Shaw Environmental & Infrastructure, Inc.

Final Report

Solidification / Stabilization Bench-Scale Treatability Study for the Mohawk Tannery Site, Nashua, New Hampshire

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List of Acronyms

ASTM	American Society for Testing and Materials
BFS	blast furnace slag
cm/sec	centimeter per second
Cr	chromium
Cr(III)	trivalent chromium
Cr(VI)	hexavalent chromium
DES	Department of Environmental Services
FAC	Fly ash Class C
FAF	Fly ash Class F
HL	hydrated lime
kg	kilogram
mg/kg	milligrams per kilograms
mg/L	milligrams per liter
PAHs	polynuclear aromatic hydrocarbon
PC	Portland cement
pH	$-\log[H^+]$
PP	Pocket Penetrometer
psi	pounds per square inch
S/S	solidification / stabilization
SPLP	Synthetic Precipitation Leaching Procedure
SVOCs	semivolatile organic compounds
tsf	tons per square foot
UCS	unconfined compressive strength
USEPA	United States Environmental Protection Agency
v/v	volume to volume

1.0 Introduction

1.1 Site Description

The Mohawk Tannery site is located in the City of Nashua, New Hampshire. The site is bordered by the Nashua River to the west, a closed landfill to the north, and residential areas to the east and southeast. The site is a former leather tannery facility, operated as Mohawk Tannery and Granite State Leathers from 1924 to 1984. While in operation, the site used several hazardous substances in the preparation and tanning of animal hides. Over the course of its operational history, the Mohawk Tannery utilized waste lagoons. See Figures 1 through 3 for aerial views of the Mohawk Tannery site and an USEPA figure showing the site layout. In Figures 1 and 2, the site is next to the river, below the bend in the river.

1.2 Site Media Characterization and Description

Disposal Area 1 is located on the west side of the site, along the Nashua River, and is an open lagoon that was part of the facility's wastewater treatment system. Disposal Area 2 is a former lagoon that has since been covered with soil, and is located adjacent to the river. Previous site investigations have indicated that the sludges in Disposal Areas 1 and 2 are impacted with polynuclear aromatic hydrocarbons (PAHs) and metals. Figures 4, 5, and 6 show the approximate locations for the Area 1 sample collection and approximate cross-section information for Areas 1 and 2.

1.3 Remedial Technology Description

The technology selected for the bench-scale treatability study is solidification / stabilization (S/S). The structural integrity and durability are often enhanced when the material is solidified. The solidification increases the material compressive strength, load-bearing capacity and decreases its permeability. By decreasing the permeability of the solidified material, the rate of contaminant release is decreased. Stabilization, or chemical fixation, transforms contaminants into their least toxic and/or mobile form, thereby reducing their impact on the environment and human health.

2.0 Treatability Study Approach

2.1 Test Objectives and Rationale

The primary objective of the S/S bench-scale treatability study was to develop and verify treatment formulations for each of the waste types identified so that the treated material meets requirements for disposal on site. These initial requirements are as follows.

- Unconfined compressive compounds (UCS) above 50 pounds per square inch (psi) at 28 days or greater. After completing the Area 1 initial screening tests, the United States Environmental Protection Agency (USEPA) lowered the UCS goal to 25 psi. The lower UCS value (25 psi) is sufficient for potential loads applied to the treated sludge with the future land use. Also, by decreasing the UCS goal to 25 psi instead of 50 psi, the reagent cost and percent volume increase due to treatment will be decreased.

- Hydraulic conductivity less than 1×10^{-6} centimeter per second (cm/sec)

- Leachability of PAHs does not increase after S/S treatment.

The optimal formulation will produce a treated material which is appropriate for placement on-site at the lowest anticipated reagent cost. As currently conceived, the Area 1 and 2 sludges will be treated in-situ where reagent slurries are injected and mixed with the sludge. Site materials (e.g., Area 5 sand) may be premixed into the sludge prior to addition of the reagent slurry.

Based on the project conceptual design, additional performance objectives were added after completing Area 1 Tier 2 testing. These were added to address potential full-scale treatment issues.

- The percent volume increase less than 75 percent; preferably less than 50 percent. This included the volume increase from adding of reagent slurries, site sand, and mixing of Areas 1 and 2 sludges.

- The strength development, measured by the Soil Test Pocket Penetrometer (PP) is greater than 2.5 tons per square foot (tsf) by 7 days and preferably >3.0 tsf at 3 days.

- Minimal liquid released during 7 day or greater PP test or 28 days or longer UCS tests.

2.2 Experimental Design and Procedures

2.2.1 Treatability Samples

Eleven composite samples were collected from within Area 1, 2 and 5, placed into 5-gallon

buckets and shipped to Shaw's Technology Development Laboratory in Knoxville, Tennessee for treatability testing. The samples are listed below:

- Area 1 composite A, B and C
- Pit 2 (Area 2) sludge composite A and B
- Pit 2 (Area 2) fill surface
- Pit 2 (Area 2) lower black sand
- Pit 2 (Area 2) upper 4 ft black sand
- Pit 2 (Area 2) chromium (Cr) sand (Sand from the P2 area that was assumed to be contaminated with chromium.
- Gravel pit fill
- Area 5 sand.

Each sample was individually homogenized before being tested for the analyses listed in Table 2.1.

Results (Table 3-1) from these initial characterization analyses were used to determine which of the samples would be used for the S/S treatability study. The selected samples were considered to be representative of the average contamination found within Areas 1 and 2.

2.2.2 Composite Sample Characterization

Based largely on the results for hexavalent chromium [Cr(VI)]) and organic compound concentrations (Table 3-1), samples were selected for further study. Areas 1 (A, B, and C) and Area 2 (A and B) composite samples were prepared and homogenized. Each of the homogenized area composite samples was analyzed for the parameters listed in Table 2-2.

2.2.3 Formulation Development

Treatment Tier

There were five and three tiers of formulations development for Areas 1 and 2, respectively. In these tests, the binder and organic adsorbent mix ratio, water to binder ratio and the addition of ferrous sulfate heptahydrate were varied to determine formulation to meet the performance specification (Section 2.1). The formulations investigated are shown in Section 3. In general, the reagent dose rate was increased and the water to binder ratio decreased as the subsequent tiers progressed. Treated sample preparation followed the procedure described above.

Treatment Procedure

S/S treatments were investigated on Areas 1 and 2 composite samples. The following regents were used in this treatability study. Reagents and reagent combinations were chosen that had been proven successful for previous S/S projects.

- Portland cement (PC)
- Lafarge blast furnace slag (BFS)
- Hydrated lime (HL)
- Fly ash Class C (FAC)
- Fly ash Class F (FAF)
- Ferrous sulfate heptahydrate
- Spill King™ absorbent
- Nochar's Petro Bond N910 polymer.

The first five reagents were binders to S/S the sludges. Ferrous sulfate heptahydrate was added to chemically reduce hexavalent to trivalent chromium [Cr(III)]. The last two reagents were organic adsorbents added to decrease the impact of the organic contaminant on the binder reactivity.

Portions of composite (~1 kilogram [kg]) were measured and used for each formulation. Reagent admixtures were weighed and dry mixed based on the wet weight of the samples. Water was added to the reagent admixtures to prepare reagent slurries. For Area 1, Area 5 sand was mixed with the untreated material prior to the addition of the reagent slurry. Area 5 sand was added on a percentage of the Area 1 sample volume. The reagent slurry was added and the treated material was mixed using an orbital planetary mixer with a spade mixing blade for about 2 minutes or until the material was visually homogeneous. The mixer was operated on one of its lowest two mixing speeds. The treated material was then compacted into 2-inch by 4-inch plastic right cylinder molds in three lifts using 25 blows of a tamping rod for each lift. Specimen cups were also filled in the same manner for each treated material.

Lids were placed onto and tightly sealed on each cylinder mold and specimen container. Cylinder molds were placed into a room temperature humidity chamber to cure until further testing. Samples in specimen containers were allowed to cure at room temperature on the bench-top until further testing.

The treated material from each formulation was subjected to daily strength development testing using a SoilTest CL-100 PP for the first 7 days. Based on the PP strength development results and comparison to objectives in Section 2.1, promising formulations were selected for UCS testing [American Society for Testing and Materials (ASTM) D1633] and Synthetic Precipitation Leaching Procedure (SPLP) testing (for SVOCs and metals) after 7 days of curing. Based on the 7-day UCS and SPLP results, selected formulations were subjected to UCS testing after 14 and 28 days of curing and to permeability testing (ASTM D5084) after 28 days of curing. Observation of free liquids was made during the ASTM D1633 UCS testing.

Combined Area 1 and Area 2 Formulation Screening Mix

Some excavation work was performed at the Mohawk site during the time of the treatability testing. This work involved excavating some Area 2 material and moving it on top of Area 1. An Area 1 - Area 2 composite formulation was prepared since it was unknown the impact of adding in Area 2 sludge into Area 1. The formulation was prepared using a composite sample consisting of 10 parts by volume Area 1 material to 1 part by volume Area 2 material. This ratio was based on a rough estimate of the amount of excavated Area 2 material placed into the Area 1 pond. Sample preparation and testing followed the same procedures used in the initial formulation screening samples as described above. The formulation investigated is listed below.

> 0.30 mix ratio PC + 0.10 mix ratio BFS + 0.06 mix ratio HL + 0.23 mix ratio water + 50 volume percent Area 5 sand where mix ratio is the weight of the reagent to as-is weight of sludge and 50 volume percent is one-half volume of Area 5 sand to one volume of sludge.

Impact of Treating Water on Top of Area 1 Sludge

Throughout the screening process it became apparent that the treatment of the Area 1 sludge was highly contingent on moisture content of the treated product. This is significant due to possible site changes, water levels and the necessity of adding stabilization reagents as a slurry blend. The following formulations were prepared to determine the amount of reagent necessary to treat the Area 1 sludge along with an additional volume of 1.5 feet of excess standing water above it. With these tests, only enough material was prepared to conduct PP tests. Approximately 100 grams of sludge was hand mixed with dry sand and then reagent slurry. The resulting product was transferred into 8-ounce specimen cup and hand compacted. The specimen cups were capped except during PP measurements. These formulations were tested for PP strength development. The 0.47 mix ratio PC formulation was based on the selected Area 1 Tier 5 formulation but added in more reagents (PC/BFS/HL) to react with the additional free-standing water. As an approximation, the amount of PC/BFS/HL was increased by approximately one pound dry reagent for each pound water floating on top of Area 1 sludge. The 0.40 and 0.64 PC mix ratio formulations were leaner and richer reagent formulations than the baseline formulation (0.47 Pc mix) to estimate the bounds of treatment.

Area 1 Water Modified Formulation Screening Mixes

0.40 mix ratio PC + 0.13 mix ratio BFS + 0.08 mix ratio HL + 0.45 mix ratio water + 50 volume percent Area 5 sand

0.47 mix ratio PC + 0.16 mix ratio BFS + 0.09 mix ratio HL + 0.50 mix ratio water + 50 volume percent Area 5 sand

0.64 mix ratio PC + 0.21 mix ratio BFS + 0.13 mix ratio HL + 0.64 mix ratio water + 50 volume percent Area 5 sand

2.2.4 Solidification / Stabilization Treatment Verification Testing

Based on formulation results in Tiers 1, 2, 3, 4 and 5, one formulation from Area 1 and one formulation from Area 2 were chosen for verification testing. The selected formulations were freshly prepared in triplicate and tested for PP strength development, UCS, permeability and SPLP leachability.

2.3 Equipment and Materials

2.3.1 Equipment

The equipment for the stabilization treatability testing included, but not limited to

- Dual-shaft helical mixer
- 1000 m L glass jars
- 2-inch diameter x 4-inch high plastic molds
- 2-quart Kitchen-Aid planetary mixer
- 2-quart stainless steel mixing bowls
- 2000 mL glass jars
- Metal spatulas and mixing blades
- Lars Land TCLP tumbler

2.3.2 Materials

The S/S treatment reagents investigated were PC, Lafarge BFS, HL, FAC, FAF, ferrous sulfate heptahydrate, Spill King™ absorbent and Nochar's Petro Bond N910 polymer.

2.4 Sampling and Analysis

Representative samples of the selected homogenized soil and sludge were collected and analyzed for the parameters described in Sections 2.2.1 and 2.2.2. Solidified samples of the soil and extraction leachates from formulation screening and verification testing produced during the treatability testing were analyzed for UCS, permeability, and SPLP leachability.

2.5 Data Management

All raw data from the bench-scale treatability study resides in bound laboratory notebooks, analytical reports from Shaw's Technology Applications Laboratory or outside analytical laboratories, or computer-generated print-outs from computer-controlled equipment.

2.5.1 Data in Bound Laboratory Notebooks

All entries in bound laboratory notebooks were made in black ink and will be considered raw data. At the end of each entry, the initials of the laboratory personnel responsible and date were entered. All corrections were initialed and dated at the time of correction and a note explaining the correction included.

2.5.2 Analysis Reports

All analytical reports from Shaw's Technology Applications Laboratory or outside analytical laboratories will be maintained as raw data. Any corrections or additions to analytical reports previously received must be accompanied by a written explanation from the analytical laboratory. Only qualified Shaw personnel are allowed to make corrections to analytical reports from the Technology Applications Laboratory.

2.5.3 Computer Print-outs

Computer printouts from computer-controlled equipment will be maintained as raw data. The initials of the equipment operator and the date of generation were added to each page of all such computer printouts. Regenerated printouts will be identified as such and any corrections noted.

2.5.4 Data Review

Prior to issuing a final report, all pertinent raw data was reviewed to ensure the data quality. The Treatability Program Manager or the Treatability Laboratory Manager reviewed all relevant laboratory notebook pages, computer printouts, and analytical reports. Any discrepancies in the raw data uncovered in this or any review were immediately brought to the attention of the appropriate laboratory personnel and corrected.

2.5.5 Data Analysis and Interpretation

Based on the UCS, SPLP metals and permeability results for the five tiers of formulation screening samples, Shaw determined the admixtures and mix ratios for verification testing. The verification testing results were used to select applicable full-scale treatment conditions for the site soil.

2.6 Deviations from Work Plan

Section 4.0 and subsequent sections 4.1, 4.2 and 4.3 of the "Solidification / Stabilization Bench-

Scale Treatability Study Work Plan for the Mohawk Tannery Site" states that samples from "Disposal Area 1, Area 2, and Areas 3, 4, 6, and 7 at the Mohawk Tannery Site will be sampled for S/S bench-scale treatability testing." Based on observations of Ed Bates of USEPA and Paul Lear formally of Shaw, samples were only taken in Areas 1 and 2 for treatability testing. No treatability testing was performed for Mohawk Tannery Site Areas 3, 4, 6 or 7.

Section 5.2 of the "Solidification / Stabilization Bench-Scale Treatability Study Work Plan for the Mohawk Tannery Site" states, "The sample material in each bucket from Disposal Areas 1 and 2 will be individually homogenized using a dual-shaft helical mixer and an aliquot removed for characterization. The homogenized samples will be characterized for solids and moisture content, bulk density, PAHs, and pH." All of tests listed above were performed as stated. In addition metals were analyzed using SW- 846 methods 3050 and 6010B.

Section 5.3 of the "Solidification / Stabilization Bench-Scale Treatability Study Work Plan for the Mohawk Tannery Site" states, "The pentachlorophenol analysis will be conducted in triplicate to assess homogeneity." Following the sampling event, it was determined that pentachlorophenol was not considered to be a concern on the site; and therefore, was not used as a marker for the sample homogeneity. The measurement of the leachable SVOC by SPLP was dropped from the scope under the direction of Ed Bates.

Sections 5.3.1, 5.3.2 and 5.3.3 of the "Solidification / Stabilization Bench-Scale Treatability Study Work Plan for the Mohawk Tannery Site" states, "Based on results of these initial formulations, one or two additional tiers of formulation development and testing may be required to optimize reagent addition." Additional tiers of testing (five for Area 1 and 3 for Area 2) were performed due to difficulties in reaching the stabilization goals outlined in Section 2.1 of this report. The UCS performance goal was decreased from 50 to 25 psi at the direction of Ed Bates. Testing was performed using this tier approach in order to minimize the use of sample and control testing costs. All formulations were tested under the consultation and guidance of the USEPA, and the New Hampshire Department of Environmental Services (DES).

Section 5.3.3 of the "Solidification / Stabilization Bench-Scale Treatability Study Work Plan for the Mohawk Tannery Site" states "Portions (~1,000 grams each) of the Disposal Areas 3, 4, 6, and 7 composite samples will be mixed with various reagents known to be proficient in the S/S of PAH-contaminated materials." Based on observations of Ed Bates of USEPA and Paul Lear formally of Shaw, samples were only taken in Areas 1 and 2 for treatability testing. No treatability testing was performed for Mohawk Tannery Site Areas 3, 4, 6 or 7.

3.0 Results and Discussion

3.1 Characterization

The initial characterization data for the Mohawk Tannery samples are summarized in Table 3-1.

Solid Content

The initial solids content for the Mohawk Tannery site materials ranged from 15.18 to 96.34 percent for the three Area 1 sludges, two Area 2 (P2) sludges, the P2 fill (surface), P2 lower black sand, P2 upper black sand, P2 Cr sand, the Area 5 sand, and the gravel pit fill. The average Area 1 sludge solid content (about 17 percent) was had less than half the solids content of Area 2 sludge (about 41 percent).

Metals Analysis

Total metals analysis of the samples indicated total Cr concentrations of 26,349; 25,221; and 24,081 milligrams per kilograms (mg/kg) for the Area 1 A, B, and C sludges, respectively. The total hexavalent Cr concentrations of these samples were 117, 257 and 959 mg/kg. The two Area 2 sludge samples had total and Cr(VI) concentrations of 24,047 and 12,560 mg/kg and 313 and 656 mg/kg, respectively. The P2 fill (surface), P2 lower black sand, P2 upper black sand, P2 Cr sand, the Area 5 sand, and the gravel pit fill had total Cr concentrations of 584, 301, 1,892, 282, 10.8 and 15 mg/kg, respectively. The Cr(VI) concentrations for these samples were 5.8, 1.4, 3.7, 8.6, 0.91, and 0.8 mg/kg, respectively. Analyses of these results show that the majority of total Cr and Cr(VI) were in the Areas 1 and 2 sludges. Since the majority of Cr (Table 3-1) and SPLP leachable organic compounds (Table 3-2) were in Areas 1 and 2 sludges, they were selected for S/S treatability testing.

Organic Analysis

Total PAH analyses indicated measureable concentrations of phenol and 4-methylphenol in samples from Area 1. The concentrations of these constituents were 0.73, 1.07 and 1.09 mg/kg phenol and 2.3, 13.6 and 11.9 mg/kg 4-methyl phenol, respectively.

Samples from Area 2 contained measureable amounts of 1, 2 dichlorobenzene, 4-methylphenol, Naphthalene, 2, 4, 5-trichlorophenol and pentachlorophenol. 1, 2 Dichlorobenzene was found at 0.80 and 1.45 mg/kg. 4-methylphenol was found at 0.61 and 0.48 mg/kg. Naphthalene was found at 1.13 and 2.11 mg/kg. 2, 4, 5-Trichlorophenol was found at 0.66, and 1.86 mg/kg and pentachlorophenol was found at 1.03 and 1.60 mg/kg, respectively. Of the other six samples

only the P2 lower black sand contained a measureable amount of phenol, 0.76 mg/kg, none of the other organics were detected in these samples.

SPLP Leachability

The three Area 1 and two Area 2 individual samples were composited to make Areas 1 and 2 composites. These Areas 1 and 2 composites and the P2 lower black sludge were each subjected to an SPLP to determine baseline leaching. The leachates were analyzed for metals and PAHs. Each of the leaching tests and analyses were performed in triplicate. Results are found in Table 3-2.

The baseline SPLP-leachable metals analysis indicates that the composite Area 1, Area 2 and the P2 lower black sludges had leachable total Cr concentrations of 0.108, .272 and <0.026 milligrams per liter (mg/L), respectively. The leachable Cr(VI) for each sample was determined to be <0.025 mg/L.

Leachable 4-methyl phenol at a concentration of 0.059 mg/L was detected in the Area 1 SPLP leachate. The SPLP leachate for the Area 2 sludge contained 1, 2 dichlorobenzene at 0.22 mg/L and naphthalene at 0.19 mg/L. The SPLP leachate for the P2 lower black contained phenol at 0.085 mg/L, and 4-methylphenol at 0.047 mg/L.

3.2 Formulation Screening Testing

Area 1 Tier 1

The first eleven Area 1 pond sludge formulations found on Table 3-3 were prepared utilizing various mix ratios (m.r.) of PC, HL, FAC and Area 5 sand. These reagents were added to increase the solid content of the sludge and to S/S the sludge. Each of the formulations also contained 0.03 mix ratio of ferrous sulfate heptahydrate and water. Ferrous sulfate heptahydrate was added to chemically reduce Cr(VI) to Cr(III). The dry reagents, with the exception of the Area 5 sand, were added as 1:1 or about 2.3:1 water to reagent slurry.

Analysis of PP Strength Gain

Analysis of the results indicates that none of the first eleven Area 1 formulations developed any measureable strength above 0.25 tsf within the first 7 days after mixing. UCS testing on Area 1 formulations 3, 7, 8 and 9 indicated strengths of 1.94, 1.62, 0.64 and 3.32 psi after 7 days, respectively. Based on the PP and the UCS results being less than the performance objectives, no further testing was performed on these formulations.

Area 1 Tier 2

Since Cr(VI) did not leach from the untreated materials above the detection limits, ferrous sulfate heptahydrate addition was omitted from all tests past Tier 1. SPLP Cr was analyzed in latter promising formulations to ensure Cr(VI) was not an issue. Nine formulations were tested in Tier 2. Based on results from previous sludges with organic studies, BFS was added to the Tier 2 formulations to improve strength formation. The Area 5 sand content was increased to provide more body feed and improve the strength characteristics.

Data from the Tier 2 strength formation testing are found in Table 3-4. Analysis of the PP results shows, except for Formulation 13, there was no strength development by day seven. This latter formulation used a 0.20 mix ratio of 75/25 PC/BFS. PP measurements were continued until day 62 to determine if the treated sludge would set up and harden with longer cure times. The PP values at 62 days showed some strength formation in Formulations 13, 15, 18 and 19. The UCS results for these samples were 15.1, 11.7, 36.2 and 24.6 psi for each of these formulations, respectively, none of which met the initial performance goal of 50 psi. The two Formulations 18 and 19, which had the largest 62-day PP and UCS values, had the largest overall binder dose rate. Their UCS values were close to 25 psi UCS goal.

The percent volume increase was calculated for several formulations. The Area 1 percent volume increase results are in Table 3-5. Formulations 18 and 19 percent volume increase exceeded the 75 percent volume expansion goal.

As none of the formulations met the PP and UCS goals, no leaching tests were performed since none of the formulations met the performance criteria for strength.

Area 1 Tier 3

Three Tier 3 formulations were prepared. Formulation containing Spill King and Petrobond absorbents were added in an attempt to further adsorb organic constituents that may be inhibiting the cement-based strength development reactions. Previous studies at other sites had shown these adsorbents may improve cement-based S/S when treating an organic containing material. These absorbents and the Area 5 sand were mixed into the sludge prior to the addition of the PC-based reagent slurries. PP results measured over a 56-day period, found in Table 3-6, indicate little strength formation for these three formulations. The maximum PP strengths were 2.00 tsf. With the Tier 3 7-day PP results, the addition of the organic adsorbents did not improve the PP measured strength development. No leaching tests were performed on these formulations as the PP values were too low.

Area 1 Tiers 4 and 5

Tiers 4 and 5 consisted of eleven additional Area 1 formulations. All formulations used PC and BFS blends. HL was added to increase solid content. The water to binder ratio was varied in these tests. Additional formulations containing the Spill King Reagent, Formulations 24 and 25, were also tested. Results for Tiers 4 and 5 are found in Tables 3-7 and 3-8. Formulations with at least 33 percent of combined PC plus BFS dose rate had PP values $\geq$3.4 tsf within 14 days. The PP results improved with lower water to binder ratios. Formulation 30 with the highest total dose rate of PC and BFS and HL and water to binder ratio of about 1:2 showed the most rapid rate of PP strength gain. Figure 4 shows the PP results for nine Area 1 formulations. Analysis of the figure shows that Formulation 30 develops PP strength faster than the other formulations. Formulations 28, 31, and 34 have similar day 7 PP results; however, Formulation 31, which had some PP strength development in 14 days, exceeded the percent volume expansion goal.

In the previous tiers, addition of Area 5 sand had little to no impact on the PP results. At these higher Tier 4 and 5 binder dose rates, addition of Area 5 sand did improve the PP results slightly; however, the volume increase with a 75 percent volume to volume (v/v) Area 5 sand addition was unacceptable (Table 3-5).

UCS measurements were taken at 7 and 28 days for Formulation 30 and were found to be 22.2 and 38.3 psi, respectively. Formulation 28 was tested at days 28 and 36 and had UCS values of 44.6 and 46.7 psi, respectively. Formulations 27 and 31 were tested at 36 and 28 days and were found to have strengths of 27.4 and 22.6 psi, respectively. None of the Tier 4 and Tier 5 Area 1 formulations had UCS strength greater than the original 50 psi goal formulations; however, Formulations 28 and 30 met the revised 25 psi goal.

Formulations 28, 30 and 31 were also tested for permeability at 14 and 28 days and SPLP leaching at 28 days of cure. The permeability and leaching results are found in Table 3-8.

Permeability results indicate permeability values of 8.2×10^{-7}, 9.7×10^{-7}, and 9.1×10^{-7} cm/sec at 28 days of cure for Formulations 28, 30 and 31, respectively all of which exceed the 1×10^{-6} cm/sec criteria.

SPLP leaching results indicate a slight increase of Cr leaching in all three formulations. Formulation 28 contained 0.186 mg/L SPLP leachable Cr. Formulation 30 contained 0.139 mg/L SPLP leachable Cr, and Formulation 31 contained 0.171 mg/L SPLP leachable Cr while the untreated Area 1 sludge contained 0.108 mg/L SPLP leachable Cr. 4-Methylphenol was the only organic constituent detected in any of the SPLP leachates at concentrations of 0.017, 0.014, and

0.017 mg/L respectively for Formulations 28, 30 and 31. Each was less than the SPLP leachable 4-methylphenol concentration in the untreated sludge material at 0.059 mg/L.

Area 2 Tier 1

The Area 2 sludge Tier 1 Formulations (1-9) are found in Table 3-9. These formulations were prepared utilizing various mix ratios of PC, HL, FAC, and FAF. Each formulation also contained 0.03 mix ratio of ferrous sulfate heptahydrate and water. The dry reagents were slurried (1:1) with water prior to being mixed with the sludge.

Formulation 3 met the PP goal of 2.5 tsf by day 3. UCS was determined on formulations with PP $\geq$0.5 tsf. Formulations 2, 3, 7, 8 and 9 had UCS of 6.5, 31.3, 8.4, 9.3 and 15.6 psi after 7 days of cure, respectively. None of these formulations had UCS values greater than the original 50 psi goal; however, Formulation 3 had an acceptable strength (31.3 psi) above the revised UCS goal of 25 psi. Additional UCS tests were conducted on days 14 and 55. None of these formulations reached the original performance criteria of 50 psi at day 55. Formulations 3, 8, and 9 all had UCS values above 25 psi.

Based on the first 7 days of PP and the 7-day UCS testing results, Area 2 Formulations 3 and 9 were chosen for SPLP analysis after 7 days of curing. Results are found in Table 3-10. SPLP results for Area 2 Formulations 3 and 9 indicated an increase of organic constituent leachability in the treated samples compared to the SPLP organic leachable concentrations found in the untreated Area 2 materials. The leachable concentration of phenol, 4-methyl phenol, and 2, 4, 5 trichlorophenol were less than the detection limit in the untreated sludge. Their SPLP concentrations increased to $\geq$0.10 mg/L in the treated materials. Pentachlorophenol was also below the detection limit in the untreated material at a concentration of less than 0.05 mg/L, but was found at concentrations of 0.20 mg/L in the SPLP leachates for both formulations. The two other compounds found in SPLP leachate of the untreated material, 1, 2-dichlorobenzene at 0.22 mg/L and naphthalene at 0.019 mg/L also increased in the SPLP leachates for Formulations 3 and 9 to 0.26, 0.27 0.25 and 0.22 mg/L, respectively.

Area 2 Tier 2

Two Tier 2 formulations were prepared for the Area 2 sludge. Results are shown in Table 3-11. Formulations included a formulation with a higher cement dosage, 0.20 mix ratio, and a formulation using a 0.20 mix ratio of a 72/25 PC BFS blend. Higher dose rates were used to increase the rate of PP strength gain from those in Tier 1. The dry reagents were slurried with equal amounts of water prior to being mixed with the sludge. Formulations 10 and 11 reached significant PP strength formation at 3 days. Formulation 11 had a PP value of 3.75 tsf while

Formulation 11 had a PP value of 4.25 tsf. At seven days of cure both formulations reached >4.5 tsf. UCS for these formulations was 50.9 and 109 psi at 28 days, respectively, which were greater than the original performance criteria of 50 psi. The percent volume increase was about 25 percent which is essentially the same as for Formulations 3 and 8 with 15 percent binder dose rates. No leaching tests were performed on Area 2 Formulations 10 and 11.

Area 2 Tier 3

Seven formulations were prepared for the Area 2 Tier 3 screening tests. These formulations were prepared to further optimize reagent loadings based on the previous screening results. Formulations 3b, 10b and 11b were repeats of previously prepared Formulations 3, 10 and 11; however ferrous sulfate heptahydrate was omitted in the repeated Formulation 3b. Formulations 3b, 10b, and 11b used binder ratios of 15 and 20 percent at water to binder ratios of approximately 1:1. Formulations 12 through 15 used binder ratios from 13 to 16 percent; however, the water to binder ratio in the reagent slurry was decreased by about 50 percent. Results are found in Table 3-12.

PP results were all greater than 2.5 tsf at 3 days cure. In addition, each formulation increased strength over the first seven days of cure. UCS was tested at 7 days for all formulations and at 28 days for Formulations 13, 14 and 15. Of these formulations, only Formulation 15 had a UCS value that exceeded the original 50 psi performance criterion at 7 days. At 28 days, the UCS results for Formulations 13, 14 and 15 exceeded the 50 psi criteria. Analysis of the PP and UCS results further show that decreasing the water to binder ratio improved the PP and UCS results.

The percent volume increase for Formulations 13, 14, and 15 were all less than 11 percent. (See Table 3-13.) Decreasing the water to binder ratio also decease the percent volume increase. Formulations 13, 14 and 15 were tested for permeability at 14 and 28 days and SPLP leaching at 28 days. The permeability and leaching results for Formulations 13, 14 and 15 are found in Table 3-14. The permeability results were 2.0×10^{-7}, 7.6×10^{-7}, and 2.0×10^{-7} cm/sec for Formulations 13, 14 and 15, respectively, all of which exceed the 1×10^{-6} cm/sec criterion.

Analysis of SPLP leaching results indicated a decrease of Cr leaching in Formulation 13, 0.195 mg/L compared to the SPLP leachable Cr concentration of 0.272 mg/L found in the untreated Area 2 sludge. The SPLP leachable Cr concentrations for Formulations 14 and 15 were slightly

above the untreated materials at 0.701 and 0.324 mg/L respectively. SPLP leachable organic constituents were the same or less than the untreated sludge.

Combined Areas 1 and 2 Material

In addition to the various tiers of formulations for the Area 1 and Area 2 sludges, a combined Area 1 and Area 2 formulation was prepared primarily to determine whether the addition of some of the Area 2 sludge would affect the set characteristics of the treated material. [Note: Some Area 2 sludge was placed within Area 1 following collection of the original treatability study samples as a result of the City of Nashua's work to upgrade the sewer line near Areas 1 and 2 during the summer of 2009.] The reagent dosage rate was chosen based upon the strength results for the Area 1 Tiers 4 and 5 formulations. The percentage of reagent added was based on Area 1 Formulation 30; however, it was tested on the combined Area 1, 10 parts by volume, and Area 2, 1 part by volume sample. Since Area 2 sludge was added to Area 1, the total mass of binder and Area 5 sand was increased from treating only Area 1 sludge. This formulation was analyzed for PP strength gain. Results are found in Table 3-15.

Analysis of the results from Formulation 30, using the combined Areas 1 and 2 samples, indicated a strength profile similar to that of Formulation 30 for Area 1 alone. After 3 days of cure, the combined sample Formulation 30 had a PP value of 0.75 tsf and after 7 days the strength improved to 3.5 tsf. Initially, after 24 hours, there was standing water above the sample, but the water was adsorbed within 48 hours after sample preparation. After 7 days of cure, the mold had no standing water above it, but water could still be expelled when exerting pressure on the mold surface with the PP testing devise.

Impact of Treating Water on Top of Area 1 Sludge

Throughout the screening process it had become apparent that the treatment of the Area 1 sludge was highly contingent on moisture content. This is significant due to possible site changes, water levels and the necessity of adding S/S reagents as a slurry blend. Three modified water content formulations were prepared based on Area 1 Formulation 30, 0.30 mix ratio PC + 0.10 mix ratio BFS + 0.06 mix ratio HL + 0.23 mix ratio water + 50 volume percent Area 5 sand, to determine the amount of reagent necessary to treat the Area 1 material with an additional 1.5 foot of free-standing water above the sludge surface. These tests were designed to estimate lower and upper bounds on reagent dosage. Formulation 30 M1 was a formulation which contained 0.93 lbs of reagent per pound of standing water, Formulation M2, 1.29 lbs/lb and Formulation M3, 0.69 lbs/lbs. The ratio of BFS to cement was kept constant (having the same ratio as in the original

Formulation 30) between the three formulations as well as the ratio of Area 1 material to the Area 5 sand. Results are found in Table 3-16.

Analyses of the results showed that the Area 1 sludge with a water cap can be solidified. Formulations 30 Ml and M3 are similar to Formulations 30 except more binder was added to react with the free water. Formulation 30 Ml PP results were similar to the original Formulation 30, but PP strength gain is more rapid. Formulation 30 M3 sets a lower bound on reagent addition as the treated samples no longer met the performance goals. Formulation 30 M2 well exceeds the PP performance goals.

Analysis of the total mass of reagents to treat Area 1 plus a water cap showed that it will take significantly more reagent to treat the combined stream compared to treating a "dewatered" Area 1 sludge.

3.3 Soil Solidification / Stabilization Verification Testing

Based on the 5 tiers of formulation screening for Areas 1 and the 3 tiers of formulation screening for Area 2, formulations were chosen for each area for verification testing. Area 1 Formulation 30, 0.30 mix ratio PC, 0.10 mix ratio BFS, 0.06 mix ratio HL, 0.23 mix ratio water and 50 percent (v/v) Area 5 sand, and Area 2 Formulation 15, 0.12 mix ratio PC, 0.04 mix ratio BFS and 0.08 mix ratio of water, were chosen for verification testing. The verification formulations were prepared similarly to the screening formulations except each formulation was prepared in triplicate to access variability between mixtures. Each formulation was tested for PP strength gain during the first 7 days of cure. UCS, permeability and leaching using the SPLP procedure were each tested at 28 days of cure. The tested formulations and the PP results are found in Table 3-17. The remaining results are found in Tables 3-18 and 3-19.

Area 1

PP results were similar to the previous Formulation 30 results; however, the rate of PP strength development was slightly slower than with the previous Formulation 30 tests. It took about 7 days to meet the 2.5 tsf goal. One equipment vendor (Lang Tool Company (http://www.langtool.com/)) who was contacted recommended a PP result of 3.0 tsf to support the weight of their heavy equipment in the full-scale process. After 7 days of cure, the PP values for the triplicate samples were 2.85, 2.35 and 3.3 tsf which were less than the vendor's desired value. It is expected that slightly higher reagent dose rate would increase the rate of strength gain. Alternatively longer than 7 day cure times may be appropriate.

Samples were allowed to cure for 28 days prior to analysis for UCS, SPLP leaching method and permeability. UCS results for the Area 1 verification formulations were 57.1, 84.7 and 77.2 psi which were all greater than the original performance criteria of 50 psi, and far greater than the 25 psi goal established by USEPA following the Tier 1 testing. The variability between the triplicate sample results could be from the high amount of organic materials, including animal hair-like materials, within the sample matrix.

The permeability results for the Area 1 verification formulations were 2.1×10^{-6}, 1.1×10^{-6}, and 2.3×10^{-6} cm/sec, respectively which are all slightly higher than the performance goal of 1.0×10^{-6} cm/sec.

Analysis of the SPLP leachability test for metals indicated that leachable barium remained relatively unchanged from the untreated Area 1 material to that of the treated Formulation 30. The untreated material had a SPLP leachable barium concentration of 0.871 while the leachable barium concentration in the treated material was 1.04, 1.02 and 1.00 which are all within the variability of the analysis method. SPLP leachable Cr was reduced from that of the untreated Area 1 material. The untreated SPLP Cr concentration was 0.108 mg/L while the SPLP leachates for Formulation 30 had SPLP Cr concentrations of 0.038, <0.026 and <0.026 mg/L. Leachable nickel increased slightly from <0.011 mg/L to 0.023, 0.024 and 0.022 mg/L. Leachable zinc was reduced from 0.069 to < 0.022 mg/L in each of the triplicate analyses.

Two organic constituents were found in the SPLP leachate of the treated Area 1 verification Formulation 30 (i.e., phenol and 4-methylphenol). Phenol was not detected above 0.01 mg/L in the SPLP leachate for the untreated sample, but was found in the extraction for the Formulation 30 triplicate formulations at 0.028, 0.026 and 0.026 mg/L, respectively. The SPLP leachates of the untreated sample contained 0.059 mg/L 4-methylphenol while the SPLP of the treated triplicates contained 1.22, 1.13 and 1.16 mg/L.

Area 2

PP results for the Area 2 Formulation 15 were all greater than 3.0 tsf after 3 days. After 7 days each of the triplicate analyses had PP values greater than 4.5 tsf. The rapid development of PP strength should allow the heavy equipment operator to move out onto the treated material after 3-days of curing.

UCS results for the Area 2 verification formulation were 177, 179 and 179 psi. These values were all greater than either of the site performance criteria of 25 or 50 psi.
The permeability results for the Area 2 verification formulation were 4.5×10^{-8}, 1.6×10^{-7}, and

1.2×10^{-6} cm/sec, respectively. Two of the triplicate formulations exceeded the performance goal of 1.0×10^{-6} cm/sec while the third sample was slightly higher than the performance goal.

Analysis of the SPLP leachability test results for metals indicated that leachable barium decreased from the untreated Area 2 material to that of the treated Formulation 15. The untreated material had a SPLP leachable barium concentration of 0.786 while the leachable barium concentrations in the SPLP samples for the triplicate treated formulations were 0.441, 0.423 and 0.410 mg/L. SPLP leachable Cr and nickel were each unchanged from that of the untreated Area 2 material. The untreated SPLP Cr concentration was 0.272 mg/L while the SPLP leachate concentrations for the verification formulations were 0.217, 0.227 and 0.234 mg/L. Nickel was not detected in levels above 0.011 mg/L in the untreated material, but leached slightly in the treated material at 0.013 mg/L for each of the triplicate analyses. This value was considered the same as the untreated analysis since the analyses were within the analytical error of the testing method. Leachable zinc was reduced from 0.041 mg/L to <0.022 mg/L in all three of the verification triplicate SPLP leachates.

Analysis of the SPLP leachability testing for PAH compounds from the treated verification formulation for Area 2 indicated that phenol, which was not detected at concentrations above 0.01 mg/L in the untreated Area 2 material, was found at 0.17 mg/L in each of the SPLP leachates for the triplicate analyses. The concentration for 1, 4-dichlorobenzene remained relatively unchanged from the SPLP analysis of the untreated material to the treated materials while the leachability of 1, 2-dichlorobenzene was reduced in the treated material. The SPLP 1, 4-dichlorobenzene concentrations for the untreated material and the triplicate Formulation 15 samples were <0.01, <0.01, 0.011 and 0.012 mg/L, respectively. The initial untreated SPLP concentration of 1, 2-dichlorobenzene was 0.22 mg/L. The treated formulations had SPLP concentrations of 0.13 mg/L for each of the triplicate samples. The SPLP leachable of 4-methyl phenol, 2, 4, 6-trichlorophenol, and pentachlorophenol all increased from the untreated to the treated Area 2 materials. None of these constituents were found in the SPLP leachate of the untreated sample above <0.01, 0.01 and 0.05 mg/L, respectively. The Area 2 verification Formulation 15 SPLP leachates contained 0.041, 0.037 and 0.04 mg/L of 4-methylphenol, 0.32, 0.33, and 0.35 mg/L of 2, 4, 6-trichlorophenol, and 0.42, 0.37 and 0.41 mg/L of pentachlorophenol. Leachable naphthalene was reduced from 0.19 mg/L in the SPLP leachate in the untreated Area 2 material to 0.098, 0.10 and 0.096 mg/L in the SPLP of final Area 2 Formulation 15.

4.0 Conclusions and Recommendations

4.1 Conclusions

The initial characterization data for the Mohawk Tannery sample materials are summarized in Tables 3-1 and 3-2. Based on these results composite samples were prepared that were expected to be representative of Areas 1 and 2 at the site. SPLP leaching results indicated that the Area 1 material contains leachable barium (0.871 mg/L), Cr (0.108 mg/L), zinc (0.069 mg/L), and 4-methylphenol (0.059 mg/L). The Area 2 material primarily leaches barium (0.786 mg/L), Cr (0.272 mg/L), zinc (0.041 mg/L), 1, 2 dichlorobenzene (0.22 mg/L) and naphthalene (0.19 mg/L).

Thirty-four (34) Area 1 and 18 Area 2 formulation screening mixes were prepared in five and three tiers of formulation screening tests, respectively. Screening results are reported in Tables 3-3 through 3-14. Various reagents and combination of reagents including PC, Lafarge BFS, HL, FAC, FAF, ferrous sulfate heptahydrate, Spill King™ organic absorbent and Nochar's Petro Bond N910 organic absorbent polymer were tested. The original performance criteria for the S/S materials were to meet a 50 psi UCS, 1 x 10^{-6} cm/sec permeability and not to increase constituent leachability in the treated material. S/S reagents were slurried with water prior to their addition to the sludges. Area 5 sand was also added to Area 1 sludge. The Area 5 sand was added dry, not as a slurry. Additional performance goals for the treated material were:

- Percent volume increase less than 75 percent (preferable 50 percent)
- PP values of 2.5 tsf at 7 days minimum (preferably 3.0 tsf by 3 days).

The UCS performance goal was modified from 50 psi to greater than 25 psi after the initial screening tests were completed. EPA provided a general guideline of 50 psi UCS for treatment of liquids using S/S. (U.S. EPA/53O/SW86/016, 1986, *Prohibition on the Placement of Bulk Liquid Hazardous Waste in Landfills, Statutory Interpretative Guidance* and other EPA documents.) This EPA guideline was partly based on assuming that significant bearing mass would be applied over the S/S treated materials. Based on the future use plans for the Mohawk Tannery site, the load applied to the treated materials will be less than 50 psi, i.e., less than 25 psi. The UCS performance goal was decreased from 50 to 25 psi for three reasons, to more accurately reflect the conditions at the site, to decrease the volume increase of the treated sludge, and to decrease the reagent and overall treatment costs.

Additional formulations were prepared to determine the amount of reagent needed to treat the Area 1 material when there was standing water in the impoundment. It was determined that

removal of the water cap will significantly decrease the amount of reagent needed to S/S the Area 1 sludge.

A formulation containing a mixture of Area 1 and Area 2 materials was also tested since some Area 2 material was placed on top of the Area 1 sludge. The addition of Area 2 sludge does not significantly affect the effectiveness of the selected Area 1 formulation. However, the addition of Area 2 sludge does increase the total mass of sludge to be treated; thus, the total mass of reagent and Area 5 sand needed to meet the performance specifications will be increased accordingly. The impact on reagent usage and associated costs from the addition to Area 1 of Area 2 sludge is expected to be small compared to the impact of having a 1.5 foot deep water cap on top of Area 1.

Based on formulation screening results, one formulation from Area 1 and one formulation from Area 2 were prepared in triplicate. The verification formulations were:

<u>Area 1 (Formulation 30)</u>

- 0.30 mix ratio PC + 0.10 mix ratio BFS + 0.06 mix ratio HL + 0.23 mix ratio water + 50 percent (v/v) Area 5 sand

<u>Area 2 (Formulation 15)</u>

- 0.12 mix ratio PC + 0.04 mix ratio BFS + 0.08 mix ratio of water,

The testing results (Tables 3-17 and 3-18) indicated that the selected Area 1 formulation was successful in meeting the 50 psi UCS criterion. The final permeabilities for these samples ranged from 1.1×10^{-6} to 2.3×10^{-6} cm/sec which was slightly higher than the performance goal. The SPLP leachabilities of phenol and 4-methyl phenol were slightly increased in the treated materials and ranged from 0.026 to 0.028 mg/L and 0.037 to 0.041 mg/L, respectively. The percent volume increase was 57 percent, which is less than the 75 percent criterion. Lower dose rates of Area 5 sand usage should decrease the percent volume increase accordingly. The PP results were slightly less than the 2.5 tsf goal after 7 days of curing.

The selected formulation for Area 2 well exceeded the UCS criterion (Tables 3-17 and 3-18). The average permeability also met the performance goal; however, the values were highly variable ranging from 1.2×10^{-6} which was slightly higher than the performance goal to 4.5×10^{-8} cm/sec. The SPLP leachabilities for the treated materials was slightly increased for phenol at 0.17 mg/L; 2, 4, 6-trichlorophenol ranging from 0.32 to 0.35 mg/L; and pentachlorophenol ranging from 0.37 to 0.41 mg/L. The selected formulation met the PP goal at 3 days and the percent volume increase.

For the samples investigated and the site conditions when the samples were collected, a *rough estimate* of the amount of reagents needed to treat the sludge can be made. In this estimate, the following was assumed.

Area 1

- Percent solid content = 17.3
- Surface area = 40,000 square feet
- Sludge depth = 10 feet
- Sludge density = 65.1 pounds/cubic foot
- Depth of water on top of the sludge = 4 feet

Option A Area 1: Add sand, at 50 percent volume of Area 1 sludge, pump off excess water on top of sand, mix sand with sludge and mix in S/S reagents to sand/sludge mixture.

- Void fraction of sand is 30 percent
- All water volume, exceeding the sand pore volume, is pumped off the pond and treated elsewhere

Option B Area 1: Pump off water from on top of sludge, add sand, mix sand with sludge and mix in S/S reagents to sand/sludge mixture.

Area 2

- Percent solid content = 41.2
- Surface area = 80,000 square feet
- Sludge depth = 15 feet
- Sludge density = 71.2 pounds/cubic foot
- Depth of water on top of the sludge = 0 feet

Area	Portland Cement (tons)	Blast Furnace Slag (tons)	Hydrated Lime (tons)
Option A Area 1	6,064	2,021	1,213
Option B Area 1	3,907	1,302	781
Area 2	1,563	521	0

An estimate of the remedial cost may also be calculated. It is assumed in these calculations the following.

- The assumptions made to calculate the amounts of reagent required are valid

- The amounts of reagents are those in the above table,

- Davis Bacon labor rates are used,

- All excess water will be treated using a sand/carbon filters and either discharged to the city sewage line and/or used in Area 2 treatment,

- There will not be a problem with water flowing into the pits during treatment and curing, and

- The sludge will be treated using normal remedial equipment such as Lang Tool rotary mixers, Allu rotary mixers, augers, and excavators.

Based on these assumptions a remediation cost range for the full-scale treatment is between 2.5 to 4.5 million dollars.

4.2 Recommendations

The verification formulations met the physical requirements for the project (UCS, PP, percent volume increase). Permeability results were close to or better than the performance specifications. The Area 1 permeabilities were about a factor or two greater than the performance specification.

Analysis of the SPLP organic compound leachability showed that a few compounds leached slightly more in both treated products than in the untreated sludges. If these SPLP and permeability results are acceptable than the verification formulations are candidates for field operations. In order to decrease the Area 1 percent volume increase, a reduction in Area 5 sand usage should be considered. In order to decrease the SPLP organic compounds leachability, Shaw recommends considering treating Area 1 using the following formulation:

- 0.30 mix ratio PC + 0.10 mix ratio BFS + 0.06 mix ratio HL + 0.01 mix ratio activated powdered carbon + 0.23 mix ratio water + 50 percent (v/v) Area 5 sand

This is the same formulation selected and confirmed in this bench-scale treatability study with the addition of 0.01 mix ratio of activated powdered carbon. Based on results from treating other organic contaminated materials at other sites, it is expected that the addition of powdered carbon will decrease the leachability of both phenol and 4-methylphenol and may decrease the permeability.

Similarly, to decrease the Area 2 SPLP organic compound leachability, Shaw recommends considering the addition of 0.01 mix ratio powdered carbon to the Formulation 15 mixture for the treatment of the Area 2 material, as follows:

0.12 mix ratio PC + 0.04 mix ratio BFS + 0.01 mix ratio activated powdered carbon + 0.08 mix ratio of water.

Tables

Table 2-1. Parameters for Characterization of The Mohawk Treatability Samples

Parameter	Methodology
pH	SW-846 Method 9045
Bulk Density	ASTM Method D2937
Solids and Water Content	ASTM Method D2216
Total SVOCs	SW-846 Method 8270
Total Metals including hexavalent chromium	SW-846 Method 3050/6010

Table 2-2. Parameters for Characterization of The Treatability Composite Samples

Parameter	Methodology
pH	SW-846 Method 9045
Bulk Density	ASTM Method D2937
Solids and Water Content	ASTM Method D2216
SPLP SVOCs and UTS Metals	SW-846 Method 1312/8270/6010

Table 3-1. Characterization Results for the Mohawk Tannery Treatability Samples

Description	SEK2580A	SEK2580B	SEK2580C	SEK2582A	SEK2582B
	Area 1 (A)	Area 1 (B)	Area 1 (C)	P2 Sludge (A)	P2 Sludge (B)
pH (s.u.)	7.1	7.0	7.2	9.4	9.8
Density (g/cm^3)	1.07	1.04	1.02	1.20	1.18
Solids Content (%)	15.18	18.40	18.35	40.84	41.48
Silver (mg/kg)	<13.11	<10.90	<10.90	<4.82	<4.80
Aluminum (mg/kg)	9420	8208	8554	4922	4315
Arsenic (mg/kg)	17.5	17.1	14.4	17.5	9.91
Barium (mg/kg)	39.0	34.2	35.4	78.1	44.6
Beryllium (mg/kg)	<1.97	<1.63	<1.63	<0.725	<0.718
Calcium (mg/kg)	111,000	113,000	124,000	179,000	204,000
Cadmium (mg/kg)	3.06	2.55	2.36	0.85	0.82
Cobalt (mg/kg)	15.1	12.5	12.5	5.56	5.50
Chromium (mg/kg)	26,349	25,221	24,081	24,047	12,560
Hexavalent Chromium (mg/kg)	117	257	959	313	656
Copper (mg/kg)	34.8	29.2	32.0	28.2	22.0
Iron (mg/kg)	17,300	14,200	13,500	3,400	3,740
Potassium (mg/kg)	339	290	297	245	280
Magnesium (mg/kg)	1,252	1,147	1,188	4,212	6,364
Manganese (mg/kg)	18,708	14,785	13,348	468	516
Molybdenum (mg/kg)	<15.1	<12.5	<12.5	<5.56	<5.50
Sodium (mg/kg)	4,670	4,984	4,048	2,412	2,628
Nickel (mg/kg)	15.2	11.6	13.2	4.7	4.5
Phosphorus (mg/kg)	5,843	5,109	5,067	3,575	3,785
Lead (mg/kg)	49.7	41.3	41.7	21.7	57.1
Sulfur (mg/kg)	24,241	21,579	20,049	8,448	7,883
Antimony (mg/kg)	413	402	386	370	191
Selenium (mg/kg)	<8.56	<7.07	<7.08	<3.13	<3.11
Tin (mg/kg)	<15.1	<12.5	<12.5	<5.56	<5.50
Strontium (mg/kg)	177	164	173	192	251
Thallium (mg/kg)	15.0	13.6	11.9	8.33	3.76
Vanadium (mg/kg)	<6.56	<5.42	<5.44	<2.42	<2.39
Zinc (mg/kg)	246	207	207	125	101
Phenol (mg/kg)	0.73	1.07	1.09	<0.33	0.35
1,4-Dichlorobenzene (mg/kg)	<0.33	<0.33	<0.33	<0.33	<0.33
1,2-Dichlorobenzene (mg/kg)	<0.33	<0.33	<0.33	0.80	1.45
4-Methylphenol (mg/kg)	2.3	13.6	11.6	0.61	0.48
Naphthalene (mg/kg)	<0.33	<0.33	<0.33	1.13	2.11
2,4,6-Trichlorophenol (mg/kg)	<0.33	<0.33	<0.33	<0.33	<0.33
2,4,5-Trichlorophenol (mg/kg)	<0.33	<0.33	<0.33	0.66	1.86
Pentachlorophenol (mg/kg)	<1.66	<1.66	<1.66	1.03	1.60

Other PAH/SVOCs less than detection limits of 0.33 or 1.66 mg/kg

Table 3-1. Characterization Results for the Mohawk Tannery Treatability Samples (continued)

Description	SEK2583	SEK2585	SEK2586	SEK2587	SEK2581	SEK2584
	P2 Fill surface	P2 Lower black sand	Upper P2 black sand	P2 Cr sand	Area 5	Gravel Pit Fill
pH (s.u.)	7.6	9.2	8.4	10.2	6.1	7.7
Density (g/cm^3)	1.82	1.97	1.91	1.94	1.43	1.62
Solids Content (%)	86.30	85.94	82.74	88.51	95.61	96.34
Silver (mg/kg)	<2.32	2.94	4.28	4.51	<2.09	<2.07
Aluminum (mg/kg)	5,272	6,598	10,719	12,541	4,717	5,989
Arsenic (mg/kg)	4.82	4.89	4.56	7.14	5.45	4.89
Barium (mg/kg)	17.5	18.0	29.7	31.6	11.0	8.32
Beryllium (mg/kg)	<0.348	<0.347	<0.474	<0.336	<0.313	<0.310
Calcium (mg/kg)	2,130	6,350	9,970	10,300	487	927
Cadmium (mg/kg)	0.93	1.20	1.86	2.11	0.698	1.74
Cobalt (mg/kg)	2.67	3.62	4.96	6.04	2.41	2.81
Chromium (mg/kg)	584	301	1,892	282	10.8	15
Hexavalent Chromium (mg/kg)	5.8	1.4	3.7	8.6	0.91	0.8
Copper (mg/kg)	5.4	4.72	8.95	9.11	3.01	3.32
Iron (mg/kg)	6,550	9,300	12,800	15,800	5,300	1,380
Potassium (mg/kg)	599	862	1,046	1,830	598	452
Magnesium (mg/kg)	1,657	2,548	3,451	5,932	1,318	2,709
Manganese (mg/kg)	117	107	183	235	102	119
Molybdenum (mg/kg)	<2.67	<2.65	<3.63	<2.58	<2.41	<2.38
Sodium (mg/kg)	40	460	380	594	21	15
Nickel (mg/kg)	7.5	10.6	14.4	22.6	4.9	8.97
Lead (mg/kg)	7.89	3.37	13.1	5.01	2.0	3.45
Antimony (mg/kg)	8.53	<4.43	27.4	3.75	<1.04	1.03
Selenium (mg/kg)	<1.51	<1.50	<2.05	<1.46	<1.36	<1.34
Tin (mg/kg)	<2.67	<2.65	<3.63	<2.58	<2.41	<2.38
Thallium (mg/kg)	<1.51	<1.50	<2.05	<1.46	<1.36	<1.34
Vanadium (mg/kg)	10.4	10.5	15.1	22.3	8.39	17.9
Zinc (mg/kg)	23.5	22.6	42.0	34.6	11.4	19.8
Phenol (mg/kg)	<0.33	0.76	<0.33	<0.33	<0.33	<0.33
1,4-Dichlorobenzene (mg/kg)	<0.33	<0.33	<0.33	<0.33	<0.33	<0.33
1,2-Dichlorobenzene (mg/kg)	<0.33	<0.33	<0.33	<0.33	<0.33	<0.33
4-Methylphenol (mg/kg)	<0.33	<0.33	<0.33	<0.33	<0.33	<0.33
Naphthalene (mg/kg)	<0.33	<0.33	<0.33	<0.33	<0.33	<0.33
2,4,6-Trichlorophenol (mg/kg)	<0.33	<0.33	<0.33	<0.33	<0.33	<0.33
2,4,5-Trichlorophenol (mg/kg)	<0.33	<0.33	<0.33	<0.33	<0.33	<0.33
Pentachlorophenol (mg/kg)	<1.66	<1.66	<1.66	<0.33	<1.66	<1.66

Other PAH/SVOCs less than detection limits of 0.33 or 1.66 mg/kg

Table 3-2. Initial Baseline SPLP Leachability Results for The Mohawk Tannery Treatability Composite Samples

Sample ID	SEK 2580 Comp	SEK 2582 Comp	SEK 2585
Description	Area 1 Composite	P2 Sludge Composite	P2 Lower black sludge
SPLP Equilibrium pH (s.u.)	7.9	9.2	9.1
Silver (mg/L)	<0.021	<0.021	<0.021
Aluminum (mg/L)	<0.054	<0.054	2.02
Arsenic (mg/L)	<0.011	<0.011	<0.011
Barium (mg/L)	0.871	0.786	0.043
Beryllium (mg/L)	<0.003	<0.003	<0.003
Calcium (mg/L)	22.6	23.8	23.1
Cadmium (mg/L)	<0.003	<0.003	<0.003
Cobalt (mg/L)	<0.025	<0.025	<0.025
Chromium (mg/L)	0.108	0.272	<0.026
Hexavalent Chromium (mg/L)	<0.025	<0.025	<0.025
Copper (mg/L)	<0.025	<0.025	<0.025
Iron (mg/L)	<0.048	<0.048	<0.048
Potassium (mg/L)	2.26	2.08	0.988
Magnesium (mg/L)	1.15	3.18	<0.750
Manganese (mg/L)	0.533	<0.015	<0.016
Molybdenum (mg/L)	<0.025	<0.025	<0.026
Sodium (mg/L)	39.5	36.9	14.3
Nickel (mg/L)	<0.011	<0.011	<0.011
Lead (mg/L)	<0.011	<0.011	<0.011
Antimony (mg/L)	<0.011	<0.011	<0.011
Selenium (mg/L)	<0.014	<0.014	<0.014
Tin (mg/L)	<0.025	<0.025	<0.026
Thallium (mg/L)	<0.014	<0.014	<0.014
Vanadium (mg/L)	<0.011	<0.011	<0.011
Zinc (mg/L)	0.069	0.041	0.019
Phenol (mg/L)	<0.01	<0.01	0.085
1, 4- Dichlorobenzene (mg/L)	<0.01	<0.01	<0.01
1,2-Dichlorobenzene (mg/L)	<0.01	0.22	<0.01
4-Methylphenol (mg/L)	0.059	<0.01	0.047
Naphthalene (mg/L)	<0.01	0.19	<0.01
2,4,6-Trichlorophenol (mg/L)	<0.01	<0.01	<0.01
2,4,5-Trichlorophenol (mg/L)	<0.01	<0.01	<0.01
Pentachlorophenol (mg/L)	<0.05	<0.05	<0.05

Table 3-3. Results for the Mohawk Tannery Area 1 Tier 1 Formulations

Formulation	Portland Cement	Blast Furnace Slag	Hydrated Lime	Class F Fly Ash	Class C Fly Ash	Ferrous Sulfate	Area 5 Sand (v/v)[2]	Water	Water to Binder Ratio	Pocket Penetrometer (tsf)[3]				Sample Bleed[4]		UCS (psi)[5]	
	Mix Ratio[1]									Day 1	Day 3	Day 5	Day 7	Day 3	Day 7	Day 7	Day 14
1	0.1	-	-	-	-	0.03	-	0.13	1:1	<0.25	<0.25	<0.25	<0.25	-	S	-	-
2	0.15	-	-	-	-	0.03	-	0.18	1:1	<0.25	<0.25	<0.25	<0.25	-	S	-	-
3	0.2	-	-	-	-	0.03	-	0.23	1:1	<0.25	<0.25	<0.25	<0.25	-	S	1.94	-
4	-	-	0.1	-	-	0.03	-	0.23	2:3:1	<0.25	<0.25	<0.25	<0.25	-	S	-	-
5	-	-	0.2	-	-	0.03	-	0.43	2:2:1	<0.25	<0.25	<0.25	<0.25	-	S	-	-
6	0.1	-	-	-	-	0.03	-	0.23	2:3:1	<0.25	<0.25	<0.25	<0.25	-	F	-	-
7	0.2	-	-	-	-	0.03	-	0.43	2:2:1	<0.25	<0.25	<0.25	<0.25	-	S	1.62	-
8	0.1	-	-	-	0.1	0.03	-	0.23	1:1	<0.25	<0.25	<0.25	<0.25	-	S	0.64	-
9	0.2	-	-	-	0.2	0.03	-	0.40	1:1	<0.25	<0.25	<0.25	<0.25	-	D	3.23	-
10	0.1	-	-	-	-	0.03	0.10[2]	0.13	1:1	<0.25	<0.25	<0.25	<0.25	-	S	-	-
11	0.15	-	-	-	-	0.03	0.15[2]	0.18	1:1	<0.25	<0.25	<0.25	<0.25	-	S	-	-

[1]Mix Ratio = [(weight reagent) / (weight waste)]
[2]Mix Ratio (defined above) instead of percent (v/v)
[3]Highlighted pocket penetrometer results greater than operations desired resistance goal of >2.5 tsf.
[4]Sample Bleed: D= dry, F= film, S= significant, E=extrudes with pressure
[5]Highlighted UCS values greater than 25 psi.

Table 3-4. Results for the Mohawk Tannery Area 1 Tier 2 Formulations

Formulation	Portland Cement	Blast Furnace Slag	Hydrated Lime	Class F Fly Ash	Class C Fly Ash	Ferrous Sulfate	Area 5 Sand (v/v)[2]	Water	Water to Binder Ratio	Pocket Penetrometer (tsf)[3]					Sample Bleed[4]		UCS (psi)[5]
	Mix Ratio[1]									Day 1	Day 3	Day 5	Day 7	Day 62	Day 3	Day 7	Day 62
11	0.15	-	-	-	-	0.03	-	0.18		<0.25	<0.25	<0.25	<0.25	-	-	S	-
13	0.15	0.05	-	-	-	-	50	0.20	1:1	<0.25	0.25	0.35	0.50	1.75	S	E	15.1
14	0.05	0.15	-	-	-	-	50	0.20	1:1	<0.25	<0.25	<0.25	<0.25	<0.25	S	F	-
15	0.20	-	-	-	-	-	50	0.20	1:1	<0.25	<0.25	0.25	0.25	1.15	S	E	11.7
16	0.15	0.05	-	-	-	-	50	0.50	2:5:1	<0.25	<0.25	<0.25	<0.25	0.50	S	F	-
17	0.20	-	-	-	-	-	50	0.50	2:5:1	<0.25	<0.25	<0.25	<0.25	0.50	S	F	-
18	0.15	0.05	-	-	0.30	-	50	0.50	1:1	<0.25	<0.25	<0.25	<0.25	3.50	S	E	36.2
19	0.20	-	-	-	0.30	-	50	0.50	1:1	<0.25	<0.25	<0.25	<0.25	3.00	S	F	24.6
20	-	-	0.40	-	-	-	40	0.80	2:1	<0.25	<0.25	<0.25	<0.25	<0.25	S	S	-

[1]Mix Ratio = [(weight reagent) / (weight waste)]
[2]Mix Ratio (defined above) instead of percent (v/v)
[3]Highlighted pocket penetrometer results greater than operations desired resistance goal of >2.5 tsf.
[4]Sample Bleed: D= dry, F= film, S= significant, E=extrudes with pressure
[5]Highlighted UCS values greater than 25 psi.

Table 3-5. Area 1 Percent Volume Increase

Formulation	Portland Cement	Blast Furnace Slag	Hydrated Lime	Class F Fly Ash	Water	Area 5 Sand	Total Binder Added (%)	Total Binder, Area 5 Sand and Water Added (%)	Percent Volume Increase
	Mix Ratio (w/w)								
18	0.15	0.05	-	0.3	0.5	0.69	50	169	86.51
19	0.2	-	-	0.3	0.5	0.69	50	169	86.51
27	0.2	0.07	0.05	-	0.16	0.69	32	117	47.50
28	0.25	0.08	0.05	-	0.19	0.69	38	126	52.62
30	0.3	0.096	0.06	-	0.23	0.69	45.6	137.6	57.39
31	0.25	0.08	0.05	-	0.21	1.04	38	163	75.33
32	0.2	0.1	0.05	-	0.2	0.69	35	124	53.26
33	0.2	0.07	0.05	-	0.2	1.04	32	156	67.45
34	0.25	0.1	0.06	-	0.25	0.69	41	135	59.74

Table 3-6. Results for the Mohawk Tannery Area 1 Tier 3 Formulations

Formulation	Portland Cement	Blast Furnace Slag	Hydrated Lime	Class F Fly Ash	Class C Fly Ash	Ferrous Sulfate	Area 5 Sand (v/v)[2]	Water	Water To Binder Ratio	Pocket Penetrometer (tsf)[3]										Sample Bleed[4]	
	Mix Ratio[1]									Day 1	Day 3	Day 7	Day 14	Day 21	Day 28	Day 35	Day 42	Day 49	Day 56	Day 3	Day 7
21	0.15	0.05	-	-	-	-	50	0.20	1:1	<0.25	0.25	0.50	0.75	1.25	1.40	1.15	1.75	1.75	1.25	F	F
22	0.15	0.05	-	-	-	-	50	0.20	1:1	<0.25	<0.25	0.25	0.50	0.50	1.00	1.00	1.50	1.50	1.25	F	F
23	0.15	0.05	-	-	-	-	50	0.20	1:1	<0.25	0.25	0.30	0.70	0.75	1.30	1.50	2.00	2.00	1.70	F	F

[1]Mix Ratio = [(weight reagent) / (weight waste)]
[2]Mix Ratio (defined above) instead of percent (v/v)
[3]Highlighted pocket penetrometer results greater than operations desired resistance goal of >2.5 tsf.
[4]Sample Bleed: D= dry, F= film, S= significant, E=extrudes with pressure

Table 3-7. Results for the Mohawk Tannery Area 1 Tier 4 and 5 Formulations

Formulation	Portland Cement	Blast Furnace Slag	Hydrated Lime	Class F Fly Ash	Class C Fly Ash	Ferrous Sulfate	Area 5 Sand (v/v)[2]	Water	Water to Binder Ratio	Pocket Penetrometer (tsf)[3]							Sample Bleed[4]		UCS (psi)[5]		
	Mix Ratio[1]									Day 1	Day 3	Day 7	Day 14	Day 21	Day 28	Day 35	Day 3	Day 7	Day 7	Day 28	Day 36
24	0.15	0.05	0.05	-	-	-	50	0.25	1.1	<0.25	0.25	0.25	0.50	0.90	0.90	1.10	F	E	-	-	-
25	0.21	0.07	0.05	-	-	-	50	0.33	1.1	<0.25	<0.25	0.50	1.50	2.20	2.40	3.20	F	E	-	-	-
26	0.21	0.07	0.05	-	-	-	50	0.33	1.1	<0.25	<0.25	0.25	1.50	1.90	1.90	2.50	S	E	-	-	-
27	0.20	0.07	0.05	-	-	-	50	0.16	0.5.1	<0.25	0.25	0.70	1.50	2.00	3.20	3.60	F	E	-	-	27.4
28	0.25	0.08	0.05	-	-	-	50	0.19	0.5.1	<0.25	<0.25	1.20	3.50	>4.50	>4.50	>4.50	F	E	-	44.6	46.7
29	0.10	0.00	0.00	-	-	-	50	0.00	1.1	<0.25	0.25	0.55	0.75	1.00	1.00	1.00	F	E	-	-	-
30	0.30	0.10	0.06	-	-	-	50	0.23	0.5.1	0.25	0.75	3.00	>4.50	>4.50	-	-	E	E	22.2	38.3	-
31	0.25	0.08	0.05	-	-	-	75	0.21	0.55.1	0.25	0.30	1.40	>4.50	>4.50	-	-	E	E	-	22.6	-
32	0.20	0.10	0.05	-	-	-	50	0.20	0.57.1	<0.25	0.30	0.65	2.00	2.80	-	-	E	E	-	-	-
33	0.20	0.07	0.05	-	-	-	75	0.20	0.63.1	<0.25	0.35	0.75	1.35	2.25	-	-	E	E	-	-	-
34	0.25	0.10	0.06	-	-	-	50	0.25	061.1	<0.25	0.25	1.15	3.40	>4.50	-	-	E	E	-	-	-

[1]Mix Ratio = [(weight reagent) / (weight waste)]
[2]Mix Ratio (defined above) instead of percent (v/v)
[3]Highlighted pocket penetrometer results greater than operations desired resistance goal of >2.5 tsf.
[4]Sample Bleed: D= dry, F= film, S= significant, E=extrudes with pressure
[5]Highlighted UCS values greater than 25 psi.

Table 3-8. SPLP Leaching Results for the Mohawk Tannery Area 1 Tiers 4 and 5 Formulations

Parameter	Units	Untreated Area 1 Composite	Formulation 28	Formulation 30	Formulation 31
Portland Cement	m.r.[1]	-	0.25	0.30	0.25
Blast Furnace Slag	m.r.	-	0.08	0.10	0.08
Hydrated Lime	m.r.	-	0.05	0.06	0.05
Water	m.r.	-	0.19	0.23	0.21
Area 5 Sand	% (v/v)	-	50	50	75
Permeability (Day 14)	cm/sec	-	1.2×10^{-6}	1.8×10^{-6}	1.3×10^{-6}
Permeability (Day 28)	cm/sec	-	8.2×10^{-7}	9.7×10^{-7}	9.1×10^{-7}
SPLP Equilibrium pH	s.u.	7.9	11.7	11.7	11.5
SPLP Silver	mg/L	<0.021	<0.022	<0.022	0.037
SPLP Arsenic	mg/L	<0.011	<0.011	<0.011	<0.011
SPLP Barium	mg/L	0.871	0.550	0.728	0.458
SPLP Beryllium	mg/L	<0.003	<0.003	<0.003	<0.003
SPLP Cadmium	mg/L	<0.003	<0.003	<0.003	<0.003
SPLP Chromium	mg/L	0.108	0.186	0.139	0.171
SPLP Nickel	mg/L	<0.011	0.021	0.022	0.028
SPLP Lead	mg/L	<0.011	<0.011	<0.011	<0.011
SPLP Antimony	mg/L	<0.011	<0.011	<0.011	<0.011
SPLP Selenium	mg/L	<0.014	<0.014	<0.014	<0.014
SPLP Thallium	mg/L	<0.014	<0.014	<0.014	<0.014
SPLP Vanadium	mg/L	<0.011	<0.011	<0.011	<0.011
SPLP Zinc	mg/L	0.069	<0.011	0.013	0.021
SPLP Phenol	mg/L	<0.01	<0.01	<0.01	<0.01
SPLP 1,4-Dichlorobenzene	mg/L	<0.01	<0.01	<0.01	<0.01
SPLP 1,2-Dichlorobenzene	mg/L	<0.01	<0.01	<0.01	<0.01
SPLP 4-Methylphenol	mg/L	0.059	0.017	0.014	0.017
SPLP Naphthalene	mg/L	<0.01	<0.01	<0.01	<0.01
SPLP 2,4,6-Trichlorophenol	mg/L	<0.01	<0.01	<0.01	<0.01
SPLP 2,4,5-Trichlorophenol	mg/L	<0.01	<0.01	<0.01	<0.01
SPLP Pentachlorophenol	mg/L	<0.05	<0.05	<0.05	<0.05

[1]m.r.= Mix Ratio=[(weight reagent)/(weight waste)]

Table 3-9. Results for the Mohawk Tannery Area 2 Tier 1 Formulations

Formulation	Portland Cement	Blast Furnace Slag	Hydrated Lime	Class F Fly Ash	Class C Fly Ash	Ferrous Sulfate	Area 5 Sand (v/v)[2]	Water	Water to Binder Ratio	Pocket Penetrometer (tsf)[3]				Sample Bleed[4]		UCS (psi)[5]		
	Mix Ratio[1]									Day 1	Day 3	Day 5	Day 7	Day 3	Day 7	Day 7	Day 14	Day 55
1	0.05	-	-	-	-	0.03	-	0.08	1:1	<0.25	0.25	0.25	0.25	-	S	-	-	-
2	0.1	-	-	-	-	0.03	-	0.13	1:1	<0.25	0.25	0.25	1.25	-	D	6.5	-	-
3	0.15	-	-	-	-	0.03	-	0.18	1:1	0.5	2.5	3.25	4.0	-	D	31.3	33.2	41.8
4	-	-	0.1	0.1	-	0.03	-	0.23	1:1	<0.25	<0.25	<0.25	<0.25	-	S	-	-	-
5	-	-	0.15	0.15	-	0.03	-	0.33	1:1	<0.25	<0.25	<0.25	<0.25	-	S	-	-	-
6	0.05	-	-	0.1	-	0.03	-	0.18	1:1	<0.25	<0.25	<0.25	<0.25	-	S	-	-	-
7	0.1	-	-	0.1	-	0.03	-	0.23	1:1	<0.25	0.25	0.75	0.75	-	D	8.4	-	21.7
8	0.05	-	-	-	0.1	0.03	-	0.18	1:1	<0.25	0.25	0.5	0.5	-	D	9.3	-	28.9
9	0.1	-	-	-	0.1	0.03	-	0.23	1:1	<0.25	0.75	1.25	1.75	-	D	15.6	27.1	38.5

[1]Mix Ratio = [(weight reagent) / (weight waste)]
[2]Mix Ratio (defined above) instead of percent (v/v)
[3]Highlighted pocket penetrometer results greater than operations desired resistance goal of >2.5 tsf.
[4]Sample Bleed: D= dry, F= film, S= significant, E=extrudes with pressure
[5]Highlighted UCS values greater than 25 psi.

Table 3-10. SPLP Leaching Results for the Mohawk Tannery Area 2 Tier 1 Formulations

Formulation Development 7 Day Cure Sample	Pit 2 Sludge		
	Untreated Composite	Formulation 3	Formulation 9
Analyte	SPLP Leachate Results mg/L		
SPLP Equilibrium pH (s.u.)	9.18	11.81	11.71
Silver (mg/L)	<0.021	<0.022	<0.022
Aluminum (mg/L)	<0.054	0.871	0.393
Arsenic (mg/L)	<0.011	<0.011	<0.011
Barium (mg/L)	0.786	0.198	0.221
Beryllium (mg/L)	<0.003	<0.003	<0.003
Calcium (mg/L)	23.8	245	258
Cadmium (mg/L)	<0.003	<0.003	<0.003
Cobalt (mg/L)	<0.025	<0.026	<0.026
Chromium (mg/L)	0.272	<0.026	<0.026
Hexavalent Chromium (mg/L)	<0.025	<0.025	<0.025
Copper (mg/L)	<0.025	<0.026	<0.026
Iron (mg/L)	<0.048	<0.050	<0.050
Potassium (mg/L)	2.08	23.1	15.1
Magnesium (mg/L)	3.18	<0.750	<0.750
Manganese (mg/L)	<0.015	<0.016	<0.016
Molybdenum (mg/L)	<0.025	<0.026	<0.026
Sodium (mg/L)	36.9	25.2	23.8
Nickel (mg/L)	<0.011	0.024	0.024
Phosphorus (mg/L)	0.130	0.037	0.038
Lead (mg/L)	<0.011	<0.011	<0.011
Sulfur (mg/L)	23.9	12.2	64.6
Antimony (mg/L)	<0.011	<0.011	<0.011
Selenium (mg/L)	<0.014	<0.014	<0.014
Tin (mg/L)	<0.025	<0.026	<0.026
Strontium (mg/L)	0.075	1.03	1.27
Thallium (mg/L)	<0.014	<0.014	<0.014
Vanadium (mg/L)	<0.011	<0.011	<0.011
Zinc (mg/L)	0.041	0.025	0.019
Phenol (mg/L)	<0.01	0.10	0.12
1,4-Dichlorobenzene (mg/L)	<0.01	<0.1	<0.1
1,2-Dichlorobenzene (mg/L)	0.22	0.27	0.26
4-Methylphenol (mg/L)	<0.01	0.12	0.16
Naphthalene (mg/L)	0.19	0.25	0.22
2,4,6-Trichlorophenol (mg/L)	<0.01	<0.1	<0.1
2,4,5-Trichlorophenol (mg/L)	<0.01	0.21	0.22
Pentachlorophenol (mg/L)	<0.05	0.20	0.20

Table 3-11. Results for the Mohawk Tannery Area 2 Tier 2 Formulations

Formulation	Portland Cement	Blast Furnace Slag	Hydrated Lime	Class F Fly Ash	Class C Fly Ash	Ferrous Sulfate	Area 5 Sand (v/v)[2]	Water	Water to Binder Ratio	Pocket Penetrometer (tsf)[3]				Sample Bleed[4]		UCS (psi)[5]		
	Mix Ratio[1]									Day 1	Day 3	Day 5	Day 7	Day 3	Day 7	Day 7	Day 14	Day 28
10	0.20	-	-	-	-	-	-	0.20	1:1	1.5	3.75	>4.5	>4.5	E	E	-	-	50.9
11	0.15	0.05	-	-	-	-	-	0.20	1:1	1.75	4.25	>4.5	>4.5	E	E	-	-	105

[1]Mix Ratio = [(weight reagent) / (weight waste)]
[2]Mix Ratio (defined above) instead of percent (v/v)
[3]Highlighted pocket penetrometer results greater than operations desired resistance goal of >2.5 tsf.
[4]Sample Bleed: D= dry, F= film, S= significant, E=extrudes with pressure
[5]Highlighted UCS values greater than 25 psi.

Table 3-12. Results for the Mohawk Tannery Area 2 Tier 3 Formulations

Formulation	Portland Cement	Blast Furnace Slag	Hydrated Lime	Class F Fly Ash	Class C Fly Ash	Ferrous Sulfate	Area 5 Sand (v/v)[2]	Water	Water to Binder Ratio	Pocket Penetrometer (tsf)[3]				Sample Bleed[4]		UCS (psi)[5]	
	Mix Ratio[1]									Day 1	Day 3	Day 5	Day 7	Day 3	Day 7	Day 7	Day 28
3b	0.15	-	-	-	-	-	-	0.18	1.2:1	1.25	2.55	2.9	3.85	E	E	30.3	-
10b	0.20	-	-	-	-	-	-	0.20	1:1	1.5	3.7	3.8	>4.5	E	E	41.5	-
11b	0.15	0.05	-	-	-	-	-	0.20	1:1	1.7	2.8	3.7	>4.5	E	E	45.4	-
12	0.13	-	-	-	-	-	-	0.07	0.52:1	2.0	3.0	3.8	>4.5	E	E	37.2	-
13	0.09	0.03	-	-	-	-	-	0.06	0.5:1	2.0	3.0	4.3	>4.5	E	E	46.9	62.6
14	0.15	-	-	-	-	-	-	0.08	0.5:1	2.0	3.6	4.5	>4.5	E	E	47.9	60.9
15	0.12	0.04	-	-	-	-	-	0.08	0.5:1	2.0	4.4	>4.5	>4.5	E	E	58.3	94.3

[1]Mix Ratio = [(weight reagent) / (weight waste)]
[2]Mix Ratio (defined above) instead of percent (v/v)
[3]Highlighted pocket penetrometer results greater than operations desired resistance goal of >2.5 tsf.
[4]Sample Bleed: D= dry, F= film, S= significant, E=extrudes with pressure
[5]Highlighted UCS values greater than 25 psi.

Table 3-13. Area 2 Percent Volume Increase

Formulation	Portland Cement	Blast Furnace Slag	Class F Fly Ash	Class C Fly Ash	Ferrous Sulfate Heptahydrate	Water	Total Binder Added (%)	Total Binder and Water Added (%)	Percent Volume Increase[1]
Mix Ratio									
3	0.15	-	-	-	0.03	0.18	18.0	36	25.5
7	0.10	-	0.10	-	0.03	0.23	23.0	46	34.7
8	0.05	-	-	0.10	0.03	0.18	18.0	36	25.5
9	0.10	-	-	0.10	0.03	0.23	23.0	46	32.6
10	0.20	-	-	-	-	0.20	20.0	40	26.2
11	0.15	0.05	-	-	-	0.20	20.0	40	25.3
3b	0.15	-	-	-	-	0.18	15.0	33	23.6
10b	0.20	-	-	-	-	0.20	20.0	40	27.2
11b	0.15	0.05	-	-	-	0.20	20.0	40	27.2
12	0.13	-	-	-	-	0.065	12.5	19	7.28
13	0.09	0.03	-	-	-	0.06	12.0	18	7.19
14	0.15	-	-	-	-	0.075	15.0	22.5	10.4
15	0.12	0.04	-	-	-	0.08	16.0	24	10.9

[1]Highlighted Percent Volume Increase less than 50 percent.

Table 3-14. SPLP Leaching and Permeability Results for The Mohawk Tannery Area 2 Tier 3 Formulations

Parameter	Units	Untreated Pit 2 Sludge Composite	Formulation 13	Formulation 14	Formulation 15
Portland Cement	m.r.[1]	-	0.09	0.15	0.12
Blast Furnace Slag	m.r.	-	0.03	-	0.04
Hydrated Lime	m.r.	-	-	-	-
Water	m.r.	-	0.06	0.08	0.08
Area 5 Sand	% (v/v)	-	-	-	-
Permeability (Day 14)	cm/sec	-	2.2×10^{-7}	7.1×10^{-7}	6.3×10^{-7}
Permeability (Day 28)	cm/sec	-	2.0×10^{-7}	7.6×10^{-7}	2.0×10^{-7}
SPLP Equilibrium pH	s.u.	9.2	11.5	11.6	11.7
SPLP Silver	mg/L	<0.021	<0.022	<0.022	<0.022
SPLP Arsenic	mg/L	<0.011	<0.011	<0.011	<0.011
SPLP Barium	mg/L	0.786	0.012	0.489	0.023
SPLP Beryllium	mg/L	<0.003	<0.003	<0.003	<0.003
SPLP Cadmium	mg/L	<0.003	<0.003	<0.003	<0.003
SPLP Chromium	mg/L	0.272	0.195	0.701	0.324
SPLP Nickel	mg/L	<0.011	0.019	0.032	0.013
SPLP Lead	mg/L	<0.011	<0.011	<0.011	<0.011
SPLP Antimony	mg/L	<0.011	<0.011	0.012	<0.011
SPLP Selenium	mg/L	<0.014	<0.014	<0.014	<0.014
SPLP Thallium	mg/L	<0.014	<0.014	<0.014	<0.014
SPLP Vanadium	mg/L	<0.011	<0.011	<0.011	<0.011
SPLP Zinc	mg/L	0.041	<0.011	0.024	<0.011
SPLP Phenol	mg/L	<0.01	<0.01	<0.01	<0.01
SPLP 1,4-Dichlorobenzene	mg/L	<0.01	<0.01	<0.01	0.010
SPLP 1,2-Dichlorobenzene	mg/L	0.22	0.11	<0.01	0.11
SPLP 4-Methylphenol	mg/L	<0.01	<0.01	<0.01	<0.01
SPLP Naphthalene	mg/L	0.19	0.11	0.012	0.086
SPLP 2,4,6-Trichlorophenol	mg/L	<0.01	<0.01	<0.01	<0.01
SPLP 2,4,5-Trichlorophenol	mg/L	<0.01	<0.01	<0.01	<0.01
SPLP Pentachlorophenol	mg/L	<0.05	<0.05	<0.05	<0.01

[1]m.r.= Mix Ratio =[(weight reagent)/(weight waste)]

Table 3-15. Results for the Mohawk Tannery Areas 1 and 2 Combined Sample Formulations

Formulation	Sample Ratio (v/v)	Portland Cement	Blast Furnace Slag	Hydrated Lime	Area 5 Sand (v/v)[2]	Water	Water to Binder Ratio	Pocket Penetrometer (tsf)[3]			
		Mix Ratio[1]						Day 1	Day 2	Day 3	Day 7
SEK 2580/82-30	10:1	0.30	0.10	0.06	0.5	0.23	0.5:1	<0.25	0.25	0.75	3.5
Sample Bleed[2]								S	F	E	E

[1]Mix Ratio = [(weight reagent) / (weight waste)]
[2]Mix Ratio (defined above) instead of percent (v/v)
[3]Highlighted pocket penetrometer results greater than operations desired resistance goal of >2.5 tsf.

Table 3-16. Results for the Mohawk Tannery Area 1 Water Modified Screening Test Formulations

Formulation	Sample Location	Portland Cement	Blast Furnace Slag	Hydrated Lime	Area 5 Sand (v/v)[2]	Water	Water to Binder Ratio	Pocket Penetrometer (tsf)[3]					Sample Bleed[4]	
		Mix Ratio[1]						Day 1	Day 2	Day 3	Day 4	Day 7	Day 3	Day 7
SEK 2580-30[A]	Area 1	0.30	0.10	0.06	0.50	0.23	0.5:1	0.25	0.5	0.75	1.75	3.0	E	E
SEK 2580-30M1	Area 1	0.47	0.16	0.09	0.50	0.50	0.69:1	<0.25	0.5	1.6	2.6	>4.5	F	E
SEK 2580-30 M2	Area 1	0.64	0.21	0.13	0.50	0.64	0.65:1	<0.25	1.75	4.0	>4.5	>4.5	F	E
SEK 2580-30M3	Area 1	0.40	0.13	0.08	0.50	0.45	0.74:1	<0.25	<0.25	0.5	1.10	2.15	S	S

[1]Mix Ratio = [(weight reagent) / (weight waste)]
[2]Mix Ratio (defined above) instead of percent (v/v)
[3]Highlighted pocket penetrometer results greater than operations desired resistance goal of >2.5 tsf.
[4]Sample Bleed: D= dry, F= film, S= significant, E=extrudes with pressure
[A]Original Tier 5 results.

Table 3-17. Results for the Mohawk Tannery Areas 1 and 2 Verification Formulations

Formulation	Sample Location	Portland Cement	Blast Furnace Slag	Hydrated Lime	Area 5 Sand (v/v)[2]	Water	Water to Binder Ratio	Pocket Penetrometer (tsf)[3]					
		Mix Ratio[1]						Day 1	Day 2	Day 3	Day 4	Day 5	Day 7
SEK 2580-30ZA	Area 1	0.30	0.10	0.06	0.5	0.23	0.5:1	0.25	0.75	1.25	1.5	1.75	2.85
SEK 2580-30ZB	Area 1	0.30	0.10	0.06	0.5	0.23	0.5:1	0.25	0.75	1.0	1.3	1.8	2.35
SEK 2580-30ZC	Area 1	0.30	0.10	0.06	0.5	0.23	0.5:1	<0.25	0.75	1.0	1.6	2.15	3.3
SEK 2582-15ZA	Area 2	0.12	0.04	-	0.5	0.08	0.5:1	1.75	2.0	3.2	4.25	>4.5	>4.5
SEK 2582-15ZB	Area 2	0.12	0.04	-	0.5	0.08	0.5:1	1.75	3.0	3.75	>4.5	>4.5	>4.5
SEK 2582-15ZC	Area 2	0.12	0.04	-	0.5	0.08	0.5:1	1.75	2.75	4.25	4.25	>4.5	>4.5

[1]Mix Ratio = [(weight reagent) / (weight waste)]
[2]Mix Ratio (defined above) instead of percent (v/v)
[3]Highlighted pocket penetrometer results greater than operations desired resistance goal of >2.5 tsf.

Table 3-18. SPLP Leaching, UCS and Permeability Results for The Mohawk Tannery Area 1 Verification Formulations

Parameter	Units	Area 1 Composite	30ZA	30ZB	30ZC
Portland Cement	m.r.[1]	-	0.30	0.30	0.30
Blast Furnace Slag	m.r.	-	0.10	0.10	0.10
Hydrated Lime	m.r.	-	0.06	0.06	0.06
Water	m.r.	-	0.23	0.23	0.23
Area 5 Sand	% (v/v)	-	50	50	50
Unconfined Compressive Strength (28 day)	psi	-	57.1	84.7	77.2
Permeability (Day 28)	cm/sec	-	2.1×10^{-6}	1.1×10^{-6}	2.3×10^{-6}
SPLP Equilibrium pH	s.u.	7.9	11.9	12.0	12.0
SPLP Silver	mg/L	<0.021	<0.022	<0.022	<0.022
SPLP Arsenic	mg/L	<0.011	<0.011	<0.011	<0.011
SPLP Barium	mg/L	0.871	1.04	1.02	1.00
SPLP Beryllium	mg/L	<0.003	<0.003	<0.003	<0.003
SPLP Cadmium	mg/L	<0.003	<0.003	<0.003	<0.003
SPLP Chromium	mg/L	0.108	0.038	<0.026	<0.026
SPLP Nickel	mg/L	<0.011	0.023	0.024	0.022
SPLP Lead	mg/L	<0.011	<0.011	<0.011	<0.011
SPLP Antimony	mg/L	<0.011	<0.011	<0.011	<0.011
SPLP Selenium	mg/L	<0.014	<0.014	<0.014	<0.014
SPLP Thallium	mg/L	<0.014	<0.014	<0.014	<0.014
SPLP Vanadium	mg/L	<0.011	<0.011	<0.011	<0.011
SPLP Zinc	mg/L	0.069	<0.022	<0.022	<0.022
SPLP Phenol	mg/L	<0.01	0.028	0.026	0.026
SPLP 1,4-Dichlorobenzene	mg/L	<0.01	<0.01	<0.01	<0.01
SPLP 1,2-Dichlorobenzene	mg/L	<0.01	<0.01	<0.01	<0.01
SPLP 4-Methylphenol	mg/L	0.059	1.22	1.13	1.16
SPLP Naphthalene	mg/L	<0.01	<0.01	<0.01	<0.01
SPLP 2,4,6-Trichlorophenol	mg/L	<0.01	<0.01	<0.01	<0.01
SPLP 2,4,5-Trichlorophenol	mg/L	<0.01	<0.01	<0.01	<0.01
SPLP Pentachlorophenol	mg/L	<0.05	<0.05	<0.05	<0.05

[1]m.r.= Mix Ratio =[(weight reagent)/(weight waste)]

Table 3-19. SPLP Leaching, UCS and Permeability Results for The Mohawk Tannery Area 2 Verification Formulations

Parameter	Units	Pit 2 Sludge Composite	15ZA	15ZB	15ZC
Portland Cement	m.r.[1]	-	0.12	0.12	0.12
Blast Furnace Slag	m.r.	-	0.04	0.04	0.04
Hydrated Lime	m.r.	-	-	-	-
Water	m.r.	-	0.08	0.08	0.08
Area 5 Sand	% (v/v)	-	-	-	-
Unconfined Compressive Strength (28 day)	psi	-	177	179	179
Permeability (Day 28)	cm/sec	-	4.5×10^{-8}	1.6×10^{-7}	1.2×10^{-6}
SPLP Equilibrium pH	s.u.	9.2	11.7	11.7	11.6
SPLP Silver	mg/L	<0.021	<0.022	<0.022	<0.022
SPLP Arsenic	mg/L	<0.011	<0.011	<0.011	<0.011
SPLP Barium	mg/L	0.786	0.441	0.423	0.410
SPLP Beryllium	mg/L	<0.003	<0.003	<0.003	<0.003
SPLP Cadmium	mg/L	<0.003	<0.003	<0.003	<0.003
SPLP Chromium	mg/L	0.272	0.217	0.227	0.234
SPLP Nickel	mg/L	<0.011	0.013	0.013	0.013
SPLP Lead	mg/L	<0.011	<0.011	<0.011	<0.011
SPLP Antimony	mg/L	<0.011	<0.011	<0.011	<0.011
SPLP Selenium	mg/L	<0.014	<0.014	<0.014	<0.014
SPLP Thallium	mg/L	<0.014	<0.014	<0.014	<0.014
SPLP Vanadium	mg/L	<0.011	<0.011	<0.011	<0.011
SPLP Zinc	mg/L	0.041	<0.022	<0.022	<0.022
SPLP Phenol	mg/L	<0.01	0.17	0.17	0.17
SPLP 1,4-Dichlorobenzene	mg/L	<0.01	<0.01	0.011	0.012
SPLP 1,2-Dichlorobenzene	mg/L	0.22	0.13	0.13	0.13
SPLP 4-Methylphenol	mg/L	<0.01	0.041	0.037	0.040
SPLP Naphthalene	mg/L	0.19	0.098	0.10	0.096
SPLP 2,4,6-Trichlorophenol	mg/L	<0.01	0.32	0.33	0.35
SPLP 2,4,5-Trichlorophenol	mg/L	<0.01	<0.01	<0.01	<0.01
SPLP Pentachlorophenol	mg/L	<0.05	0.42	0.37	0.41

[1]m.r.= Mix Ratio =[(weight reagent)/(weight waste)]

Figures

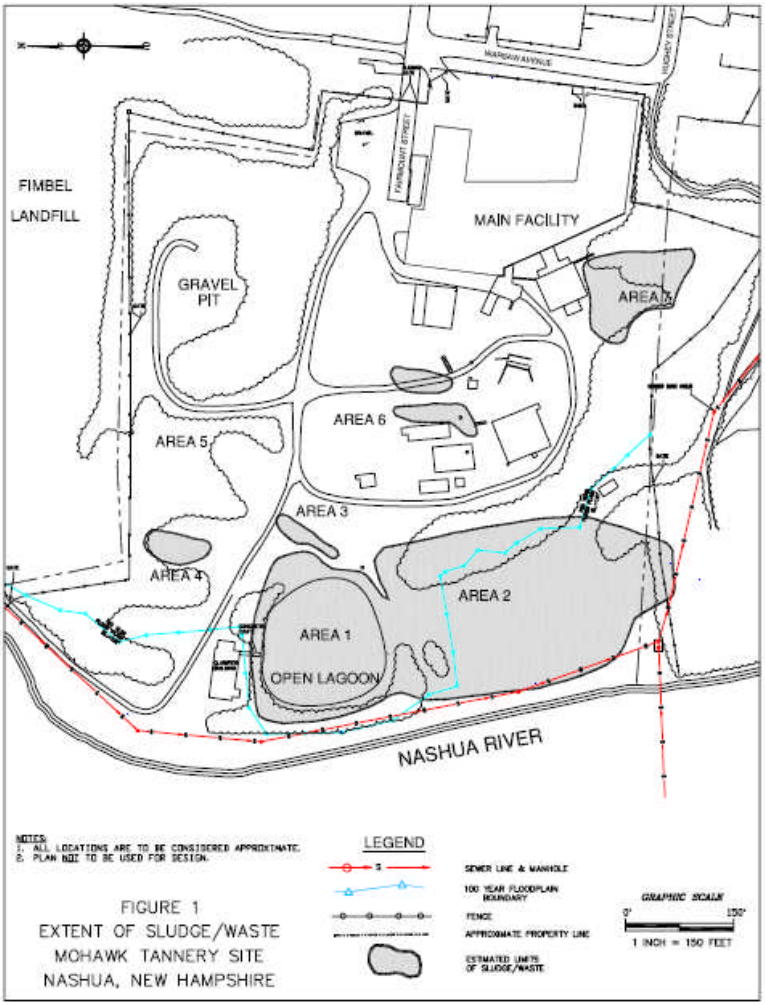
Figure 1. Aerial View of Mohawk Tannery

(Picture from GlobeXplorer)

Figure 2. Aerial View of Mohawk Tannery

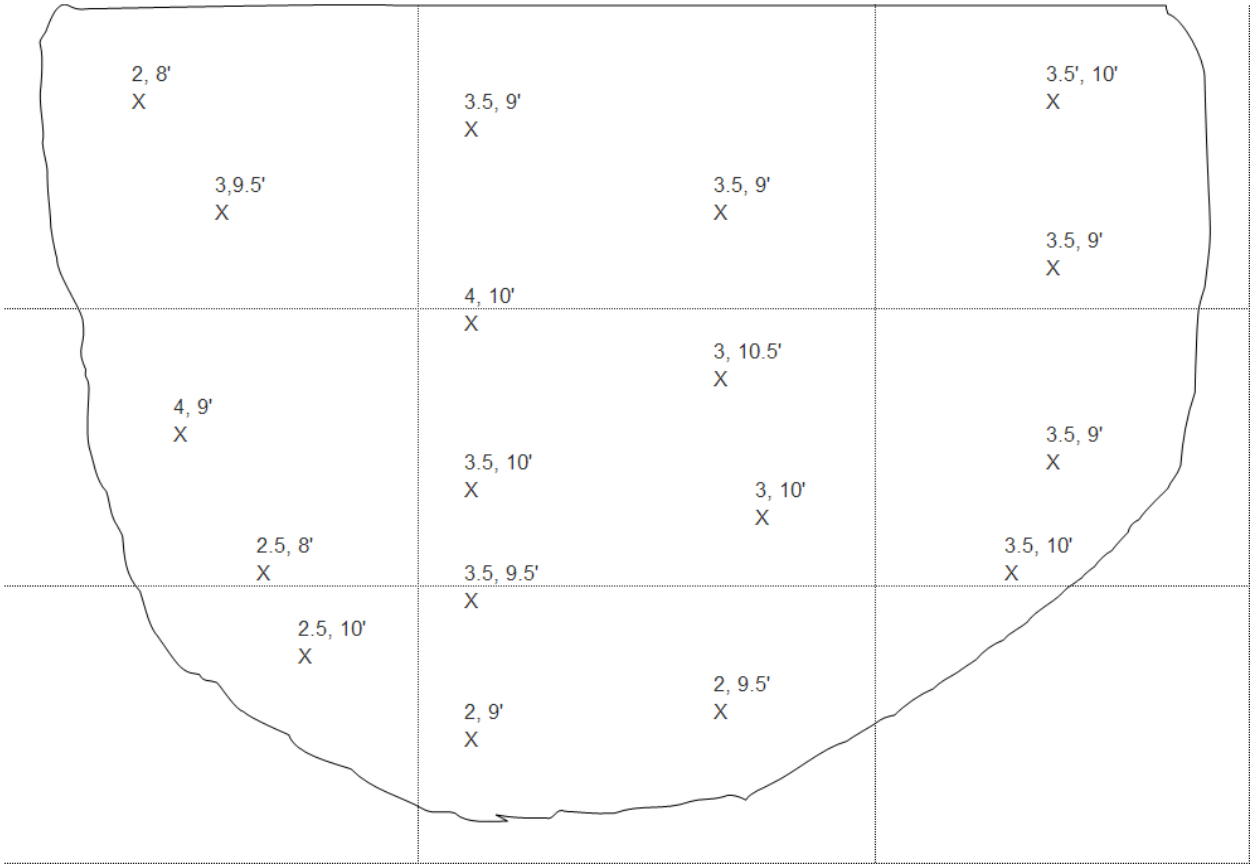
(Figure from GlobeXplorer)

Figure 3. Site Layout



(From USEPA "Mohawk Tannery Site Fact Sheet EPA Plans Cleanup for Waste Disposal Areas, July 2002").

Figure 4. Mohawk Area 1 Pond



Reported values are water depths followed by sludge depth in feet.

Figure 5. Mohawk Tannery Other Cross Sections

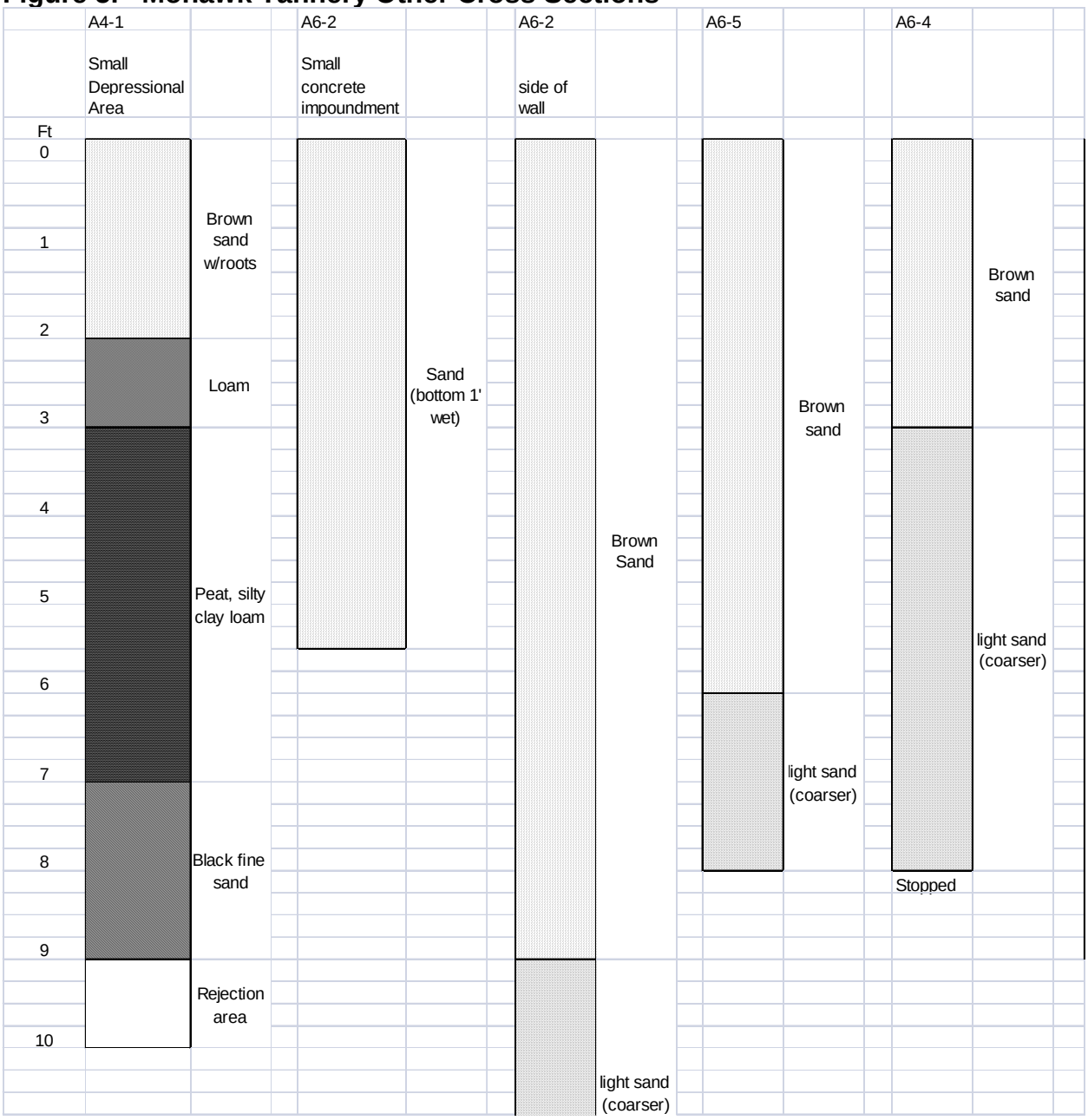


Figure 6. Mohawk Tannery Other Cross Sections

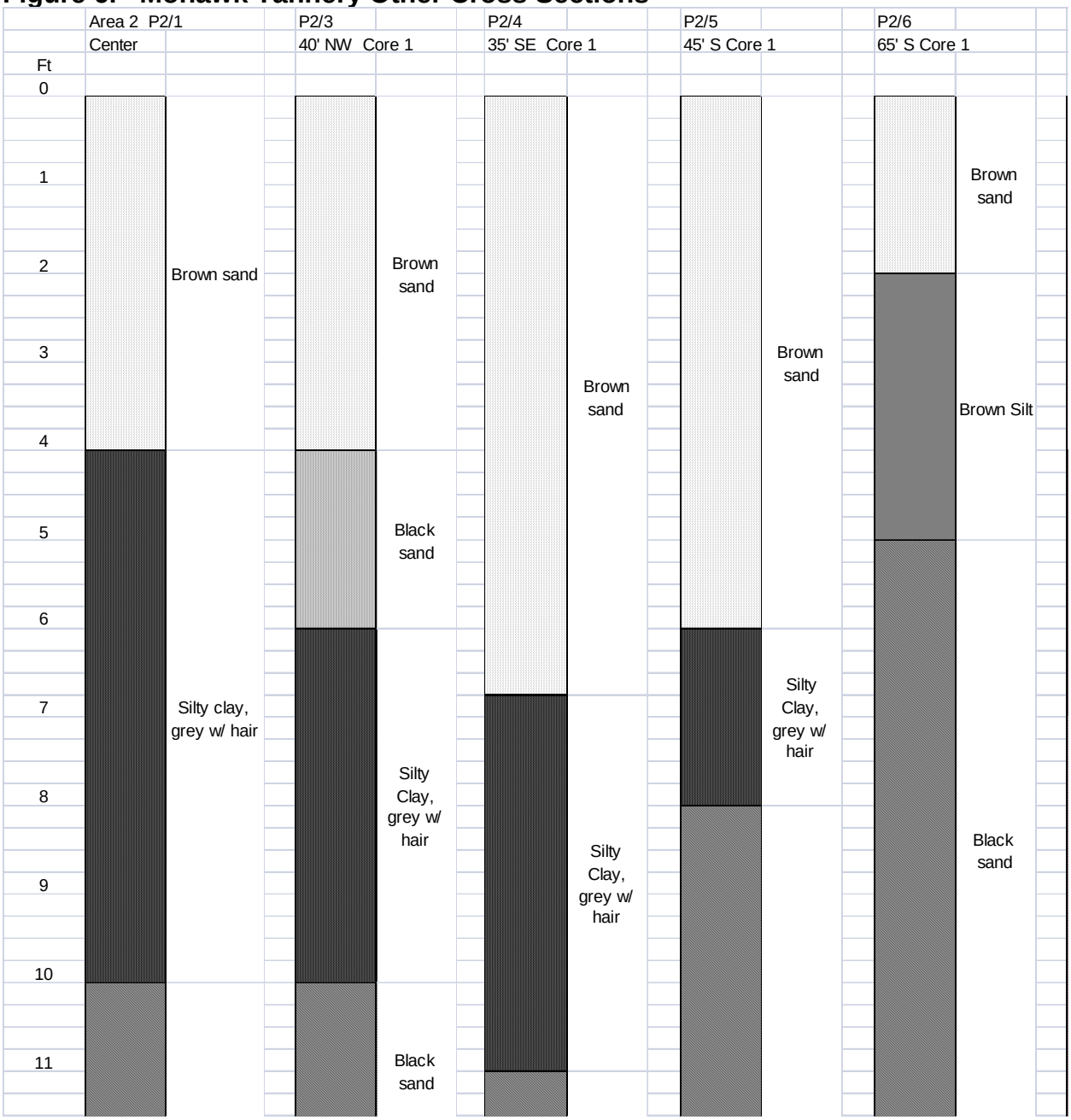
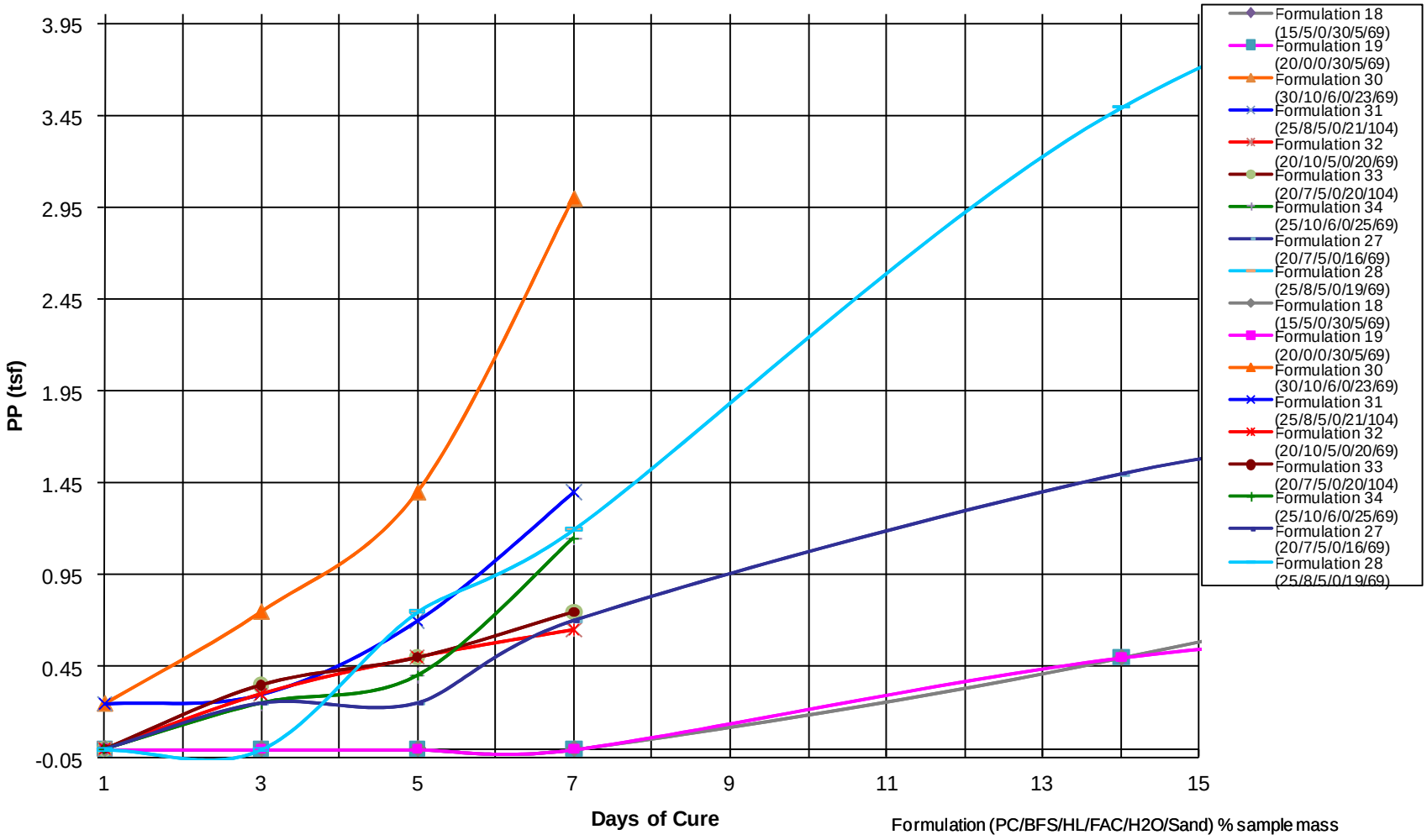



Figure 7. Mohawk Area 1 Formulations Pocket Penetrometer Values