5.91	
	4.93		5.85	
TP 32	4.26	1466.07	5.32	1461.81
	3.60		4.79	
	5.13	1464.70	4.41	
TP 33	4.13	1467.	5.50	1460.57
	3.13		4.59	
			6.01	DON'T USE
6. OUTFALL	←//→		5.85	$\boxed{1468.85}$
			5.69	
	4.20		5.14	
TP 34	5.30	1465.86	4.14	1460.56 ~~1468.84~~
	4.40		3.14	

#11. METAL STAKE IN
DOWN PONDED AREA.
$\boxed{1460.75}$ FINAL ADJ. ELEV.

#6 OUTFALL $\boxed{1458.81}$
FINAL ADJ. ELEV.

1465.86

STA	BS+	HI	FS−	ELEV.
	9.16		4.84	
TP35	8.25	1470.33	3.78	1462.08
	7.34		2.73	
	7.09		1.65	1469.28
TP36	6.24	1475.52	1.05	~~1469.30~~ ~~1461.03~~
	5.40		0.44	
	4.54		9.98	
TP37	3.63	1470.09	9.06	1466.46
	2.73		8.14	
	5.31		5.44	
TP38	4.31	1469.87	4.53	1465.56
	3.32		3.63	
	8.68		6.23	
TP39	7.65	1472.27	5.25 4.27 ~~3.27~~	1464.62
	6.61			
Check Bridge			2.14 1.96 1.77	~~1470.29~~ 1470.31

* SEE PAGE 54 BOOK 003

BRIDE 1470.32
$-$ 1470.31

.01

$.03\sqrt{1.12} = 0.03$ = ALLOWABLE ERROR

0.01 ERROR IS WELL WITHIN ALLOWABLE ERROR

* NOTE THIS ELEV. IS ONE OF THREE USED TO FIND MEAN ELEV. OF

$\boxed{1470.31}$ DONT USE

* SEE PAGES

$\boxed{1470.27}$ FINAL ADJ. ELEV.

1472.27

(60) (61)

STA	BS+	HI	FS−	ELEV.
	9.65		1.85	
TP 40	9.23	1480.36	1.14	1471.13
	8.82		0.44	
	9.75		0.92	
TP 41	9.51	1489.21	0.66	1479.70
	9.26		0.39	
	9.39		0.76	
TP 42	9.20	1497.86	0.55	1488.66
	9.01		0.33	
	7.81		1.21	
TP43	7.59	1504.45	1.00	1496.86
	7.37		0.79	
	4.80		3.31	
TP 44	4.30	1506.08	2.67	1501.78
	3.80		2.03 1.23	

1506.08

STA	BS+	HI	FS-	ELEV
			4.16	DON'T USE
9. Hiaw. Ray. Steel	← // →		4.04	$\boxed{1502.04}$
			3.91	
	3.30		4.80	
TP 45	2.47	1504.45	4.30	1501.78
	2.03		3.80 5.60	
	9.51		4.45	
TP 46	8.64	1509.41	3.68	1500.77
	7.76		2.91	
	6.68		2.74	
TP 47	5.63	1513.25	1.79	1507.62
	4.58		0.84	
	3.46		5.51	
TP 48	2.24	1511.02	4.47	1508.78
	1.01		3.43	

#9 HIAWATHA (RAYMOND IRON + METAL)

$\boxed{1502.00}$ FINAL ADJ. ELEV.

1511.02

STA	BS+	H I	FS−	ELEV
	7.77		4.95	
TP49	6.87	1513.89	4.00	1507.02
	5.96		3.04	
	18.45		4.20	
TP50	17.41	1528.13	3.17	1510.72
	16.37		2.15	
	4.12		3.78	DON'T USE
Hiaw. 7 west 189 SW cor	3.87	1528.47	3.53	$\boxed{1524.60}$
	3.63		3.29	
	9.41		18.11	
TP 51	8.54	1519.82	17.19	1511.28
	7.67		16.27	
	8.34		0.99	
TP 52	8.15	1527.11	0.86	1518.96
	7.96		0.72	

#7. HIAWATHA WEST 189 - Southwest CORNER

$\boxed{1524.56}$ FINAL ADJ. ELEV.

[STOPPED FOR TODAY]

9 BILLABLE HOURS.

15° ~~FAIR~~

1-05-05

C. OTCHINGK

J. BUTLER

1527.11

STA	BS +	H I	FS−	ELEV
8. Churn Hole			5.03	DON'T USE
			4.76	$\boxed{1522.35'}$
			4.49	
	4.48		18.83	
TP53	3.55	1512.83	17.83	1509.28
	2.61		16.83	
	2.69		7.13	
TP54	2.82 ~~7.33~~	1514.70	5.85	1506.98
	5.75		4.57	
	3.94		6.10	1509.27
TP55	3.17	1512.44	4.93	~~1511.20~~
	2.40		3.76	
			~~2.40~~	
	2.13		8.67	
TP56	1.28	1505.75	7.97	1504.47
	0.44		7.28	

63

−27

#8 CHURN HOLE $\boxed{1522.31}$

FINAL ADJ. ELEV.

STA	BS+	H I	FS−	ELEV.
		1505.75		
			11.90	
	1.11		~~4.87~~	
TP57	0.90	1495.61	11.04	1494.71
	0.69		10.18	
	0.80		10.56	
TP58	0.58	1485.90	10.29	1485.32
	0.35		10.02	
	0.75		9.63	
TP59	0.35	1476.88	9.37	1476.53
	—		9.12	
	4.37			
	~~3.47~~		8.57	
			3.14	
TP60	3.70	1472.44	~~8.15~~	1468.74
	3.03		7.72	
	9.66		2.34	
T61	9.10	1479.76	1.78	1470.66
	8.53		1.21	
			1.29	
			.88	
			.47	

SEE PAGE 54 - 003
BRIDGE 1470.31
1470.29
.02 = ERROR
.03/1.01 @ .03 ALLOWABLE ERROR

0.02 - ERROR IS
* STILL WITH ALLOWABLE ERROR *

TBM#2
Bridge
Check

7.22
6.59
5.94

1470.29

Bridge check

7.22
4.50
~~5~~.94

* NOTE THIS ELEV. IS ONE OF THREE USED TO FIND MEAN ELEV OF

$\boxed{1470.31}$ * SEE PAGES

DON'T USE

$\boxed{1470.27}$

FINAL ADJ. ELEV.

CONTINUED PAGES BOOK 004

STA	BS+	HI	FS-	ELEV
			1479.76	
	9.99		1.29	
TP62	9.41	1488.29	0.88	1478.88
	8.83		0.47	
	9.23		1.72	
TP63	8.57	1495.93	1.03 ~~7.82~~	1487.26
	7.91		0.34	
	12.59		1.39	
TP64	12.00	1507.06	0.77	1495.06
	11.41		0.16	
	9.41		0.81	1506.57 ~~1503.57~~ ~~+3.00~~
TP65	9.10	1515.67	0.49	
	8.79		0.17	
	5.73		1.45	
TP66	5.25	1519.95	0.97	1514.70
	4.76		0.49	
			4.82	
TBM1			4.27	1515.68
			3.72	

BOOK 004 (5)

1515.68

4.82
4.27
3.72

PAGE 14 OF BOOK 004

SEE PAGE 53 OF BOOK 003

TBM 1 = 1515.67
TBM 1 = 1515.68
3rd ORDER

-.01 ACTUAL ERROR

$(.03)\sqrt{1.01} = 0.03 =$ ACCEPTABLE ERROR

$\boxed{\text{WITHIN ALLOWABLE ERROR}}$

6

			1519.95	
STA	BS+	HI	FS-	ELEV
	4.54		7.39	
TP67	3.54	1517.02	6.47	1513.48
	2.53		5.55	
	8.61		4.98	
TP68	7.74	1520.85	3.91	1513.11
	6.86		2.84	
	12.06		1.56	
TP69	11.38	1531.34	0.89	1519.96
	10.71		0.21	
	9.52		0.98	
TP70	9.15	1539.87	0.62	1530.72
	8.78		0.26	
	9.43		0.82	
TP71	9.07	1548.47	0.47	1539.40
	8.71		0.12	

7

STA	BS+	HI	FS−		ELEV
		1548.47			
	9.36		0.97		
			0.59		
TP72	9.00	1556.88	~~0.60~~		1547.88
	8.64		0.21		
	9.66		0.93		
TP73	9.29	1565.61	0.56		1556.32
	8.91		1.19		
	9.30		0.83		
TP74	8.93	1574.06	0.48		1565.13
	8.57		0.12		
	9.41		1.12		
TP75	9.06	1582.35	0.77		1573.29
	8.71		0.42		
	9.45		0.95		
TP76	9.09	1590.87	0.57		1581.78
	8.73		0.19		

1590.97

STA	BS+	HI	FS−	ELEV.
	9.99		1.20	
TP77	9.61	1599.65	0.83	1590.04
	9.23		0.46	
	9.43		0.90	
TP78	9.07	1608.18	0.54	1599.11
	8.71		0.17	
	9.06		0.89	
TP79	8.70	1616.35	0.53	1607.65
	8.34		0.17 0.16	
	9.33		1.04	
TP80	8.94	1624.66	0.63	1615.72
	8.55		0.23	
	10.10		1.33	
TP81	9.47	1633.28	0.85	1623.81
	8.84		0.37	

1633.28

STA	BS+	HI	FS-		ELEV
	6.91		4.25		
TP82	5.91	1636.06	3.13		1630.15
	4.91		2.01		
	4.13		8.34		
TP83	3.59	1632.12	7.53		1628.53
	3.05		6.73		
			10.49		
R124			9.64	1622.44	1622.48
			8.80		

$$\begin{array}{r} 1622.41 \\ -\ 1622.48 \\ \hline -.07 \end{array} = \text{ERROR}$$

$(.03)\sqrt{1.97} = 0.04$ = ALLOWABLE ERROR

* THIS LOOP ERROR EXCEEDS ALLOWABLE ERROR - MUST BE BE RERUN FROM R124 BM → TO TBM 1 AND BACK.

(7 HOURS BILLABLE TODAY)

DOBER MINE

Re-level Section R124 → TBM # 1

STA	BS+	HI	FS−		ELEV.
	9.02			USE THIS	[illegible] DON'T USE
R124	8.97		1631.38	1622.37	1622.41
	8.31				
	8.89		3.02		
TP1	7.49	1636.605	2.265		1629.115
	6.495		1.520		
	4.97		7.27		
TP2	4.20	1634.325	6.48		1630.125
	3.43		5.68		
	2.78		7.32		
TP3	2.53	1630.645	6.16		1628.165
	2.03	—	5.00		
	2.28		7.55		
TP4	1.92	1625.425	7.19		1623.505
	1.56		6.82		

20° F PARTLY CLOUDY

01-06-05

•SOKKIA C3 SN# 383163

C. OTCHING ⊼

E. OTCHING ⌀

10

11

1625.425

STA	BS+	HI	FS−		ELEV
	1.98		9.13		
TP5	1.645	1618.31	8.765		1616.665
	1.31		8.395		
	1.64		8.605		
TP6	1.34	1611.38	8.27		1610.09
	1.05		7.94		
	1.88		8.93		
TP7	1.59	1604.35	8.62		1602.76
	1.29		8.32		
	2.03		9.19		
TP8	1.74	1597.22	8.87		1595.48
	1.46		8.55		
	2.10		9.28		
TP9	1.80	1590.05	8.92		1588.25
	1.505		8.66		

STA	BS+	H I	FS−	ELEV
		1590.05		
	1.81		8.87	
TP10	1.51	1583.00	8.56	1581.49
	1.20		8.25	
	1.64		9.00	
TP11	1.34	1575.64	8.70	1574.30
	1.04		8.39	
	1.93		8.82	
TP12	1.645	1568.785	8.50 ~~8.47~~	1567.14
	1.36		8.18	
	1.65		9.07	
TP13	1.36	1561.405	8.74	1560.045
	1.06		8.42	
	1.76		8.77	
TP14	1.465	1554.41	8.46	1552.945
	1.17		8.15	

STA	BS+	HI	FS-	ELEV
		1554.41		
	1.90		8.77	
TP 15	1.61	1547.56	8.46	1545.95
	1.32		8.15	
	1.34		8.86	
TP 16	1.04	1540.055	8.545	1539.015
	0.73		8.23	
	2.12		8.82	
TP17	1.85	1533.395	8.51	1531.595
	1.58		8.20	
	2.44		8.91	
TP18	2.15	1526.945	8.60	1524.795
	1.855		8.295	
	3.01		7.87	
TP19	2.65	1522.045	7.55	1519.395
	2.29		7.235	

1522,045

STA	BS+	HI	FS-	ELEV
	3.94		7.04	
TP20	3.46	1518.84	6.665	1519.38
	2.99		6.29	
	4.97		6.565	
TP21	4.50	1517.25	6.09	1512.75
	4.02		5.61	
	5.945		5.31	
TP22	5.465	1517.88	4.83	1512.42
	4.98		4.36	
	6.24		4.58	
TP23	5.68	1519.46	4.10	1513.78
	5.12		3.61	
	4.67		4.61	
TP24 $\boxed{\text{TBM1}}$	3.81	1519.50	3.77	1515.69
	2.95		2.93	

* SEE PAGES 53 BOOK 003,
PAGE 05 BOOK 004

STA	BS+	HI	FS-		ELEV
		1519.50			
	4.52		6.26		
	4.035				
TP25	~~[illegible]~~	1517.815	5.72		1513.78
	3.55		5.18		
	5.26		5.88		
TP26	4.79	1517.205	5.40		1512.415
	4.32		4.92		
	4.47		4.99		
			4.43		
TP27	5.99	1518.745	3.45		1512.755
	5.52		3.97		
	7.07	1522.07	3.84		
TP28	6.69	~~122~~	3.365		1515.38
	6.31		2.89		
			3.03		1519.39
TP29	7.84		2.68		~~1524.75~~
	9.52	1526.91	2.32		
	7.20				

(10)

STA	BS+	HI	FS−	ELEV
		1526.91		
			~~7.84~~	
~~TP30~~			~~9.62~~	
			~~7.20~~	
	8.61		2.40	
TP31	8.32	1533.12	2.11	1524.80
	8.02		1.825	
	8.72		1.85	
TP32	8.41	1539.97	1.56	1531.56
	8.11		1.27	
	1.25	1547.42	8.70	1539.03
TP33	0.94	~~1538.52~~	8.39	~~1531.58~~
	0.608		8.085	
		1554.36		
		~~1554.67~~		
	8.71	~~1547.43~~	1.75	1545.96
TP34	8.40	~~1539.46~~	1.46	~~1531.06~~
	~~7.46~~			
	8.10		1.16	

STA	BS +	H I	FS −		ELEV
		~~1539.46~~	~~1554.67~~ 1554.36		
	8.59	1561.24	1.71		1552.95
TP35	8.29	~~1546.34~~	1.41		~~1538.05~~
	7.98		1.11		
	9.00	1568.745	1.485		1560.06
TP36	8.685	~~1553.845~~	1.18		~~1545.16~~
	8.37		0.88		
	8.80		~~9.00~~	1.88	1567.155
TP37	8.49	1575.645	~~8.685~~	1.59	~~1558.055~~
	8.17		~~4.97~~	1.30	
	8.65		1.64		
TP38	8.36	1582.465	1.34		1574.305
	8.07		1.04		
	8.63		1.48		
TP39	8.32	1589.815	1.17		1581.495
	8.02		0.85		

17

1579.815

STA	BS+	HI	FS-		ELEV
	8.83		1.87		
TP40	8.645	1596.79 8.	1.57		1588.245
	8.25		1.26		
	8.99		1.62		
TP41	8.68	1604.15 ~~1596.925~~	1.32		1595.47
	8.37		1.01		
	8.93		1.71		
TP42	8.62	1611.37	1.40		1602.75
	8.31		1.10		
	~~6.98~~		~~1.64~~		
~~TP43~~	~~6.91~~		~~1.34~~		
	~~6.84~~		~~1.045~~		
	8.83		1.64		
TP43	8.47	1618.50	1.34		1610.03
	8.11		1.045		

1618.50

STA	BS+	HI	FS−	ELEV
	8.10		2.15	
TP44	7.81	1624.46	1.85	1616.65
	7.52		1.54	
	7.50		1.40	
TP45	7.14	1630.64	0.96	1623.50
	6.78		0.52	
	7.045		2.78	
TP46	6.04	1634.20	2.48	1628.16
	5.03		1.18	
TP47	6.45		5.01	
	5.77	1635.89	4.08	1630.12
	5.09		3.15	
	3.20		7.50	
TP48	2.46	1631.56	6.79	1629.10
	1.73		6.08	

STA	BS+	HI	FS-		ELEV
.					
.			9.84	AD	DON'T USE GPS
R124			9.16	1622.36	1622.40
			8.49		

(6 HOURS BILLABLE)

1622.41
1622.40
.01 = ERROR

$(.03)\sqrt{1.97} = .04$ = ALLOWABLE ERROR

* 0.01 ERROR IS WELL WITHIN ALLOWABLE ERROR

FINAL NOTE FOUR DIFFERENT LOOPS WERE RUN ALL WITHIN THE MAIN LOOP. INITIALLY 3 LOOPS CLOSED WITHIN ALLOWABLE ERROR 1 LOOP did NOT AND WAS RERUN AND CLOSED. THE ERROR WAS IN AN AREA THAT DID NOT EFFECT RELEVANT ELEVATIONS THE FINAL ELEVATIONS WERE 0000.04 LOWER THEN ELEV. READ IN FIELD BECAUSE WE READ WRONG ELEV. OF NGS SHEET. ALL CORRECT ELEV. ARE CLEARLY LABLED IN NOTES.

~~WITHIN~~ $\boxed{\text{3RD ORDER}}$