Alternative Feasibility Study
Final Creek, Settling Ponds, and Spoils Disposal Areas
Badger Army Ammunition Plant

Prepared for:

United States Department of the Army
Badger Army Ammunition Plant
2 Badger Road
Baraboo, Wisconsin 53913-5000

August 2012

BTS
BADGER TECHNICAL SERVICES

Badger Technical Services, LLC
Badger Army Ammunition Plant
Baraboo, WI 53913-5000

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

ACRONYMS

BAAP	Badger Army Ammunition Plant (WDNR designation)
BAAAP	Badger Army Ammunition Plant (Department of Defense designation)
BERA	Baseline Ecological Risk Assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	Contaminant of Concern
CPAH	Carcinogenic Polycyclic Aromatic Hydrocarbon
CSM	Conceptual Site Model
DBG	Deterrent Burning Ground
DNT	Dinitrotoluene
IFCR	In-Field Conditions Report
IRM	Interim Remedial Measures
kg	Kilogram
mg	Milligram
mg/kg	Milligrams per kilogram
MIRM	Modified Interim Remedial Measures
NR	Natural Resources
OSHA	Occupational Safety and Health Administration
PAH	Polycyclic Aromatic Hydrocarbon
PBG	Propellant Burning Ground
RCL	Residual Contaminant Level
RCRA	Resource Conservation and Recovery Act
RSL	Residential Screening Level
STH	State Highway
SPA	Spoils Disposal Area
SPLP	Synthetic Precipitation Leaching Procedures
TCLP	Toxicity Characteristic Leaching Procedure
USEPA	United States Environmental Protection Agency
WDNR	Wisconsin Department of Natural Resources
WDOT	Wisconsin Department of Transportation
Wis. Adm. Code	Wisconsin Administrative Code
WWTP	Wastewater Treatment Plant

1.0 CERTIFICATION PAGE

In accordance with section NR 712.09, Wisconsin Administrative Code (Wis. Adm. Code), a registered professional engineer, a hydrogeologist, or a scientist from the State of Wisconsin shall certify this report. The required certification statements are presented, and signed and sealed, as follows:

Report prepared by:

"I, **Brenda H. Boyce, P.G.**, *hereby certify that I am a scientist as that term is defined in s. NR 712.03(1), Wis. Adm. Code, and that, to the best of my knowledge, all of the information contained in this document is correct and the document was prepared in compliance with all applicable requirements in chs. NR 700 to 726, Wis. Adm. Code."*

Environmental Geologist — August 9, 2012

Signature and title — **Date**

Report reviewed by:

"I, **Clair E. Ruenger P.G.**, *hereby certify that I am a hydrogeologist as that term is defined in s. NR 712.03(1), Wis. Adm. Code, and that, to the best of my knowledge, all of the information contained in this document is correct and the document was prepared in compliance with all applicable requirements in chs. NR 700 to 726, Wis. Adm. Code."*

Environmental Services Manager — August 9, 2012

Signature and title — **Date**

2.0 EXECUTIVE SUMMARY

The Settling Ponds Area of the Badger Army Ammunition Plant (BAAAP) is located in the southern portion of the installation and consists of Final Creek, four Settling Ponds, and five Spoils Disposal Areas. The Settling Ponds Area was constructed in 1942 to serve as aeration and settling basins for the installation's wastewater. The area, consisting of approximately 70 acres, received sanitary and industrial wastewater from the west side of the installation via Final Creek, and also received storm and wastewater from the east-central area of the installation via the Main Ditch. These waters carried with them various metals and propellant constituents which were deposited in the shallow sediment and soil of the ditches and Ponds. Sediment in the Settling Ponds was removed via dredging during the 1970s. The sediment was placed in the Spoils Disposal Areas.

Several environmental investigations have been conducted in the Settling Ponds Area to define the extent and degree of contamination over the past 30 years. Initially, investigation work focused on groundwater as well as soil contamination in the Settling Ponds Area. However, the results of these investigations showed that the source of the groundwater impacts in the southern portion of BAAAP was the Propellant Burning Ground (PBG), located to the north of Final Creek. The Settling Ponds Area was ruled out as a source for groundwater contamination based on the following factors: depth to groundwater is approximately 10 to 80 feet below ground surface, soil contamination is primarily limited to the shallow soil interval (0-4 feet below ground surface), and previous studies indicate that the contaminants in the soil are not leaching to groundwater. Therefore, the focus of subsequent investigation work was directed primarily at determining the extent and degree of shallow soil contamination.

In 1994, BAAAP issued the *Final Feasibility Study* (ABB Environmental Services, Inc.) for the Settling Ponds Area. The Wisconsin Department of Natural Resources (WDNR) and the United States Environmental Protection Agency (USEPA) approved that document's proposed soil remediation goals and in-situ stabilization/solidification as the corrective measure for the soil and sediment in the Settling Ponds, Spoils Disposal Areas, and Final Creek. Since that regulatory approval, further investigation work has been conducted at the site to fully define the extent and degree of contamination in the soil. Based upon a comprehensive review of all the site investigation data, along with a more definitive plan for future use of the site, the Department of the Army (Army) decided to re-evaluate the Settling Ponds Area remedy.

In this document, the Army is proposing revised remediation goals for the Settling Ponds Area using current state and federal regulatory standards, BAAAP-established background levels, and site-specific residual contaminant levels. The revised remediation goals were developed using scientifically valid procedures, toxicological values, and alternative assumptions and are protective of public health, safety and welfare, and the environment.

Three remedial alternatives are evaluated based on the revised remediation goals presented. The first alternative considered is a "no action" alternative, which would rely completely on natural attenuation to degrade contaminants in the soil over time. The second alternative is the previously proposed remedy of solidification and soil cover, which would involve the mixing of shallow soil with a cementing agent to bind the particles of soil together, thus binding contaminants within the matrix (solidification), and then covering the area with a layer of soil to prevent direct contact. The third alternative proposed is excavation and on-site disposal. This alternative would include the excavation of areas where contamination is found to be above the proposed remediation goals and proper disposal of impacted soil. After thorough evaluation of all the criteria and comparative aspects associated with the three proposed alternatives, Alternative 3 (excavation and proper disposal of impacted soil) is selected as the Army's preferred final remedy for the Settling Ponds Area of BAAAP.

3.0 INTRODUCTION

The Settling Ponds Area of the BAAAP is located in the southern portion of the installation and consists of Final Creek, four Settling Ponds, and five Spoils Disposal Areas. The Settling Ponds Area was constructed in 1942 (Master Environmental Plan, 1987).

During the years of production at BAAAP, the Settling Ponds received surface water and sanitary and industrial wastewater from the west side of the installation (the Nitrocellulose and Ball Powder® production areas) via Final Creek into Settling Pond 1. Surface runoff and production wastewater from the east side of the installation (Nitroglycerin, Rocket Paste, Rocket, and Magazine areas) entered Settling Pond 3 via the Main Ditch.

The Settling Ponds were constructed to allow particulates to settle out of the waters before they discharged into the Wisconsin River. Sediment in the Settling Ponds was removed via dredging during the 1970s. The sediment was placed nearby, creating the Spoils Disposal Areas. The dredging increased the width of the original Settling Ponds to their present size.

In August 1994, BAAAP issued the *Final Feasibility Study*, which addressed 11 sites on the installation and selected preferred remedies for each site. The Settling Ponds Area was one of these sites. The proposed site remedy was in-situ soil stabilization and soil cover.

In June 1995, the WDNR issued a plan modification to the September 14, 1987, *In-Field Conditions Report* (IFCR) under authority of the Wisconsin Environmental Response and Repair Regulations and Wisconsin solid/hazardous waste regulations. The WDNR plan modification adopted the remediation goals and preferred final remedies set forth for the sites documented in the *Final Feasibility Study*.

Similarly, in December 1995, the USEPA Region 5, under authority of the Resource Conservation and Recovery Act (RCRA), issued a modification to BAAAP's RCRA Permit (Department of the Army, 1995). This permit modification also adopted in-situ stabilization/solidification as the proposed corrective measure for the soil and sediment in the Settling Ponds, Spoils Disposal Areas, and Final Creek.

Since that regulatory approval, further investigation work has been conducted at the site to fully delineate the extent and degree of contamination in the soil and groundwater. This investigation work was conducted in accordance with the IFCR.

Based upon a review of the recent site investigation data, the effectiveness of soil stabilization methods, the more definitive plan for future use of the site, and the Natural Resources (NR) 700 series of state regulations allowing for the calculation of site-specific cleanup values, the Army decided to re-evaluate the Settling Ponds Area remedy.

This Alternative Feasibility Study will present a concise summary of the site investigation data, develop and evaluate remedial alternatives based on site-specific remediation goals, and propose a remedy that will be protective of human health and the environment.

4.0 SITE BACKGROUND AND SETTING

The BAAAP, located in south-central Wisconsin within Sumpter and Merrimac Townships in Sauk County, was constructed in 1942 to produce smokeless gunpowder and solid rocket propellant as munitions components for World War II. The installation is located on a portion of the pre-settlement Sauk Prairie, between the Baraboo Range and the Wisconsin River. The impoundment of the Wisconsin River forms Lake Wisconsin, which borders the southeast side of the BAAAP. Figure 1 shows the location of BAAAP.

Production of nitric acid, sulfuric acid, oleum, nitrocellulose, and nitroglycerin occurred in support of munitions components production. Production periods were as follows: World War II (1942 to 1945), Korean War (1951 to 1958), and Vietnam Conflict (1966 to 1975). Disposal of collected excess waste substances from production occurred at primarily two locations on-site: the PBG and Deterrent Burning Ground (DBG). Wastewater from production efforts discharged to ditches and sewer, eventually reaching the Settling Ponds, and then the Wisconsin River. As a result of production and on-site waste disposal practices that were common at the time, soil and groundwater at the BAAAP were impacted.

The primary land uses in the immediate vicinity of the BAAAP are agricultural, recreational, and residential. The United States Department of Agriculture has used the land in and around the installation for grazing and crop development research for many years. The Dairy Forage Research Center Farm was constructed in the 1980s on land transferred from the Army to the United States Department of Agriculture and now controls about 2,000 acres of the installation.

The primary land use to the north of the installation is for recreation at Devil's Lake State Park, managed by the WDNR. It is located hydrologically upgradient and water flows from the bluffs on the state park border onto the installation.

Lake Wisconsin and the Wisconsin River, to the south and southeast of the BAAAP, are hydraulically connected to the installation. Groundwater from the installation generally moves toward the river. Lake Wisconsin was formed in 1914 by the Wisconsin Power and Light dam on the Wisconsin River, near Prairie du Sac.

Based on BAAAP groundwater monitoring well data and Wisconsin Geological and Natural History Survey (Water-Table Elevation Map of Sauk County) data, the farmland south of the installation receives groundwater flow from the installation. The farmland west of the installation has groundwater flow toward the installation.

Approximately 75 of the private residential wells to the south and east of the installation are currently part of the groundwater monitoring program at BAAAP, which began in 1980. Of these, five residential drinking water wells, downgradient of the installation, have been replaced by the Army due to groundwater impacts.

4.1 BAAAP History

The BAAAP originally encompassed over 10,000 acres of farmland and was constructed in 1942 as the Badger Ordnance Works to manufacture small arms and ordnance propellants as part of the United States military manufacturing effort during World War II. BAAAP also operated as a propellant manufacturing facility during the Korean War and Vietnam Conflict. The installation, inactive since 1977 and reduced in size to 7,275 acres, was declared “excess” in 1999.

During World War II, BAAAP employed approximately 7,500 workers. Approximately 271 million pounds of single- and double-base propellants were produced. Oleum and smokeless powder production began in 1943. Rocket paste powder production began in 1945. The solventless extrusion smokeless propellant process was installed in 1944 and 1945. From 1945 to 1951, the installation was in standby status.

BAAAP was reactivated for the Korean War in 1951. Reactivation activities were completed by 1954. Facilities for the manufacture of Ball Powder® propellant were constructed during 1954 and 1955. A facility to recycle old cannon powder as a source of nitrocellulose for the new propellant was also constructed in 1954 and 1955. BAAAP remained in production until the Korean War ended and the propellant magazines were full (1958). During the Korean War, approximately 286 million pounds of single- and double-base propellant were manufactured with a peak production employment of 5,022 employees. The installation was in standby status again from 1958 to 1966.

BAAAP was reactivated in 1966 for the Vietnam Conflict. The installation manufactured Ball Powder® propellant, rocket propellant, and smokeless propellant from 1966 to 1975. In 1972, construction included additional sewage treatment systems at the wastewater treatment plant (WWTP), new acid production, and new nitroglycerin production facilities. Production activities stopped in 1975. During the Vietnam Conflict, approximately 487 million pounds of single- and double-base propellant were manufactured with a peak production employment of 5,400 employees.

After the Vietnam Conflict production ended, the installation was in standby status. A new continuous-process nitroglycerin facility was constructed but not tested. New facilities constructed for the manufacture of nitric acid, sulfuric acid, and oleum were test operated to confirm production capacity. The government declared the BAAAP “excess to the Army’s needs” in 1999 and began the decommissioning and dismantling process.

The PBG, DBG, and Rocket Paste Area have been identified as source areas of soil and groundwater contamination at the BAAAP. Figure 2 shows the locations of these areas. During production periods, the PBG was used as a disposal area for waste and excess production chemicals, primarily solvents, plasticizers, and explosives. Excess chemicals and munitions components were placed in open pits and burned to dispose of them. During the 1960s, the DBG was created and also used for burning of wastes held in large tanks. By 1971, the only burning involved excess propellant in containment at the PBG, and other wastes were disposed in accordance with federal regulations (Goc, 2002).

During production periods, surface runoff and production wastewater from the New Acid Area, Old and New Nitroglycerin Areas, Rocket Paste, and Rocket Roll and Press Houses (referred to collectively in this report as the Rocket Paste Area) was conveyed in open ditches from the east-central to the south side of the installation where it subsequently flowed to Settling Pond 3. Process wastewater from the Nitrocellulose production areas and Ball Powder® areas on the western side of the installation flowed into sewers, then into Final Creek where it was joined by treated wastewater from the sanitary WWTP. This flow, joined by the Rocket Paste Area flows in Settling Pond 3, eventually discharged to Lake Wisconsin at Gruber's Grove Bay.

Environmental investigation and restoration activities began at the BAAAP in 1977. Groundwater monitoring and characterization activities began in 1980, with groundwater treatment beginning in 1990. These activities are still in progress today.

Demolition and recycling of BAAAP infrastructure began in 2004. Ongoing demolition activities include the following: removal of all process chemicals, equipment, piping, and process and storage tanks; removal of all munitions and explosives of concern that may reasonably be expected to cause an environmental or safety hazard; and removal of the majority of the structures on the installation. Many of the concrete slabs that lay underneath these structures have been removed or are planned for removal and recycling.

Current environmental restoration activities include the following: soil investigation and remediation; groundwater monitoring and remediation; impacted industrial and sanitary sewer removal; friable asbestos removal; and munitions/munitions components screening, clearance, and certification. All known hazardous substance or petroleum releases have been investigated and remediated, as needed. Waste materials that cannot be recycled are properly disposed off-site or are placed in the BAAAP on-site construction and demolition landfill in accordance with the state permit requirements.

A perimeter fence around the installation boundary and individual sites inside the fence, patrols by armed guards, and posted no trespassing signs have been used by the Army to discourage access to the BAAAP lands, including the Settling Ponds area and other restoration areas.

4.2 Settling Ponds Area Background and History

The Settling Ponds Area is located in the southern portion of BAAAP. Created by the Army specifically to handle wastewater produced by the Army facilities, it consists of Final Creek, four separate Settling Ponds, and five Spoils Disposal Areas. Figure 3 shows the location of the Settling Ponds Area within the BAAAP.

During the first approximately 30 years of intermittent operations at BAAAP, Final Creek and the Settling Ponds received sewage, which had undergone primary treatment at the sanitary

WWTP, and pH-neutralized industrial wastewater from most areas of the installation, and surface runoff from the Nitroglycerin, Rocket Paste, and Magazine Areas. Over the years, the sanitary WWTP was upgraded to meet the regulatory standards of the day.

The industrial WWTP, located at the southwest corner of BAAAP, was brought online in the mid-1970s to further neutralize the acidic production wastewaters before they entered Final Creek.

Domestic sewage from BAAAP and Bluffview (the small community to the west of BAAAP) currently flows to the sanitary WWTP through a new sewer line installed in 2009. The old sanitary sewer was abandoned or removed and the surrounding soil checked for contamination. The WWTP facility provides primary and secondary treatment of collected sanitary wastewater with a capacity of 0.5 million gallons per day. Now, effluent from the sanitary WWTP flows into the unlined outfall ditch at Final Creek where it combines with overland storm water flow.

The industrial sewer was blocked in 2009 and has been investigated and abandoned or removed. It no longer contributes to the flow in Final Creek. Backwash water from the Interim Remedial Measure/Modified Interim Remedial Measure (IRM/MIRM) groundwater treatment systems also is discharged to this section of Final Creek. Based on analytical testing of this discharge, contaminants are not at levels that would adversely affect the soil. Further information on the IRM/MIRM is provided in Section 7.1 of this document.

This combined flow infiltrates into the soil of Final Creek and does not reach Settling Pond 1 except in extreme precipitation or snowmelt situations. One area of Settling Pond 1 (less than one acre in size) is low enough in elevation to remain wet year round. The rest of the Settling Ponds Area is dry.

The Settling Ponds, with a total area of approximately 70 acres, served as settling basins for the treated effluent. As a result, clarified wastewater only discharged into Gruber's Grove Bay during production periods. During modification of the Settling Ponds after the Vietnam Conflict, weirs (barriers) were placed on the eastern ends of each pond to form deeper catchment areas to further retard flow and to increase settling of solids from the water before discharge to Gruber's Grove Bay.

The Settling Ponds were first used in 1942. The characteristics of the Settling Ponds are as follows:

- Final Creek is approximately one mile long from the WWTP to Settling Pond 1.
- Settling Pond 1 has an effective surface area of 26 acres and potential volume of approximately 31 million gallons, based on an average depth of four feet.
- Settling Pond 2 received overflow from Settling Pond 1 and is the smallest pond with an effective surface area of 5.4 acres and potential volume of about 1 million gallons, based on an average depth of four feet.

- Settling Pond 3 has a surface area of approximately 13 acres with a water volume capacity of approximately 32 million gallons, based on four foot depth. Settling Pond 3 received overflow from Settling Pond 2 and discharges from the east-central area of BAAAP, including the Rocket Paste Areas described above.

- Settling Pond 4 received overflow from Settling Pond 3 and based on an average depth of three feet and a surface area of 10 acres, has a potential volume of approximately 5.4 million gallons.

Propellant production ceased in 1975, diminishing the water flow through this area. The production facilities that generated the water are being or have been removed. Currently, only small portions of Final Creek (approximately 2,000 feet) and Settling Pond 1 (0.22 acres) remain wet for any length of time due to precipitation and the permitted IRM/MIRM and WWTP discharges.

The Spoils Disposal Areas, consisting of five unlined spoil sites, are adjacent to the north and south banks of Settling Ponds 3 and 4. Some of these areas were originally used as gravel or sand borrow sites during installation construction in the 1940s. Each Spoils Disposal Area was reportedly further excavated in the 1970s to create depressions to contain dredged sediment from the Settling Ponds. Spoils Disposal Areas I through IV have been used for collecting and dewatering sludge and dredge spoils removed from the Settling Ponds. Dredging activities began in late 1971 and ended in early 1973. Spoils Disposal Area I covers approximately 2.5 acres, SDA II is approximately 1.3 acres, SDA III is 3.4 acres and SDA V is a four-acre area. SDA V initially was developed in the early 1970s to receive dredged spoils and water from planned dredging operations in Gruber's Grove Bay; however, it was never used for that purpose. It was lined with silty soil material approximately one foot deep, which reportedly was dredged from the Settling Ponds. The depth of the sediment in SDA I extends to approximately nine feet below grade, and SDA II extends to approximately 12 feet below grade. The depth of sediment in SDA III and IV is approximately three feet based on soil boring data.

It should be noted that information pertaining to the southeastern portion of Settling Pond 4 is not included in this Alternative Feasibility Study. It is omitted because remedial work was previously completed in that area to allow for reconstruction of State Highway 78. The WDNR granted closure for this portion of Settling Pond 4 in the December 12, 2008 *Final Case Closure for the BAAP - WDOT Projects Area Within Settling Pond 4* letter and in the January 26, 2010 *Final Case Closure for BAAP - STH 78 North Ditch Contaminated Soil Case* letter. The parcels that contain the remediated portions of Settling Pond 4 have been transferred to the Wisconsin Department of Transportation (WDOT) and United States Department of Agriculture.

4.3 Climate

The climate of the installation area is typically continental with some influence from the Great Lakes system. Average annual temperatures in the state vary from 40 degrees Fahrenheit to 48 degrees Fahrenheit. The freeze-free season is typically 100 to 180 days per year. From approximately December through March the ground is frozen. Long-term mean annual precipitation ranges from 30 to 34 inches, with approximately 40 thunderstorm days per year.

Average annual snow cover ranges from 65 to 140 days per year in the state (Wisconsin State Climatology Office on the Web, 2010).

4.4 Topography

The land surface at the installation is the result of glaciation. The installation is located on the southern edge of the Baraboo Range, also commonly referred to as the Baraboo Hills. The terminal moraine, deposited by the leading edge of the last glacier as it moved from east to west, extends from north to south across the central portion of the installation. The topography in the eastern two-thirds of the installation consists of gently rolling hills with numerous depressions. The northwestern third of the installation is an outwash plain that is nearly level to gently sloping towards the southwest.

4.5 Surface Water Hydrology

Pre-construction aerial photographs from 1940 show the Settling Ponds Area as agricultural land that may have possibly been artificially drained during the European settlement of the Sauk Prairie. Gruber's Grove Bay, in the east part of the Settling Ponds Area, extended through what is considered Settling Pond 4 today. From 1942 through the 1970s, the Army developed this area as a drainage and infiltration system for production wastewater and treated sanitary effluent.

Treated sanitary effluent and overland flow moved through this area since 1942, joined by production wastewaters during active production and testing periods. From the 1990s to the present, backwash water from the IRM/MIRM treatment system has been discharged to Final Creek as needed for system operations. That addition to the treated sanitary effluent and stormwater will continue until the IRM/MIRM is shut down.

Currently, the Settling Ponds are predominantly dry, low-lying areas that may become wet during heavy rainfall and snow melt events. The majority of the water reaching the Settling Ponds Area evaporates or infiltrates due to the permeable soil. There has been no drainage of storm water runoff to Gruber's Grove Bay on Lake Wisconsin since the early 1990s. It should be noted Final Creek, the four separate Settling Ponds, and the five Spoils Disposal Areas are an artificial wetland which serves as sedimentation and stormwater detention basins and associated conveyance features operated and maintained only for sediment and detention purposes and therefore, in accordance with NR 103.06 (4) (a) are exempt from the requirements of all regulatory, planning, resource management, liaison, and financial aid determinations that affect wetlands.

4.6 Geology

A thick sequence of unconsolidated sediment was deposited during the late Wisconsin Stage glaciation, approximately 18,000 years ago. A glacial terminal moraine transects the installation from north to south. West of the terminal moraine, a thick sequence of glacial outwash sand and gravel was deposited. Glacial tills to the east are primarily silty sands. Several feet of clayey silt overlie the glacial sediments on-site, with some loess present.

Bedrock geology at BAAAP is dominated by Cambrian sandstones beneath most of the site, with some Precambrian metamorphosed granites and rhyolites. The Baraboo Hills to the north and west of the installation consist of Precambrian quartzite conglomerates and sandstones, which are part of the Baraboo Syncline, rising approximately 500 feet above the installation to the north. The bedrock surface dips steeply toward the south, where soil deposits quickly thicken to a maximum of approximately 250 feet.

Along the northern installation boundary, soil deposits are thin or absent. Quartzite and sandstone bedrock outcrops are common in this area. A Precambrian quartzite occurs at the southern base of the hills. South of the Baraboo Range, the quartzite surface dips steeply to the south and is overlain unconformably by Cambrian fine to medium sandstones with minor amounts of shale and dolomite.

Three cross sections showing the geology underneath the Settling Ponds Area are provided. Figure 4 depicts the location and orientation of the cross sections. Figures 5, 6, and 7 show the cross sections. Cross section A-A' extends from the PBG south to the installation boundary. Cross section B-B' extends from the southwest corner of the installation to the southeast corner at Gruber's Grove Bay. Cross section C-C' extends through Spoils Disposal Area I, Settling Pond 3, and a portion of Spoils Disposal Area III to the southern boundary of BAAAP.

4.7 Hydrogeology

Two major aquifers are present beneath the installation: the surficial sand and gravel aquifer and the underlying sandstone bedrock aquifer. The bedrock aquifer varies between 80 to 280 feet below ground surface. The general direction of groundwater flow is south to southeast. Steep gradients exist along the northern boundary of the installation. The gradient flattens substantially in the central and southern portions of the installation. Recharge to the sand and gravel aquifer is limited by infiltration through a fine-grained loess unit in some areas. On the north side of the installation, some fine-grained glacio-lacustrine layers occur above the water table. This condition results in a locally elevated groundwater table in this area with downward gradients.

The Lake Wisconsin Reservoir, caused by the hydroelectric dam on the Wisconsin River, influences groundwater flow across the installation. The reservoir is north of the dam where there is an approximate 40-foot surface water drop from the lake to the river. The water level in the reservoir is elevated above the water table for much of the southeastern portion of the installation. Subsequently, the Lake Wisconsin Reservoir discharges to the groundwater in the Gruber's Grove Bay area. The net result is groundwater flow parallel to the reservoir with discharge to the Wisconsin River south of the dam. Groundwater in the northeast portion of the installation is higher in elevation than the Lake Wisconsin Reservoir; therefore, the groundwater discharges to the Lake Wisconsin Reservoir.

The depth to groundwater across the Settling Ponds Area ranges from approximately 80 feet below grade at the northern edge to near the surface at Settling Pond 4. The water table is depicted on the cross sections.

5.0 SITE INVESTIGATIONS

Since 1979 there have been numerous investigations in the Settling Ponds Area of BAAAP. The Army Corps of Engineers first installed monitoring wells at BAAAP in 1979 and 1980. Many of the wells were installed in the area of the Settling Ponds and Final Creek. The following is a summary of the previous investigations conducted at the Settling Ponds Area.

5.1 BAAAP Contamination Survey

Between September 1979 and October 1980, Envirodyne Engineers, Inc., conducted a preliminary contamination survey (Envirodyne Engineers, Inc., 1981) to determine if detectable contaminant concentrations had migrated off-site and to evaluate the potential for additional off-site migration. It should be noted, as part of the development of the Data Collection Work Plan (Olin, 1997), it was determined that the results of the Envirodyne Engineers, Inc., investigation were not suitable for soil contaminant delineation. This determination was made based on several factors, including the uncertainty in the sampling locations, the large vertical interval over which the subsurface soil samples were composited, and the limited set of analytical parameters. In addition, several of the soil samples contained anomalously high contaminant concentrations compared with subsequent investigations. As the data was not usable, additional sampling was performed (Olin, 2001) to confirm the degree of contamination detected.

5.2 Near Surface Soil Investigation of Selected Areas at BAAAP

In 1984, Ayres Associates, Inc., performed a near-surface soil investigation in six of the solid waste management units, which included the Settling Ponds Area. Di-n-butyl phthalate and dinitrotoluene (DNT) were detected in soil samples collected from all four Settling Ponds. Various metals, including lead, were also detected in the Settling Ponds Area samples. Results of the Extraction Procedure Toxicity leaching analysis indicated that the inorganic contaminants were not mobile and did not appear to pose a threat to groundwater quality.

5.3 Field Sampling Report, Settling Ponds and Spoils Disposal Areas

In 2001, Olin completed the *Field Sampling Report, Settling Ponds & Spoils Disposal Areas*. Investigation work was conducted in the Settling Ponds Area in order to better define the extent and degree of contamination prior to remedial design. Field activities were performed in two major phases from 1997 to 2000. This report provides the most comprehensive summary of the site investigation data collected to date.

5.4 Development of Site-Specific Soil Residual Contaminant Levels, Settling Ponds and Spoils Disposal Areas

In 2002, Environmental Compliance Consultants, Inc., was retained to develop site-specific soil residual contaminant levels (RCLs) for the protection of human health and the environment. Direct contact site-specific soil RCLs were established based on statistical analyses of the contaminant concentrations per Chapter NR 720, Wis. Adm. Code. According to the WDNR, the direct contact exposure pathway is restricted to the upper four feet of soil. Site-specific soil

RCLs protective of groundwater quality were established using procedures presented in Chapter NR 720, Wis. Adm. Code, and the WDNR Polycyclic Aromatic Hydrocarbon Guidance document (Publication RR-519-97). Initial site-specific soil RCLs were established using the soil:water partitioning and dilution attenuation factor equations. Transport and fate modeling was performed for contaminants detected above the initial site-specific soil RCLs. Modeling was performed using the Seasonal Soil Compartment Model (SESOIL) and Analytical, Transient, one-, two-, and three-Dimensional Model (AT123D). Based on the results of this evaluation, the following recommendations relating to the Settling Ponds Area were made:

- Groundwater monitoring should continue as part of the overall BAAAP groundwater monitoring plan.
- Perform further studies as to the transport and fate of DNT in the Settling Ponds Area soil and groundwater, in the form of soil column studies.

5.5 Final Report on Residual DNTs in Settling Ponds and Spoils Disposal Area Soil at BAAAP: Microcosm and Soil Column Studies

In 2005, microcosm and soil column studies (Spain and Hughes et al, Georgia Institute of Technology) were designed as a direct follow-up to the recommendations made in the 2002 *Development of Site-Specific Soil Residual Contaminant Levels* (Environmental Compliance Consultants, Inc.) report.

The first objective was to provide a yes or no answer as to whether there are microorganisms capable of growth on 2,4-DNT in the surface and subsurface soil from the Settling Ponds Area. Microcosms and most probable number plates constructed with soil and water from the site showed that biological activity is responsible for the destruction of DNT in the site materials. Concentrations of DNT in the samples from the site were negligible so DNT was added to the microcosms where it was degraded rapidly and repeatedly. Finally, isolation and identification of the DNT-degrading bacteria provided conclusive evidence of the biodegradation potential at the BAAAP site.

The second objective was to evaluate the rate and extent of natural attenuation of DNT in the vadose zone soil under simulated field conditions, including rainwater infiltration, transport, and degradation. In batch sorption experiments, 2,4-DNT and 2,6-DNT behaved similarly for each soil, giving similar isotherms (shape and magnitude) and derived soil/water adsorption coefficient values. 2,4-DNT was never detected in the effluent after 123 days of operation from columns designed to simulate leaching through the vadose zone. Breakthrough occurred in the column fed 2,6-DNT at 22 days and reached equilibrium at around 40 days; however, 2,6-DNT has not been detected at levels of concern at the site. The results indicated that 2,4-DNT and, to a lesser degree, 2,6-DNT were biodegraded in the soil columns under conditions that simulate rainfall.

5.6 Baseline Ecological Risk Assessment - Settling Ponds and Spoils Disposal Areas Site

Section NR 720.07(1)(a), Wis. Adm. Code, states that residual contaminant levels shall be determined for each exposure or migration pathway of concern. In addition, Section NR 720.07(c)(3) , Wis. Adm. Code, states residual soil contamination at the site shall not concentrate through plant uptake and adversely affect the food chain. Therefore, a baseline ecological study was performed at the Settling Ponds Area to address these regulatory requirements.

A Draft Baseline Ecological Risk Assessment (BERA) was submitted to the WDNR in June 2008 in response to the WDNR's request for additional information on potential risks to wildlife. The document was reviewed by the USEPA and WDNR over a six-month time period. Their comments and suggestions were provided to SpecPro and the Army, and a revised BERA was then completed in October 2009 which addressed their questions and concerns. The following is a summary of the BERA.

The BERA provided information to support decisions concerning selection and implementation of remedies related to contaminants in soil and groundwater at the Settling Ponds Area. The objective of the BERA (developed in consultation with the WDNR) was to evaluate ecological risks for wildlife that may inhabit the Settling Ponds Area. The BERA process included developing a site-specific conceptual site model (CSM), re-evaluating ecological risk (based on new data and current toxicity information), relating these risks spatially, and developing/implementing the BERA work plan.

Additional soil sampling was conducted as part of this investigation. A select group of representative wildlife species and associated parameters evaluated in the BERA process were used to determine if wildlife populations were at risk due to chemical exposure associated with the Settling Ponds Area. The results indicate there is no effect on the plant and wildlife receptors. Based on the results of the BERA, there are no risks to wildlife (meaning the survival, development, and reproductive success of the different wildlife receptors selected for evaluation) from the existing residual contamination associated with the Settling Ponds Area. Further details of the BERA and ecological risk are provided in Section 7.0 Conceptual Site Model, under the Receptors subsection.

6.0 NATURE AND EXTENT OF CONTAMINATION

Initially, investigation work focused on groundwater as well as soil contamination in the Settling Ponds Area. However, the results of the numerous soil and groundwater investigations show the source of the groundwater impacts in the Settling Ponds portion of BAAAP is the PBG located to the north of Final Creek and Settling Pond 1. Figure 2 shows the location of the source areas and groundwater plumes originating on the installation. The *Alternative Feasibility Study, Groundwater Remedial Strategy* (SpecPro/BTS, December 2011) addresses the groundwater contamination plumes at BAAAP.

There are currently, 3 extraction wells (EW-163R, EW-164 and EW-170R), 22 monitoring well nests and 4 singular monitoring wells located in the Settling Ponds Area. The extraction wells remove water from the PBG plume area, which is then piped to the north for treatment at the MIRM. Figure 8 shows the locations of these wells, well nests, the MIRM/IRM, and the industrial and sanitary Wastewater Treatment Plant. Groundwater data collected from these monitoring wells have consistently indicated that the Settling Ponds Area is not a source for groundwater contamination.

Analytical data from Toxicity Characteristic Leaching Procedures (TCLPs) and Synthetic Precipitation Leaching Procedures (SPLPs) performed on soil samples from the Settling Ponds Area have consistently shown that even high levels of contaminants in the soil do not partition from the soil to groundwater. As discussed in the preceding section (see Section 5.5), the rate, and extent of DNT natural attenuation in the vadose zone soil was studied under simulated field conditions, and the results indicated that DNT is effectively degraded by indigenous bacteria and/or adsorbed in the shallow vadose zone soil.

Because there was no evidence to indicate that the Settling Ponds Area soil contamination was a source for groundwater contamination, the focus of subsequent investigation work was directed primarily at determining the extent and degree of shallow soil contamination. Figure 9 shows all site investigation soil boring locations from 1984 to 2006.

The primary contaminants of concern (COCs) in the Settling Ponds Area are 2,4-DNT, 2,6-DNT, nitroglycerin, chromium, and lead. Other compounds listed in the IFCR plan modification approved in 1995 included 2n-nitrodiphenylamine, carcinogenic polycyclic aromatic hydrocarbons (CPAHs or PAHs), diethyl phthalate, diphenylamine, nitrocellulose, aluminum, tin, and zinc. A complete list of the historical and current COCs is found on Table 1.

SpecPro compared the list of COCs to USEPA and state standards as the investigation phases of work progressed and several COCs were eliminated. Nitrocellulose does not have a state standard or a USEPA Regional Screening Level (RSL). None of the other compounds were reported in soil samples at concentrations above their respective residential RSLs, except for the carcinogenic PAHs benzo(a)anthracene and benzo(b)fluoranthene. It should be noted that these two carcinogenic PAHs were reported above the USEPA residential RSL in only one soil sample from one boring (SPB-91-01). Therefore, they are not considered pervasive enough to qualify as COCs. Similarly, arsenic was reported above the BAAAP background concentration at only one sample location (SPA-W-33); therefore, it is not considered a ubiquitous contaminant in the Settling Ponds Area.

To show contaminant distribution throughout the Settling Ponds Area, locations where each COC was detected are shown on Figures 10 through 14. Due to the high number of lead detections, Figure 13 shows only total lead concentrations exceeding a possible applicable standard (50 milligrams per kilograms (mg/kg) and above).

Generally, the data show that the soil and sediment along Final Creek are impacted primarily with organic compounds such as 2,4-DNT and nitroglycerin. Inorganics, such as chromium and lead, appear to be highest in Settling Ponds 1 and 2 and Spoils Disposal Areas I and II. Please note that sample duplicates are identified with a "Q" in the sample identifier. Some of these duplicate results were used on the figures when the duplicate concentration was higher than the corresponding sample.

As stated previously, the proposed and WDNR/USEPA-approved remedy in the mid-1990s for the Settling Ponds Area was in-situ stabilization/solidification. However, with a better understanding of the extent and degree of contamination, up-to-date toxicological information, established future land use plans, and the ability to derive site-specific remediation goals, the Army decided to conduct a study to re-evaluate remedial alternatives for feasibility.

7.0 CONCEPTUAL SITE MODEL

The CSM is the depiction of site conditions that relate to contaminant sources, environmental media, potential human and ecological receptors, and exposure pathways to those receptors. The CSM is based on the known presence and transport of COCs. The CSM diagram is graphically depicted on Figure 15. This diagram takes each environmental medium, considers the potential exposure pathways for each receptor, and based on current and future land uses and controls, determines the level of risk to that receptor. The criteria that make up the CSM are evaluated and discussed in further detail in the following subsections.

7.1 Sources

During production periods, water was drawn from Weigand's Bay of Lake Wisconsin at the River Pump House east of the main portion of the installation. The water was filtered, then stored in open reservoirs in the northern portion of the installation, and gravity-fed throughout the production areas of the installation via underground pipes. Industrial wastewater from the Old Acid Area, Nitrocellulose Lines, and Single-Base Lines underwent neutralization before it was piped to the industrial WWTP in the southwest corner of the installation. Sanitary wastewater from the installation and Bluffview area underwent primary treatment at the sanitary WWTP. Both of these effluents discharged to Final Creek and through the Settling Ponds before discharging to Lake Wisconsin at Gruber's Grove Bay.

Industrial wastewater from manufacturing operations in the east-central portion of the installation flowed into unlined ditches, drained towards the southern portion of the installation, through Settling Pond 3 and 4, and eventually into Gruber's Grove Bay. Since production ended, these ditches have received precipitation and meltwater. These production areas included the following: Old and New Nitroglycerin Areas, Rocket Paste, and the Rocket Roll and Press Houses. Investigations in these ditch areas revealed lead and propellant residues in some of the shallow soils.

In 1974, the WWTP was improved to include secondary treatment of sanitary wastewater. Propellant production ceased in 1975, decreasing the worker population and sanitary load. Treated sanitary effluent for the installation and the Bluffview community continues to discharge to Final Creek today. It evaporates and infiltrates the soil prior to reaching Settling Pond 1.

A groundwater treatment system, the IRM, was installed in 1990 to pump and treat contaminated groundwater from the PBG source area. The MIRM groundwater treatment system began operation in 1996 to capture water in the contaminant plume and minimize its migration past the installation boundary. Both continue to operate today. The treated effluent from the IRM/MIRM is discharged directly into Lake Wisconsin via an underground pipeline in compliance with the Wisconsin Pollutant Discharge Elimination System permit issued by the WDNR. Backwash water from these systems is discharged to Final Creek, as discussed previously, but is not considered an ongoing source of contamination based on analytical results.

7.2 Receptors

7.2.1 Human

The potential human pathways of exposure to the COCs are direct contact dermal exposure, ingestion, and inhalation. A detailed analysis of soil-related human exposure pathways is contained in Section 8.0, under the Risk Analysis subsection. Potential human pathways of exposure to COCs in groundwater and surface water are only considered in general terms as they pertain to the BAAAP as a whole, as there is no evidence to indicate that soil contamination in the Settling Ponds Area is impacting surface water or groundwater quality.

7.2.2 Ecological

Initially, ecological risks associated with the Settling Ponds Area were overestimated. The 1993 site investigation predicted this might be the case due to limited data collected for the initial assessment (less than 20 samples collected per area), and the conservative approach taken in the initial ecological risk assessment. More investigation and evaluation of the Settling Ponds was recommended in the subsequent feasibility study in 1994 (ABB-ES, 1993 and 1994).

The BERA (SpecPro, 2009) included a review of available data as well as research on health effects to plants, avian, and mammal species. Field studies included the following: bird survival evaluations, small mammal trapping, and chemical analysis of soil, sediment, surface water, and plant and animal tissues for nitroaromatics (DNTs) and metals. In addition, laboratory rodent sperm analysis was conducted by the United States Army Center for Health Promotion and Preventive Medicine to evaluate small mammal reproduction. The following findings are supported by multiple lines of evidence:

- Nitroaromatics are not bioaccumulating in plants, insects, or small mammals.
- Nitroaromatics and metals are bioaccumulating in earthworms at low levels.
- Metals are bioaccumulating in insects and small mammals at low levels.
- Small mammals feeding on soil, insects, earthworms, and plants have not been and would not be harmed by exposure to COCs.

- Small mammal diversity and population in the Settling Ponds Area are consistent with the background areas.

- Small mammal rodent sperm analysis showed no effects to reproduction.

- Large mammals, insectivorous birds, and carnivorous birds showed no health effects in modeling and field studies.

Although the small ponds located at the outfall of Final Creek in Settling Pond 1 are not considered large enough to provide habitat or drinking water for the majority of wildlife under consideration within the 70-mile area, comments provided on the draft BERA report (2006) expressed concern regarding this potential exposure pathway. Therefore, the Army directed SpecPro to collect a surface-water sample from one of the small ponds and analyze it for the COCs that were evaluated in the BERA. No organic COCs were detected in the surface water. The only metal COC detected was lead, but it was at a trace concentration (6.8 micrograms per liter (µg/l)) not far above its method detection limit (5.0 µg/l). For further details on the surface water sampling, please refer to Section 5.1.6 and Appendix C3 of the BERA. Based on these analytical results, the surface water within the small ponds is not considered a source of chemical exposure to wildlife in the site area.

The BERA concluded that wildlife, such as songbirds, raptors, and mammals that inhabit the Settling Ponds Area, is not at a significant risk from site-related COCs.

7.3 Pathways

7.3.1 Potential Pathways

Industrial demolition and restoration workers are subject to some level of risk when working on a hazardous waste site. Workers may experience accidental ingestion, exposure, or inhalation of contaminated soil. The Army currently manages this through a health and safety program that complies with all Occupational Safety and Health Administration, Department of Defense, and other state and federal health and safety requirements. More details are available in the BAAAP Health and Safety Plan (BTS, 2012), which is updated annually.

Contamination of shallow groundwater used for private drinking water supplies has been a potential pathway of exposure down-gradient of the installation. However, there is no evidence that any soil contamination within the Settling Ponds Area is a source of groundwater contamination. The current groundwater monitoring plan, with supplied bottled water and private well replacement occurring if a regulatory exceedance is reported and persists, limits possible ingestion exposure to contaminants in groundwater. The Army has proposed installation of a public water system for these residents that would completely eliminate this pathway. See the *Alternative Feasibility Study, Groundwater Remedial Strategy* (SpecPro/BTS, December 2011).

Institutional controls, such as groundwater use deed restrictions, can provide protection to potential human receptors. The Settling Ponds Area will serve as recreational land for Parcel M1 under National Park Service/WDNR control and as a public utility (WWTP) for Parcels T and T1 under Wisconsin Health and Human Services/Bluffview Sanitary District control. Deed restrictions are imposed at the time of land transfer which prohibit the installation of water supply wells and residential development on the parcels.

7.3.2 Non-Existent and Eliminated Pathways

Pathways that have been or will be eliminated through the use of engineering or institutional controls are addressed through land use controls, site fencing/signage, soil remediation, and deed restrictions. These controls have and will effectively prevent exposure of current and future users to potentially impacted soil. The final remedy chosen for the area will limit exposure for future recreational or industrial users. Residential use of the property is currently prohibited and will be prohibited in the future. These exposure pathways with their associated institutional controls are summarized in Table 2.

8.0 REGULATORY REQUIREMENTS

Under Section NR 722.09(2), Wis. Adm. Code, *Selection of a Remedial Action: Environmental Laws and Standards*; responsible parties shall select a remedial action that shall comply with all applicable state and federal public health and environmental laws and standards. All soil-related regulatory requirements are listed in Table 3, along with their applicability status. An "applicable" requirement is an enforceable standard set by either federal or state law. A "relevant and appropriate" requirement is not enforceable by law, but still may apply to the development of any remedial actions taken at the installation.

The initial site-wide screening of applicable or relevant and appropriate requirements was conducted during the *Final Remedial Investigation Report*/*Final Feasibility Study* (ABB-ES, 1993 and 1994). The following sections consider each federal and state regulation as it pertains to the soil remedial action at the Settling Ponds Area.

8.1 Federal Soil Cleanup Regulations

8.1.1 Resource Conservation and Recovery Act (RCRA)

The RCRA Act (42 United States Code 6901 et sequentes) was passed in 1976 and was substantially amended by the Hazardous and Solid Waste Amendments in 1984. RCRA required the BAAAP to obtain a RCRA Part B permit to continue to store containerized hazardous wastes on-site for more than 90 days or dispose of waste propellant by thermal treatment. The permit was issued jointly by the USEPA and WDNR in 1988 for BAAAP's hazardous waste storage facility. The RCRA permit required site investigations and/or corrective actions at identified Solid Waste Management Units at the BAAAP. The Settling Ponds Area was designated as one of the Solid Waste Management Units requiring corrective action. A memorandum of understanding (MOU) between the USEPA and WDNR in 2006 transferred authority to the WDNR to administer the site through the IFCR. When BAAAP closed the hazardous waste storage facility, the RCRA Part B permit was no longer required but the requirements of the IFCR continued.

All demolition, investigation, and remedial derived hazardous waste is currently managed under the state hazardous waste program and regulated under the Chapter NR 600 series, Wis. Adm. Code. Management practices include, but are not limited to the following: waste identification, sampling, and characterization; generator and transporter documentation and reporting; land disposal restrictions; and compliance with all additional health-related federal, state, and local laws.

8.1.2 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Superfund Amendments and Reauthorization Act

The CERCLA (42 United States Code 9601 et sequentes) was passed in 1980 and is commonly referred to as the "Superfund Act". CERCLA was substantially amended in 1986 under the Superfund Amendments and Reauthorization Act. CERCLA requires a response to any release of hazardous substances over a reportable quantity, whether current or historic. Under CERCLA, BAAAP was proposed as a National Priority List site, but not selected. The WDNR was designated by the USEPA as the lead agency. Thus, all CERCLA requirements are implemented under state statutes, yet are at least as protective as the federal requirements. A more detailed discussion of CERCLA and Superfund Amendments and Reauthorization Act is available in the *Final Remedial Investigation Report* (ABB-ES, 1993).

8.1.3 Emergency Planning and Community Right to Know Act

Emergency Planning and Community Right to Know Act requirements are known as Title III of Superfund Amendments and Reauthorization Act, promulgated in 1986. Under Section 301, State Emergency Response Commissions have been formed as well as Local Emergency Planning Committees. All appropriate reporting of storage and release of hazardous materials at BAAAP is carried out in accordance with applicable federal, state, and local Emergency Planning and Community Right to Know Act-related emergency planning laws.

8.2 Wisconsin Environmental Investigation and Remediation Regulations

Environmental investigation and remediation in Wisconsin are regulated under the Chapter NR 700 series, Wis. Adm. Code. Although the IFCR serves as the regulatory framework for cleanup at BAAAP, WDNR applies the Wisconsin Administrative Code through modifications to the IFCR. Several of these regulations are discussed further below. Chapter NR 700, Wis. Adm. Code, regulations are available at: http://legis.wisconsin.gov/rsb/code/nr/nr700.html.

8.2.1 General Requirements

Chapter NR 720, Wis. Adm. Code, provides uniform standards and procedures that allow for specific identification, investigation, and remediation of sites and facilities subject to Wisconsin environmental regulations. Definitions, confidentiality, site classification, submittals, and sample preservation and analysis are addressed. Chapter NR 720, Wis. Adm. Code, also incorporates by reference SW-846 Test Methods for Evaluating Solid Waste from USEPA Office of Solid Waste and Emergency Response (1986, Updated 1987 and 1990).

8.2.2 Public Information and Participation

Chapter NR 714, Wis. Adm. Code, outlines public participation and information requirements under the investigation and remediation regulations. The Army has supported public involvement through a Restoration Advisory Board, and encourages public and stakeholder comments on any environmental submittals sent to the WDNR for approval. Documents are available to the public through repositories located in the libraries of Sauk City and Prairie du Sac, Wisconsin, and at BAAAP.

8.2.3 Site Investigations

Site investigations conducted at the installation comply with the requirements set forth in Chapter NR 716, Wis. Adm. Code, *Site Investigations*. The Army adheres to all procedural and substantive requirements of this chapter. These include scoping and planning requirements, data quality objectives, field investigation sampling, and laboratory analysis procedures, as well as reporting and submittal requirements.

8.2.4 Wisconsin Soil Cleanup Standards

Wisconsin Soil Cleanup Standards are codified in Chapter NR 720, Wis. Adm. Code, where default values and methodology are codified for developing site-specific soil cleanup standards. General requirements have been met under Section NR 720.05, Wis. Adm. Code, as the Army has completed site investigations of the area, and an IFCR has been issued and revised by the WDNR.

Under Section NR 720.07, Wis. Adm. Code, *Procedures for establishing soil cleanup standards applicable to a site or facility*, the general requirements have been met through use of methodology in Section NR 720.19, Wis. Adm. Code, on a location, contaminant, and pathway-specific basis. In addition, residual soil contamination levels have been determined to not affect surface water, a sensitive environment, or concentrate in plants and the food chain (as shown in the BERA in 2009), in accordance with Section NR 720.07 (1)(c), Wis. Adm. Code.

Soil and groundwater investigations in the Settling Ponds Area have also shown that COCs are not a threat to groundwater due to the shallow nature of the contaminants, depth to groundwater, groundwater monitoring data, and studies on the leachability of contaminants in the soil. Thus, the Section NR 720.09, Wis. Adm. Code, *Determination of residual contaminant levels based on protection of groundwater*, development of residual contaminant levels is not necessary at the Settling Ponds Area.

Land use classification is discussed in Section NR 720.11, Wis. Adm. Code, *Determining residual contaminant levels based on protection of human health from direct contact with contaminated soils*. Non-industrial land use (the Wisconsin equivalent of residential land use) applies if all the following criteria are not met under Section NR 720.11(1)(b), Wis. Adm. Code, *Land use classification:* 1) the site is currently zoned for industrial use, 2) the site is expected to be used as industrial, and 3) more stringent residual soil contaminant levels are needed to protect human health. None of these requirements are met currently or are anticipated to be met in the future. However, Section NR 720.19, Wis. Adm. Code, *Procedures for determining soil cleanup standards specific to a site or facility*, allows for the use of alternative assumptions to calculate site-specific soil RCLs with WDNR review and approval. The previous chapter, Chapter 7.0, describes the methodology and assumptions used to derive the site-specific soil RCLs.

Under Section NR 720.11(5)(b), Wis. Adm. Code, *Exceptions*, background levels may be used as the remediation goal when concentrations of a contaminant are higher than the RCL or site-specific soil RCL and with WDNR approval. This is the case with two of the metals, arsenic and chromium.

8.2.5 Standards for Selecting Remedial Actions

Standards for development and selection of remedial action options are identified in Chapter NR 722, Wis. Adm. Code. All remedial actions, except those that are interim and/or petroleum related, must evaluate remedial options in accordance with Chapter NR 722, Wis. Adm. Code. Evaluation criteria set forth in this regulation are discussed in more detail in Chapter 11.0 Analysis of Alternatives, under Alternative Evaluation Criteria. Technical and economic factors weigh into this evaluation. Additional requirements are outlined for engineering and institutional controls as well as the requirements for site-specific evaluation documents.

8.3 USEPA Region 9 Regional Screening Levels

USEPA RSLs have been formulated as risk-based soil screening levels using USEPA Superfund guidance. Standardized equations using USEPA-developed toxicity data and exposure assumptions are used. The RSLs are protective of humans over a lifetime when used as screening levels, indicating further investigation may be warranted on a site-by-site basis to evaluate health risks to humans. The screening levels are not intended for use as regulatory cleanup standards, but may be used as preliminary remediation goals until site-specific cleanup standards are developed. Summary tables and more information on RSLs are available on the USEPA website at: http://www.epa.gov/region9/superfund/prg/.

8.4 Background Soil Concentrations

Background surface and subsurface soil samples were collected from areas not used for industrial operations and analyzed during site investigation activities in 1990. Near-surface soil samples were collected at one to two feet below ground surface. Sub-surface soil samples were collected during soil boring and monitoring well installation near the northwest boundary of the installation. Samples were analyzed for volatile organic compounds, base neutral acids, nitrosamines, DNTs, metals, and other indicator parameters.

Concentrations were compared to available regional soil background data (Shacklette and Boerngen, 1984, and Kabata-Pendias and Pendias, 1984). Surface soil sample results were comparable to regional data, with zinc concentrations above regional levels and sodium concentrations below regional levels. Subsurface soil sample results were comparable to regional data, with calcium and magnesium higher than the regional levels, and barium, potassium, and zinc concentrations lower than the regional level. Metals background concentrations are available in Tables 2-3, 2-4, and 2-5 of the *Final Remedial Investigation Report*.

Chromium RCL values are provided in Chapter NR 720, Wis. Adm. Code, Table 2 for trivalent and hexavalent chromium; however, there is no RCL for total chromium. Although chromium was never used at BAAAP in the manufacturing operations, the acids used at BAAAP could have dissolved this metal from machinery. These dissolved metals then could have been discharged via wastewater to the Settling Ponds Area. The background concentration for total chromium was derived by calculating the mean concentration of five soil samples (BSS-90-01 to BSS-90-05). The mean concentration was 35.5 mg/kg total chromium. (See Table 2-3 in the 1993 *Final Remedial Investigation Report*.)

Chapter NR 720, Wis. Adm. Code, Table 2 also provides non-industrial and industrial RCLs for arsenic. However, these concentrations are orders of magnitude below the BAAAP site-wide WDNR-accepted background level of 10 mg/kg. The WDNR has indicated that this arsenic background level is acceptable as the BAAAP background level (See Section 9).

These regulations pertaining to soil remediation and setting remediation goals for soil cleanup were all considered and applied as appropriate to determine remediation goals and remedial alternatives for the Settling Ponds Area.

9.0 REMEDIATION GOALS

The Army is proposing a revision to the previously established remediation goals for the Settling Ponds Area based on current state and federal regulatory standards, BAAAP-established background levels, and site-specific RCLs based on Section NR 720.19, Wis. Adm. Code, which provides the procedures for determining site-specific soil RCLs. The proposed remediation goals are protective of public health, safety, and welfare, and the environment, and have been developed using scientifically valid procedures, toxicological values, and alternative assumptions specifically approved by the WDNR per Section NR 720.19(5)(b), Wis. Adm. Code. These remediation goals have been and continue to be based on the direct contact exposure pathway. Protection of the groundwater pathway has not been considered a pathway of concern for the reasons discussed previously in Section 6.0.

On November 16, 2009, the Army submitted the *Draft Revised Remediation Goals Proposal for the Alternative Feasibility Study* for the Settling Ponds Area to the WDNR for review and comment. The document proposed a methodology for determining site-specific soil RCLs for the COCs in accordance with Section NR 720.19(5)(b), Wis. Adm. Code. After clarification and expansion of the original proposal by the Army, on August 11, 2010, the WDNR responded to the request with comments and stated, "… the WDNR has no objections to the assumptions of the Army's draft proposal nor to the proposed remediation goals". The following sections review the history of the previously established remediation goals, the screening process whereby the current COCs have been determined, and explain the methodology used in deriving the site-specific soil RCLs.

9.1 Previously Established Remediation Goals

In August 1994, BAAAP issued the *Final Feasibility Study*, which addressed 11 sites on the installation, including Final Creek, the Settling Ponds, and Spoils Disposal Areas. The document identified the Army's preferred final remedy for each site.

The remediation goals were based on information available at the time the *Final Feasibility Study* was written in 1994, such as laboratory detection limits, protection of human health per proposed Chapter NR 720, Wis. Adm. Code, protection of ecological receptors per toxicological information, and background concentrations. The WDNR approved the Army's proposed remedy for the Settling Ponds Area, modified in-situ soil stabilization with a soil cover at an estimated cost of $67 million.

In June 1995, the WDNR issued a Plan Modification to the September 14, 1987, *In-Field Conditions Report* (IFCR) under authority of the Wisconsin Environmental Response and Repair Regulations and Wisconsin solid/hazardous waste regulations. The WDNR Plan Modification adopted the remediation goals and preferred final remedies set forth in the *Final Feasibility Study*.

Similarly, in January 1996, the USEPA Region 5, under authority of the RCRA, issued a modification to BAAAP's RCRA Part B permit. This permit modification also adopted the same preferred remedies, including in-situ stabilization/solidification as the proposed corrective measure for the soil and sediment in the Settling Ponds, Spoils Disposal Areas, and Final Creek. The 1996 permit modification's soil remediation goals for Final Creek, Settling Ponds, and Spoils Disposal Areas are summarized in Table 1.

9.2 Screening of Contaminants of Concern

As stated in Section 6.0 of this document, the primary COCs in the Settling Ponds Area are 2,4-DNT, 2,6-DNT, nitroglycerin, chromium, and lead. Of the six possible DNT isomers, only 2,4-DNT and 2,6-DNT are considered as they are the only DNT isomers that have regulatory standards for soil. Although groundwater standards exist for the other isomers, they have not been detected in the groundwater in the Settling Ponds Area wells that are outside the PBG plume.

Other compounds listed in the *Final Feasibility Study*, IFCR, and Plan Modification included 2n-nitrodiphenylamine, carcinogenic PAHs, diethyl phthalate, diphenylamine, nitrocellulose, aluminum, tin, and zinc. Nitrocellulose does not have a state standard or USEPA RSL and none of the other compounds were reported at concentrations above their respective RSLs except for the carcinogenic PAHs, benzo(a)anthracene, and benzo(b)fluoranthene. As stated previously, they are not considered pervasive enough to qualify as COCs.

Based on a review of the site investigation analytical results, two additional parameters, total arsenic and total chromium, were added to the list of COCs as concentrations in some samples exceeded previously established background levels for BAAAP. Further discussion on how background soil concentrations were determined is found in Section 9.5.

All the parameters listed in the *Final Feasibility Study*, IFCR, and Plan Modification, plus arsenic and chromium, are provided on Table 1 along with the current alternative regulatory standards. The maximum concentration found in the Settling Ponds Area for each compound is compared to the *Final Feasibility Study*, IFCR, and Plan Modification and the current regulatory standards used at BAAAP to evaluate whether the COCs in the *Final Feasibility Study*, IFCR, and Plan Modification are still relevant.

Many of the COCs previously established are no longer considered to be of concern based on current USEPA RSLs. Although concentrations of 2,6-DNT do not exceed the industrial RSL, this compound is found throughout the Settling Ponds Area and was included as a COC due to the "mixture" effect with 2,4-DNT. Further information on USEPA RSLs and how the background concentrations were derived is provided in Sections 9.4 and 9.5, respectively.

9.3 Risk Analysis

In order to determine site-specific soil RCLs per Section NR 722.11, Wis. Adm. Code, a risk analysis must be performed that takes into consideration several factors such as land use, exposure frequency, cancer risk, and ingestion. These criteria are evaluated and input parameters are developed based on these factors to determine risk to receptors.

9.3.1 Land Use

At the time the *Final Feasibility Study* was written in 1994, the Army's intention for future land use was continued government ownership as a propellant manufacturing facility in "standby" or active status. Since that time, the Army has deemed the installation "excess" to its needs, which means the Army no longer has any use for the installation. The Army has been in the process of decommissioning the BAAAP and transferring parcels to other government agencies over the past few years.

The Army found it convenient to divide the 7,275 acres into parcels to more easily manage demolition, restoration, and transfer activities. As a parcel is certified ready, it is made available for transfer to the new land managers. The General Services Administration (GSA) serves as the real estate agent for these transfers. Consistent with GSA's disposal authority under the 49 Act, as amended, the purpose of the Proposed Action is to effectively manage Federal government real property assets through disposition of excess and surplus property. The need for the Proposed Action is to (1) minimize Federal protection and maintenance expenses by eliminating property from the Federal inventory that no longer serves a mission need; (2) ensure that real property is returned to productive use, thereby supporting important State and local public benefit programs and generating tax revenues; and (3) avoid waste and protect real property value, including cultural, environmental, and historical values, through careful and efficient disposition.

In the March 2003 GSA *Final Environmental Impact Statement* by The Louis Berger Group, Inc., land use designations for the most likely scenario for BAAAP reuse take into consideration the recommendations from the 1998 *Preliminary Highest and Best Use Analysis of BAAAP* performed by Daylor Consulting Group, Inc. The objective of the study was to identify and evaluate the issues affecting the disposition of Badger AAP. It should be noted, as defined by the Federal Property Management Regulations, Subpart 101-47.49, the highest and best use is "the most likely use to which a property can be put, so as to produce the highest monetary return from the property, promote its maximum value, or serve a public or institutional purpose".

Three parcels encompass the Settling Ponds Area: M1, T, and T1. Parcel M1 contains Settling Ponds 2 and 3, and all five Spoils Disposal Areas. The GSA plans to transfer this parcel to the WDNR through the National Park Service for use by the WDNR as the proposed Sauk Prairie Recreation Area. Parcels T and T1 contain Final Creek and Settling Pond 1. The GSA intends to transfer these parcels to the Bluffview Sanitary District under the auspices of the Wisconsin Department of Health Services, as they contain the WWTP servicing the Bluffview community directly west of BAAAP and land for possible future expansion.

Currently, the BAAAP land is zoned "governmental-agricultural conservation" by the Town of Merrimac and "exclusive agriculture" by the Town of Sumpter. However, during years of operation, the BAAAP as a federal facility would have been considered an industrial facility exempt from local zoning. Deed restrictions prohibit residential use after Parcels M1, T, and T1 are transferred.

The current and future land use in Parcels T and T1 would be most similar to industrial because they contain a wastewater treatment facility and a groundwater treatment system. Potential exposure rates to impacted soil would be similar to a worker at an industrial facility.

The current and future land use in Parcel M1 as a recreational area is anticipated to be somewhat similar because human contact with soil is of a short duration (a few hours) and only on occasion per individual. The specific recreational uses of the Settling Ponds Area as part of the proposed Sauk Prairie Recreation area are yet to be determined by the WDNR. Currently, the only people allowed routine access to this area are employees contracted by the Army conducting demolition and environmental restoration work. Other interest groups (prairie restoration, bird monitoring) are also allowed access by the Army. Therefore, the exposure rate for this type of land use would be even less than an industrial setting.

Under existing regulations, current and future land use must be considered in order to determine the appropriate potential human exposure risk. Chapter NR 720, Wis. Adm. Code, identifies two types of land uses, industrial and non-industrial. Section NR 720.11(1)(b), Wis. Adm. Code, states that "Responsible parties shall classify the land use of a site or facility as non-industrial unless certain criteria are met". These criteria are not met currently nor anticipated in the future at the Settling Ponds Area. However, Section NR 720.19, Wis. Adm. Code, allows for site-specific derivation of cleanup standards with assumptions approved by the WDNR in writing. Under this method, classification of the Settling Ponds as either industrial or non-industrial is not required, but potential exposure rate based on land use must be determined.

One factor to consider when evaluating exposure rates in these areas is that the ground is usually frozen and snow-covered for approximately four months per year from December through March, thus reducing the potential for direct contact with the impacted soil. In addition, Devil's Lake State Park, which would manage part of this area after transfer, has limited hours of access for the public except for designated camping areas.

9.3.2 Exposure Frequency

As previously stated, the current and future land use for Parcels T and T1 is similar to an industrial setting. In accordance with Chapter NR 720, Wis. Adm. Code, the WDNR industrial exposure frequency value is 250 days per year. The 250 days per year is based on five working days out of a seven-day week, or 71 percent of the residential value of 350 days. Although there are no known tasks that would require a WWTP worker to enter Final Creek or Settling Pond 1, an estimate of one third of a WWTP worker's time was used. Based on this assumption, the number of days is reduced from 250 to 83 days per year (33% of 250).

The future land use for Parcel M1 will be recreational as part of Devil's Lake State Park. Devil's Lake State Park is open seventeen hours per day. Although many exposure scenarios could be envisioned in Parcel M1, the most likely would be an individual or family hiking through the area. The estimated average amount of time that a recreator(s) would spend in any one area of the park is estimated at 5.0 hours (USEPA Exposure Factors Handbook recreation values fall in the range of 3 to 4 hours and limited state park data suggests 4 to 6 hours). Based on information provided on the Risk Assessment Information System website (http://rais.ornl.gov/ accessed on 31 May 2012) the default value for a recreator is 75 days per year.

However, considering the ground is snow-covered and frozen four months out of the year, limiting exposure to soil to eight months during a year (or 66% of a year), an adjusted maximum exposure frequency would be equivalent to 55 days per year (66% of 83) for Parcels T and T1, and 50 days per year (66% of 75) for Parcel M1. For purposes of calculating a site-specific exposure frequency, the more conservative value of 55 days per year is utilized.

9.3.3 Cancer Risk

The WDNR has established a cancer risk level of 1 in 1,000,000 ($1x10^{-6}$) as an appropriate cancer risk level in Chapter NR 720, Wis. Adm. Code. In addition, Section NR 720.11(3), Wis. Adm. Code, requires that the cumulative excess cancer risk may not exceed 1 in 100,000 ($1x10^{-5}$) and the hazard index for non-carcinogens may not exceed one for the COCs at a site or facility.

9.3.4 Ingestion Factor

The ingestion factor is a value used in calculating site-specific RCLs that is expressed in milligrams per day of soil that could potentially adhere to human hands and be ingested by hand-to-mouth transfer. For an adult, this value is typically in the range of 10 to 50 milligrams per day, based on a low exposure type of activity (recreational). In scenarios where there is greater possibility of exposure to the soil (e.g., agricultural use/farmer, construction worker), this value would increase to a range of 100 to 200 milligrams per day.

The USEPA default value for age-adjusted soil ingestion factor is 114 milligrams per year per kilograms per day. This default value is based on a 24-hour period. The total time a recreator would be in the area of Parcel M1 would be less than 24 hours. Therefore, the default age-adjusted soil ingestion factor and adult/child soil intake rates are changed to reflect a more suitable 5.0 hours per day exposure for calculating a site-specific soil RCL. Based on this modification, the soil ingestion factor is 23.77 milligrams per year per kilograms per day, the adult soil intake rate is 20.8 milligrams per day, and the child soil intake rate is 41.6 milligrams per day.

It should be noted that the Settling Ponds Area is currently thickly vegetated with prairie grasses, trees, and shrubs. The root systems of these plants bind the soil particles beneath the surface and prevents them from becoming airborne or exposed. The above-ground vegetation mass itself decreases wind velocity at the soil surface, lessening the likelihood of airborne particles. Areas where soil is disturbed quickly revegetates naturally.

9.4 Proposed Soil Remediation Goals

The COCs listed in the IFCR were originally developed in 1993. These were screened based on current regulatory standards and background concentrations listed in Table 1. These COCs were further screened in Table 4 with several of the compounds disqualified as COCs.

An evaluation of the Final Creek, Settling Ponds, and Spoils Disposal Areas soil data indicates the cleanup standard for 2,4-DNT is the most stringent of all the COCs. The remediation goal for 2,4-DNT established previously in the IFCR was based on the laboratory detection limit for 2,4-DNT in 1993, and is, therefore, quite low. The rationale for basing the 2,4-DNT remediation goal at the detection limit is not fully explained in the *Final Feasibility Study* other than to indicate that it is between the protection of groundwater and human health values; therefore, the detection limit was used as an apparent default.

There is also a recently established 2,4- and 2,6-DNT mixture component that merits evaluation. This DNT mixture aspect was not considered at the time of the *Final Feasibility Study*/IFCR as toxicological information was not available at the time on the combined effects of the two isomers. Although USEPA RSL values are available for the individual isomers of 2,4-DNT and 2,6-DNT, the RSL for the 2,4/2,6-DNT mixture is more stringent than the levels for the individual isomers. Therefore, site-specific remediation goals for 2,4-DNT and 2,4/2,6-DNT mixture were calculated.

It should be noted that the USEPA RSLs are screening levels that are used when a site is initially investigated to determine if potentially significant levels of contamination are present to warrant further investigation such as a remedial investigation/feasibility study. In order to set chemical-specific RSLs in a site-specific context, information must be evaluated on the chemicals that are present on-site, the specific contaminated media, land-use assumptions, and the exposure assumptions behind pathways of individual exposure (direct contact).

The USEPA RSLs for Chemical Contaminants at Superfund Sites screening level/preliminary remediation goal website (http://www.epa.gov/region9/superfund/prg/ accessed on 31 May 2012) was used for determining the direct contact site-specific RCL based on site-specific conditions. The website contains a screening level calculator that allows the site-specific factors to be input into the calculation.

Using a recreator scenario, a cancer risk factor of one in 1,000,000 (10^{-6}), and site-specific values that include: an adult soil intake rate of 20.8 milligrams per day (default adjusted to account for a conservative exposure estimate of 5 hours per day); a child soil intake rate of 41.6 milligrams per day (default adjusted to account for a conservative exposure estimate of 5 hours per day); and an exposure frequency of 55 days per year (as calculated in Section 9.3.2), the direct contact site-specific soil RCL for 2,4/2,6-DNT mixture would be 11.4 mg/kg, and the site-specific soil RCL for 2,4-DNT would be 24.7 mg/kg. The summary of the soil equation input data and equation results are included in Appendix A.

For the other COCs at the Settling Ponds Area, the remediation goals, which are listed in Table 4, would be the industrial RCL (total lead at 500 mg/kg), industrial RSL (nitroglycerin at 62 mg/kg and 2,6-DNT at 620 mg/kg), or the background concentration (total chromium at 35.5 mg/kg). These revised remediation goals are consistent with the findings of the risk analysis and with current cleanup objectives applied site-wide at BAAAP and state-wide. Although site-specific soil RCLs could have been calculated for other COCs using the recreator values, the concentrations at the site did not warrant this level of effort; therefore, adopting the industrial values is more appropriate and provides an even more stringent level of protection.

On November 16, 2009, the Army submitted the *Draft Revised Remediation Goals Proposal for the Alternative Feasibility Study* for the Settling Ponds Area to the WDNR for review and comment. The document proposed a methodology for determining site-specific soil RCLs for the COCs in accordance with Section NR 720.19(5)(b), Wis. Adm. Code. After clarification and expansion of the original proposal by the Army, on August 11, 2010, the WDNR responded to the request with comments and stated, "… the WDNR has no objections to the assumptions of the Army's draft proposal nor to the proposed remediation goals".

10.0 DEVELOPMENT OF REMEDIAL ALTERNATIVES

This section discusses remedial objectives and regulatory requirements at the Settling Ponds Area.

10.1 Remedial Objectives

Remedial objectives were initially established as part of the site-wide *Final Remedial Investigation Report*/*Final Feasibility Study* in 1993 and 1994 (ABB-ES, 1993 and 1994). A summary of initial remedial objectives for soil related to the Settling Ponds Area is as follows:

- Prevent the migration of contaminated soil by soil erosion.
- Prevent the exposure of terrestrial receptors to surface soil in the Settling Ponds Area containing concentrations of COCs that pose unacceptable risk.
- Prevent the exposure of human receptors to soil at the Settling Ponds Area containing concentrations of COCs that pose unacceptable risk.

- Prevent concentrations of COCs in soil at the Settling Ponds which exceed cleanup standards for protection of groundwater (developed from the proposed Chapter NR 720, Wis. Adm. Code, 1994) from degrading groundwater quality in excess of Chapter NR 140, Wis. Adm. Code, Preventive Action Limits.

These remedial objectives require re-evaluation, considering the very limited knowledge of site conditions at the time of the original *Final Remedial Investigation Report*/*Final Feasibility Study*. Subsequent site investigation work has been extensive within the Settling Ponds Area.

The following points correspond to the remedial objectives above and provide justification for why some of these are no longer valid.

- Contaminated soil migration via soil erosion is not considered a significant transport mechanism for COCs at the Settling Ponds Area. The area is low lying, and thickly vegetated with grasses, trees, and shrubs with mature root systems. Even during periods of heavy rain or snow melt, the surface water infiltrates the ground or evaporates in place. Otherwise, flow in Final Creek only occurs when water is discharged from the IRM/MIRM treatment system or the WWTP, and usually infiltrates into the ground before reaching Settling Pond 1.

- The BERA evaluated the risk to fauna at the Settling Ponds Area and determined that the COCs do not present an exposure or migration pathway of concern, nor is there evidence that residual soil contamination at the site is concentrating through plant uptake and adversely affecting the food chain.

- The risk to human receptors through direct contact and incidental ingestion are still valid pathways of concern and will be addressed in the revised remedial objective.

- Concentrations of COCs in soil have been evaluated at the Settling Ponds Area and have minimal, if any effect on groundwater quality. Although no navigable surface waters exist at the Settling Ponds Area, chemical-specific surface water and groundwater standards are applicable to the BAAAP in general.

The current remedial objectives can be summarized in one statement:

> Address shallow soil contamination in the Settling Ponds Area that exceeds background, regulatory, and site-specific, risk-based RCLs to minimize the risk to ecological and human receptors as well as the risk to surface and groundwater quality.

10.2 Remedial Alternatives

Three alternatives are considered in this Alternative Feasibility Study. These alternatives were selected based on the following:

- There is a federal requirement for alternative feasibility studies that at least one option be a “no action” alternative.
- The selected remedy in the previous *Final Feasibility Study* was modified in-situ soil stabilization/solidification and soil cover.
- The remedial technique employed at other portions of BAAAP where non-hazardous soil contamination has been discovered has been primarily excavation and on-site disposal.

Each alternative is described below with an estimated or actual time to complete.

10.2.1 Alternative 1 – No Action

A no action alternative would rely completely on natural attenuation to degrade contaminants in the soil over time. This alternative serves as a baseline for alternative comparisons. Time to complete: immediate

10.2.2 Alternative 2 – Solidification and Soil Cover

This alternative would involve the mixing of shallow soil with a cementing agent to bind the particles of soil together, thus binding contaminants within the matrix and covering the area with a layer of soil to prevent direct contact. A soil cover without solidification could be considered as a variation on this alternative. Time to complete: one to two years

10.2.3 Alternative 3 – Excavation and On-Site Disposal

This alternative would include the excavation of areas where contamination is found to be above remediation goals and disposal of impacted soil in the on-site construction and demolition waste landfill. Soil would be characterized prior to removal to ensure that only non-hazardous soil is disposed on-site in a state-permitted demolition landfill. Any soils identified as hazardous waste would be properly disposed off-site. Soil confirmation samples would be collected to confirm the removal of impacted soil. This work began in 2009 and was completed in 2012.

11.0 ANALYSIS OF ALTERNATIVES

The following subsections describe the conceptual design and criteria for detailed analysis of each alternative. Each alternative is evaluated against the same criteria established by the WDNR in accordance with Chapter NR 722, Wis. Adm. Code, *Standards for Selecting Remedial Actions*, which is derived from the National Contingency Plan and CERCLA.

Relative performance of each alternative is evaluated using the following nine criteria:

1. Overall protection of human health and the environment
   This shall consider human as well as ecological receptors.

2. Compliance with applicable regulations
   This shall include federal and state regulations.

3. Long-term effectiveness and permanence
   This shall consider the risks remaining after completion of the remedial action and the adequacy and suitability of controls, if any, that are used to manage exposure to contaminated soil remaining at the site.

4. Reduction of toxicity, mobility, and volume through treatment
   This shall include the expected reduction in toxicity, mobility, and volume measured as a percentage or order of magnitude, and the type and quantity of treatment residuals that will remain following treatment.

5. Short-term effectiveness
   This shall include protection of the community during the remedial action, protection of workers during remedial action, environmental impacts to natural resources, and time until remedial response objectives are achieved.

6. Implementability
   This shall consider feasibility, including: construction and operation; reliability of technology; ease of undertaking additional remediation, if necessary; and monitoring considerations, addressing the ability to adequately monitor the effectiveness of the remedy and the risks, should monitoring be insufficient to detect a system failure.

7. Cost
   This shall consider source removal costs; capital costs, both direct and indirect; annual operation and maintenance costs; and present worth analysis (or net present value) of costs.

8. State Acceptance
   This shall consider the issues and concerns that the state may have regarding each alternative. This criterion will be evaluated throughout the development, screening, and evaluation of alternatives based on comments and input received from the WDNR.

9. Community Acceptance
   This involves an evaluation of issues and concerns the public may have regarding each alternative. This criterion will be evaluated throughout the development, screening, and evaluation of alternatives based on comments and input received from the Restoration Advisory Board and public.

11.1 Alternative 1 – No Action

11.1.1 Protectiveness of Human Health and Environment

This alternative would be the least protective of human health as it would not address the soil that is present at levels above direct contact values. Institutional controls would be the only means of limiting human contact with the soil. This option would rely completely upon natural attenuation to reduce contaminant mass and minimize the effect on the environment.

11.1.2 Compliance with Applicable Regulations

This alternative would not comply with Section 292.11(3), Wisconsin Statutes, requirements to restore the environment to the extent practicable and minimize the harmful effects of the discharge to the air, land, and waters of the state. Neither would this alternative meet the requirements of the remedial objective.

11.1.3 Long-Term Effectiveness and Permanence

It is unknown how effective the institutional controls will be in the future at preventing residential development and other deed-prohibited land uses.

11.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

This alternative relies completely on natural attenuation to reduce contaminant concentrations over time. Certain contaminants have decreased over the period when samples have been taken, but no timetable can be developed for that natural attenuation, and not all compounds of concern break down over time. No active method to reduce toxicity, mobility, or volume of contaminants would be implemented.

11.1.5 Short-Term Effectiveness

Since this alternative does not include a remedial action, protection of the community, workers, environment, and time until remedial response objectives are achieved are not applicable.

11.1.6 Implementability

This alternative would be the easiest to implement as no active remediation is involved.

11.1.7 Cost

This alternative would be the least costly to implement as no active remediation is involved. The present worth costs were estimated for Alternative 1 as follows:

Capital Cost	$0
Post-Treatment Monitoring	$0
Monitoring and Closeout Plan/Report	$25,000
Total present worth	**$25,000**

11.1.8 State Acceptance

This alternative is the least protective of human health and the environment and would not be compliant with regulations requiring cleanup.

11.1.9 Community Acceptance

This alternative is perceived to be the least protective of human health and the environment, based on comments received to date at the Restoration Advisory Board meetings.

11.2 Alternative 2 – Solidification and Soil Cover

11.2.1 Protectiveness of Human Health and Environment

This alternative would not only prevent direct contact with contaminated soil, but would also solidify the contaminants within the soil to prevent them from potentially migrating to groundwater.

11.2.2 Compliance with Applicable Regulations

This alternative would be compliant with state and federal regulations by eliminating the direct contact and groundwater exposure pathways. In fact, it is overly protective as it has been determined that the shallow residual contamination in the Settling Ponds Area does not pose a significant threat to groundwater.

11.2.3 Long-Term Effectiveness and Permanence

The long-term effectiveness of this alternative is unknown. Heavy precipitation events prior to establishment of vegetative stabilization could saturate and erode the soil cover, exposing the solidified layer. Furthermore, the long-term effectiveness of the soil cover will depend on compliance with the institutional controls and periodic monitoring, which will limit land use, specifically excavating or other erosive activities, such as trail establishment in the area. Periodic maintenance will be required to ensure the integrity of the soil cover. Solidification is believed to be a permanent, irreversible treatment method for the soil.

11.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

This alternative limits mobility of contaminants; however, it does not reduce the toxicity or volume of the contamination.

11.2.5 Short-Term Effectiveness

This alternative would provide for protection of the community during the remedial action via dust suppression methods and protection of workers during remedial action with Occupational Safety and Health Administration (OSHA) Level D personal protective equipment. Natural resources would be safeguarded with silt-fencing and other storm water pollution prevention methods. The time until remedial objectives are achieved would be within two years.

11.2.6 Implementability

This alternative is the most difficult to implement as it must cover an expansive area, approximately 70 acres in size.

11.2.7 Cost

This alternative would be the most expensive to implement as it involves treatment via mechanical mixing of the soil with a binding agent, grading, transporting, and evenly distributing a soil cover over the entire area. Maintenance costs are based on the first five years only.
The present worth costs are estimated for Alternative 2 as follows:

Solidification/Stabilization	$70,732,394
Professional Labor Management	$7,073,239
Soil Cover Installation	$10,216,245
Monitoring and Cap Maintenance	$20,000
Site Closeout Documentation	$55,000
Total present worth	**$88,096,878**

11.2.8 State Acceptance

The state would likely accept this remedy as it would be the most protective of human health. However, there could be resistance to this alternative due to the long-term effectiveness issues expressed above. This criterion will continue to be evaluated based on comments and input received from the WDNR.

11.2.9 Community Acceptance

There could be public resistance to this alternative due to the long-term effectiveness issues expressed above. This criterion will continue to be evaluated based on comments and input received from the Restoration Advisory Board and public.

11.3 Alternative 3 – Excavation and On-Site Disposal

11.3.1 Protectiveness of Human Health and Environment

This alternative would address the known areas where soil is impacted above the remediation goals. Soil that contains levels of contaminants above the direct contact exposure value would be removed. Due to the random nature of the contaminant distribution, impacted soil above the remediation goals could remain following remediation in areas not previously investigated/remediated.

11.3.2 Compliance with Applicable Regulations

Alternative 3 would comply with state and federal regulations and meet the requirements of the remedial objectives. The soil that is impacted with elevated levels of 2,4-DNT and lead would need to be adequately characterized prior to removal to ensure that characteristically hazardous soil is not being disposed in the on-site landfill. Hazardous soil will be treated to below hazardous levels or disposed off-site.

11.3.3 Long-Term Effectiveness and Permanence

The long-term effectiveness of this remedial alternative would be indefinite and permanent as the areas of known contamination would be removed.

11.3.4 Reduction of Toxicity, Mobility, or Volume through Treatment

The volume of impacted soil would be significantly reduced by removal and on-site disposal in the landfill. This reduction in volume will minimize the risk of contaminants mobilizing to groundwater and the potential of exposure to toxins by terrestrial organisms.

11.3.5 Short-Term Effectiveness

This alternative would provide for protection of the community during the remedial action via dust suppression methods and protection of workers during remedial action with OSHA Level D personal protective equipment. Natural resources would be safeguarded with silt-fencing and other storm water pollution prevention methods. The time until remedial response objectives are achieved would be within two years.

11.3.6 Implementability

This remedial alternative would be relatively easy to implement. The soil could be used at the landfill for daily cover as a beneficial reuse.

11.3.7 Cost

The present worth costs were estimated for Alternative 3 as follows:

Excavation and Disposal	$1,003,00
Backfilling, Grading, and Restoration	$100,000
Monitoring and Closeout Plan/Report	$35,000
Total present worth	**$1,138,000**

11.3.8 State Acceptance

This alternative complies with state and federal regulations, is protective of human health, and minimizes the harmful effects to the environment. However, this criterion will continue be evaluated based on comments and input received from the WDNR.

11.3.9 Community Acceptance

This alternative removes the contaminated soil that exceeds the direct contact levels. However, this criterion will continue to be evaluated based on comments and input received from the public.

12.0 COMPARISON OF ALTERNATIVES

A comparative analysis was conducted to evaluate the relative performance of each alternative based on each criterion. The presentation of the comparative analysis refers to each alternative by its number. The alternatives are: Alternative 1 – No Action, Alternative 2 – Solidification and Soil Cover, and Alternative 3 – Excavation and On-Site Disposal.

12.1 Protectiveness of Human Health and Environment

Alternatives 2 and 3 would be protective of human health as they involve an active remedy. However, the long-term effectiveness and integrity of the soil cover with Alternative 2 is questionable due to erosion concerns. In addition, a soil cover maintenance plan may be required by the WDNR which could include long-term inspection and maintenance. Alternative 1 would be the least protective as it relies completely upon natural attenuation and institutional controls to reduce the contaminant mass and limit direct contact with humans.

12.2 Compliance with Regulations

Alternatives 2 and 3 would be compliant with state and federal regulations as they involve an active remedy to address soil contamination. Alternative 1 does not involve any active remediation and relies solely on natural attenuation and institutional controls to reduce contaminant mass and protect human health. The WDNR is likely to consider these mechanisms insufficient; therefore, Alternative 1 is primarily presented for comparison purposes.

12.3 Long-Term Effectiveness

Since Alternative 1 relies solely on natural attenuation to reduce the contaminant mass and land use controls to limit human direct contact, the long-term effectiveness of this remedy is directly related to those conditions. Although solidification of the soil as proposed in Alternative 2 would bind contaminants in the soil, the long-term effectiveness of the overlying soil cover is susceptible to erosion due to the impermeability of the underlying solidified soil. This could become problematic in the long-term and require perpetual maintenance. The majority of the contaminant mass would be removed from the area with Alternative 3; therefore, there would be no concerns regarding maintaining a soil cover over the affected soil. Alternative 3 would be a permanent and effective long-term solution.

12.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 2 would result in the reduction in mobility of contaminants and limit the toxic effect in the shallow soil via solidification; however, this remedial method does not effectively reduce the volume of the contaminants. Alternative 3 would effectively reduce the volume, toxicity and mobility of the contaminants by removal of the areas of greatest contaminant mass. With Alternative 1, toxicity and volume of contaminants would be reduced slowly over time through natural attenuation; however, there would be nothing to reduce the mobility of the contaminants.

12.5 Short-Term Effectiveness

Alternatives 2 and 3 could have an effect on the surrounding community from fugitive dust created during soil tilling and excavation during dry periods. Dust on roadways at BAAAP is minimized by application of water. Precautions would be taken to protect workers from fugitive dust during the remedial action as with any construction site. There would be no short-term effects with Alternative 1 as this option does not involve disturbing the ground surface.

12.6 Implementability

Alternative 1 would be the easiest to implement as it does not involve any active remedial measure. Alternative 3 would be the next easiest to implement due to the fact that only certain areas of known contamination are targeted for remediation within the Settling Ponds Area, as opposed to the “broad brush” approach with Alternative 2. Alternative 2 would be the most difficult to implement as it involves treatment over a large area (70 acres), grading, and covering the area with at least two feet of fill material. Placing this cover in the area designated for the WWTP would limit future expansion of the facility, unless restoration of the soil cover was part of the expansion effort.

12.7 Cost

Alternative 1 would be the least costly remedial option; however, it does not meet the requirements of the remedial objectives. Alternative 2 would be the most costly due to the large treatment area, mechanical mixing of the soil, grading, and soil cover placement. A soil cover only option would reduce the overall cost of this alternative, but it is still significantly more expensive than Alternative 3. Alternative 3 achieves the remedial objectives at a reasonable cost and within a reasonable timeframe. Appendix B contains a summary of costs for the three alternatives.

12.8 State Acceptance

The WDNR would likely accept either Alternative 2 or 3 as both of these remedies would be compliant with state and federal regulations to protect human health and restore the environment to the extent practicable. As stated above, Alternative 1 is provided and considered for comparison purposes as it does not meet the remedial objectives nor does it comply with state regulations. Therefore, the WDNR would not accept Alternative 1 as the selected remedy for this site.

12.9 Community Acceptance

All three alternatives would leave the Settling Ponds Area in a condition that is compatible with the BAAAP Reuse Plan because the area would be a natural landscape for recreational use (Parcel M1) and public utility use (Parcel T1). Both Alternatives 2 and 3 would be protective of the future users of the WDNR property, and thus, most likely to be acceptable to the community members. Stabilization with a soil cover would be a hindrance to the Bluffview Sanitary District property.

13.0 REMEDY SELECTION

Considering all the evaluation criteria and comparative aspects associated with the three proposed alternatives, Alternative 3 – Excavation and On-site Disposal, is selected as the preferred final remedy for the Settling Ponds Area of the BAAAP. Alternative 3 meets the remedial objective and regulatory requirements because it is protective of human health and the environment, involves a reasonable implementation and restoration time frame, is feasible, and is compatible with future land uses of the BAAAP.

14.0 REFERENCES

ABB Environmental Services, Inc., 1993. *Final Remedial Investigation Report, Badger Army Ammunition Plant.* Prepared for United States Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, Maryland. April.

ABB Environmental Services, Inc., 1994. *Final Feasibility Study, Badger Army Ammunition Plant.* Prepared for United States Army Environmental Center, Aberdeen Proving Ground, Maryland. August.

Attig, J.W., 1990. *Geology of the Badger Army Ammunition Plant Area.* Wisconsin Geological and Natural History Survey.

Clayton, L. and Attig, J.W., 1990. *Geology of Sauk County, Wisconsin.* Wisconsin Geological and Natural History Survey, Information Circular 67.

Department of the Army, 2009. *Letter Report, Subject: Draft Revised Remediation Goals Proposal for the Alternative Feasibility Study, Final Creek, Settling Ponds, and Spoils Disposal Areas, Badger Army Ammunition Plant.* November 16.

Goc, Michael J., 2002. *Powder, People and Place*

Olin Corporation, 2002. *Development of Site-Specific Soil Residual Contaminant Levels, Settling Ponds & Spoils Disposal Areas, Badger Army Ammunition Plant.* April 10.

Olin Corporation, 2001. *Field Sampling Report, Settling Ponds & Spoils Disposal Areas, Badger Army Ammunition Plant.* May 21.

Spain, J.C. and Hughes, J.B., et al., 2005. *Final Report on Residual Dinitrotoluenes in Settling Ponds and Spoils Disposal Area Soils at Badger Army Ammunition Plant: Microcosm and Soil Column Studies.* June 1.

Badger Technical Services, LLC, 2012. *Health and Safety Plan Prepared for the Badger Army Ammunition Plant.* March.

SpecPro, Inc. and Exponent, Inc., 2009. *Baseline Ecological Risk Assessment, Settling Ponds and Spoils Disposal Areas Site, Badger Army Ammunition Plant, Baraboo, Wisconsin.* October.

Tsai, S.Y., et al., 1988. *Master Environmental Plan for the Badger Army Ammunition Plant, Final Report.* Prepared for United States Army Toxic and Hazardous Materials Agency. January.

United States Department of Energy, Office of Environmental Management, 2010. *The Risk Assessment Information System.* http://rais.ornl.gov/.

United States Environmental Protection Agency, 2010. *Integrated Risk Information System Database.* http://www.epa.gov/IRIS/index.html.

United States Environmental Protection Agency, 2010. *Regional Screening Levels (Formerly PRGs).* http://www.epa.gov/region9/superfund/prg/.

United States Environmental Protection Agency, 1998. *Statement of Basis for the Badger Army Ammunition Plant Facility, Baraboo, Wisconsin, Permit Modification, WI19 210 020 054.* June.

Wisconsin Department of Natural Resources, 2008. *Letter, Subject: Final Case Closure for the BAAP- WDOT Projects Area Within Settling Pond 4; Sauk County; BRRTS Number- 02-57-553034.* December 12.

Wisconsin Department of Natural Resources, 1987. *Letter, Subject: Final Review of In-Field Conditions Report at the Badger Army Ammunition Plant (BAAP), Sauk County.* September 14.

Wisconsin Department of Natural Resources, 1995. *Letter, Subject: Plan Modification of the September 14, 1987, In-Field Conditions Report Approval: Approval of Corrective Measures Selected in the Final Feasibility Study Report/Corrective Measures Study Report for the Badger Army Ammunition Plant.* June 1.

Wisconsin Department of Natural Resources, 2010. *Letter, Subject: WDNR Comments on Army's "Draft Revised Remediation Goals Proposal for the Alternative Feasibility Study, Final Creek, Settling Ponds, and Spoils Disposal Areas, Badger Army Ammunition Plant".* August 11.

Wisconsin Department of Natural Resources, 2010. *Letter, Subject: Final Case Closure for the BAAP - STH 78 North Ditch Contaminated Soil Case (an area south of Badger Army Ammunition Plant and north of Gruber's Grove Bay); Sauk County; BRRTS Number 02-57-554197.* January 26.

Wisconsin Department of Natural Resources, 2007. *WPDES Permit No. WI-0043975-05-0, Badger Army Ammunition Plant. (Effective July 1, 2007, through June 30, 2012).* June 29.

United States Environmental Protection Agency, 1995. *Letter, Subject: Resource Conservation and Recovery Act Permit Modification, W19 210 020 054,* May

Department of the Army, 1995. *Memorandum, Subject: RCRA Permit Modification – Final Conditions.* December 5.

Figures

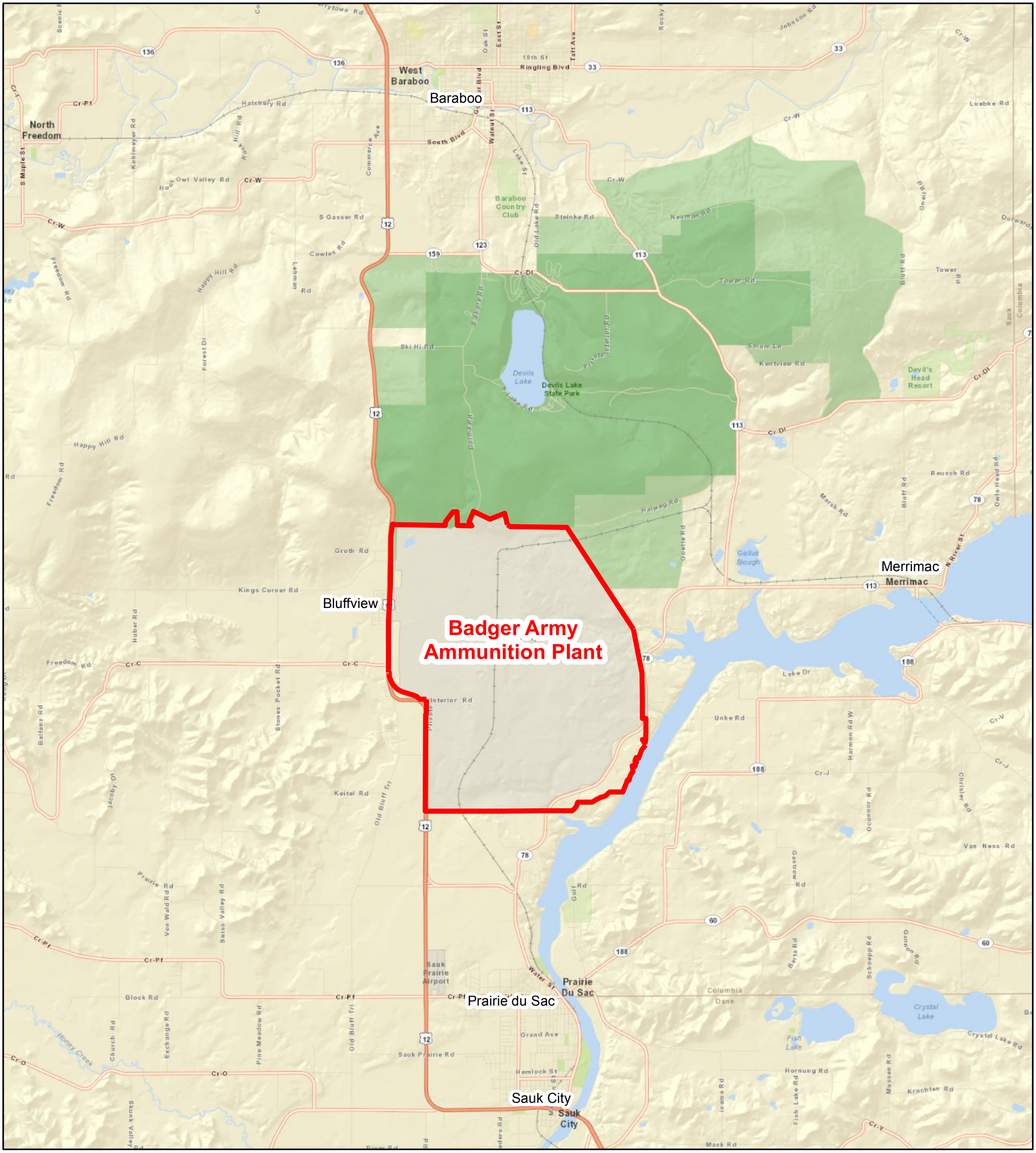


Figure 1

General Site Location
Alternative Feasibility Study
Final Creek, Settling Ponds, & Spoils Disposal Areas
Badger Army Ammunition Plant

Legend

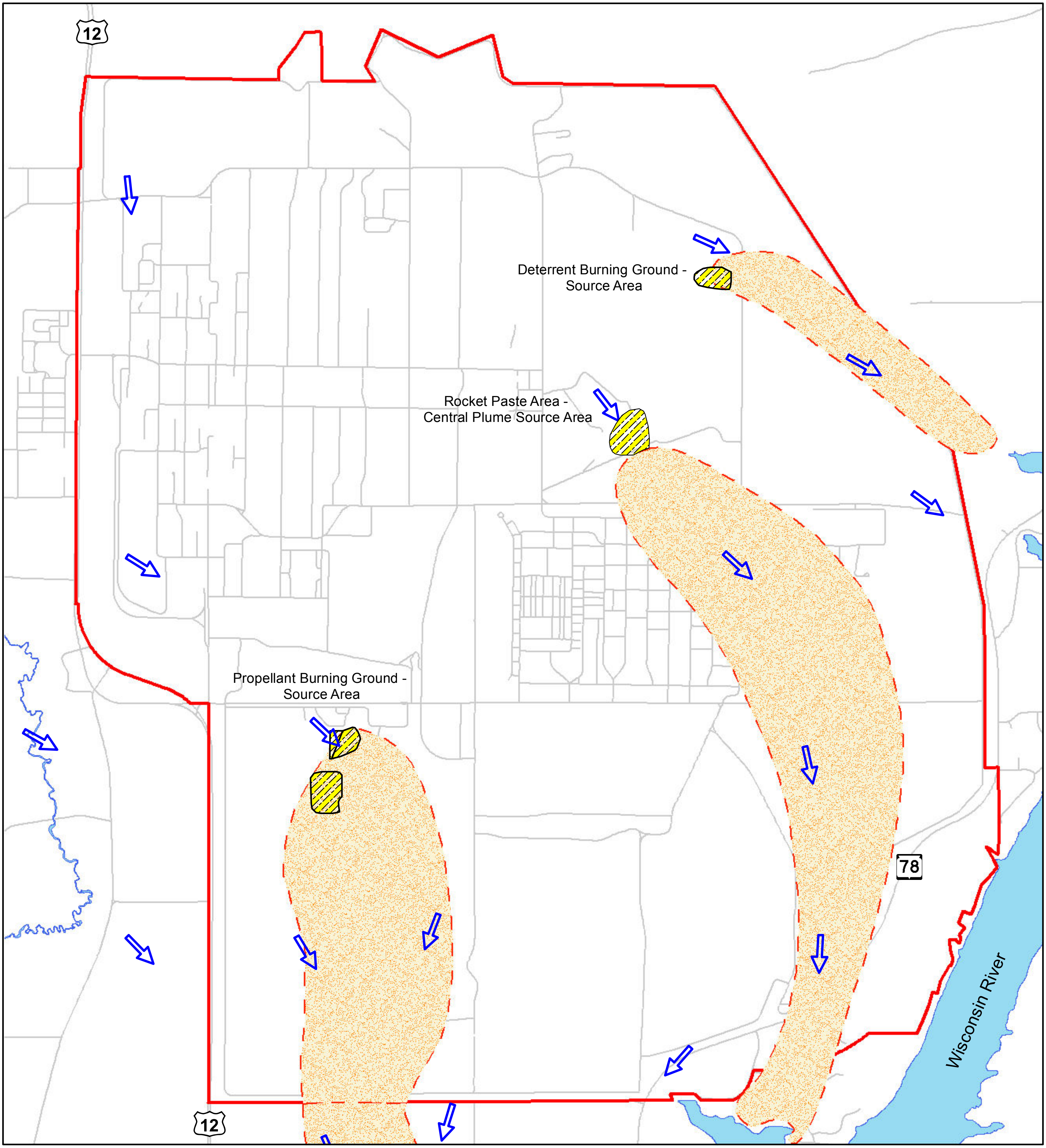
Badger Army Ammunition Plant Boundary

1 inch = 8,925 feet

0 5,000 10,000 20,000 Feet

BTS
BADGER TECHNICAL SERVICES

\\Pc-gis\maingis_disk\GIS_Projects\Settling_Ponds\AFS_FC_SP_SDA\mxds\Fig_1_General Site



Legend

- Badger Army Ammunition Plant Boundary
- Paved Road
- Groundwater Flow
- Final Creek
- Settling Pond
- Spoils Disposal Area
- Plume
- Wisconsin River
- Source Area

Figure 2

Source Areas for Groundwater Contamination Map
Alternative Feasibility Study
Final Creek, Settling Ponds, & Spoils Disposal Areas
Badger Army Ammunition Plant

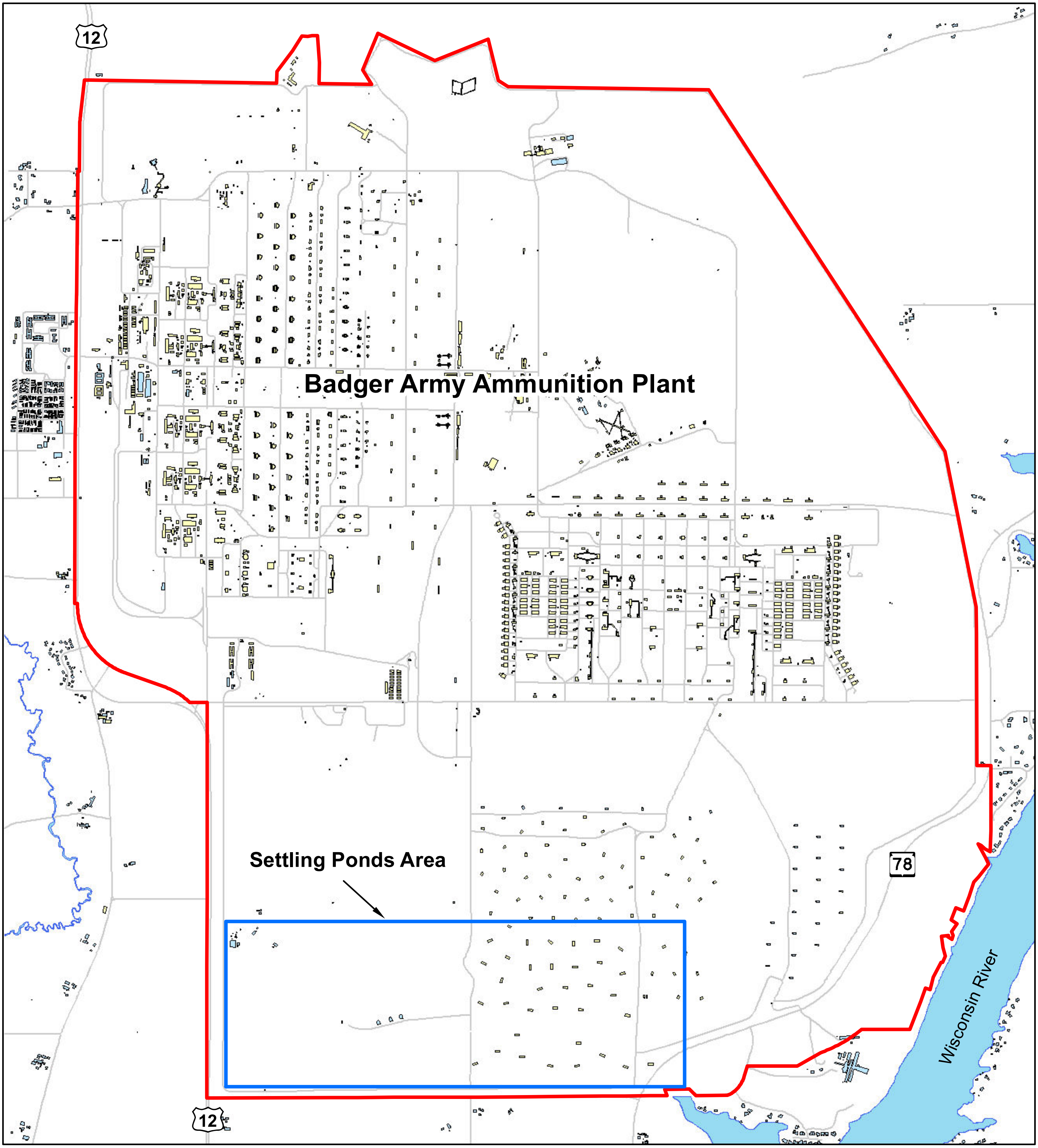
1 inch = 2,500 feet

0 1,800 3,600 7,200 Feet

BTS BADGER TECHNICAL SERVICES

N

\\Pc-gis\maingis_disk\GIS_Projects\Settling_Ponds\AFS_FC_SP_SDA\mxds\Fig_2_Source_Areas



Legend

- Badger Army Ammunition Plant Boundary
- Final Creek
- Paved Road
- Settling Pond
- Spoils Disposal Area
- Existing Building
- Former Building Footprint

Figure 3

Settling Ponds Area Location Map
Alternative Feasibility Study
Final Creek, Settling Ponds, and Spoils Disposal Areas
Badger Army Ammunition Plant

1 inch = 2,500 feet

0 1,500 3,000 6,000 Feet

BTS
BADGER TECHNICAL SERVICES

N

\\Pc-gis\maingis_disk\GIS_Projects\Settling_Ponds\AFS_FC_SP_SDA\mxds\Fig_3_Site_Loc

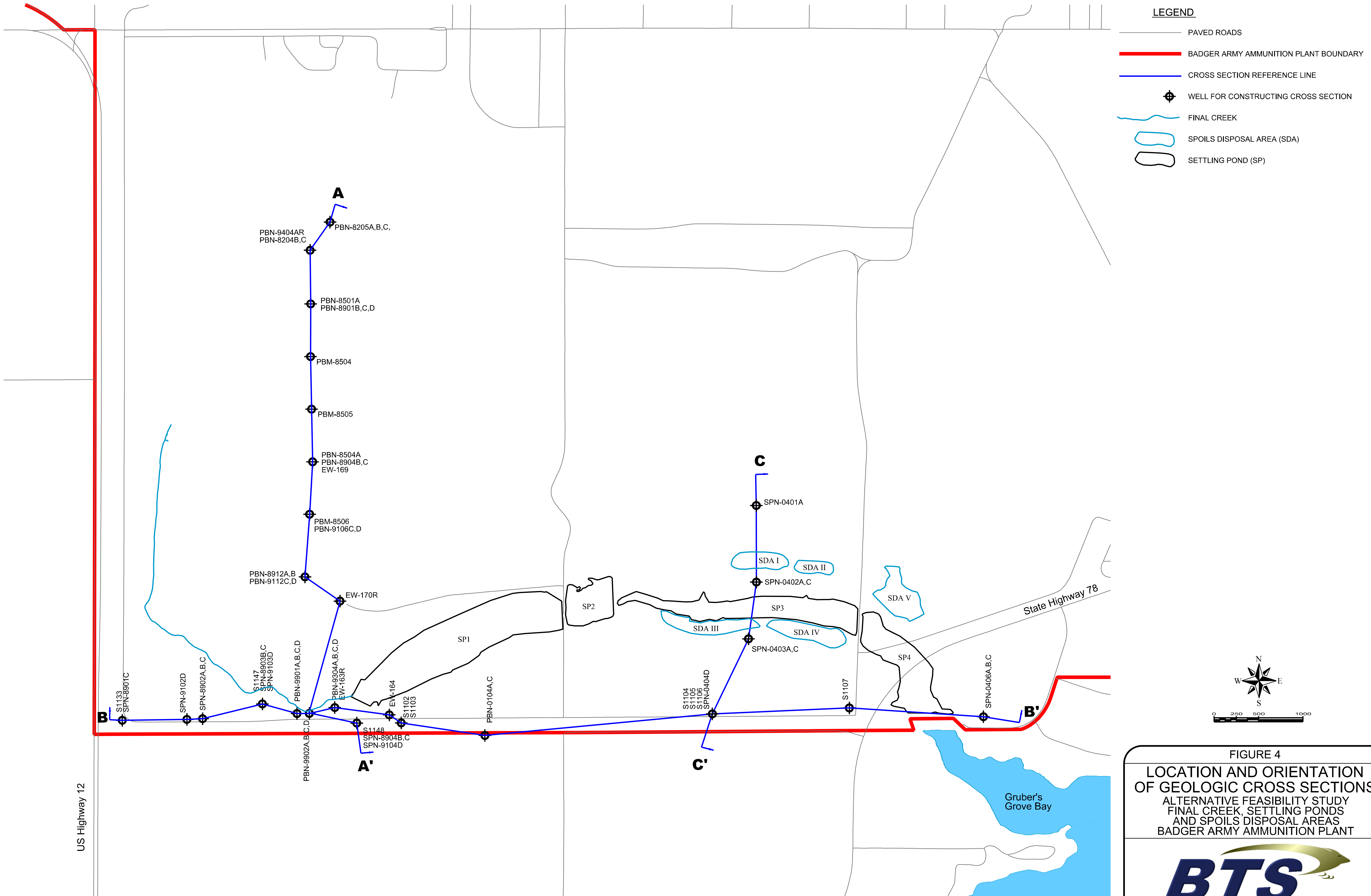
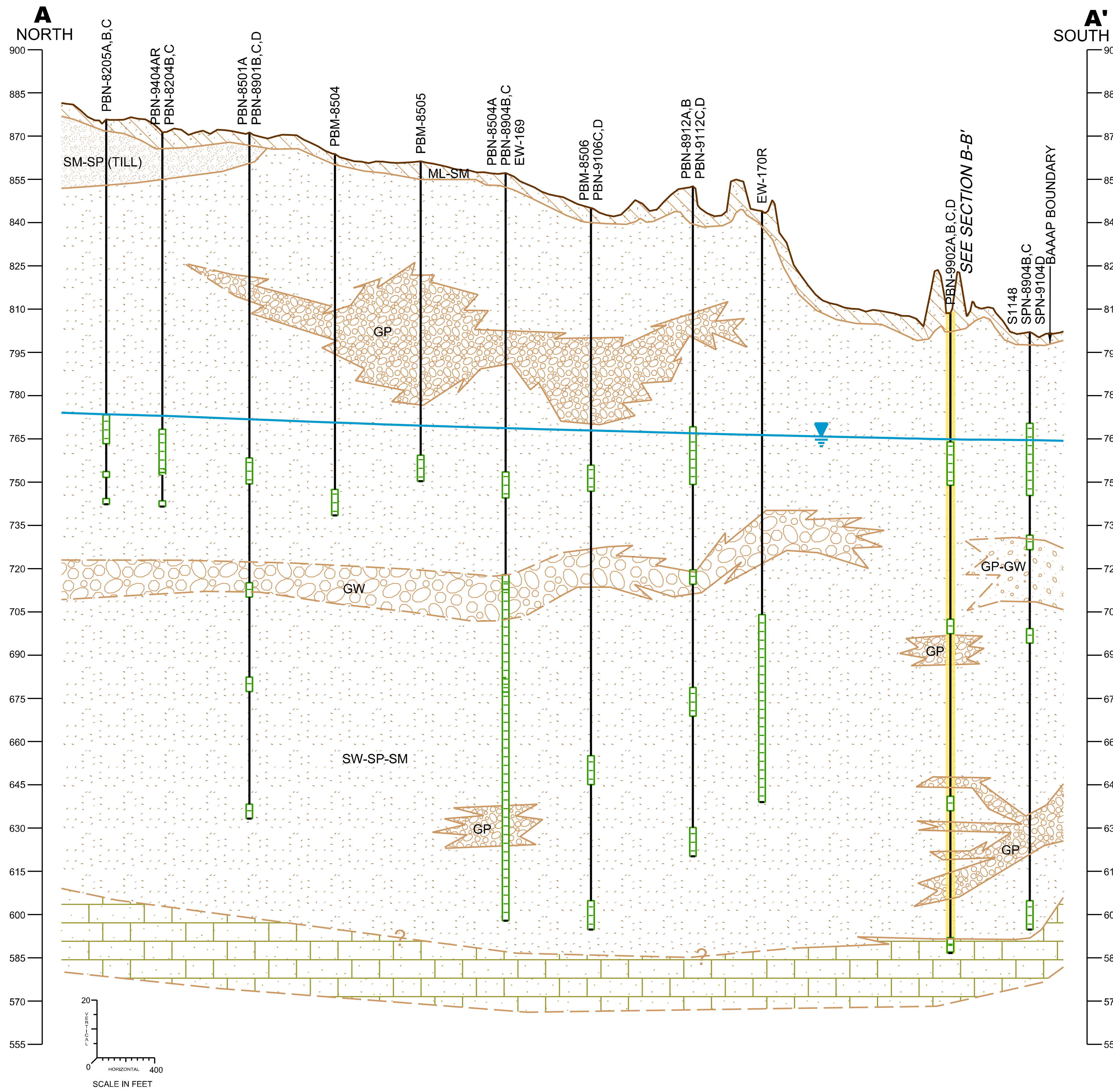


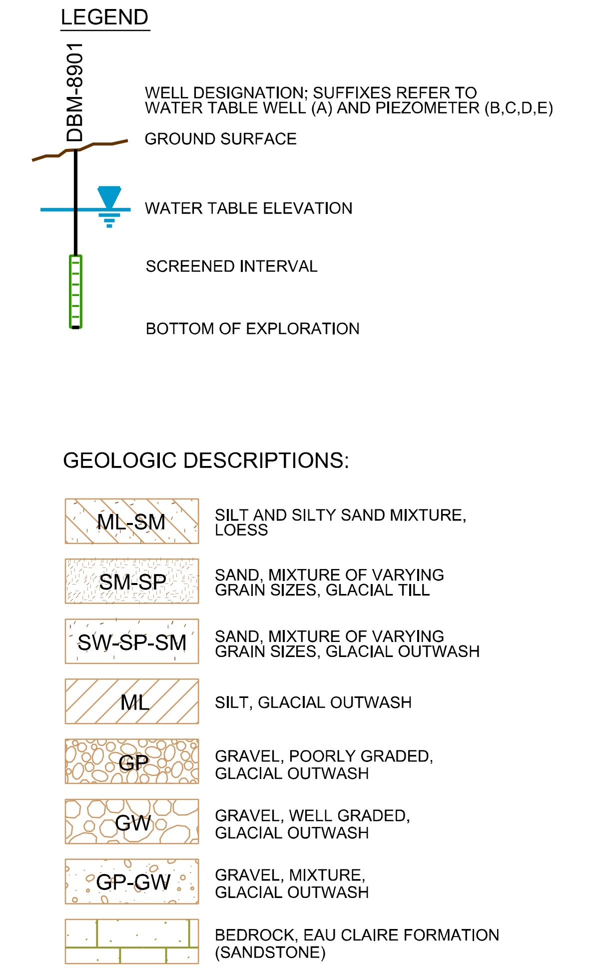
FIGURE 4

LOCATION AND ORIENTATION
OF GEOLOGIC CROSS SECTIONS

ALTERNATIVE FEASIBILITY STUDY
FINAL CREEK, SETTLING PONDS
AND SPOILS DISPOSAL AREAS
BADGER ARMY AMMUNITION PLANT

BTS
BADGER TECHNICAL SERVICES





NOTES:

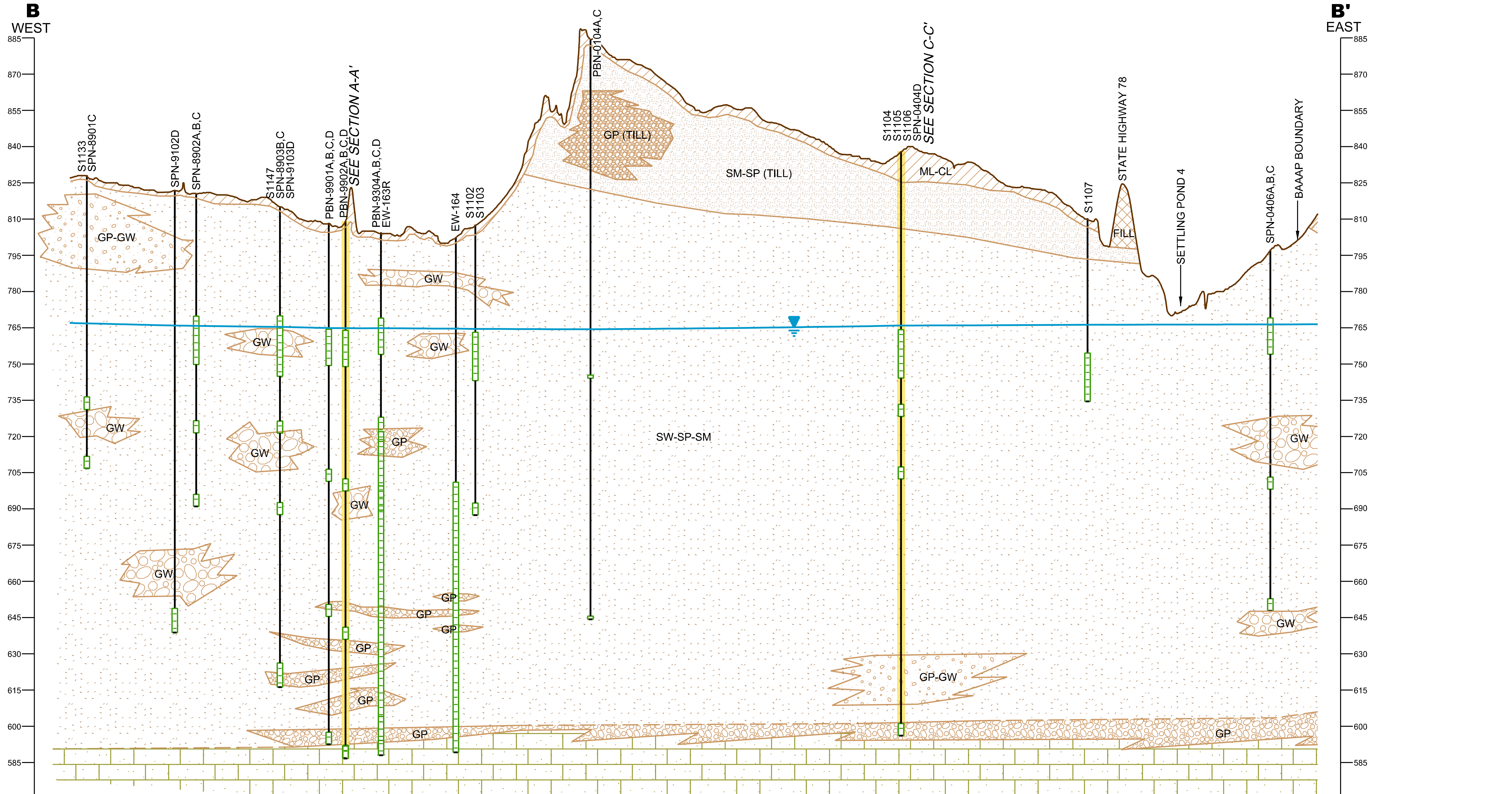
1. SEE FIGURE 4 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. WATER LEVELS ARE BASED ON DATA COLLECTED DURING 8/10, 9/10, AND 10/10
4. MSL - MEAN SEA LEVEL
5. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW

FIGURE 5

GEOLOGIC CROSS SECTION A-A'

ALTERNATIVE FEASIBILITY STUDY
FINAL CREEK, SETTLING PONDS
AND SPOILS DISPOSAL AREAS
BADGER ARMY AMMUNITION PLANT

BTS
BADGER TECHNICAL SERVICES



SCALE IN FEET
VERTICAL EXAGGERATION 1:20

LEGEND

Symbol	Description
DBM-8901	WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E)
	GROUND SURFACE
	WATER TABLE ELEVATION
	SCREENED INTERVAL
	BOTTOM OF EXPLORATION

GEOLOGIC DESCRIPTIONS:

Symbol	Description
FILL	FILL MATERIAL
ML-CL	SILT AND CL AY MIXTURE, LOESS
SM-SP	SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL
SW-SP-SM	SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH
GP	GRAVEL, POORLY GRADED, GLACIAL TILL
GP	GRAVEL, POORLY GRADED, GLACIAL OUTWASH
GW	GRAVEL, WELL GRADED, GLACIAL OUTWASH
GP-GW	GRAVEL, MIXTURE, GLACIAL OUTWASH
	BEDROCK, EAU CLAIRE FORMATION (SANDSTONE)

NOTES:

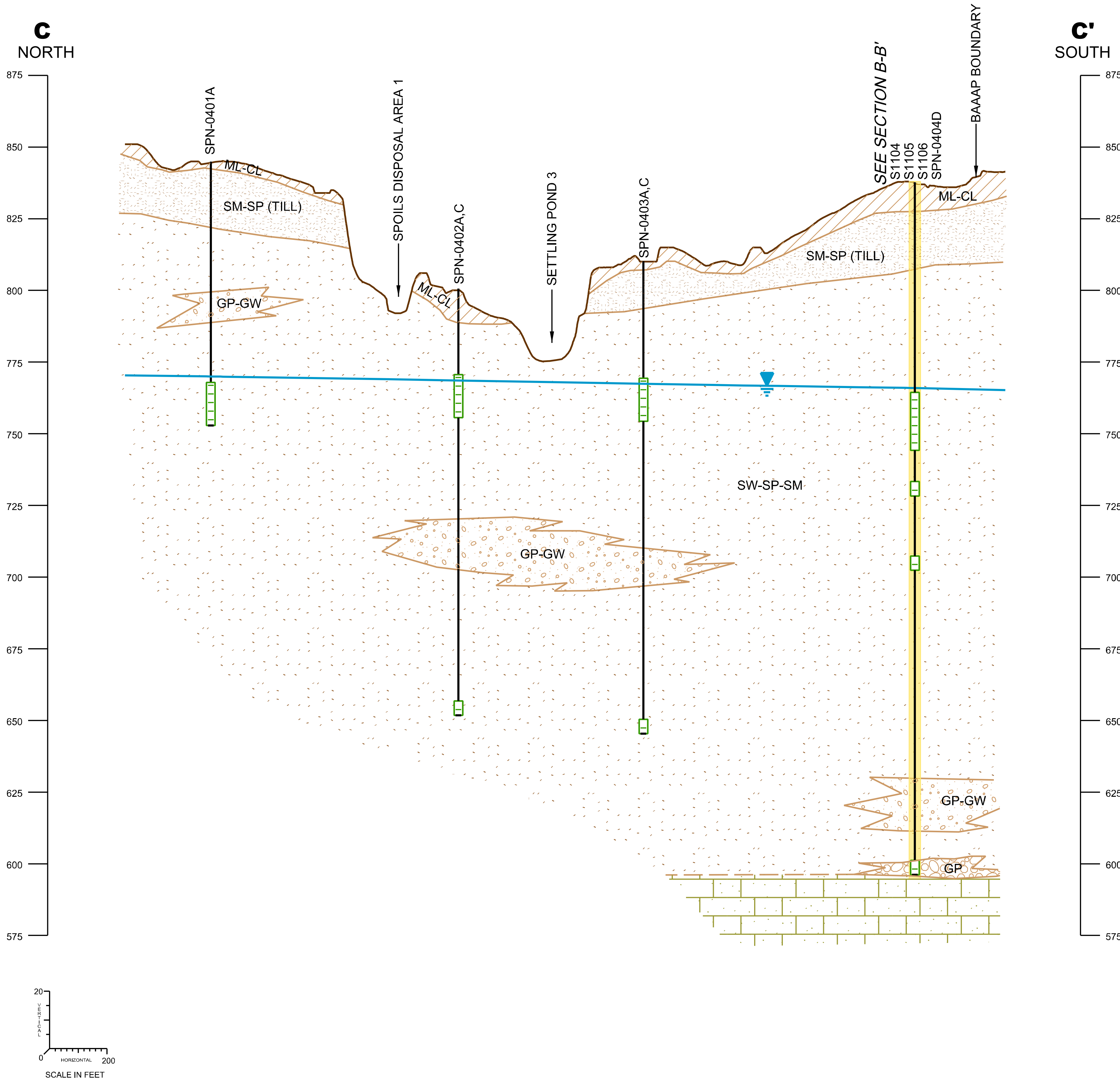
1. SEE FIGURE 4 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. WATER LEVELS ARE BASED ON DATA COLLECTED DURING 8/10, 9/10, AND 10/10
4. MSL - MEAN SEA LEVEL
5. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW

FIGURE 6

GEOLOGIC CROSS SECTION B-B'

ALTERNATIVE FEASIBILITY STUDY
FINAL CREEK, SETTLING PONDS
AND SPOILS DISPOSAL AREAS
BADGER ARMY AMMUNITION PLANT

BTS
BADGER TECHNICAL SERVICES



LEGEND

- DBM-8901 — WELL DESIGNATION; SUFFIXES REFER TO WATER TABLE WELL (A) AND PIEZOMETER (B,C,D,E)
- GROUND SURFACE
- WATER TABLE ELEVATION
- SCREENED INTERVAL
- BOTTOM OF EXPLORATION

GEOLOGIC DESCRIPTIONS:

- ML-CL — SILT AND CLAY MIXTURE, LOESS
- SM-SP — SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL TILL
- SW-SP-SM — SAND, MIXTURE OF VARYING GRAIN SIZES, GLACIAL OUTWASH
- GP — GRAVEL, POORLY GRADED, GLACIAL OUTWASH
- GP-GW — GRAVEL, MIXTURE, GLACIAL OUTWASH
- BEDROCK, EAU CLAIRE FORMATION (SANDSTONE)

NOTES:

1. SEE FIGURE 4 FOR LOCATION AND ORIENTATION OF PROFILES
2. PROFILES ARE BASED ON AN INTERPRETATION OF AVAILABLE SUBSURFACE DATA AND THE APRIL 1993 REMEDIAL INVESTIGATION REPORT PREPARED BY ABB ENVIRONMENTAL SERVICES, INC.
3. WATER LEVELS ARE BASED ON DATA COLLECTED DURING 8/10, 9/10, AND 10/10
4. MSL - MEAN SEA LEVEL
5. WELLS COMMON TO INTERSECTING CROSS SECTIONS ARE HIGHLIGHTED IN YELLOW

FIGURE 7

GEOLOGIC CROSS SECTION C-C'

ALTERNATIVE FEASIBILITY STUDY
FINAL CREEK, SETTLING PONDS AND SPOILS DISPOSAL AREAS
BADGER ARMY AMMUNITION PLANT

BTS
BADGER TECHNICAL SERVICES

Legend

- Well Location
- Badger Army Ammunition Plant Boundary
- Paved Road
- Parcel Boundary
- *T1* Parcel
- Settling Pond (SP)
- Spoils Disposal Area (SDA)
- Final Creek
- Buildings

Figure 8
Locations of Wells
Alternative Feasibility Study
Final Creek, Settling Ponds, and Spoils Disposal Areas
Badger Army Ammunition Plant
1 inch = 300 feet

0 625 1,250 2,500 Feet

BTS BADGER TECHNICAL SERVICES

\\Pc-gis\maingis_disk\GIS_Projects\Settling_Ponds\AFS_FC_SP_SDA\mxds\Fig_8_Onsite_Wells

Figure 9

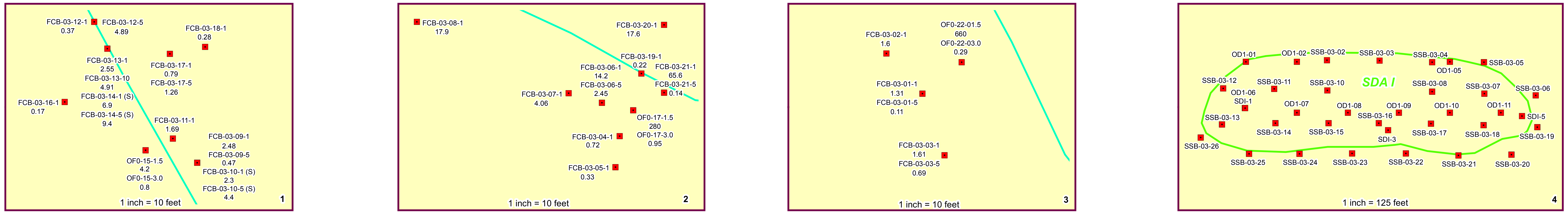
Remedial Investigation Boring Locations

Alternative Feasibility Study

Final Creek, Settling Ponds, and Spoils Disposal Areas

Badger Army Ammunition Plant

1 inch = 275 feet



SDA I - 2,4-Dinitrotoluene Analytical Results

BORING ID	SAMPLE ID	RESULT (mg/kg)
OD1-01	OD1-01-01.5	0.71
OD1-01	OD1-01-03.0	1.7
OD1-02	OD1-02-01.5	1.1
OD1-02	OD1-02-03.0	0.045
OD1-05	OD1-05-01.5	0.98
OD1-05	OD1-05-03.0	0.75
OD1-06	OD1-06-1.5	37
OD1-06	OD1-06-3.0	470
OD1-06	OD1-06-SS-01	1.62
OD1-07	OD1-07-1.5	130
OD1-07	OD1-07-3.0	33
OD1-07	OD1-07-SS-02	7.8
OD1-08	OD1-08-01.5	0.79
OD1-09	OD1-09-01.5	0.93
OD1-09	OD1-09-03.0	0.8
OD1-10	OD1-10-01.5	0.89
OD1-10	OD1-10-03.0	0.55
OD1-11	OD1-11-03.0	390
OD1-01	OQ2-12-01.5	0.43
OD1-01	OQ2-12-03.0	1.8
OD1-11	OQ2-13-01.5	1.5
OD1-11	OQ2-13-03.0	160
SDI-1	SDI-1	9.8
SDI-3	SDI-3	0.51
SDI-5	SDI-5	12
SSB-03-02	SSB-03-02-01	0.78
SSB-03-03	SSB-03-03-01	0.5
SSB-03-04	SSB-03-04-01	0.81
SSB-03-04	SSB-03-04-01 (S)	0.85
SSB-03-05	SSB-03-05-01	1.1
SSB-03-05	SSB-03-05-03	0.53
SSB-03-05	SSB-03-05-09	0.25
SSB-03-06	SSB-03-06-01	0.83
SSB-03-06	SSB-03-06-03	0.38
SSB-03-07	SSB-03-07-01	0.34

SDA I - 2,4-Dinitrotoluene Analytical Results

BORING ID	SAMPLE ID	RESULT (mg/kg)
SSB-03-07	SSB-03-07-03	0.34
SSB-03-07	SSB-03-07-05	6.58
SSB-03-08	SSB-03-08-01	0.81
SSB-03-08	SSB-03-08-03	0.36
SSB-03-08	SSB-03-08-05	0.82
SSB-03-10	SSB-03-10-01	0.22
SSB-03-11	SSB-03-11-03	4.81
SSB-03-11	SSB-03-11-05	4.37
SSB-03-12	SSB-03-12-01	0.94
SSB-03-12	SSB-03-12-03	12.4
SSB-03-12	SSB-03-12-05	1.4
SSB-03-13	SSB-03-13-01	0.22
SSB-03-13	SSB-03-13-03	0.71
SSB-03-13	SSB-03-13-05	6.68
SSB-03-14	SSB-03-14-01	5.11
SSB-03-14	SSB-03-14-03	7.76
SSB-03-14	SSB-03-14-05	7.77
SSB-03-14	SSB-03-14-07	1.62
SSB-03-14	SSB-03-14-09	22
SSB-03-15	SSB-03-15-01	0.35
SSB-03-15	SSB-03-15-03	1.85
SSB-03-15	SSB-03-15-09	0.68
SSB-03-16	SSB-03-16-01	1.28
SSB-03-16	SSB-03-16-03	0.57
SSB-03-16	SSB-03-16-05	0.58
SSB-03-17	SSB-03-17-01	0.22
SSB-03-17	SSB-03-17-01 (S)	0.71
SSB-03-17	SSB-03-17-03	0.57
SSB-03-17	SSB-03-17-03 (S)	0.37
SSB-03-17	SSB-03-17-05	13
SSB-03-17	SSB-03-17-05 (S)	22
SSB-03-18	SSB-03-18-01	0.23
SSB-03-18	SSB-03-18-01 (S)	1.4
SSB-03-18	SSB-03-18-03 (S)	0.99

SDA I - 2,4-Dinitrotoluene Analytical Results

BORING ID	SAMPLE ID	RESULT (mg/kg)
SSB-03-18	SSB-03-18-03	1.41
SSB-03-18	SSB-03-18-05	22.4
SSB-03-18	SSB-03-18-05 (S)	240
SSB-03-18	SSB-03-18-09 (S)	9.5
SSB-03-19	SSB-03-19-01	0.91
SSB-03-19	SSB-03-19-03	1.48
SSB-03-19	SSB-03-19-05	3.79
SSB-03-20	SSB-03-20-01	1.16
SSB-03-20	SSB-03-20-03	1.53
SSB-03-20	SSB-03-20-05	0.77
SSB-03-20	SSB-03-20-07	41.9
SSB-03-20	SSB-03-20-09	31.8
SSB-03-21	SSB-03-21-01	0.48
SSB-03-21	SSB-03-21-03	1.58
SSB-03-22	SSB-03-22-01	0.29
SSB-03-22	SSB-03-22-03	2.41
SSB-03-22	SSB-03-22-05	0.18
SSB-03-22	SSB-03-22-07	4.37
SSB-03-23	SSB-03-23-01	0.87
SSB-03-23	SSB-03-23-03	0.14
SSB-03-23	SSB-03-23-05	4.22
SSB-03-24	SSB-03-24-01	80.2
SSB-03-24	SSB-03-24-03	22.6
SSB-03-24	SSB-03-24-05	9.71
SSB-03-24	SSB-03-24-07	0.4
SSB-03-24	SSB-03-24-SS-08	16.3
SSB-03-25	SSB-03-25-01	23.5
SSB-03-25	SSB-03-25-05	82.1
SSB-03-25	SSB-03-25-07	13.7
SSB-03-25	SSB-03-25-09	0.18
SSB-03-25	SSB-03-25-SS-09	33.7
SSB-03-26	SSB-03-26-01	2.95
SSB-03-26	SSB-03-26-03	0.23
SSB-03-26	SSB-03-26-05	1.58

Legend

- 2,4-Dinitrotoluene Sample Location
- 0.74 Analytical Results (milligrams per kilogram)
- Badger Army Ammunition Plant Boundary
- Investigation/Remedial Action Area
- Final Creek
- Paved Road
- Settling Pond (SP)
- Spoils Disposal Area (SDA)
- Parcel Boundary
- T1 Parcel

Figure 10

2,4-Dinitrotoluene Detection Sample Locations
Alternative Feasibility Study
Final Creek, Settling Ponds, and Spoils Disposal Areas
Badger Army Ammunition Plant

1 inch = 275 feet

0 600 1,200 2,400 Feet

BTS
BADGER TECHNICAL SERVICES

\\Pc-gis\maingis_disk\GIS_Projects\Settling_Ponds\AFS_FC_SP_SDA\mxds\Fig_10_2_4_DNT

SDA I - 2,6-Dinitrotoluene Analytical Results

BORING ID	SAMPLE ID	RESULT (mg/kg)
OD1-02	OD1-02-01.5	0.13
OD1-06	OD1-06-1.5	2.7
OD1-06	OD1-06-3.0	32
OD1-06	OD1-06-SS-01	65.7
OD1-07	OD1-07-SS-02	0.215
OD1-09	OD1-09-01.5	0.1
OD1-09	OD1-09-03.0	0.1
OD1-10	OD1-10-01.5	0.11
OD1-11	OD1-11-03.0	27
OD1-11	OQ2-13-01.5	0.17
OD1-11	OQ2-13-03.0	18
SDI-5	SDI-5	1
SSB-03-04	SSB-03-04-01 (S)	0.1
SSB-03-07	SSB-03-07-05	0.96
SSB-03-08	SSB-03-08-05	0.09
SSB-03-11	SSB-03-11-03	0.59
SSB-03-11	SSB-03-11-05	0.52
SSB-03-12	SSB-03-12-03	1.64
SSB-03-12	SSB-03-12-05	0.17
SSB-03-13	SSB-03-13-05	0.74
SSB-03-14	SSB-03-14-01	0.45
SSB-03-14	SSB-03-14-03	0.54
SSB-03-14	SSB-03-14-05	0.6
SSB-03-14	SSB-03-14-07	0.21
SSB-03-14	SSB-03-14-09	2.17
SSB-03-15	SSB-03-15-03	0.21
SSB-03-15	SSB-03-15-09	0.07

SDA I - 2,6-Dinitrotoluene Analytical Results

BORING ID	SAMPLE ID	RESULT (mg/kg)
SSB-03-17	SSB-03-17-01 (S)	0.08
SSB-03-17	SSB-03-17-05	2.49
SSB-03-17	SSB-03-17-05 (S)	2.2
SSB-03-18	SSB-03-18-01 (S)	0.17
SSB-03-18	SSB-03-18-03	0.19
SSB-03-18	SSB-03-18-03 (S)	0.13
SSB-03-18	SSB-03-18-05	3.16
SSB-03-18	SSB-03-18-05 (S)	15
SSB-03-18	SSB-03-18-09 (S)	0.67
SSB-03-19	SSB-03-19-05	0.33
SSB-03-20	SSB-03-20-07	6.63
SSB-03-20	SSB-03-20-09	4.22
SSB-03-21	SSB-03-21-03	0.18
SSB-03-22	SSB-03-22-03	0.32
SSB-03-22	SSB-03-22-07	0.46
SSB-03-23	SSB-03-23-05	0.44
SSB-03-24	SSB-03-24-01	13.2
SSB-03-24	SSB-03-24-03	4.31
SSB-03-24	SSB-03-24-05	1.04
SSB-03-24	SSB-03-24-SS-08	0.376
SSB-03-25	SSB-03-25-01	1.8
SSB-03-25	SSB-03-25-05	11.3
SSB-03-25	SSB-03-25-07	1
SSB-03-25	SSB-03-25-SS-09	19.6
SSB-03-26	SSB-03-26-01	0.25
SSB-03-26	SSB-03-26-05	0.19

Legend

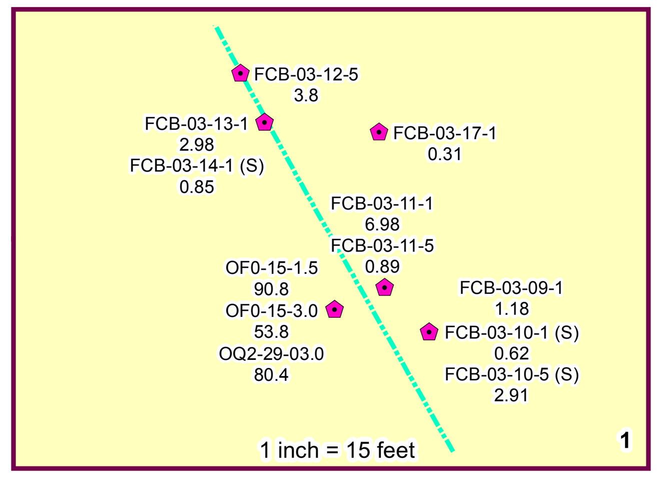
- ▲ 2,6-Dinitrotoluene Sample Location
- 0.74 Analytical Results (milligrams per kilogram)
- Badger Army Ammunition Plant Boundary
- Investigation/Remedial Action Area
- Final Creek
- Paved Road
- Settling Pond (SP)
- Spoils Disposal Area (SDA)
- Parcel Boundary
- T1 Parcel

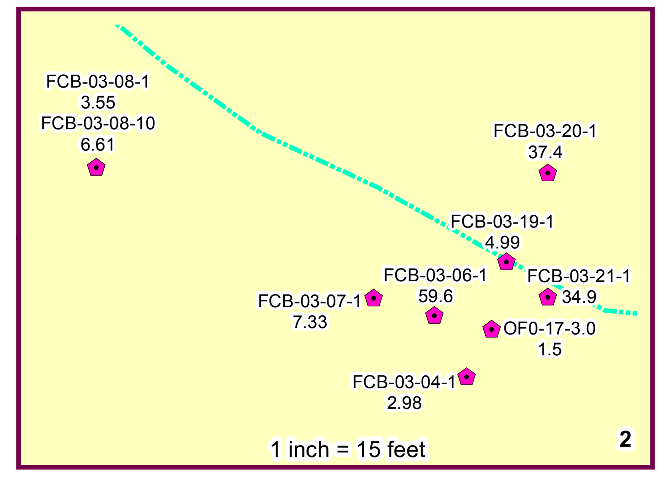
Figure 11
2,6-Dinitrotoluene Detection Sample Locations
Alternative Feasibility Study
Final Creek, Settling Ponds, and Spoils Disposal Areas
Badger Army Ammunition Plant
1 inch = 275 feet

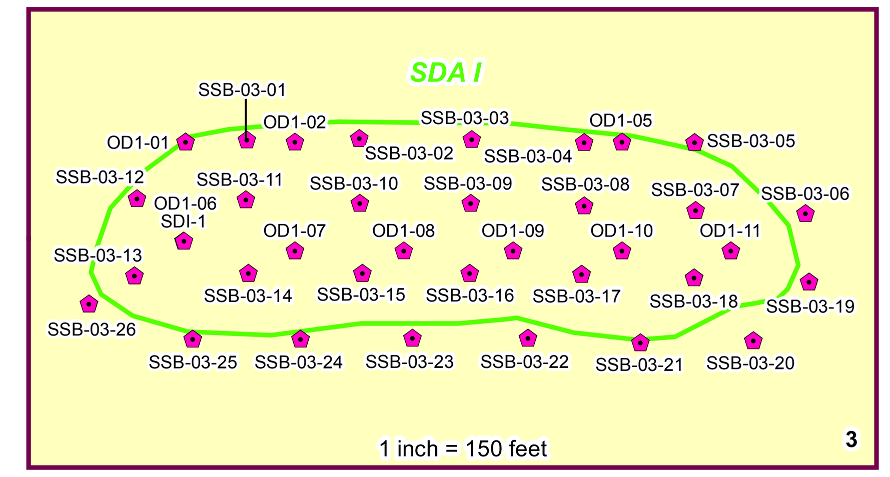
0 600 1,200 2,400 Feet

BTS
BADGER TECHNICAL SERVICES

\\Pc-gis\maingis_disk\GIS_Projects\Settling_Ponds\AFS_FC_SP_SDA\mxds\Fig_11_2,6-DNT





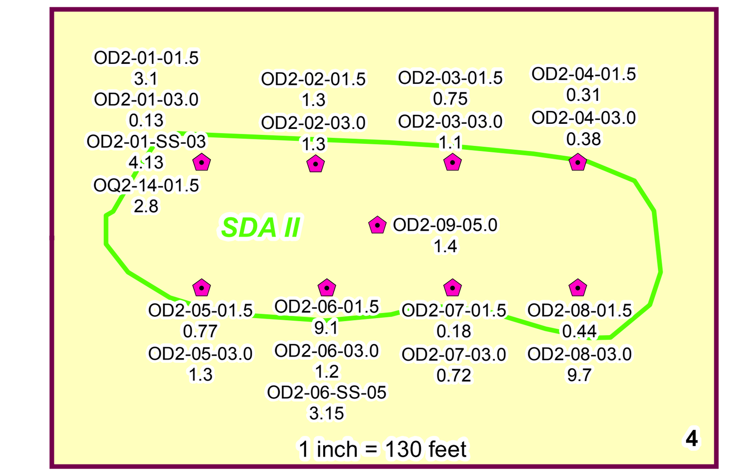


SDA I - Nitroglycerin Analytical Results

BORING ID	SAMPLE ID	RESULT (mg/kg)
OD1-01	OD1-01-01.5	0.56
OD1-01	OD1-01-03.0	8.4
OD1-01	OQ2-12-01.5	0.18
OD1-01	OQ2-12-03.0	6.1
OD1-02	OD1-02-01.5	0.62
OD1-05	OD1-05-01.5	1.3
OD1-05	OD1-05-03.0	0.51
OD1-06	OD1-06-1.5	150
OD1-06	OD1-06-3.0	1500
OD1-06	OD1-06-SS-01	396
OD1-07	OD1-07-1.5	800
OD1-07	OD1-07-3.0	47
OD1-07	OD1-07-SS-02	781
OD1-08	OD1-08-01.5	0.56
OD1-09	OD1-09-01.5	1.2
OD1-09	OD1-09-03.0	0.39
OD1-10	OD1-10-01.5	0.51
OD1-10	OD1-10-03.0	0.94
OD1-11	OD1-11-01.5	8.5
OD1-11	OD1-11-03.0	380
OD1-11	OQ2-13-01.5	1.6
OD1-11	OQ2-13-03.0	390
SDI-1	SDI-1	19
SSB-03-01	SSB-03-01-01	0.545
SSB-03-02	SSB-03-02-01	0.356
SSB-03-02	SSB-03-02-07	0.233
SSB-03-03	SSB-03-03-01	0.451
SSB-03-04	SSB-03-04-01	0.536
SSB-03-04	SSB-03-04-01 (S)	0.419
SSB-03-05	SSB-03-05-01	6.8
SSB-03-05	SSB-03-05-05	8.03
SSB-03-05	SSB-03-05-07	0.312
SSB-03-06	SSB-03-06-01	0.758
SSB-03-06	SSB-03-06-03	5.62
SSB-03-07	SSB-03-07-01	0.728
SSB-03-07	SSB-03-07-05	9.28
SSB-03-08	SSB-03-08-01	7.82
SSB-03-08	SSB-03-08-03	0.414
SSB-03-09	SSB-03-09-01	0.886
SSB-03-09	SSB-03-09-07	0.307
SSB-03-10	SSB-03-10-01	6.62
SSB-03-10	SSB-03-10-03	6.5
SSB-03-10	SSB-03-10-11	0.678
SSB-03-11	SSB-03-11-01	0.983
SSB-03-11	SSB-03-11-05	1.44
SSB-03-12	SSB-03-12-03	27.1
SSB-03-12	SSB-03-12-05	1.48
SSB-03-13	SSB-03-13-01	2.18
SSB-03-13	SSB-03-13-03	16.2
SSB-03-13	SSB-03-13-05	5.58
SSB-03-13	SSB-03-13-09	3.55
SSB-03-14	SSB-03-14-01	6.01
SSB-03-14	SSB-03-14-03	0.293
SSB-03-14	SSB-03-14-07	5.97

SDA I - Nitroglycerin Analytical Results

BORING ID	SAMPLE ID	RESULT (mg/kg)
SSB-03-14	SSB-03-14-09	3.74
SSB-03-15	SSB-03-15-01	8.36
SSB-03-15	SSB-03-15-03	17.2
SSB-03-15	SSB-03-15-05	4.65
SSB-03-15	SSB-03-15-09	5.42
SSB-03-16	SSB-03-16-01	1.43
SSB-03-16	SSB-03-16-03	0.52
SSB-03-16	SSB-03-16-09	23.7
SSB-03-17	SSB-03-17-01	5.89
SSB-03-17	SSB-03-17-01 (S)	4.94
SSB-03-17	SSB-03-17-03 (S)	5.82
SSB-03-17	SSB-03-17-05	3.94
SSB-03-17	SSB-03-17-05 (S)	2.66
SSB-03-17	SSB-03-17-07 (S)	0.658
SSB-03-17	SSB-03-17-09	0.351
SSB-03-17	SSB-03-17-11	1.74
SSB-03-18	SSB-03-18-01 (S)	4.98
SSB-03-18	SSB-03-18-03	8.42
SSB-03-18	SSB-03-18-03 (S)	8.31
SSB-03-18	SSB-03-18-05	2.47
SSB-03-18	SSB-03-18-07	0.45
SSB-03-18	SSB-03-18-07 (S)	0.402
SSB-03-18	SSB-03-18-09 (S)	30
SSB-03-18	SSB-03-18-11	0.568
SSB-03-19	SSB-03-19-01	0.751
SSB-03-19	SSB-03-19-03	6.64
SSB-03-19	SSB-03-19-07	23.5
SSB-03-20	SSB-03-20-01	4.98
SSB-03-20	SSB-03-20-03	0.737
SSB-03-20	SSB-03-20-05	1.04
SSB-03-20	SSB-03-20-09	2.3
SSB-03-21	SSB-03-21-01	6.03
SSB-03-21	SSB-03-21-03	3.77
SSB-03-22	SSB-03-22-01	1.21
SSB-03-22	SSB-03-22-03	0.854
SSB-03-22	SSB-03-22-05	4.67
SSB-03-22	SSB-03-22-07	9.67
SSB-03-23	SSB-03-23-01	10.9
SSB-03-23	SSB-03-23-05	18.9
SSB-03-24	SSB-03-24-03	10.4
SSB-03-24	SSB-03-24-05	66.1
SSB-03-24	SSB-03-24-07	18
SSB-03-24	SSB-03-24-SS-08	12.7
SSB-03-24	SSB-03-24-09	10.2
SSB-03-25	SSB-03-25-01	64.7
SSB-03-25	SSB-03-25-03	5.75
SSB-03-25	SSB-03-25-05	3.88
SSB-03-25	SSB-03-25-07	2.76
SSB-03-25	SSB-03-25-09	5.65
SSB-03-25	SSB-03-25-SS-09	183
SSB-03-26	SSB-03-26-01	0.707
SSB-03-26	SSB-03-26-03	1.4
SSB-03-26	SSB-03-26-05	4.38
SSB-03-26	SSB-03-26-09	2.18



Legend

- Nitroglycerin Sample Location
- 0.74 Analytical Results (milligrams per kilogram)
- Badger Army Ammunition Plant Boundary
- Investigation/Remedial Action Area
- Final Creek
- Paved Road
- Settling Pond (SP)
- Spoils Disposal Area (SDA)
- Parcel Boundary
- T1 Parcel

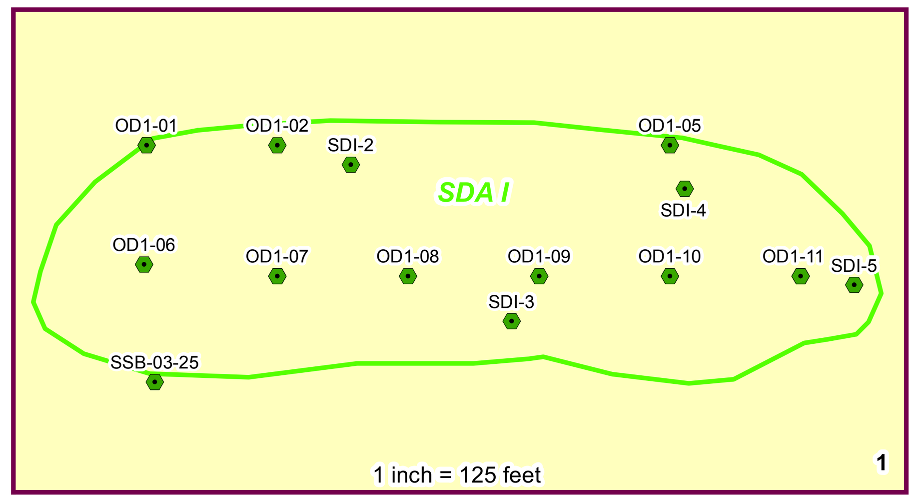
Figure 12
Nitroglycerin Detection Sample Locations
Alternative Feasibility Study
Final Creek, Settling Ponds, and Spoils Disposal Areas
Badger Army Ammunition Plant

1 inch = 275 feet

0 500 1,000 2,000 Feet

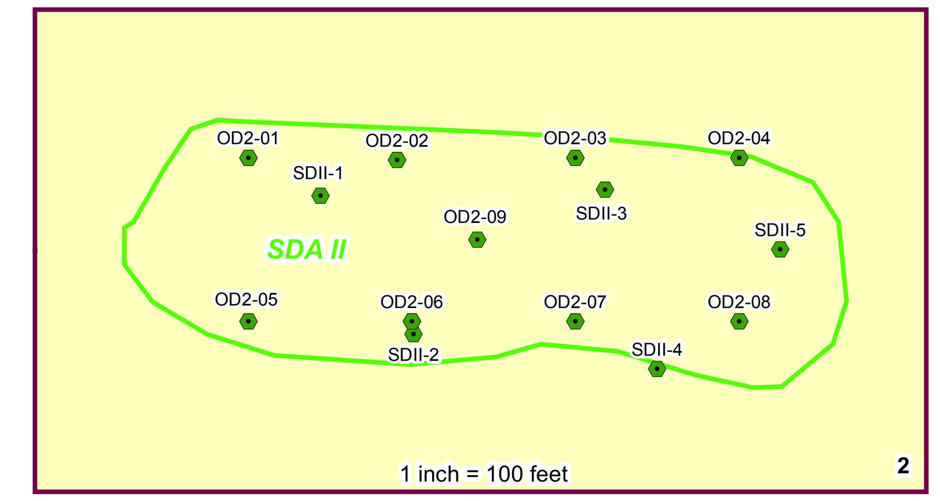
BTS
BADGER TECHNICAL SERVICES

\\Pc-gis\maingis_disk\GIS_Projects\Settling_Ponds\AFS_FC_SP_SDA\mxds\Fig_12_NG



SDA I - Lead Analytical Results

BORING ID	SAMPLE ID	RESULT (mg/kg)
OD1-01	OQ2-12-03.0	89
OD1-01	OD1-01-03.0	110
OD1-01	OQ2-12-01.5	160
OD1-01	OD1-01-01.5	170
OD1-02	OD1-02-01.5	190
OD1-05	OD1-05-03.0	150
OD1-05	OD1-05-01.5	160
OD1-06	OD1-06-SS-01	86.7
OD1-06	OD1-06-3.0	140
OD1-07	OD1-07-1.5	87
OD1-07	OD1-07-SS-02	188
OD1-07	OD1-07-3.0	370
OD1-08	OD1-08-01.5	130
OD1-09	OD1-09-01.5	120
OD1-09	OD1-09-03.0	180
OD1-10	OD1-10-01.5	100
OD1-10	OD1-10-03.0	160
OD1-11	OQ2-13-03.0	100
OD1-11	OD1-11-01.5	160
OD1-11	OQ2-13-01.5	160
OD1-11	OD1-11-03.0	210
SDI-2	SDI-2	119
SDI-3	SDI-3	349
SDI-4	SDI-4	75
SDI-5	SDI-5	210
SSB-03-25	SSB-03-25-SS-09	180



SDA II - Lead Analytical Results

BORING ID	SAMPLE ID	RESULT (mg/kg)
OD2-01	OQ2-14-01.5	200
OD2-01	OD2-01-SS-03	255
OD2-01	OD2-01-01.5	290
OD2-02	OD2-02-03.0	250
OD2-02	OD2-02-01.5	330
OD2-02	OD2-02-SS-04	353
OD2-02	OD2-02-SS-04	361
OD2-03	OD2-03-03.0	280
OD2-03	OD2-03-01.5	320
OD2-04	OD2-04-03.0	310
OD2-04	OD2-04-01.5	320
OD2-05	OD2-05-03.0	140
OD2-05	OD2-05-01.5	220
OD2-06	OD2-06-01.5	270
OD2-06	OD2-06-03.0	330
OD2-06	OD2-06-SS-05	367
OD2-07	OD2-07-03.0	270
OD2-07	OD2-07-01.5	350
OD2-08	OD2-08-01.5	230
OD2-08	OD2-08-03.0	310
OD2-09	OD2-09-10.0	116
SDII-1	SDII-1	239
SDII-2	SDII-2	326
SDII-3	SDII-3	370
SDII-4	SDII-4	373
SDII-5	SDII-5	299

Legend

- Lead Sample Location Analytical Result (greater than or equal to 50 milligrams per kilogram) — 76
- Badger Army Ammunition Plant Boundary
- Investigation/Remedial Action Area
- Final Creek
- Paved Road
- Settling Pond (SP)
- Spoils Disposal Area (SDA)
- Parcel Boundary
- T1 Parcel

Figure 13

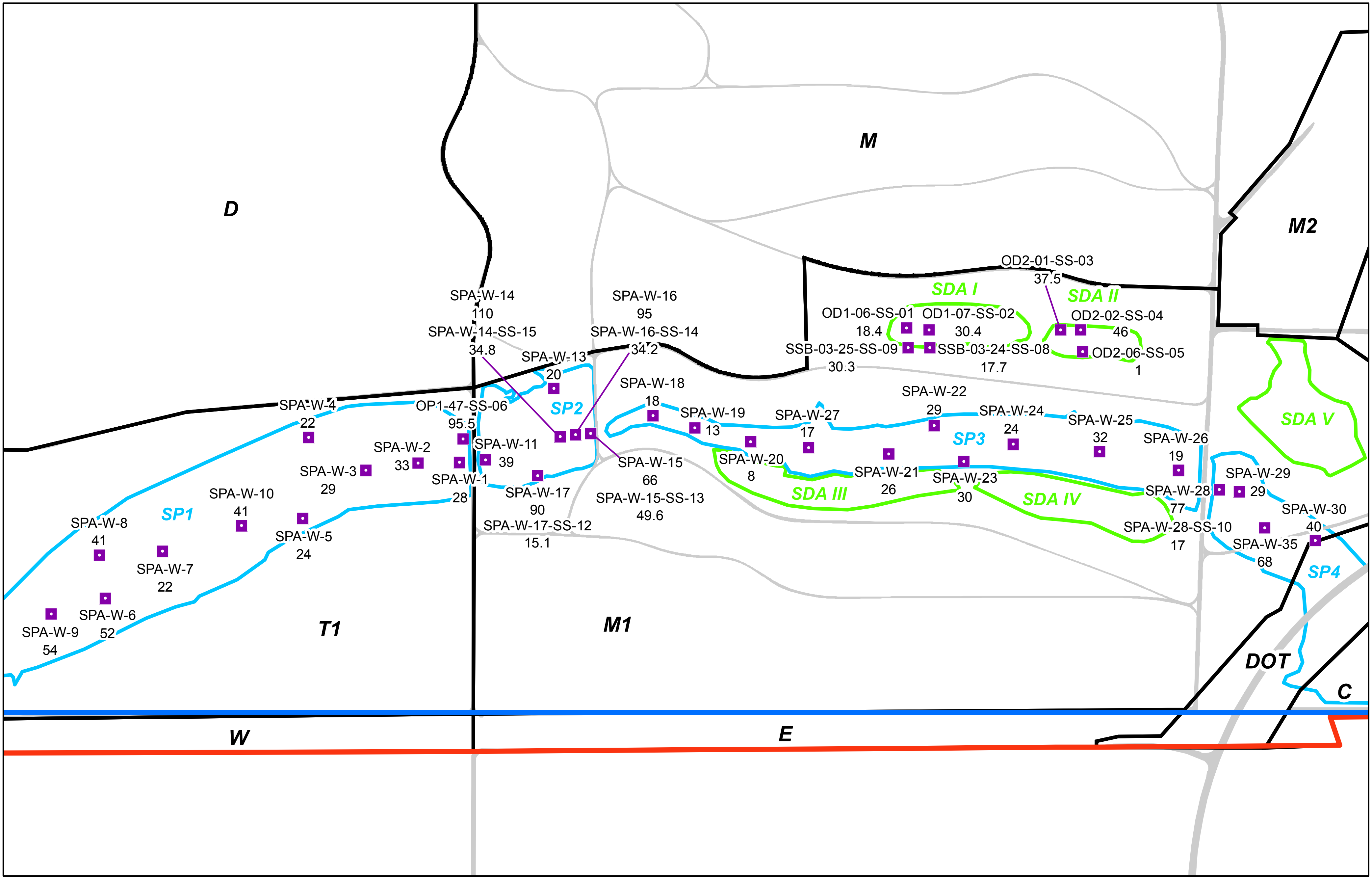
Total Lead Sample Locations
Alternative Feasibility Study
Final Creek, Settling Ponds, and Spoils Disposal Areas
Badger Army Ammunition Plant

1 inch = 300 feet

0 650 1,300 2,600 Feet

BTS
BADGER TECHNICAL SERVICES

\\Pc-gis\maingis_disk\GIS_Projects\Settling_Ponds\AFS_FC_SP_SDA\mxds\Fig_13_Pb_50



Legend

- Chromium Sample Location
- 17.7 Analytical Results (milligrams per kilogram)
- Badger Army Ammunition Plant Boundary
- Investigation/Remedial Action Area
- Paved Road
- Settling Pond (SP)
- Spoils Disposal Area (SDA)
- Parcel Boundary
- *T1* Parcel

Figure 14
Chromium Detection Sample Locations
Alternative Feasibility Study
Final Creek, Settling Ponds, and Spoils Disposal Areas
Badger Army Ammunition Plant

1 inch = 575 feet

0 500 1,000 2,000 Feet

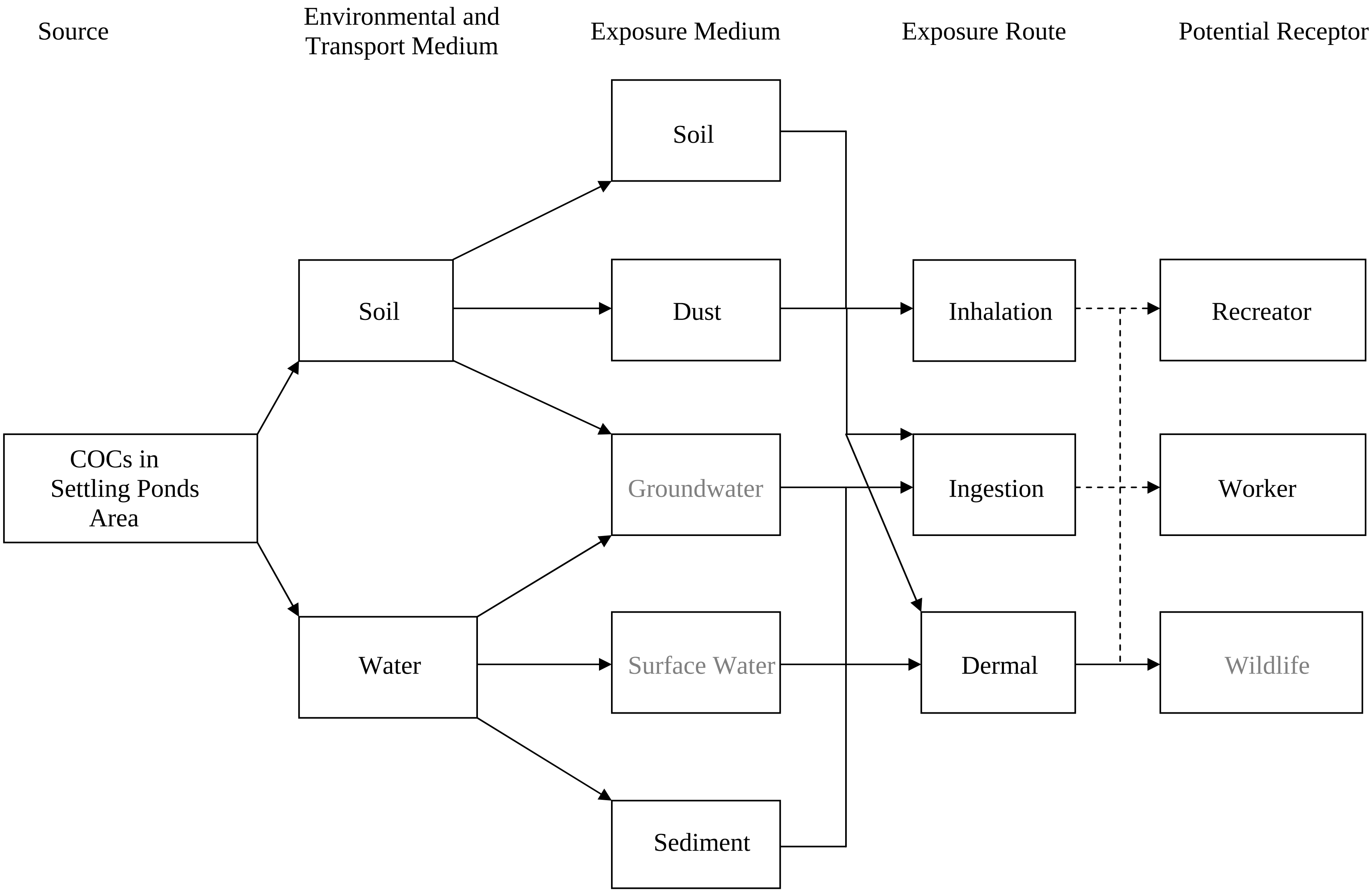
N

BTS
BADGER TECHNICAL SERVICES

\\Pc-gis\maingis_disk\GIS_Projects\Settling_Ponds\
AFS_FC_SP_SDA\mxds\Fig_14_Chromium

Figure 15

Conceptual Site Model
Alternative Feasibility Study - Final Creek, Settling Ponds, and Spoils Disposal Areas



Notes: Grey text indicates that this is not an exposure medium or receptor of concern based on empirical data.
Dashed lines indicate that this is a low risk pathway based on land use and/or institutional controls.

Tables

Table 1

Previously Established Remediation Goals and Screening of Contaminants of Concern

Alternative Feasibility Study - Final Creek, Settling Ponds, and Spoils Disposal Areas

Badger Army Ammunition Plant

Contaminant of Concern	FS/IFCR/PM Remediation Goal	NR 720 Table 2 RCL		BAAAP Background	USEPA RSL		Maximum Detected Concentration
		Non-Industrial	Industrial		Residential	Industrial	
Aluminum (Al)	19[1]	NE	NE	NE	77,000	990,000	*60,000*
Arsenic (As)	NE	0.039	1.6	10	0.39	1.6	**17**
Chromium (Cr)	NE	14/16,000*	200/NE*	35.5	280	1400	**110**
Lead (Pb)	30[2]	50/250†	500	NE	400	800	***830***
Tin (Sn)	10[2]	NE	NE	NE	47,000	610,000	9.5
Zinc (Zn)	81.3[2]	NE	NE	NE	23,000	77,000	*748*
2,4-DNT	2.5[3]	NE	NE	NE	1.6	5.5	***660***
2,6-DNT	4.29[4]	NE	NE	NE	61	620	***65.7***
2,4-DNT/2,6-DNT mixture	NE	NE	NE	NE	0.72	2.5	**701**
Nitroglycerin (NG)	3.6[1]	NE	NE	NE	6.1	62	***1,500***
Diphenylamine (DPA)	3.5[1]	NE	NE	NE	1,500	15,000	*1,200*
Diethylphthalate (DEP)	20[1]	NE	NE	NE	49,000	490,000	1.1
CPAH benzo(a)anthracene	0.4[4]	NE	NE	NE	0.15	2.1	**0.185**
CPAH benzo(b)fluoranthene							***0.723***

FS/IFCR/PM - Feasibility Study/In-Field Conditions Report/Plan Modification

NR 720 - Chapter NR 720, Wisconsin Administrative Code

RCL - Residual Contaminant Level

BAAAP - Badger Army Ammunition Plant

USEPA - United States Environmental Protection Agency

RSL - Regional Screening Level

NE - None established

DNT - Dinitrotoluene

CPAH - Carcinogenic Polyaromatic Hydrocarbons (consisting of benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene and chrysene)

Results expressed in milligrams per kilogram (mg/kg)

Bold text identifies NR 720 Table 2 RCL, BAAAP Background, or USEPA RSL exceedance

Metals expressed as totals, except as indicated for chromium

Italicized value indicates FS/IFCR/PM remediation goal exceedance

* Hexavalent/Trivalent values

† When lead is the only contaminant of concern

1 - Based on protection of ecological receptors per toxicologic information at the time (1994)

2 - Based on background concentration at the time (1994)

3 - Based on laboratory detection limit at the time (1994)

4 - Based on protection of human health per proposed NR 720 at the time (1994)

Table 2
Exposure Pathways and Institutional Controls
Alternative Feasibility Study - Final Creek, Settling Ponds, and Spoils Disposal Areas
Badger Army Ammunition Plant

Category	Media and Exposure Pathway	Activity/Land Use	Institutional/Engineering Controls
Pathway of Risk/Regulatory Concern	Soil - Ingestion & Dermal, Dust - Inhalation, Groundwater - Dermal	Demolition Contractor - Current	Health and Safety Program
	Groundwater - Ingestion & Dermal	WWTP & Recreational - Future	Deed Groundwater Use Restriction
	Groundwater - Ingestion & Dermal	Off-site Residential - Current & Future	Monitoring and Private Well Replacement or Public Water System
	Surface Water - Dermal	WWTP - Current & Future	Site Fencing/Posting and Land Use Controls
Pathway Has/Will Be Eliminated	Soil - Ingestion & Dermal, Dust - Inhalation, Groundwater - Ingestion & Dermal	Recreational & Residential - Current	Site Fencing and Land Use Controls
	Soil - Ingestion & Dermal, Dust - Inhalation	Recreational & WWTP - Future	Soil Removed/ Deed Dig Restriction
	Soil - Ingestion & Dermal, Dust - Inhalation	Residential - Future	Deed Residential Use Restriction

WWTP - Waste Water Treatment Plant

Table 3

Regulatory Requirements

Alternative Feasibility Study - Final Creek, Settling Ponds, and Spoils Disposal Areas

Badger Army Ammunition Plant

Type	Law	Criteria	Citation	Applicable	Relevant/ Appropriate	Reason
Chemical/Action/Federal	RCRA	General	See Below	X		Remedial Actions will Comply
Chemical/Action/Federal	CERCLA	General	See Below	X		Remedial Actions will Comply
Chemical/Action/Federal	SARA	General	See Below	X		Remedial Actions will Comply
Chemical/Action/Federal	EPCRA	General	See Below	X		Remedial Actions will Comply
Chemical/Action/State	Env Protection	General	NR 700 Series	X		Remedial Actions will Comply
Chemical/Action/State	Soil Cleanup Standards	Soil	NR 720	X		Remedial Actions will Comply
Chemical/Federal	USEPA Region 9 RSLs	Soil	NA		X	Soil Screening Guidelines Are Considered
Chemical/Site Specific	Background Levels	Soil	NA		X	Background Levels Over Cleanup Standards are Applicable

RCRA - Resource Conservation and Recovery Act - 42 United States Code (USC) 6901 et sequentes

CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act - 42 USC 9601 et sequentes

SARA - Superfund Amendments and Reauthorization Act - Pub. L. No. 99-499

EPCRA - Emergency Planning and Community Right to Know - 42 USC 11001 et sequentes

Env Protection - Wisconsin Environmental Protection - Investigation and Remediation - NR 700 Series, Wisconsin Administrative Code

USEPA Region 9 RSLs - United States Environmental Protection Agency, Region 9 - Regional Screening Levels

Table 4

Proposed Remediation Goals

Alternative Feasibility Study - Final Creek, Settling Ponds, and Spoils Disposal Areas

Badger Army Ammunition Plant

Contaminant of Concern	Qualified/Disqualified	Basis	Proposed Remediation Goals	Regulatory Reference
Aluminum (Al)	DQ	maximum concentration does not exceed residential USEPA RSL	NA	NA
Arsenic (As)	DQ	maximum concentration exceeds BAAAP Background and industrial USEPA RSL; however, not pervasive*	NA	NA
Chromium (Cr)	**Q**	**maximum concentration exceeds BAAAP Background**	**35.5**	**BAAAP Background**
Lead (Pb)	**Q**	**maximum concentration exceeds industrial USEPA RSL**	**500**	**NR 720 Table 2 Industrial RCL**
Tin (Sn)	DQ	maximum concentration does not exceed residential USEPA RSL or IFCR/PM	NA	NA
Zinc (Zn)	DQ	maximum concentration does not exceed residential USEPA RSL	NA	NA
2,4-DNT	**Q**	**maximum concentration exceeds industrial USEPA RSL**	**24.7**	**NR 720.19 SSRCL**
2,6-DNT	**Q**	**maximum concentration does not exceed industrial USEPA RSL; however, must be included due to "DNT mixture" effect**	**620**	**Industrial USEPA RSL**
2,4/2,6-DNT Mixture	**Q**	**maximum concentration exceeds industrial USEPA RSL**	**11.4**	**NR 720.19 SSRCL**
Nitroglycerin (NG)	**Q**	**maximum concentration exceeds industrial USEPA RSL**	**62**	**Industrial USEPA RSL**
Diphenylamine (DPA)	DQ	maximum concentration does not exceed residential USEPA RSL	NA	NA
Diethylphthalate (DEP)	DQ	maximum concentration does not exceed residential USEPA RSL or IFCR/PM	NA	NA
Carcinogenic Polyaromatic Hydrocarbons (CPAH)	DQ	maximum concentration does not exceed industrial USEPA RSL, nor is it pervasive**	NA	NA

Metals are considered as totals.
Q - Qualified
DQ - Disqualified
USEPA - United States Environmental Protection Agency
RSL - Regional Screening Level
NA - Not Applicable
BAAAP - Badger Army Ammunition Plant
RCL - Residual Contaminant Level
NR 720 - Chapter NR 720, Wisconsin Administrative Code
IFCR/PM - In Field Conditions/Plan Modification
DNT - Dinitrotoluene
SSRCL - Site-Specific Residual Contaminant Level
CPAH - consists of benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, and chrysene.
* Not statistically significant based on one sample out of 40 tested reported arsenic above the BAAAP Background level of 10 mg/kg.
** Not statistically significant based on one sample out of 50 tested reported a PAH above the industrial USEPA RSL.

Appendix A

Site-specific

Recreator Equation Inputs for Soil

Variable	Value
TR (target cancer risk) unitless	0.000001
SA_{recsc} (skin surface area - child) cm^2/day	2800
SA_{recsa} (skin surface area - adult) cm^2/day	5700
SA_{0-2} (skin surface area - mutagenic) cm^2/day	2800
SA_{2-6} (skin surface area - mutagenic) cm^2/day	2800
SA_{6-16} (skin surface area - mutagenic) cm^2/day	5700
SA_{16-30} (skin surface area - mutagenic) cm^2/day	5700
SA_{recsa} (skin surface area - adult) cm^2/day	5700
THQ (target hazard quotient) unitless	1
LT (lifetime - recreator) year	70
$IFS_{rec-adj}$ (age-adjusted soil ingestion factor) mg/kg	1308.552
$DFS_{rec-adj}$ (age-adjusted soil dermal factor) mg/kg	19865.559
$IFSM_{rec-adj}$ (mutagenic age-adjusted soil ingestion factor) mg/kg	11401.867
$DFSM_{rec-adj}$ (mutagenic age-adjusted soil dermal factor) mg/kg	158504.5
EF_{0-2} (exposure frequency) day/year	55
EF_{2-6} (exposure frequency) day/year	55
EF_{6-16} (exposure frequency) day/year	55
EF_{16-30} (exposure frequency) day/year	55
EF_{recsc} (exposure frequency - child) day/year	55
EF_{recsa} (exposure frequency - adult) day/year	55
EF_{recsa} (exposure frequency - adult) day/year	55
EF_{recs} (exposure frequency - recreator) day/year	55
IRS_{0-2} (soil intake rate) mg/day	41.6
IRS_{2-6} (soil intake rate) mg/day	41.6
IRS_{6-16} (soil intake rate) mg/day	20.8
IRS_{16-30} (soil intake rate) mg/day	20.8
IRS_{recsc} (soil intake rate - child) mg/day	41.6
IRS_{recsa} (soil intake rate - adult) mg/day	20.8
IRS_{recsa} (soil intake rate - adult) mg/day	20.8
ED_{0-2} (exposure duration) year	2
ED_{2-6} (exposure duration) year	4
ED_{6-16} (exposure duration) year	10
ED_{16-30} (exposure duration) year	14
ED_{recsc} (exposure duration - child) year	6
ED_{recsa} (exposure duration - adult) year	24
ED_{recsa} (exposure duration - adult) year	24
ED_{recs} (exposure duration - recreator) year	30
ET_{0-2} (exposure time) hr/day	5
ET_{2-6} (exposure time) hr/day	5
ET_{6-16} (exposure time) hr/day	5
ET_{16-30} (exposure time) hr/day	5
ET_{recsc} (exposure time - child) hr/day	5
ET_{recsa} (exposure time - adult) hr/day	5
ET_{recsa} (exposure time - adult) hr/day	5
ET_{recs} (exposure time - recreator) hr/day	5
BW_{0-2} (body weight) kg	5
BW_{2-6} (body weight) kg	20

BW_{6-16} (body weight) kg	50
BW_{16-30} (body weight) kg	84
BW_{recsc} (body weight - child) kg	15
BW_{recsa} (body weight - adult) kg	69.8
BW_{recsa} (body weight - adult) kg	69.8
AF_{0-2} (skin adherence factor) mg/cm^2	0.2
AF_{2-6} (skin adherence factor) mg/cm^2	0.2
AF_{6-16} (skin adherence factor) mg/cm^2	0.07
AF_{16-30} (skin adherence factor) mg/cm^2	0.07
AF_{recsc} (skin adherence factor - child) mg/cm^2	0.2
AF_{recsa} (skin adherence factor - adult) mg/cm^2	0.07
AF_{recsa} (skin adherence factor - adult) mg/cm^2	0.07
City (Climate Zone) PEF Selection	Default
A_s (acres) PEF Selection	0.5
Q/C_{wp} (g/m^2-s per kg/m^3) PEF Selection	93.77
V (fraction of vegetative cover) unitless	0.5
U_m (mean annual wind speed) m/s	4.69
U_t (equivalent threshold value)	11.32
F(x) (function dependant on U_m/U_t) unitless	0.194
City (Climate Zone) VF Selection	Chicago, IL (7)
A_s (acres) VF Selection	0.5
Q/C_{wp} (g/m^2-s per kg/m^3) VF Selection	98.43071
foc (fraction organic carbon in soil) g/g	0.006
ρ$_b$ (dry soil bulk density) g/cm^3	1.5
ρ$_s$ (soil particle density) g/cm^3	2.65
θ$_w$ (water-filled soil porosity) L_{water}/L_{soil}	0.15
T (exposure interval) s	950000000

Output generated 26JUN2012:08:27:38

Site-specific

Recreator Risk-Based Screening Levels for Soil

ca=Cancer, nc=Noncancer, ca* (Where nc SL < 100 x ca SL),
ca** (Where nc SL < 10 x ca SL),
max=SL exceeds ceiling limit (see User's Guide), sat=SL exceeds csat

Chemical	CAS Number	Ingestion SF $(mg/kg\text{-}day)^{-1}$	SFO Ref	Inhalation Unit Risk $(ug/m^3)^{-1}$	IUR Ref	Chronic RfD (mg/kg-day)	RfD Ref	Chronic RfC (mg/m^3)	RfC Ref	GIABS	ABS	Volatilization Factor (m^3/kg)	Soil Saturation Concentration (mg/kg)
Dinitrotoluene, 2,4-	121-14-2	3.10E-01	C	8.90E-05	C	2.00E-03	I	-		1	0.102	-	-

Chemical	Particulate Emission Factor (m^3/kg)	Ingestion SL TR=1.0E-6 (mg/kg)	Dermal SL TR=1.0E-6 (mg/kg)	Inhalation SL TR=1.0E-6 (mg/kg)	Carcinogenic SL TR=1.0E-6 (mg/kg)	Ingestion SL HQ=1 (mg/kg)	Dermal SL HQ=1 (mg/kg)	Inhalation SL HQ=1 (mg/kg)	Noncarcinogenic SL HI=1 (mg/kg)	Screening Level (mg/kg)
Dinitrotoluene, 2,4-	1.36E+09	6.30E+01	4.07E+01	1.14E+06	2.47E+01	4.79E+03	3.49E+03	-	2.02E+03	2.47E+01 ca*

Output generated 06SEP2011:14:19:19

Site-specific

Recreator Equation Inputs for Soil

Variable	Value
TR (target cancer risk) unitless	0.000001
SA_{recsc} (skin surface area - child) cm^2/day	2800
SA_{recsa} (skin surface area - adult) cm^2/day	5700
SA_{0-2} (skin surface area - mutagenic) cm^2/day	2800
SA_{2-6} (skin surface area - mutagenic) cm^2/day	2800
SA_{6-16} (skin surface area - mutagenic) cm^2/day	5700
SA_{16-30} (skin surface area - mutagenic) cm^2/day	5700
SA_{recsa} (skin surface area - adult) cm^2/day	5700
THQ (target hazard quotient) unitless	1
LT (lifetime - recreator) year	70
$IFS_{rec-adj}$ (age-adjusted soil ingestion factor) mg/kg	1308.552
$DFS_{rec-adj}$ (age-adjusted soil dermal factor) mg/kg	19865.559
$IFSM_{rec-adj}$ (mutagenic age-adjusted soil ingestion factor) mg/kg	11401.867
$DFSM_{rec-adj}$ (mutagenic age-adjusted soil dermal factor) mg/kg	158504.5
EF_{0-2} (exposure frequency) day/year	55
EF_{2-6} (exposure frequency) day/year	55
EF_{6-16} (exposure frequency) day/year	55
EF_{16-30} (exposure frequency) day/year	55
EF_{recsc} (exposure frequency - child) day/year	55
EF_{recsa} (exposure frequency - adult) day/year	55
EF_{recsa} (exposure frequency - adult) day/year	55
EF_{recs} (exposure frequency - recreator) day/year	55
IRS_{0-2} (soil intake rate) mg/day	41.6
IRS_{2-6} (soil intake rate) mg/day	41.6
IRS_{6-16} (soil intake rate) mg/day	20.8
IRS_{16-30} (soil intake rate) mg/day	20.8
IRS_{recsc} (soil intake rate - child) mg/day	41.6
IRS_{recsa} (soil intake rate - adult) mg/day	20.8
IRS_{recsa} (soil intake rate - adult) mg/day	20.8
ED_{0-2} (exposure duration) year	2
ED_{2-6} (exposure duration) year	4
ED_{6-16} (exposure duration) year	10
ED_{16-30} (exposure duration) year	14
ED_{recsc} (exposure duration - child) year	6
ED_{recsa} (exposure duration - adult) year	24
ED_{recsa} (exposure duration - adult) year	24
ED_{recs} (exposure duration - recreator) year	30
ET_{0-2} (exposure time) hr/day	5
ET_{2-6} (exposure time) hr/day	5
ET_{6-16} (exposure time) hr/day	5
ET_{16-30} (exposure time) hr/day	5
ET_{recsc} (exposure time - child) hr/day	5
ET_{recsa} (exposure time - adult) hr/day	5

ET_{recsa} (exposure time - adult) hr/day	5
ET_{recs} (exposure time - recreator) hr/day	5
BW_{0-2} (body weight) kg	5
BW_{2-6} (body weight) kg	20
BW_{6-16} (body weight) kg	50
BW_{16-30} (body weight) kg	84
BW_{recsc} (body weight - child) kg	15
BW_{recsa} (body weight - adult) kg	69.8
BW_{recsa} (body weight - adult) kg	69.8
AF_{0-2} (skin adherence factor) mg/cm^2	0.2
AF_{2-6} (skin adherence factor) mg/cm^2	0.2
AF_{6-16} (skin adherence factor) mg/cm^2	0.07
AF_{16-30} (skin adherence factor) mg/cm^2	0.07
AF_{recsc} (skin adherence factor - child) mg/cm^2	0.2
AF_{recsa} (skin adherence factor - adult) mg/cm^2	0.07
AF_{recsa} (skin adherence factor - adult) mg/cm^2	0.07
City (Climate Zone) PEF Selection	Default
A_s (acres) PEF Selection	0.5
Q/C_{wp} (g/m^2-s per kg/m^3) PEF Selection	93.77
V (fraction of vegetative cover) unitless	0.5
U_m (mean annual wind speed) m/s	4.69
U_t (equivalent threshold value)	11.32
F(x) (function dependant on U_m/U_t) unitless	0.194
City (Climate Zone) VF Selection	Default
A_s (acres) VF Selection	0.5
Q/C_{wp} (g/m^2-s per kg/m^3) VF Selection	68.18
foc (fraction organic carbon in soil) g/g	0.006
ρ$_b$ (dry soil bulk density) g/cm^3	1.5
ρ$_s$ (soil particle density) g/cm^3	2.65
θ$_w$ (water-filled soil porosity) L_{water}/L_{soil}	0.15
T (exposure interval) s	950000000

Output generated 26JUN2012:08:39:02

Site-specific

Recreator Risk-Based Screening Levels for Soil

ca=Cancer, nc=Noncancer, ca* (Where nc SL < 100 x ca SL),
ca** (Where nc SL < 10 x ca SL),
max=SL exceeds ceiling limit (see User's Guide), sat=SL exceeds csat

Chemical	CAS Number	Ingestion SF $(mg/kg\text{-}day)^{-1}$	SFO Ref	Inhalation Unit Risk $(ug/m^3)^{-1}$	IUR Ref	Chronic RfD (mg/kg-day)	RfD Ref	Chronic RfC (mg/m^3)	RfC Ref	GIABS	ABS	Volatilization Factor (m^3/kg)	Soil Saturation Concentration (mg/kg)
Dinitrotoluene Mixture, 2,4/2,6-	25321-14-6	6.80E-01	I	-		-		-		1	0.1	-	-

Chemical	Particulate Emission Factor (m^3/kg)	Ingestion SL TR=1.0E-6 (mg/kg)	Dermal SL TR=1.0E-6 (mg/kg)	Inhalation SL TR=1.0E-6 (mg/kg)	Carcinogenic SL TR=1.0E-6 (mg/kg)	Ingestion SL HQ=1 (mg/kg)	Dermal SL HQ=1 (mg/kg)	Inhalation SL HQ=1 (mg/kg)	Noncarcinogenic SL HI=1 (mg/kg)	Screening Level (mg/kg)
Dinitrotoluene Mixture, 2,4/2,6-	1.36E+09	2.87E+01	1.89E+01	-	1.14E+01	-	-	-	-	1.14E+01 ca**

Output generated 06SEP2011:12:31:20

Recreational Soil/Sediment Equations

- **Noncarcinogenic**

Ingestion

$$SL_{rec\text{-}sol\text{-}nc\text{-}ing}\left(mg/kg\right)=\frac{THQ\times AT_{rec}\left(\frac{365\ days}{year}\times ED_{recsc}\left(years\right)\right)\times BW_{recsc}\left(Kg\right)}{EF_{recsc}\left(\frac{days}{year}\right)\times ED_{recsc}\left(years\right)\times\frac{1}{RfD_{o}\left(\frac{mg}{Kg\text{-}day}\right)}\times IRS_{recsc}\left(\frac{200\ mg}{day}\right)\times\frac{10^{-6}Kg}{1\,mg}}$$

Dermal

$$SL_{rec\text{-}sol\text{-}nc\text{-}der}\left(mg/kg\right)=\frac{THQ\times AT_{rec}\left(\frac{365\ days}{year}\times ED_{recsc}\left(years\right)\right)\times BW_{recsc}\left(Kg\right)}{EF_{recsc}\left(\frac{days}{year}\right)\times ED_{recsc}\left(year\right)\times\frac{1}{\left(RfD_{o}\left(\frac{mg}{Kg\text{-}day}\right)\times GIABS\right)}\times SA_{recsc}\left(\frac{cm^{2}}{day}\right)\times AF_{recsc}\left(\frac{mg}{cm^{2}}\right)\times ABS_{d}\times\frac{10^{-6}Kg}{1\,mg}}$$

Inhalation

$$SL_{rec\text{-}sol\text{-}nc\text{-}inh}\left(mg/kg\right)=\frac{THQ\times AT_{rec}\left(\frac{365\ days}{year}\times ED_{recsc}\left(years\right)\right)}{EF_{recsc}\left(\frac{days}{year}\right)\times ED_{recsc}\left(year\right)\times ET_{recsc}\left(\frac{hours}{day}\right)\times\left(\frac{1\ day}{24\ hours}\right)\times\frac{1}{RfC\left(mg/m^{3}\right)}\times\left(\frac{1}{VF_{s}\left(\frac{m^{3}}{Kg}\right)}+\frac{1}{PEF_{w}\left(\frac{m^{3}}{Kg}\right)}\right)}$$

Total

$$SL_{rec\text{-}sol\text{-}nc\text{-}tot}\left(mg/kg\right)=\frac{1}{\frac{1}{SL_{rec\text{-}sol\text{-}nc\text{-}ing}}+\frac{1}{SL_{rec\text{-}sol\text{-}nc\text{-}der}}+\frac{1}{SL_{rec\text{-}sol\text{-}nc\text{-}inh}}}$$

- **Carcinogenic**

Ingestion

$$SL_{rec\text{-}sol\text{-}ca\text{-}ing}\,(mg/kg)=\frac{TR\times AT_{rec}\left(\frac{365\ days}{year}\times LT\ (70\ years)\right)}{CSF_o\left(\frac{mg}{Kg\text{-}day}\right)^{-1}\times IFS_{adj}\left(\frac{mg}{Kg}\right)\times\left(\frac{10^{-6}Kg}{mg}\right)}$$

where:

$$IFS_{rec\text{-}adj}\left(\frac{mg}{Kg}\right)=\frac{ED_{recsc}\,(years)\times EF_{recsc}\left(\frac{days}{year}\right)\times IRS_{recsc}\left(\frac{200\ mg}{day}\right)}{BW_{recsc}\,(Kg)}+\frac{ED_{recsa}\,(years)\times EF_{recsa}\left(\frac{days}{year}\right)\times IRS_{recsa}\left(\frac{100\ mg}{day}\right)}{BW_{recsa}\,(Kg)}$$

Dermal

$$SL_{rec\text{-}sol\text{-}ca\text{-}der}\,(mg/kg)=\frac{TR\times AT_{rec}\left(\frac{365\ days}{year}\times LT\ (70\ years)\right)}{\left(\frac{CSF_o\left(\frac{mg}{Kg\text{-}day}\right)}{GIABS}\right)^{-1}\times DFS_{adj}\left(\frac{mg}{Kg}\right)\times ABS_d\times\left(\frac{10^{-6}Kg}{mg}\right)}$$

where:

$$DFS_{rec\text{-}adj}\left(\frac{mg}{Kg}\right)=\frac{ED_{recsc}\,(years)\times EF_{recsc}\left(\frac{days}{year}\right)\times SA_{recsc}\left(\frac{cm^2}{day}\right)\times AF_{recsc}\left(\frac{mg}{cm^2}\right)}{BW_{recsc}\,(Kg)}+\frac{ED_{recsa}\,(years)\times EF_{recsa}\left(\frac{days}{year}\right)\times SA_{recsa}\left(\frac{cm^2}{day}\right)\times AF_{recsa}\left(\frac{mg}{cm^2}\right)}{BW_{recsa}\,(Kg)}$$

Inhalation

$$SL_{rec\text{-}sol\text{-}ca\text{-}inh}\,(mg/kg)=\frac{TR\times AT_{rec}\left(\frac{365\ days}{year}\times LT\ (70\ years)\right)}{IUR\left(\mu g/m^3\right)^{-1}\times\left(\frac{1000\ \mu g}{mg}\right)\times EF_{recs}\left(\frac{days}{year}\right)\times\left(\frac{1}{VF_s\left(\frac{m^3}{Kg}\right)}+\frac{1}{PEF_w\left(\frac{m^3}{Kg}\right)}\right)\times ED_{recs}\,(years)\times ET_{recs}\left(\frac{hours}{day}\right)\times\left(\frac{1\ day}{24\ hours}\right)}$$

Total

$$SL_{rec\text{-}sol\text{-}ca\text{-}tot}\,(mg/kg)=\frac{1}{\frac{1}{SL_{rec\text{-}sol\text{-}ca\text{-}ing}}+\frac{1}{SL_{rec\text{-}sol\text{-}ca\text{-}der}}+\frac{1}{SL_{rec\text{-}sol\text{-}ca\text{-}inh}}}$$

- **Mutagenic**

Ingestion

$$SL_{rec\text{-}sol\text{-}mu\text{-}ing}\,(mg/kg)=\frac{TR\times AT_{rec}\left(\frac{365\ days}{year}\times LT\ (70\ years)\right)}{CSF_o\left(\frac{mg}{Kg\text{-}day}\right)^{-1}\times IFSM_{adj}\left(\frac{mg}{Kg}\right)\times\left(\frac{10^{-6}Kg}{mg}\right)}$$

where:

$$IFSM_{rec\text{-}adj}\left(\frac{mg}{Kg}\right)=\frac{ED_{0\text{-}2}\,(yr)\times EF_{0\text{-}2}\left(\frac{days}{year}\right)\times IRS_{0\text{-}2}\left(\frac{200\ mg}{day}\right)\times 10}{BW_{0\text{-}2}\,(Kg)}+\frac{ED_{2\text{-}6}\,(yr)\times EF_{2\text{-}6}\left(\frac{days}{year}\right)\times IRS_{2\text{-}6}\left(\frac{200\ mg}{day}\right)\times 3}{BW_{2\text{-}6}\,(Kg)}+$$
$$\frac{ED_{6\text{-}16}\,(yr)\times EF_{6\text{-}16}\left(\frac{days}{year}\right)\times IRS_{6\text{-}16}\left(\frac{100\ mg}{day}\right)\times 3}{BW_{6\text{-}16}\,(Kg)}+\frac{ED_{16\text{-}30}\,(yr)\times EF_{16\text{-}30}\left(\frac{days}{year}\right)\times IRS_{16\text{-}30}\left(\frac{100\ mg}{day}\right)\times 1}{BW_{16\text{-}30}\,(Kg)}$$

Dermal

$$SL_{rec\text{-}sol\text{-}mu\text{-}der}\,(mg/kg)=\frac{TR\times AT_{rec}\left(\frac{365\ days}{year}\times LT\ (70\ years)\right)}{\left(\frac{CSF_o\left(\frac{mg}{Kg\text{-}day}\right)^{-1}}{GIABS}\right)\times DFSM_{adj}\left(\frac{mg}{Kg}\right)\times ABS_d\times\left(\frac{10^{-6}Kg}{mg}\right)}$$

where:

$$DFSM_{rec\text{-}adj}\left(\frac{mg}{Kg}\right)=\frac{ED_{0\text{-}2}\,(yr)\times EF_{0\text{-}2}\left(\frac{days}{year}\right)\times AF_{0\text{-}2}\left(\frac{mg}{cm^2}\right)\times SA_{0\text{-}2}\left(\frac{cm^2}{day}\right)\times 10}{BW_{0\text{-}2}\,(Kg)}+\frac{ED_{2\text{-}6}\,(yr)\times EF_{2\text{-}6}\left(\frac{days}{year}\right)\times AF_{2\text{-}6}\left(\frac{mg}{cm^2}\right)\times SA_{2\text{-}6}\left(\frac{cm^2}{day}\right)\times 3}{BW_{2\text{-}6}\,(Kg)}+$$

$$\frac{ED_{6\text{-}16}\,(yr)\times EF_{6\text{-}16}\left(\frac{days}{year}\right)\times AF_{6\text{-}16}\left(\frac{mg}{cm^2}\right)\times SA_{6\text{-}16}\left(\frac{cm^2}{day}\right)\times 3}{BW_{6\text{-}16}\,(Kg)}+\frac{ED_{16\text{-}30}\,(yr)\times EF_{16\text{-}30}\left(\frac{days}{year}\right)\times AF_{16\text{-}30}\left(\frac{mg}{cm^2}\right)\times SA_{16\text{-}30}\left(\frac{cm^2}{day}\right)\times 1}{BW_{16\text{-}30}\,(Kg)}$$

Inhalation

$$SL_{rec\text{-}sol\text{-}mu\text{-}inh}\,(mg/kg)=\frac{TR\times AT_{rec}\left(\frac{365\ days}{year}\times LT\ (70\ years)\right)}{\left(\frac{1\ day}{24\ hours}\right)\times\left(\frac{1000\ \mu g}{mg}\right)\times\left(\frac{1}{VF_s\left(\frac{m^3}{Kg}\right)}+\frac{1}{PEF_w\left(\frac{m^3}{Kg}\right)}\right)\times\left(\begin{array}{l}\left(ED_{0\text{-}2}\,(yrs)\times EF_{0\text{-}2}\left(\frac{days}{year}\right)\times ET_{0\text{-}2}\left(\frac{hours}{day}\right)\times IUR\left(\mu g/m^3\right)^{-1}\times 10\right)+\left(ED_{2\text{-}6}\,(yrs)\times EF_{2\text{-}6}\left(\frac{days}{year}\right)\times ET_{2\text{-}6}\left(\frac{hours}{day}\right)\times IUR\left(\mu g/m^3\right)^{-1}\times 3\right)+\\ \left(ED_{6\text{-}16}\,(yrs)\times EF_{6\text{-}16}\left(\frac{days}{year}\right)\times ET_{6\text{-}16}\left(\frac{hours}{day}\right)\times IUR\left(\mu g/m^3\right)^{-1}\times 3\right)+\left(ED_{16\text{-}30}\,(yrs)\times EF_{16\text{-}30}\left(\frac{days}{year}\right)\times ET_{16\text{-}30}\left(\frac{hours}{day}\right)\times IUR\left(\mu g/m^3\right)^{-1}\times 1\right)\end{array}\right)}$$

Total

$$SL_{rec\text{-}sol\text{-}mu\text{-}tot}\,(mg/kg) = \frac{1}{\frac{1}{SL_{rec\text{-}sol\text{-}mu\text{-}ing}} + \frac{1}{SL_{rec\text{-}sol\text{-}mu\text{-}der}} + \frac{1}{SL_{rec\text{-}sol\text{-}mu\text{-}inh}}}$$

Source: http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/equations.htm as of 4 October 2011.

Appendix B

Alternative 1 Cost Summary
Alternative Feasibility Study - Final Creek, Settling Ponds, and Spoils Disposal Areas
Badger Army Ammunition Plant

Alternative	Task	Task Description	Total Costs
No Action	**Capital Cost**	No capital cost to implement alternative	$0
	Post-Treatment/Long-Term Monitoring	No post-treatment monitoring or long-term monitoring required	$0
	Closeout Report	Prepare final report requesting closure	$25,000
			$25,000

Alternative 2 Cost Summary
Alternative Feasibility Study - Final Creek, Settling Ponds, and Spoils Disposal Areas
Badger Army Ammunition Plant

Alternative	Task	Task Description	Total Costs
Solidification and Soil Cover	**Solidification/Stabilization**	Perform soil solidification/stabilization utilizing portland cement mixture to a depth of 4 feet over an area of 70 acres	$70,732,394
	Professional Labor Management	Engineering, Services During Construction, Administration, Health and Safety, and Project Management/Oversight	$7,073,239
	Soil Cover Installation	Placement of a 2-foot thick dermal soil cap over 70 acres of solidified/stabilized soil	$10,216,245
	Monitoring and Cap Maintenance	Long-term monitoring of cap integrity and repair/replacement as needed. (Estimate based on semiannual monitoring over 10 years).	$20,000
	Closeout Report	Prepare final report requesting closure	$55,000
			$88,096,878

Notes:
Costs are based on current engineering estimates and RACER estimate.

Alternative 3 Cost Summary
Alternative Feasibility Study - Final Creek, Settling Ponds, and Spoils Disposal Areas
Badger Army Ammunition Plant

Alternative	Task	Task Description	Total Costs
Excavation and On-Site Disposal	**Excavation and Disposal**	Excavate hotspot areas to soil concentration values less than the proposed soil remediation goals; collect soil confirmation samples	$1,003,000
	Backfilling, Grading, and Restoration	Backfill excavations in Settling Ponds and Spoils Disposal Areas, Grade excavated areas to a natural slope and restore excavated areas	$100,000
	Monitoring and Closeout Plan/Report	Prepare final report requesting closure	$35,000
			$1,138,000

Notes:
Costs are based on historic/reoccurring costs and current engineering estimates.