ESC
ENVIRONMENTAL STRATEGIES CORPORATION
Four Penn Center West • Suite 315 • Pittsburgh, Pennsylvania 15276 • (412) 787-5100 • Fax (412) 787-8065

DESIGN REPORT
(FINAL SUBMITTAL)

MORGANTOWN ORDNANCE WORKS
OPERABLE UNIT NO. 1
MORGANTOWN, WEST VIRGINIA

PREPARED

BY

ENVIRONMENTAL STRATEGIES CORPORATION

APRIL 3, 2002

Morgantown\457302\Tar and Soil WP\Final Submittal\Final Design Report.doc

ESC
ENVIRONMENTAL STRATEGIES CORPORATION
Four Penn Center West • Suite 315 • Pittsburgh Pennsylvania 15276 • (412) 787-5100 • Fax (412) 787-8065

DESIGN REPORT
(FINAL SUBMITTAL)

MORGANTOWN ORDNANCE WORKS
OPERABLE UNIT NO. 1
MORGANTOWN, WEST VIRGINIA

PREPARED

BY

ENVIRONMENTAL STRATEGIES CORPORATION

APRIL 3, 2002

Morgantown\457302\Tar and Soil WP\Final Submittal\Final Design Report.doc

Reston, VA • San Jose, CA • Boxborough, MA • Minneapolis, MN • Houston, TX • Cazenovia, NY • Burbank, CA • Durham, NC • Tulsa OK

Contents

List of Figures:

Contents
(continued)

List of Tables:

List of Appendices:

1.0 Introduction

This design report was prepared by Environmental Strategies Corporation (ESC) on behalf of the Respondents for Operable Unit No. 1 (OU-1) for the Morgantown Ordnance Works (MOW) site in Monongalia County, West Virginia (Figure 1). Specifically, this design report addresses all actions necessary to properly implement the selected remedy for the OU-1 component of the MOW site, excluding the tar and soil excavation component[1]. This work is being performed by ESC on behalf of the respondents[2] to the MOW OU-1 Administrative Order and U.S. Army Corps of Engineers, Omaha District (the OU-1 Group). This design report submittal is supplemented by a calculations brief (Appendix A), Draft Technical Specifications (Appendix B) and Construction Drawings (bound separately).

This submittal was prepared to fulfill the requirements of the Pre-Design and Remedial Design Work Plan dated August 15, 2000. This submittal describes the approach to implementing the chosen remedy at 100 percent completion.

The elements of the selected remedy as presented in the 1999 Record of Decision (ROD) include:

- excavate all visibly stained tar-like material (covered under the Tar and Soil Excavation Work Plan dated May 29, 2001)
- thermal treatment of tar-like material at an offsite facility (covered under the Tar and Soil Excavation Work Plan dated May 29, 2001)
- excavate soils in excess of cleanup standards (covered under the Tar and Soil Excavation Work Plan dated May 29, 2001)
- excavate sediments above the cleanup standards (covered under this submittal)
- consolidate OU-2 materials (covered under detailed design documents)
- restore streams and wetland areas where sediment was excavated (covered under this submittal)
- construct a multi-layer Resource Conservation and Recovery Act (RCRA) cap over the existing landfill (covered under this submittal)

---

[1] The tar and soil excavation component of the remedy has been addressed separately via work plan dated May 29, 2001, in an attempt to expedite these activities.

[2] Named respondents are Rockwell International Corporation, Olin Corporation, General Electric Company, and Morgantown Industrial Park Associates, Limited Partnership.

- long-term monitoring (covered under post closure plan [Appendix D of this submittal])
- maintain the perimeter fence (covered under post closure plan [Appendix D of this submittal])
- implement institutional controls (to be addressed separately by the OU-1 Group; not addressed by the design documents)

To gather additional site information for use in detailed design efforts, a pre-design investigation was performed by ESC in Summer and Fall 2000. A summary of the efforts and analytical results are presented in the Pre-Design Investigation Report dated June 1, 2001. The data collected during the pre-design investigation are reflected in this detailed design.

2.0 Site Description

The Morgantown Ordnance Works (MOW) (the Site) is located in Monongalia County along the west bank of the Monongahela River approximately one mile southwest of the City of Morgantown, West Virginia (Figure 1). The property on which the Site is located consists of approximately 800 acres and is wooded with rolling hills. A small portion of this property was used as a disposal ground and later became known to the United States Environmental Protection Agency (USEPA) as OU-1 of the Site. The remaining tracts of land within the property containing, among other things, the manufacturing facilities, are known to USEPA as Operable Unit 2 (OU-2) of the Site. OU-2 was addressed through a removal action and was certified complete by USEPA in 1997.

OU-1 consists of approximately four to six acres and is located at the southern end of the Site property. Major OU-1 features include an inactive, abandoned landfill, a former lagoon area, an area referred to as the "scraped area" formerly used for the shallow disposal of wastes, and contaminated stream sediments (Figure 2). The OU-1 features with the drainage swales and wetlands area occupy a combined area of approximately 14 to 16 acres. The landfill, scraped area, and former lagoon areas are located inside a chain-link perimeter fence. The drainage swales (Swale 1, Swale 2, and Swale 3) extend beyond the limits of the fence.

2.1 Scraped Area Features

This area consisted of bare soil adjacent to the landfill where solid wastes (e.g., construction debris, oil-stained soils, and catalyst pellets) were buried. This area slopes north and east in the direction of the Monongahela River. Ten test pits were dug in the Scraped Area during the Remedial Investigation Report (RI), prepared by Roy F. Weston, Inc. in 1988 (Roy F. Weston 1988). The pits contained cinder-like backfill material, catalyst pellets (blue and black), and yellow solid materials.

In 1996, as part of the Phase II Interim Design Tasks work, samples were taken from the Scraped Area, Lagoon Area, and the streams in an attempt to further define volumes of soil/sediment to be remediated. Thirty-six soil borings were drilled in the Scraped Area within an area approximately 150 by 350 feet. Visible tar was present in samples up to eight feet in depth. The detected concentrations of total cPAHs in this area ranged from 94 parts per million (ppm) to 36,000 ppm. The estimated volume of soils that are contaminated above the total cPAH cleanup standard is 2,000 yd^3.

2.2 Former Lagoon Area Features

Between approximately 1970 and 1976, a subsidiary of Rockwell International Corporation disposed of metal plating wastes containing chromium in two lagoons located adjacent to the landfill. Between March and September 1981, under the supervision of the West Virginia Department of Natural Resources (now known as the West Virginia Division of Environmental Protection), these lagoons were excavated and their contents disposed of offsite. During the OU-1 soil boring program, USEPA observed miscellaneous wastes, including coal tars, in this area.

Sample results from soil borings taken during the RI indicate that chromium was present at concentrations only slightly above background levels, the highest concentration being 2,690 ppm--well below Region III's current risk-based concentration level for Chromium VI (10,000 ppm). Arsenic and copper were also detected in the test pit samples, but not at concentrations above their respective soil cleanup standards.

Organic contamination was also detected in soil borings from the Lagoon Area during the RI. Xylene (10,000 parts per billion [ppb]), toluene (4,100 ppb), benzene (3,400 ppb), and methylene chloride (2,900 ppb) were detected at elevated levels. However, these concentrations are below the Region III RBC's for industrial soils.

The most notable organic contamination found in the Lagoon Area was cPAHs, which are semi-volatile in nature. Total cPAHs were detected at concentrations as high as 31,800 ppm.

In 1996, as part of the Phase II Interim Design Tasks work, 103 soil borings were drilled in the Lagoon Area within an area approximately 330 by 380 feet. Fill material such as brick/concrete fragments, black cinders, and tar were visible in most of the borings. Detected cPAH concentrations in this area ranged from 3.2 ppm to 30,000 ppm. The estimated volume of soils contaminated above the cPAH cleanup standard (including visibly stained tar-like material) is 24,000 yd^3. Analysis of samples taken in this area in 1996 did not confirm the presence of inorganic contaminants at concentrations detected during the 1988 RI.

2.3 Swales

Surface water and sediment samples were obtained from four swales during the RI, which was completed in 1988. Elevated levels of total cPAHs (up to 318 ppm) were detected in stream sediments. The Remedial investigation/Feasibility Study (RI/FS) Report also indicated that surface water and sediments downgradient of the Site contained elevated levels of several inorganic compounds. The concentrations of such inorganic compounds in sediments are above the background levels. Swale 1, Swale 2, and Swale 3 were further characterized during the pre-design investigation to delineate excavation requirements. Concentrations for arsenic were detected up to 21.2 ppm, concentrations for cadmium were detected up to 25.5 ppm, concentrations for chromium were detected up to 213 ppm, concentrations for copper were detected up to 15,900 ppm, concentrations for lead were detected up to 89.9 ppm, concentrations for mercury were detected up to 3.9 ppm, and concentrations for zinc were detected up to 224,000 ppm. No action is required for the fourth swale.

2.4 Landfill

The currently inactive landfill was formed when solid and chemical wastes were disposed of in and around an existing ravine. The landfill was reportedly active from 1942 to 1962. There are no records regarding the types or quantities of waste material that were disposed of in the landfill. Information obtained from various witnesses indicates that landfilled wastes included construction debris, slag, ash, and catalyst pellets. To characterize the Landfill Area, three test pits were dug and samples were collected during the RI. Test pits indicated a fill depth of 16 to 20 feet. The following table provides a summary of the analytical testing of landfill test pit samples collected during the RI:

Concentrations for Constituents of Concern From Landfill Soil Samples

Constituents of Concern	**Concentration Range (mg/kg) (from table 4-9 of RI)**
Arsenic	non-detect to 380
Cadmium	non-detect to 15
Calcium	664 to 145,000
Copper	32 to 67,000
Iron	15,700 to 108,000
Mercury	0.23 to 48
Selenium	-----
Zinc	31 to 138,000
	Maximum Concentration (mg/kg) (from page 4-64 of RI)
PAHs	1,046
cPAHs	298

The 1989 Focused Feasibility Study (FFS) Report estimated the volume of the landfill at 29,150 yd^3, based on an estimated area of 1.08 acres. During the 1997 removal action at OU-2, approximately 10,000 yd^3 of soils contaminated with lead and total cPAHs were removed from the Coke Ovens and By-Products Area and relocated to OU-1 for consolidation into the landfill. These contaminated soils were placed adjacent to the landfill and covered with a geotextile layer and approximately eight inches of backfill material. Temporary erosion controls were installed.

Based on data collected during the pre-design investigation, the responsible parties have estimated the area of the landfill to be approximately 2.75 acres. Using this figure, the revised estimates of landfill volume becomes approximately 46 yd^3 to 66,000 yd^3, depending on the actual average depth. This volume estimate is conservative and was used to estimate the cost of the remedial alternatives identified in the 1998 FFS Report. The actual boundaries/volumes associated with the Landfill Area are reflected by the final design.

2.5 Applicable or Relevant and Appropriate Requirements

The Applicable or Relevant and Appropriate Requirements (ARARs) for the OU-1 remedy are listed in the ROD and presented in Table 1 of this design report. The actions to be taken to satisfy the ARARs are also presented in Table 1. The remedy will be implemented in a manner that satisfies the ARARs, as necessary.

3.0 Basis of Design

The respondents have retained ESC, a qualified, independent, registered professional engineering consultant (the "Engineer") to perform the design activities, be its representative on site during future construction activities, and serve as the Construction Quality Assurance Officer. ESC will be present throughout the construction process to observe and document the stripping, moving, placement, and capping of the waste material. The work will be done in accordance with the Technical Specifications, Construction Drawings, and Supplemental Plans. After construction has been completed, the activities will be certified to have been conducted in accordance with the approved Design and Contract Documents.

The following documents are appended to this report:

Appendix A - Calculation Brief
Appendix B - Technical Specifications
Appendix C - Construction Quality Assurance Plan
Appendix D - Post Closure Plan
Appendix E - Constructed Wetlands Treatment System Design
Appendix F - Wetlands Mitigation Plan

3.1 Soil and Sediment Relocation and Grading

The activities described in this section overlap with the activities covered by the Tar and Soil Excavation Work Plan. To provide clarification, the following sequence of events is presented:

- tar and soil excavation (covered by separate work plan and contract)
- tar processing and offsite thermal treatment (covered by separate work plan and contract)
- soil stockpile within landfill limits (covered by separate work plan and contract)
- sediment excavation from the swales (covered under this design and contract)
- contaminated soil and sediment grading to produce cap subgrade (covered under this design and contract)

The construction activities will be performed in accordance with the Technical Specifications and Construction Drawings. Soil and sediment material from the former lagoon area, scraped area, and swales will be excavated and stockpiled within the limits of capping. These materials will be placed beneath the final cap for ultimate disposal. The tar will be taken to an offsite facility for ultimate thermal treatment. The tar and soil excavation activities are described in a separate work plan. Actual volumes of tar and soil are unknown at this time. However, the soil volume requiring excavation is expected to fall within the range of 10,000 cubic yards to 45,000 cubic yards.

Sediments will be excavated from the swales. Sediment volume requiring excavation is expected to fall within the range of 2,000 cubic yards to 5,000 cubic yards. The excavation will be performed to match existing conditions (i.e., side slopes will remain the same). Sediment will be excavated to a depth of 2 feet. The width will vary depending on the actual drainage channel dimension. The excavation areas will be backfilled with 2 feet of clean fill from the onsite borrow area to promote positive drainage. The actual volume of sediment requiring excavation is unknown at this time. The excavated swales will be seeded with a grass variety mixture and protected from erosion with jute mat material.

The excavation and grading activities will be implemented to minimize the area of the final area requiring capping. Debris within the landfill will be spread out into a thin layer and ultimately covered with contaminated soils and sediment to create the cap subgrade. A minimum cover of 2 feet will be maintained between the debris and cap liner system. Natural soils will be exposed in the excavation areas. The maximum and minimum slopes of the pile will be 25 percent and 3 percent, respectively. The anticipated extent of the proposed excavation and capped areas are shown on the Construction Drawings.

3.2 Cap Design

The cap will enclose the area shown on the Construction Drawings. The final cap will consist of a multi-layer cover system that includes components recommended by the USEPA. The cap will prevent direct contact with, and inhalation of, potentially harmful dust generated from contaminated soil. The cap will also prevent offsite migration of contaminated soil and reduce the amount of precipitation which infiltrates through contaminated soil.

A multi-layer RCRA-cap shall be installed over the existing landfill. This cap will be designed, constructed, and maintained to meet the performance requirements of RCRA Subtitle C regulations found at 40 C.F.R. §§ 265.19, 265.111, 265.117, 265.118, and 265.310. The cap will cover the areal extent of the existing landfill as determined during remedial design.

The cap will also be designed to meet the performance requirements of the following USEPA technical guidance documents: "Final Covers on Hazardous Waste Landfills and Surface Impoundments" (USEPA/530-SW-89-047, July 1989), "Design and Construction of RCRA/CERCLA Final Covers (USEPA/625/4-91/025, May 1991), and "Construction Quality Management for Remedial Action and Remedial Design Waste Containment Systems" (USEPA/540/R-92/073, October 1992).

Details of the final cover system are presented on the Construction Drawings. Specifically, the final cover system will consist of the following components from top to bottom:

1. A vegetated top cover that: (a) is 24 inches thick; (b) will support vegetation that will minimize erosion; (c) will be planted with vegetative species that do not have a root system which will penetrate beyond the vegetative layer; and (d) will have a final top slope between 3 and 25 percent.

2. A lateral drainage layer that: (a) consists of a synthetic drainage composite with a thickness of 0.20 inch; (b) has a non-woven geosynthetic filter fabric bonded to both sides; (c) has a transmissivity not less than 1 x 10^{-4} meters squared per second (m^2/sec); (d) has a final bottom slope of at least 3 percent; and (e) will be designed so that discharge flows freely in the lateral direction to minimize head on and flow through the low-permeability layer.

3. A low-permeability layer consisting of two components:

   a. The upper component will: (a) consist of a 40-mil textured high density polyethylene (HDPE) synthetic membrane; (b) be protected from damage below the membrane by visual inspection of clay liner for objects and by providing a double-sided composite drainage net above the liner; (c) have a final upper slope of at least 3 percent; and (d) be located wholly below the 24 inches of vegetated top cover.

   b. The lower component will consist of geosynthetic clay liner (GCL); and provide a safeguard to the HDPE liner.

4. A gas vent layer that: (a) will allow gas to be passively released from below the liner system; and (b) will consist of a stone trench and perforated pipe placed along the ridge (high point) of the cap.

A more detailed description of the cap components is provided in the Technical Specifications and Construction Drawings. The cap will be constructed in accordance with the Technical Specifications and Construction Drawings.

3.2.1 Slope Stability

A deep failure analysis was not performed due to the heterogeneity of the material. However, the proposed stabilization activities will provide sufficient protection against a deep failure. The proposed configuration of the final cap system will provide protection against damaging slope movements by increasing the existing factor of safety against sliding. This will be accomplished by reducing the existing slope to a maximum slope of 25 percent and constructing a soil buttress at the toe of the existing landfill slope. The existing slopes are as steep as 100 percent and show no signs of mass failure. The details are presented in the Construction Drawings.

A cover material stability analyses (veneer stability) will be conducted using infinite slope analyses using actual internal friction angles obtained from testing the materials proposed for construction. (See technical Specification Sections 02120, 02121, 02205, and 02206.) The resulting analyses will demonstrate that the cover materials have a minimum factor of safety of 1.25 against cover material movements under static conditions. Interface friction angle tests obtained from selected manufacturers' literature and/or USEPA guidance documents depict sufficient factors of safety against sliding on 25 percent slopes.

3.2.2 Surface Water Controls

The surface water controls have been designed to direct surface runoff away from the capping system. The surface water control design includes the following:

- The capping system will be contoured to direct runoff away from the landfill without creating the potential for significant surface erosion.
- Runoff from the landfill will be directed around the cap perimeter via new drainage ditches designated to resist erosion during peak flow.
- The drainage ditches were designed to convey runoff from a 100-year, 24-hour recurrence interval rainfall event without overtopping or erosion damage.

Hydraulic design of the drainage ditches was based on Manning's equation for open channel flow. The procedure considers channel gradient, lining roughness, and shape. The drainage ditches are provided with trapezoidal cross sections and a minimum gradient of one percent. The design calculations are contained in the Calculation Brief (Appendix A).

3.2.3 Capping System Drainage Layer

The capping system drainage layer has been designed using the Hydrologic Evaluation of Landfill Performance (HELP) Model.[3] The drainage layer consists of a geonet/geotextile composite material, which consists of a drainage net composite with geotextile on both sides for stability purposes. As shown by manufacturer laboratory testing, the double-sided drainage net composite offers a transmissivity of 1×10^{-4} m^2/sec at a compressive load of 4,000 psf and hydraulic gradient of 1.0.

The transmissivities were used to calculate flow capacities of each drainage net composite arrangement. The flow capacities were compared to the estimated infiltration rate calculated using the HELP Model to verify proper function of the designed drainage layer. Because the head of water on the FML is less than the thickness of the drainage layer during peak storm events, all surface water infiltration will be effectively discharged by the drainage layer.

From the drainage layer perimeter, infiltration will be collected with 4-inch PE corrugated perforated pipe and transferred to a 4-inch PE corrugated solid pipe for ultimate conveyance to the wetlands. The pipes were sized to accommodate the peak daily infiltration rate into the drainage layer as provided by the HELP model.

Design calculations are contained in the Calculations Brief (Appendix A).

---

[3] "Hydrologic Evaluation of Landfill Performance," Prepared by Paul R. Schroeder, et. al., Vicksburg, Mississippi. U.S. Army Engineer Waterways Experiment Station, Environmental Laboratory, September 1989.

3.2.4 Soil Loss Evaluation

A soil loss evaluation was performed for the site to verify an acceptable soil loss rate after complete vegetation has been established. Temporary controls will be constructed to minimize erosion loss during construction (e.g., silt fence). The soil loss was estimated by utilizing the Revised Universal Soil Loss Equation (RUSLE) software[4] provided by the Soil and Water Conservation Society. The following factors are considered by RUSLE:

- climate
- erodibility of site-specific soil
- drainage slope length
- drainage slope steepness
- type of cover
- earthwork/grading support practices (i.e., benching, strip cropping, etc.)

Results of running the program RUSLE for the OU-1 site show that minimal erosion loss should occur after vegetation has been fully established (see the Calculation Brief, Appendix A). The calculated soil loss is 1.2 ton/acre/year as compared to the 2 tons/acre/year design criteria.

3.2.5 Gas Vent Evaluation

The landfill at the OU-1 site was in operation from 1942 to 1962. It is comprised of approximately 2.75 acres of mostly industrial waste piled at an average of 15 feet in depth across the landfill area. The absence of a large amount of municipal waste indicates that there will be less methane production as compared to a municipal waste landfill because of the decreased amount of cellulose content within a standard industrial waste. This implies that the theoretical value of methane production estimated herein may never be reached. As such, this approach provides a conservative estimate of a worst-case scenario.

Landfill gas (LFG) emissions are a result of the biological degradation of products contained within the landfill. As such, they are highly site-specific, leading to difficulty in accurately predicting the rate of LFG production from a landfill. The current approach to modeling the gas generation is to employ a simplified model, consistent with sound principals. Several models exist

---

[4] "Revised Universal Soil Loss Equation User Guide, " K.G. Renard, Tucson, Arizona. Soil and Water Conservation Society, May 1993.

for estimating LFG emission based upon site specific input parameters. The Scholl Canyon Model was applied to the OU-1 landfill to determine if a gas vent system is warranted. The gas production rate is assumed to be at its highest at initial placement of the waste and then decrease exponentially as the organic matter within the landfill is decomposed. The Scholl Canyon Model calculations predict a methane generation rate of 0.72 cubic feet per minute (ft^3/min).

While the predicted rate of methane production is very small, a gas venting system is recommended to prevent potential damage to the cap system from long term gas build-up. Due to the very small generation rate, an active venting system is not warranted because a passive system will be adequate to vent the gas safely.

Design calculations are contained in the Calculations Brief (Appendix A).

3.3 Leachate Collection and Conveyance System

The leachate collection system will consist of a gravel-filled trench. The trench will be located at the toe of slope of the existing landfill along the east side. The trench will consist of coarse stone and perforated pipe to collect and convey (via gravity) leachate to a passive wetlands treatment system. The pipe will consist of 6-inch HDPE perforated pipe. The pipe will exhibit a minimum slope of 1.0 percent. Cleanouts will be incorporated into the leachate collection system to allow sediment to be removed from the collection pipe, if necessary.

The leachate collection and conveyance system will be incorporated into the design to provide for a release of leachate from the landfill. Without this control, the leachate could potentially accumulate beneath the cap liner and build sufficient pressure to cause failure of the cap system. The leachate collection and conveyance system will prevent leachate accumulation and buildup of hydrostatic pressure.

Over time, the OU-1 group anticipates that the leachate flow rate will dissipate and eventually cease after installation of the low permeability cap. The landfill surface currently has many voids and depressions that trap surface water and provide pathways for infiltration that create leachate flow at the toe of the landfill. The multi-layer cap will eliminate surface water infiltration and leachate production caused by surface water infiltration.

3.4 Leachate Treatment System

The landfill leachate will be treated via constructed wetlands treatment to address metals. Based on the RI data, metals are the only constituents of concern, primarily zinc, copper, and nickel. Organic constituents were not identified as a concern based on sampling and analysis during the RI.

Constructed wetlands are an effective and reliable water reclamation technology if they are properly designed, constructed, operated, and maintained. They can remove most pollutants associated with municipal and industrial wastewater and stormwater and are usually designed to remove contaminants such as biochemical oxygen (BOD) and suspended solids. Constructed wetlands also have been used to remove metals, including cadmium, chromium, copper, iron, lead, manganese, nickel, selenium, zinc, and toxic organics from wastewater.

A natural wetland acts as a watershed filter, a sink for sediments and precipitates, and a biogeochemical engine that recycles and transforms some of the nutrients. A constructed wetland performs the same functions for wastewater, and a constructed wetland can perform many of the functions of conventional wastewater treatment trains (sedimentation, filtration, digestion, oxidation, reduction, adsorption, and precipitation). These processes occur sequentially as wastewater moves through the wetland, with wastewater constituents becoming commingled with detritus of marsh plants.

Ecological Restoration, Inc. (ESC's wetlands consultant) has prepared the design for the constructed treatment wetlands (Appendix E).

3.5 Wetlands Restoration

The wetlands identified by the jurisdictional delineation are shown on the Construction Drawings (bound separately). Any of these designated wetlands that are disturbed during remediation will be restored or replaced at a 1.5:1 ratio. Ecological Restoration, Inc. has prepared the design for the wetlands restoration or replacement (Appendix F).

4.0 Quality Assurance

Quality assurance monitoring will be performed in accordance with the Construction Quality Assurance Plan (CQAP, Appendix C). The Construction Quality Assurance (CQA) Officer will be responsible for implementation of the CQAP. Full-time site monitoring and inspection will be provided for the duration of the formal remedial activities.

Records of all quality assurance testing and recommendations to rectify any materials or installations failing to meet specifications will be maintained by the Engineer. Retesting following remedial work will be conducted to monitor the effectiveness of the repairs.

During the construction, monthly progress reports will be submitted to the USEPA outlining the current closure activities, problems encountered, and projected activities for the next month. Pursuant to the requirements of the consent decree, the first monthly report will be submitted by the 10th day of the first month following the USEPA approval of the design and thereafter on the 15th day of every month until the final closure certification report is submitted.

5.0 Decontamination

All heavy equipment used at the site will be decontaminated by pressure washing before leaving the site. Decontamination will take place within a specified diked and temporary lined area near the work area. Decontamination water and any solids (e.g., soil) generated during the closure activities will be contained, tested, and characterized to ensure disposal in accordance with the proper regulations. All sampling equipment will be decontaminated in accordance with the QAPP (appended to the Tar and Soil Excavation Work Plan).

6.0 Monitoring Well Abandonment

Monitoring wells will be closed in compliance with the West Virginia protocols (see Technical Specifications [Appendix B]) by removing the protective casing and grouting the boreholes from bottom to top (refer to Title 47, Series 60 Monitoring Well Design Standards [§47-60-19 Abandonment Requirements]). The wells to be abandoned at this time are DGW-02, DGW-03, and DGW-04. DGW-01, DGW-05, and DGW-06 will remain in place for use during post closure groundwater monitoring.

See the Technical Specification for well abandonment procedures.

7.0 Health and Safety

A health and safety plan (HASP) will be prepared by the contractor that is awarded the construction phase of this project. The HASP must be consistent with Occupational Safety and Health Administration (OSHA) requirements for hazardous waste site activities 29 CFR 1910.120 and other applicable regulations and guidance. All work will be required to be conducted in accordance with the HASP.

The HASP elements shall be developed by the contractor before construction and will apply to all subcontractors working on the site. The intent of the HASP is to establish procedures to protect the construction work force and surrounding populace from exposure to anticipated physical and chemical hazards that could reasonably be expected during construction activities. The HASP will address the site specific hazards associated with remedial construction activities.

The HASP shall provide, at a minimum, detailed clarification of the items listed below:

- Organization of Health and Safety Program and integration into the organization of the construction project team
- identification of the health and safety hazards pertinent to the construction activities
- identification of the medical monitoring requirements for the construction work force (if any)
- identification of the training requirements for the construction work force including OSHA's hazard communication requirements
- establishment of site control procedures
- identification of appropriate levels of personal protection equipment (PPE)
- establishment of site communication procedures
- establishment of decontamination procedures
- identification of appropriate exposure monitoring requirements
- establishment of emergency response procedures
- identification of site sanitation procedures

A draft of the HASP has been submitted along with the Tar and Soil Excavation Work Plan.

8.0 References

Administrative Order for Remedial Design and Remedial Action: Operable Unit No. 1, United States Environmental Protection Agency, Region III, Docket No. III-90-27-DC, June 20, 1990.

"Hydrologic Evaluation of Landfill Performance," Prepared by Paul R. Schroeder, et. al., Vicksburg, Mississippi. U.S. Army Engineer Waterways Experiment Station, Environmental Laboratory, September 1989.

Phase II Interim Tasks for Morgantown Ordnance Works Site OU-1, Morgantown, West Virginia, ABB Environmental Services, Inc., July 1996.

Pre-Design and Remedial Design Work Plan, Environmental Strategies Corporation, August 15, 2000.

Record of Decision, Ordnance Works Disposal Areas Superfund Site, Operable Unit One, US Environmental Protection Agency, September 30, 1999.

Remedial Design/Remedial Action Handbook. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. June 1995.

Remedial Investigation/Feasibility Study Report, Roy F. Weston, Inc. and Clement Associates, Inc., January 1988.

"Revised Universal Soil Loss Equation User Guide," K.G. Renard, Tucson, Arizona. Soil and Water Conservation Society, May 1993.

West Virginia Erosion and Sediment Control Handbook for Developing Areas, United States Department of Agriculture Soil Conservation Service, May 1993.

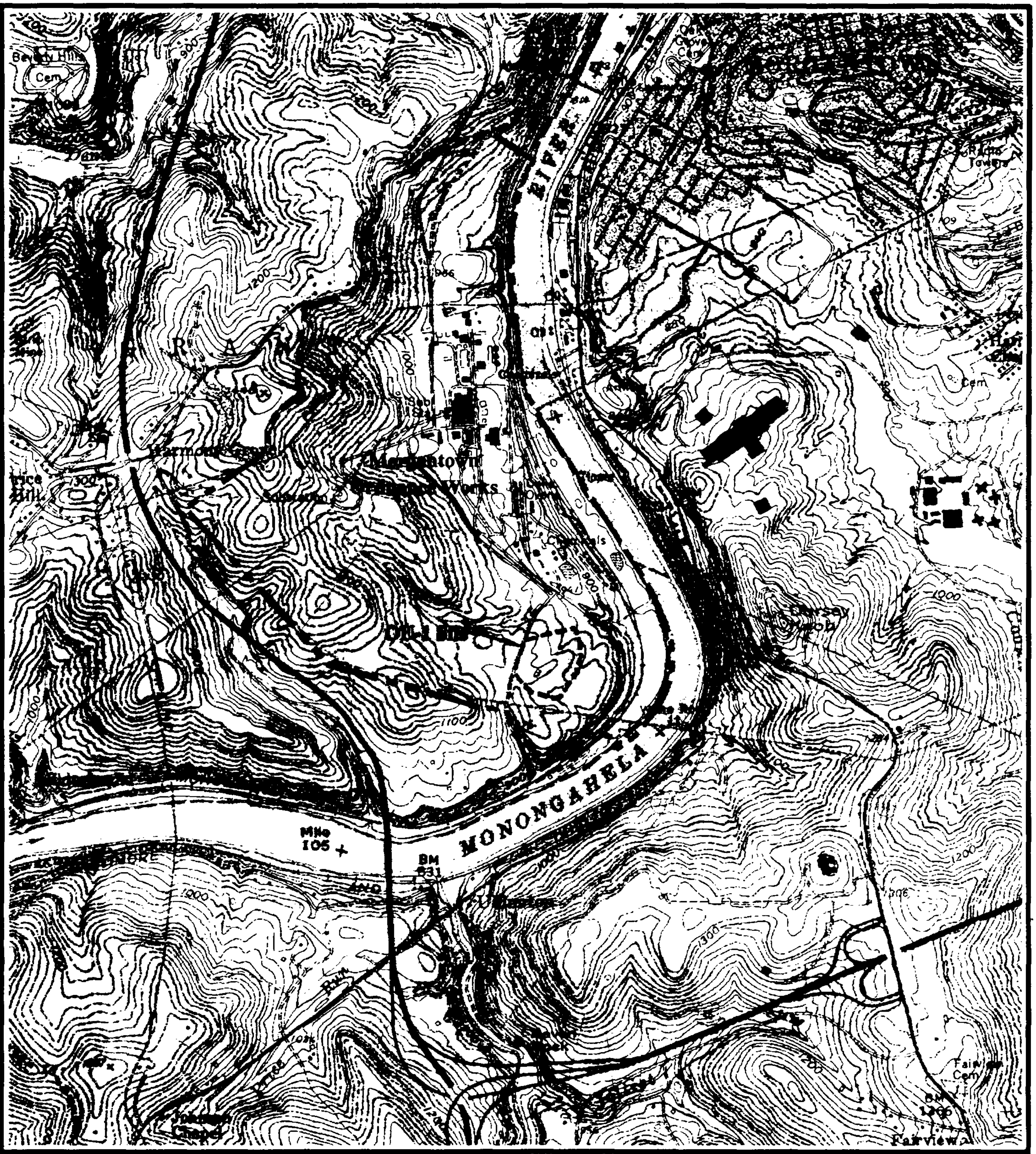
Figures

DWG Name: 302-A05

Drawn By: ARz 032201

Checked:

Approved:



REFERENCE:

USGS 7.5 MINUTE TOPOGRAPHIC QUADRANGLE,
MORGANTOWN SOUTH, WV, DATED 1957,
PHOTOREVISED 1976. SCALE 1:24000.

QUADRANGLE LOCATION

ENVIRONMENTAL STRATEGIES CORPORATION
ESC
Four Penn Center West, Suite 315
Pittsburgh, Pennsylvania 15276
(412) 787-5100

Figure 1

SITE LOCATION MAP

OU-1, MORGANTOWN
ORDNANCE WORKS
MORGANTOWN, WEST VIRGINIA
PREPARED FOR
OPERABLE UNIT 1 GROUP

.450\457302 Morg\457302A05.dwg, 05/11/2001 06:58:35 AM, rez

SDMS US EPA Region III

Imagery Insert Form

Document ID: 2019138

Some images in this document may be illegible or unavailable in SDMS. Please see reason(s) indicated below:

ORdnance Works

☐ Illegible due to bad source documents. Image(s) in SDMS is equivalent to hard copy.

Specify Type of Document(s) / Comments:

☐ Includes ____ COLOR or ____ RESOLUTION variations.
Unless otherwise noted, these pages are available in monochrome. The source document page(s) is more legible than the images. The original document is available for viewing at the Superfund Records Center.

Specify Type of Document(s) / Comments:

☐ Confidential Business Information (CBI).
This document contains highly sensitive information. Due to confidentiality, materials with such information are not available in SDMS. You may contact the EPA Superfund Records Manager if you wish to view this document.

Specify Type of Document(s) / Comments:

☒ Unscannable Material:
Oversized X or ____ Format.
Due to certain scanning equipment capability limitations, the document page(s) is not available in SDMS. The original document is available for viewing at the Superfund Records center.

Specify Type of Document(s) / Comments:

5A Box 55 5.003 - Site Layout

☐ Document is available at the EPA Region 5 Records Center.

Specify Type of Document(s) / Comments:

Rev. 07/10/02

Tables

Table 1

Applicable or Relevant and Appropriate Requirements
Morgantown Ordnance Works, Operable Unit No. 1, Superfund Site
Morgantown, West Virginia

I. LOCATION SPECIFIC

Statute/Authority	Regulation	Classification	Requirement Synopsis	Action
Groundwater Protection Act (State)	47 CSR 58-4.10	Relevant and Appropriate	Facility or activity design must adequately address the issues arising from locating in karst, wetlands, faults, subsidences, delineated wellhead protection areas determined vulnerable.	Wetlands are being properly addressed. No other applicable actions appear necessary. However, this regulation shall apply if implementation of the remedy affects such vulnerable areas.
Executive Order 11990, Protection of Wetlands (Federal)	40 C.F.R. 6, Appendix A Clean Water Act of 1972 (CWA) Section 404	Applicable	Action to minimize the destruction, loss, or degradation of wetlands.	This applies to ensure the minimization of wetland impacts to remedial action activities. Wetlands were delineated during the pre-design investigation activities. Any disturbed wetlands will be restored or replaced.

II. ACTION SPECIFIC

Statute/Authority	Regulation	Classification	Requirement Synopsis	Action
Resource Conservation and Recovery Act (Federal)	40 C.F.R. 265.19	Relevant and Appropriate	Construction Quality Assurance Program.	Construction of the cap will comply with these quality assurance requirements. A site-specific construction quality assurance plan will be developed for implementation during construction.
Resource Conservation and Recovery Act (Federal)	40 C.F.R. 265.111	Relevant and Appropriate	For a closing facility, owner must minimize need for further maintenance; control, minimize, or eliminate post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated run-off, or hazardous waste decomposition products to the ground or surface waters or to the atmosphere; and comply with other closure requirements.	Post-closure monitoring and maintenance of the landfill shall comply with these requirements.
Resource Conservation and Recovery Act (Federal)	40 C.F.R. 265.114	Relevant and Appropriate	During final closure, all contaminated equipment, structures, and soil must be properly disposed of, or decontaminated.	During implementation of the selected remedy, all required decontamination procedures will be complied with.

Table 1 (continued)

Applicable or Relevant and Appropriate Requirements
Morgantown Ordnance Works, Operable Unit No. 1, Superfund Site
Morgantown, West Virginia

Statute/Authority	Regulation	Classification	Requirement Synopsis	Action
Resource Conservation and Recovery Act (Federal)	40 C.F.R. 265.117	Relevant and Appropriate	Post-closure care for each hazardous waste management unit must begin after completion of closure and continue for 30 years after that date. It must consist of monitoring and reporting of environmental media and maintenance and monitoring of waste containment systems.	Post-closure monitoring and maintenance of the landfill shall comply with these requirements.
Resource Conservation and Recovery Act (Federal)	40 C.F.R. 265.118	Relevant and Appropriate	The owner or operator must develop a written post-closure plan. The post-closure plan must identify activities to be carried on after closure and the frequency of these activities.	To ensure the integrity of the cap and the function of the monitoring equipment, post-closure monitoring and maintenance of the landfill shall comply with these requirements.
Resource Conservation and Recovery Act (Federal)	40 C.F.R. 265.310	Relevant and Appropriate	Final cover to provide long-term minimization of infiltration. Function with minimum maintenance. Promote drainage and minimize erosion. 30-year post-closure care to ensure site is maintained and monitored.	These requirements shall apply to construction and post closure requirements for the cap.

AIR

Clean Air Act, National Ambient Air Quality Standards (Federal)	40 C.F.R. Part 50	Applicable	Defines air quality standards that are necessary to protect human health.	Applicable if work at the Site affects ambient air quality.
Air Pollution Control Act (State)	45 CSR4	Applicable	Regulations to prevent and control the discharge of air pollutants into the open air which causes or contributes to an objectionable odor or odors.	The remedial action will comply with the substantive requirements of these regulations.
Air Pollution Control Act and the Hazardous Waste Management Act (State)	45CSR25-4.3	Relevant and Appropriate	Facilities shall be designed, constructed, maintained, and operated in a manner to minimize hazardous waste constituents to the air.	During construction of the cap and excavation activities, any fugitive air emissions shall be in compliance with this state regulation.

Table 1 (continued)

Applicable or Relevant and Appropriate Requirements
Morgantown Ordnance Works, Operable Unit No. 1, Superfund Site
Morgantown, West Virginia

Statute/Authority	Regulation	Classification	Requirement Synopsis	Action
Air Pollution Control Act (State)	45CSR27-4.1 thru 4.2	Applicable	Best Available Technology requirements for Fugitive Emissions of Toxic Air Pollutants.	During construction of the cap and excavation activities, any fugitive air emissions shall be in compliance with this state regulation.
Air Pollution Control Act (State)	45CSR30	Applicable	Requirements for the air quality permitting system.	During construction of the cap and excavation activities, any fugitive air emissions shall be in compliance with the substantive requirements of this regulation. Air monitoring will be conducted to verify this requirement.

WATER

Groundwater Protection Act (State)	47CSR58-4.2	Applicable	Subsurface borings of all types shall be constructed, operated and closed in a manner which protects groundwater.	Installation of new monitoring wells, as well as abandonment of existing monitoring wells (if appropriate) shall comply with this requirement.
Groundwater Protection Act (State)	47CSR58-4.4(a)	Applicable	Loading and unloading stations including but not limited to drums, trucks, and railcars shall have spill prevention and control facilities and procedures as well as secondary containment, if appropriate or otherwise required. Spill containment and cleanup equipment shall be readily accessible.	Excavation and offsite transportation of wastes shall comply with these loading requirements.

Table 1 (continued)

Applicable or Relevant and Appropriate Requirements
Morgantown Ordnance Works, Operable Unit No. 1, Superfund Site
Morgantown, West Virginia

Statute/Authority	Regulation	Classification	Requirement Synopsis	Action
Groundwater Protection Act (State)	47CSR58-4.9.d to 4.9.g	Applicable	Groundwater monitoring stations shall be located and constructed in a manner that allows accurate determination of groundwater quality and levels, and prevents contamination of groundwater through the finished well hole or casing. All groundwater monitoring stations shall be accurately located utilizing latitude and longitude by surveying, or other acceptable means, and coordinates shall be included with all data collected.	Development and implementation of the long-term groundwater monitoring plan shall comply with these requirements.
Groundwater Protection Act (State)	47CSR58-8.1(c)	Applicable	Adequate groundwater monitoring shall be conducted to demonstrate control and containment of the substance.	Groundwater monitoring program shall comply with this requirement.
Groundwater Protection Act (State)	47CSR 60-1 to 23	Applicable	Monitoring well design standards.	Monitoring well design shall comply with these standards.
Environment Quality Board (State)	46CSR 1-1 to 9	Applicable	Requirements governing water quality standards.	The on-site streams and wetlands are designated "for the Propagation and Maintenance of Fish and Other Aquatic Life (Category B) and for Water Contact Recreation (Category C) pursuant to 46 CSR1-6.1. The water quality standards established in these regulations will be applicable to the remedial action.
Groundwater Protection Act (State)	47CSR59-1-47 CSR59-9	Applicable	Monitoring well rules.	The remedial action will comply with the substantive requirements of these regulations.

Table 1 (continued)

Applicable or Relevant and Appropriate Requirements
Morgantown Ordnance Works, Operable Unit No. 1, Superfund Site
Morgantown, West Virginia

MISCELLANEOUS

Statute/Authority	Regulation	Classification	Requirement Synopsis	Action
Resource Conservation and Recovery Act (Federal)	40 C.F.R. 264.10 to 264.18	Relevant and Appropriate	Requirements regarding waste analysis, security, training, inspections, and location applicable to a facility that stores, treats, or disposes of hazardous wastes.	These requirements shall be met when handling wastes onsite.
Resource Conservation and Recovery Act (Federal)	40 C.F.R. 262.34	Relevant and Appropriate	Generator may accumulate waste onsite for 90 days or less or must comply with requirements for operating a storage facility.	If it is necessary to store waste onsite during implementation of the selected remedy, this requirement shall apply.
Resource Conservation and Recovery Act (Federal)	40 C.F.R. Part 268	Relevant and Appropriate	Movement of excavated materials to new location and placement in or on land will trigger land disposal restrictions (LDRs) for the excavated waste or closure requirements for the unit in which the waste in being placed.	Consolidation of materials within an area of contamination does not trigger LDRs. Therefore, implementation of the selected remedy will be in compliance with this ARAR.

Appendix A - Calculations Brief

Contents

Drainage Layer Calculations

Subject Drainage Layer Calculations

By DCH Date 1.02.01 Checked EEP Date 1/3/01

Project Name Morgantown Project Number 457302 Sheet No. 1 of 21

Objective:

To determine the peak discharge from the drainage layer component of the cap system and calculate the depth of head that will accumulate in the drainage layer.

Reference:

Schroeder, Paul R., Lloyd, Cheryl M., Zappi, Paul, A., and Aziz, Nadim M. "The Hydrologic Evaluation of Landfill Performance (HELP) Model (software)", Version 3.04. Office of Research and Development. September, 1994.

Given:

1. The cap will consist of a geosynthetic clay liner (GCL) layer, a 40 mil high density polyethylene (HDPE) layer, a composite drainage net, and a 24-inch sandy loam capable of supporting grass vegetation.

2. The analysis was performed for two separate scenarios. Both assume a maximum drainage slope length of 350 feet, one with a slope of 3 % (the average slope of the landfill) and the second with a gradient of 25 % to determine the maximum discharge from the drainage layer.

Calculations:

1. The HELP model calculates a daily peak value of 3049 cubic feet of water collected from the drainage net layer (layer 2). This equates to approximately 0.07 ac-ft of water.

2. In order to calculate peak discharge of the drainage layer, it was assumed that water would flow uniformly through the drainage net for the duration of the 24-hour period. The discharge is calculated as follows:

   $$(3049\ ft^3/day) / (24 * 60 * 60\ seconds/day) = 0.0353\ cfs$$

3. Because the maximum head on top of the GCL (layer 3 in the HELP model) is 0.124 inches and the overall thickness of the drainage layer is 0.25 inches, the drainage layer adequately conveys all surface water infiltration during peak daily storm events.

```
*******************************************************************************
*******************************************************************************
**                                                                           **
**                                                                           **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                **
**                 HELP MODEL VERSION 3.04a  (10 JULY 1995)                  **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                    USAE WATERWAYS EXPERIMENT STATION                      **
**               FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                           **
**                                                                           **
*******************************************************************************
*******************************************************************************


PRECIPITATION DATA FILE:    C:\Help3\PRECIP.D4
TEMPERATURE DATA FILE:      C:\HELP3\TEMP.D7
SOLAR RADIATION DATA FILE:  C:\help3\SOLAR.D13
EVAPOTRANSPIRATION DATA:    C:\help3\EVAPO.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\DESIGN3.D10
OUTPUT DATA FILE:           C:\help3\MORGAN3.OUT


TIME: 10:12     DATE: 12/20/2000


*******************************************************************************

     TITLE:  Morgantown, WV Landfill

*******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  23
           THICKNESS                    =     24.00    INCHES
           POROSITY                     =      0.4610 VOL/VOL
           FIELD CAPACITY               =      0.3600 VOL/VOL
           WILTING POINT                =      0.2030 VOL/VOL
           INITIAL SOIL WATER CONTENT   =      0.4073 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =   0.900000032000E-05 CM/SEC
         NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.90
                  FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
```

```
                        LAYER  2
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER  20
THICKNESS                  =       0.25    INCHES
POROSITY                   =       0.8500 VOL/VOL
FIELD CAPACITY             =       0.0100 VOL/VOL
WILTING POINT              =       0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT =       0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =    10.0000000000      CM/SEC
SLOPE                      =        3.00   PERCENT
DRAINAGE LENGTH            =     350.0     FEET


                        LAYER  3
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                  =       0.16    INCHES
POROSITY                   =       0.0000 VOL/VOL
FIELD CAPACITY             =       0.0000 VOL/VOL
WILTING POINT              =       0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT =       0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =   0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY        =       0.50    HOLES/ACRE
FML INSTALLATION DEFECTS   =       1.00    HOLES/ACRE
FML PLACEMENT QUALITY      =   3 - GOOD


                        LAYER  4
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  17
THICKNESS                  =       0.25    INCHES
POROSITY                   =       0.7500 VOL/VOL
FIELD CAPACITY             =       0.7470 VOL/VOL
WILTING POINT              =       0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT =       0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =   0.300000003000E-08 CM/SEC


        GENERAL DESIGN AND EVAPORATIVE ZONE DATA
        ----------------------------------------
```

```
      NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
               SOIL DATA BASE USING SOIL TEXTURE #23 WITH A
               GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
               AND A SLOPE LENGTH OF  350. FEET.

     SCS RUNOFF CURVE NUMBER                 =     86.90
     FRACTION OF AREA ALLOWING RUNOFF        =    100.0    PERCENT
     AREA PROJECTED ON HORIZONTAL PLANE      =      2.750  ACRES
     EVAPORATIVE ZONE DEPTH                  =     20.0    INCHES
     INITIAL WATER IN EVAPORATIVE ZONE       =      8.334  INCHES
     UPPER LIMIT OF EVAPORATIVE STORAGE      =      9.220  INCHES
     LOWER LIMIT OF EVAPORATIVE STORAGE      =      4.060  INCHES
     INITIAL SNOW WATER                      =      0.000  INCHES
     INITIAL WATER IN LAYER MATERIALS        =      9.964  INCHES
     TOTAL INITIAL WATER                     =      9.964  INCHES
     TOTAL SUBSURFACE INFLOW                 =      0.00   INCHES/YEAR


                  EVAPOTRANSPIRATION AND WEATHER DATA
                  -----------------------------------

      NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
               PITTSBURGH           PENNSYLVANIA

          STATION LATITUDE                          =  40.50 DEGREES
          MAXIMUM LEAF AREA INDEX                   =   4.00
          START OF GROWING SEASON (JULIAN DATE)     =    114
          END OF GROWING SEASON (JULIAN DATE)       =    288
          EVAPORATIVE ZONE DEPTH                    =  20.0  INCHES
          AVERAGE ANNUAL WIND SPEED                 =   9.20 MPH
          AVERAGE 1ST QUARTER RELATIVE HUMIDITY     =  67.00 %
          AVERAGE 2ND QUARTER RELATIVE HUMIDITY     =  63.00 %
          AVERAGE 3RD QUARTER RELATIVE HUMIDITY     =  71.00 %
          AVERAGE 4TH QUARTER RELATIVE HUMIDITY     =  70.00 %


      NOTE:  PRECIPITATION DATA FOR     PITTSBURGH          PENNSYLVANIA
               WAS ENTERED FROM THE DEFAULT DATA FILE.


      NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
               COEFFICIENTS FOR    PITTSBURGH          PENNSYLVANIA

          NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

    JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
    -------     -------     -------     -------     -------     -------
     26.70       28.80       38.50       50.10       59.70       68.10
     72.00       70.60       64.10       52.50       41.60       31.40
```

```
         NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                  COEFFICIENTS FOR     PITTSBURGH           PENNSYLVANIA
                    AND STATION LATITUDE  =  40.50 DEGREES


*******************************************************************************

                          ANNUAL TOTALS FOR YEAR 1974
-------------------------------------------------------------------------------
                                             INCHES          CU. FEET     PERCENT
                                            --------        ----------    -------
  PRECIPITATION                               41.83         417567.656    100.00

  RUNOFF                                       8.405         83904.789     20.09

  EVAPOTRANSPIRATION                          28.822        287711.156     68.90

  DRAINAGE COLLECTED FROM LAYER  2             4.6005        45924.855     11.00

  PERC./LEAKAGE THROUGH LAYER  4               0.000001          0.007      0.00

  AVG. HEAD ON TOP OF LAYER  3                 0.0026

  CHANGE IN WATER STORAGE                      0.003            27.275      0.01

  SOIL WATER AT START OF YEAR                  9.964         99469.320

  SOIL WATER AT END OF YEAR                    9.967         99496.594

  SNOW WATER AT START OF YEAR                  0.000             0.000      0.00

  SNOW WATER AT END OF YEAR                    0.000             0.000      0.00

  ANNUAL WATER BUDGET BALANCE                  0.0000           -0.416      0.00

*******************************************************************************


*******************************************************************************

                          ANNUAL TOTALS FOR YEAR 1975
-------------------------------------------------------------------------------
                                             INCHES          CU. FEET     PERCENT
                                            --------        ----------    -------
  PRECIPITATION                               46.42         463387.562    100.00

  RUNOFF                                      14.097        140723.187     30.37

  EVAPOTRANSPIRATION                          28.485        284354.969     61.36

  DRAINAGE COLLECTED FROM LAYER  2             4.1638        41565.344      8.97

  PERC./LEAKAGE THROUGH LAYER  4               0.000001          0.008      0.00
```

```
 AVG. HEAD ON TOP OF LAYER  3             0.0024

 CHANGE IN WATER STORAGE                 -0.331          -3305.049     -0.71

 SOIL WATER AT START OF YEAR              9.967          99496.594

 SOIL WATER AT END OF YEAR                9.636          96191.547

 SNOW WATER AT START OF YEAR              0.000              0.000      0.00

 SNOW WATER AT END OF YEAR                0.000              0.000      0.00

 ANNUAL WATER BUDGET BALANCE              0.0049            49.105      0.01

*******************************************************************************


*******************************************************************************

                      ANNUAL TOTALS FOR YEAR 1976
-------------------------------------------------------------------------------
                                        INCHES          CU. FEET     PERCENT
                                       --------        ----------    -------
 PRECIPITATION                           31.78          317243.875    100.00

 RUNOFF                                   8.095          80810.570     25.47

 EVAPOTRANSPIRATION                      22.069         220304.844     69.44

 DRAINAGE COLLECTED FROM LAYER  2         1.4261         14236.041      4.49

 PERC./LEAKAGE THROUGH LAYER  4           0.000000           0.004      0.00

 AVG. HEAD ON TOP OF LAYER  3             0.0008

 CHANGE IN WATER STORAGE                  0.184           1834.877      0.58

 SOIL WATER AT START OF YEAR              9.636          96191.547

 SOIL WATER AT END OF YEAR                9.734          97164.727

 SNOW WATER AT START OF YEAR              0.000              0.000      0.00

 SNOW WATER AT END OF YEAR                0.086            861.699      0.27

 ANNUAL WATER BUDGET BALANCE              0.0058            57.544      0.02

*******************************************************************************


*******************************************************************************
```

```
                         ANNUAL TOTALS FOR YEAR 1977
-------------------------------------------------------------------------------
                                          INCHES         CU. FEET     PERCENT
                                         --------       ----------    -------
  PRECIPITATION                           33.20         331419.031    100.00

  RUNOFF                                   8.422         84070.641     25.37

  EVAPOTRANSPIRATION                      23.167        231268.781     69.78

  DRAINAGE COLLECTED FROM LAYER  2         1.3793        13768.917      4.15

  PERC./LEAKAGE THROUGH LAYER  4           0.000000          0.002      0.00

  AVG. HEAD ON TOP OF LAYER  3             0.0008

  CHANGE IN WATER STORAGE                  0.216          2156.586      0.65

  SOIL WATER AT START OF YEAR              9.734         97164.727

  SOIL WATER AT END OF YEAR               10.036        100183.008

  SNOW WATER AT START OF YEAR              0.086           861.699      0.26

  SNOW WATER AT END OF YEAR                0.000             0.000      0.00

  ANNUAL WATER BUDGET BALANCE              0.0154          154.113      0.05

*******************************************************************************


*******************************************************************************

                         ANNUAL TOTALS FOR YEAR 1978
-------------------------------------------------------------------------------
                                          INCHES         CU. FEET     PERCENT
                                         --------       ----------    -------
  PRECIPITATION                           37.24         371748.312    100.00

  RUNOFF                                   7.464         74512.461     20.04

  EVAPOTRANSPIRATION                      25.415        253708.906     68.25

  DRAINAGE COLLECTED FROM LAYER  2         4.7601        47517.770     12.78

  PERC./LEAKAGE THROUGH LAYER  4           0.000001          0.006      0.00

  AVG. HEAD ON TOP OF LAYER  3             0.0027

  CHANGE IN WATER STORAGE                 -0.400         -3990.883     -1.07

  SOIL WATER AT START OF YEAR             10.036        100183.008

  SOIL WATER AT END OF YEAR                9.636         96192.125
```

```
  SNOW WATER AT START OF YEAR                0.000              0.000      0.00

  SNOW WATER AT END OF YEAR                  0.000              0.000      0.00

  ANNUAL WATER BUDGET BALANCE                0.0000             0.061      0.00

*******************************************************************************




*******************************************************************************

        AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1974 THROUGH 1978
-------------------------------------------------------------------------------

                          JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                          -------  -------  -------  -------  -------  -------
  PRECIPITATION
  -------------
    TOTALS                  3.67     1.98     3.69     2.47     3.20     3.95
                            3.49     3.68     3.74     2.88     1.92     3.41

    STD. DEVIATIONS         1.55     1.61     1.24     0.84     1.54     0.99
                            1.19     2.35     0.95     1.11     0.80     1.11

  RUNOFF
  ------
    TOTALS                  2.341    1.315    3.371    0.698    0.098    0.078
                            0.069    0.177    0.236    0.077    0.005    0.830

    STD. DEVIATIONS         2.004    1.443    2.343    0.981    0.168    0.075
                            0.088    0.377    0.272    0.126    0.012    0.463

  EVAPOTRANSPIRATION
  ------------------
    TOTALS                  0.511    0.387    0.509    2.654    3.862    4.594
                            3.915    2.471    2.926    2.158    1.020    0.585

    STD. DEVIATIONS         0.105    0.111    0.149    0.391    1.168    1.371
                            1.014    0.778    0.984    0.215    0.224    0.073

  LATERAL DRAINAGE COLLECTED FROM LAYER  2
  ----------------------------------------
    TOTALS                  0.0000   0.2189   0.4518   1.4432   0.0151   0.0071
                            0.0005   0.0005   0.1873   0.2447   0.0707   0.6264

    STD. DEVIATIONS         0.0000   0.4894   0.6140   0.2010   0.0147   0.0089
                            0.0004   0.0005   0.4177   0.5429   0.1004   0.9531

  PERCOLATION/LEAKAGE THROUGH LAYER  4
  ------------------------------------
    TOTALS                  0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                            0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
```

```
   STD. DEVIATIONS          0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
                            0.0000    0.0000    0.0000    0.0000    0.0000    0.0000


-------------------------------------------------------------------------------
              AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


  DAILY AVERAGE HEAD ON TOP OF LAYER  3
  -------------------------------------
   AVERAGES                 0.0000    0.0016    0.0030    0.0099    0.0001    0.0000
                            0.0000    0.0000    0.0013    0.0016    0.0005    0.0042

   STD. DEVIATIONS          0.0000    0.0036    0.0041    0.0014    0.0001    0.0001
                            0.0000    0.0000    0.0029    0.0036    0.0007    0.0063

*******************************************************************************



*******************************************************************************

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1974 THROUGH 1978
-------------------------------------------------------------------------------
                                         INCHES           CU. FEET      PERCENT
                                   ------------------   ------------   ---------
 PRECIPITATION                      38.09    (   6.079)    380273.2     100.00

 RUNOFF                              9.297   (  2.7113)     92804.32     24.405

 EVAPOTRANSPIRATION                 25.592   (  3.0464)    255469.73     67.181

 LATERAL DRAINAGE COLLECTED          3.26597 (  1.71495)    32602.586     8.57346
   FROM LAYER  2

 PERCOLATION/LEAKAGE THROUGH         0.00000 (  0.00000)        0.006     0.00000
   LAYER  4

 AVERAGE HEAD ON TOP                 0.002 (    0.001)
   OF LAYER  3

 CHANGE IN WATER STORAGE            -0.066   (  0.2865)      -655.44     -0.172
*******************************************************************************
```

```
******************************************************************************

               PEAK DAILY VALUES FOR YEARS 1974 THROUGH 1978
   ------------------------------------------------------------------------
                                                    (INCHES)      (CU. FT.)
                                                   ----------   -------------
      PRECIPITATION                                   2.29        22859.924

      RUNOFF                                          3.384       33783.0547

      DRAINAGE COLLECTED FROM LAYER  2                0.30532      3047.85156

      PERCOLATION/LEAKAGE THROUGH LAYER  4            0.000000        0.00012

      AVERAGE HEAD ON TOP OF LAYER  3                 0.063

      MAXIMUM HEAD ON TOP OF LAYER  3                 0.124

      LOCATION OF MAXIMUM HEAD IN LAYER  2
            (DISTANCE FROM DRAIN)                     4.2 FEET

      SNOW WATER                                      3.44        34298.0781


      MAXIMUM VEG. SOIL WATER (VOL/VOL)                       0.4487

      MINIMUM VEG. SOIL WATER (VOL/VOL)                       0.2030


       ***  Maximum heads are computed using McEnroe's equations.  ***

            Reference:  Maximum Saturated Depth over Landfill Liner
                        by Bruce M. McEnroe, University of Kansas
                        ASCE Journal of Environmental Engineering
                        Vol. 119, No. 2, March 1993, pp. 262-270.

******************************************************************************
```

```
******************************************************************************

              FINAL WATER STORAGE AT END OF YEAR 1978
    ----------------------------------------------------------------------
               LAYER        (INCHES)       (VOL/VOL)
               -----        --------       ---------
                 1           9.4402          0.3933

                 2           0.0083          0.0333

                 3           0.0000          0.0000

                 4           0.1875          0.7500

             SNOW WATER      0.000

******************************************************************************
******************************************************************************
```

```
*******************************************************************************
*******************************************************************************
**                                                                           **
**                                                                           **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                **
**                 HELP MODEL VERSION 3.04a  (10 JULY 1995)                  **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                    USAE WATERWAYS EXPERIMENT STATION                      **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                           **
**                                                                           **
*******************************************************************************
*******************************************************************************


PRECIPITATION DATA FILE:     C:\Help3\PRECIP.D4
TEMPERATURE DATA FILE:       C:\HELP3\TEMP.D7
SOLAR RADIATION DATA FILE:   C:\help3\SOLAR.D13
EVAPOTRANSPIRATION DATA:     C:\help3\EVAPO.D11
SOIL AND DESIGN DATA FILE:   C:\HELP3\DESIGN25.D10
OUTPUT DATA FILE:            C:\help3\MORGAN25.OUT


TIME:  10: 4     DATE:  12/20/2000


*******************************************************************************

     TITLE:  Morgantown, WV Landfill

*******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                        TYPE 1 - VERTICAL PERCOLATION LAYER
                           MATERIAL TEXTURE NUMBER  23
           THICKNESS                    =     24.00   INCHES
           POROSITY                     =      0.4610 VOL/VOL
           FIELD CAPACITY               =      0.3600 VOL/VOL
           WILTING POINT                =      0.2030 VOL/VOL
           INITIAL SOIL WATER CONTENT   =      0.4070 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =  0.900000032000E-05 CM/SEC
         NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.90
                FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
```

```
                              LAYER  2
                              --------

                 TYPE 2 - LATERAL DRAINAGE LAYER
                   MATERIAL TEXTURE NUMBER  20
   THICKNESS                    =       0.25    INCHES
   POROSITY                     =       0.8500 VOL/VOL
   FIELD CAPACITY               =       0.0100 VOL/VOL
   WILTING POINT                =       0.0050 VOL/VOL
   INITIAL SOIL WATER CONTENT   =       0.0100 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =    10.0000000000      CM/SEC
   SLOPE                        =      25.00    PERCENT
   DRAINAGE LENGTH              =     350.0     FEET


                              LAYER  3
                              --------

                 TYPE 4 - FLEXIBLE MEMBRANE LINER
                   MATERIAL TEXTURE NUMBER  35
   THICKNESS                    =       0.16    INCHES
   POROSITY                     =       0.0000 VOL/VOL
   FIELD CAPACITY               =       0.0000 VOL/VOL
   WILTING POINT                =       0.0000 VOL/VOL
   INITIAL SOIL WATER CONTENT   =       0.0000 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =   0.199999996000E-12 CM/SEC
   FML PINHOLE DENSITY          =       0.50    HOLES/ACRE
   FML INSTALLATION DEFECTS     =       1.00    HOLES/ACRE
   FML PLACEMENT QUALITY        =   3 - GOOD


                              LAYER  4
                              --------

                   TYPE 3 - BARRIER SOIL LINER
                   MATERIAL TEXTURE NUMBER  17
   THICKNESS                    =       0.25    INCHES
   POROSITY                     =       0.7500 VOL/VOL
   FIELD CAPACITY               =       0.7470 VOL/VOL
   WILTING POINT                =       0.4000 VOL/VOL
   INITIAL SOIL WATER CONTENT   =       0.7500 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =   0.300000003000E-08 CM/SEC


           GENERAL DESIGN AND EVAPORATIVE ZONE DATA
           ----------------------------------------
```

```
 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE #23 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF 25.%
          AND A SLOPE LENGTH OF  350. FEET.

SCS RUNOFF CURVE NUMBER               =     87.60
FRACTION OF AREA ALLOWING RUNOFF      =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE    =      2.750  ACRES
EVAPORATIVE ZONE DEPTH                =     20.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE     =      8.327  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE    =      9.220  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE    =      4.060  INCHES
INITIAL SNOW WATER                    =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS      =      9.957  INCHES
TOTAL INITIAL WATER                   =      9.957  INCHES
TOTAL SUBSURFACE INFLOW               =      0.00   INCHES/YEAR


                EVAPOTRANSPIRATION AND WEATHER DATA
                -----------------------------------

 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          PITTSBURGH           PENNSYLVANIA

     STATION LATITUDE                             =  40.50 DEGREES
     MAXIMUM LEAF AREA INDEX                      =   4.00
     START OF GROWING SEASON (JULIAN DATE)        =    114
     END OF GROWING SEASON (JULIAN DATE)          =    288
     EVAPORATIVE ZONE DEPTH                       =  20.0  INCHES
     AVERAGE ANNUAL WIND SPEED                    =   9.20 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY        =  67.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY        =  63.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY        =  71.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY        =  70.00 %


 NOTE:  PRECIPITATION DATA FOR     PITTSBURGH          PENNSYLVANIA
          WAS ENTERED FROM THE DEFAULT DATA FILE.


 NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    PITTSBURGH          PENNSYLVANIA

     NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL      FEB/AUG      MAR/SEP      APR/OCT      MAY/NOV      JUN/DEC
-------      -------      -------      -------      -------      -------
 26.70        28.80        38.50        50.10        59.70        68.10
 72.00        70.60        64.10        52.50        41.60        31.40
```

```
          NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                   COEFFICIENTS FOR    PITTSBURGH          PENNSYLVANIA
                     AND STATION LATITUDE  =  40.50 DEGREES


*******************************************************************************

                       ANNUAL TOTALS FOR YEAR 1974
-------------------------------------------------------------------------------
                                          INCHES         CU. FEET     PERCENT
                                         --------       ----------    -------
  PRECIPITATION                           41.83         417567.656    100.00

  RUNOFF                                   8.538         85227.969     20.41

  EVAPOTRANSPIRATION                      28.704        286532.719     68.62

  DRAINAGE COLLECTED FROM LAYER  2         4.5850        45770.207     10.96

  PERC./LEAKAGE THROUGH LAYER  4           0.000000          0.001      0.00

  AVG. HEAD ON TOP OF LAYER  3             0.0013

  CHANGE IN WATER STORAGE                  0.004            37.081      0.01

  SOIL WATER AT START OF YEAR              9.957         99398.672

  SOIL WATER AT END OF YEAR                9.961         99435.750

  SNOW WATER AT START OF YEAR              0.000             0.000      0.00

  SNOW WATER AT END OF YEAR                0.000             0.000      0.00

  ANNUAL WATER BUDGET BALANCE              0.0000           -0.320      0.00

*******************************************************************************


*******************************************************************************

                       ANNUAL TOTALS FOR YEAR 1975
-------------------------------------------------------------------------------
                                          INCHES         CU. FEET     PERCENT
                                         --------       ----------    -------
  PRECIPITATION                           46.42         463387.562    100.00

  RUNOFF                                  14.316        142910.531     30.84

  EVAPOTRANSPIRATION                      28.405        283555.406     61.19

  DRAINAGE COLLECTED FROM LAYER  2         4.0183        40112.496      8.66

  PERC./LEAKAGE THROUGH LAYER  4           0.000000          0.002      0.00
```

```
  AVG. HEAD ON TOP OF LAYER  3            0.0011

  CHANGE IN WATER STORAGE                -0.325        -3239.950     -0.70

  SOIL WATER AT START OF YEAR             9.961        99435.750

  SOIL WATER AT END OF YEAR               9.636        96195.805

  SNOW WATER AT START OF YEAR             0.000            0.000      0.00

  SNOW WATER AT END OF YEAR               0.000            0.000      0.00

  ANNUAL WATER BUDGET BALANCE             0.0049          49.089      0.01

*******************************************************************************


*******************************************************************************

                      ANNUAL TOTALS FOR YEAR 1976
-------------------------------------------------------------------------------
                                        INCHES         CU. FEET     PERCENT
                                       --------       ----------    -------
  PRECIPITATION                          31.78        317243.875    100.00

  RUNOFF                                  8.149        81350.203     25.64

  EVAPOTRANSPIRATION                     22.025       219864.344     69.30

  DRAINAGE COLLECTED FROM LAYER  2        1.4216       14191.281      4.47

  PERC./LEAKAGE THROUGH LAYER  4          0.000000         0.001      0.00

  AVG. HEAD ON TOP OF LAYER  3            0.0004

  CHANGE IN WATER STORAGE                 0.178         1780.499      0.56

  SOIL WATER AT START OF YEAR             9.636        96195.805

  SOIL WATER AT END OF YEAR               9.728        97114.602

  SNOW WATER AT START OF YEAR             0.000            0.000      0.00

  SNOW WATER AT END OF YEAR               0.086          861.699      0.27

  ANNUAL WATER BUDGET BALANCE             0.0058          57.544      0.02

*******************************************************************************


*******************************************************************************
```

```
                       ANNUAL TOTALS FOR YEAR 1977
-------------------------------------------------------------------------------
                                           INCHES         CU. FEET     PERCENT
                                          --------       ----------    -------
  PRECIPITATION                            33.20         331419.031    100.00

  RUNOFF                                    8.460         84447.859     25.48

  EVAPOTRANSPIRATION                       23.159        231182.156     69.76

  DRAINAGE COLLECTED FROM LAYER  2          1.3744        13720.341      4.14

  PERC./LEAKAGE THROUGH LAYER  4            0.000000          0.000      0.00

  AVG. HEAD ON TOP OF LAYER  3              0.0004

  CHANGE IN WATER STORAGE                   0.192          1914.558      0.58

  SOIL WATER AT START OF YEAR               9.728         97114.602

  SOIL WATER AT END OF YEAR                10.007         99890.859

  SNOW WATER AT START OF YEAR               0.086           861.699      0.26

  SNOW WATER AT END OF YEAR                 0.000             0.000      0.00

  ANNUAL WATER BUDGET BALANCE               0.0154          154.139      0.05

*******************************************************************************


*******************************************************************************

                       ANNUAL TOTALS FOR YEAR 1978
-------------------------------------------------------------------------------
                                           INCHES         CU. FEET     PERCENT
                                          --------       ----------    -------
  PRECIPITATION                            37.24         371748.312    100.00

  RUNOFF                                    7.611         75979.273     20.44

  EVAPOTRANSPIRATION                       25.328        252837.000     68.01

  DRAINAGE COLLECTED FROM LAYER  2          4.6773        46690.953     12.56

  PERC./LEAKAGE THROUGH LAYER  4            0.000000          0.001      0.00

  AVG. HEAD ON TOP OF LAYER  3              0.0013

  CHANGE IN WATER STORAGE                  -0.377         -3758.927     -1.01

  SOIL WATER AT START OF YEAR              10.007         99890.859

  SOIL WATER AT END OF YEAR                 9.630         96131.930
```

```
   SNOW WATER AT START OF YEAR              0.000           0.000      0.00

   SNOW WATER AT END OF YEAR                0.000           0.000      0.00

   ANNUAL WATER BUDGET BALANCE              0.0000          0.018      0.00

*****************************************************************************




*****************************************************************************

        AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1974 THROUGH 1978
-----------------------------------------------------------------------------

                         JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                         -------  -------  -------  -------  -------  -------
  PRECIPITATION
  -------------
    TOTALS                 3.67     1.98     3.69     2.47     3.20     3.95
                           3.49     3.68     3.74     2.88     1.92     3.41

    STD. DEVIATIONS        1.55     1.61     1.24     0.84     1.54     0.99
                           1.19     2.35     0.95     1.11     0.80     1.11

  RUNOFF
  ------
    TOTALS                 2.340    1.313    3.370    0.700    0.106    0.097
                           0.083    0.198    0.261    0.090    0.007    0.850

    STD. DEVIATIONS        2.004    1.442    2.338    0.980    0.175    0.089
                           0.101    0.415    0.290    0.139    0.016    0.464

  EVAPOTRANSPIRATION
  ------------------
    TOTALS                 0.513    0.387    0.512    2.652    3.858    4.573
                           3.897    2.467    2.921    2.154    1.006    0.583

    STD. DEVIATIONS        0.104    0.111    0.149    0.378    1.168    1.363
                           1.006    0.775    0.978    0.217    0.207    0.071

  LATERAL DRAINAGE COLLECTED FROM LAYER  2
  ----------------------------------------
    TOTALS                 0.0000   0.2178   0.4458   1.4395   0.0119   0.0121
                           0.0006   0.0007   0.1704   0.2320   0.0635   0.6209

    STD. DEVIATIONS        0.0000   0.4870   0.6060   0.1972   0.0128   0.0118
                           0.0004   0.0006   0.3803   0.5173   0.0909   0.9271

  PERCOLATION/LEAKAGE THROUGH LAYER  4
  ------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
```

```
    STD. DEVIATIONS          0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
                             0.0000    0.0000    0.0000    0.0000    0.0000    0.0000


-------------------------------------------------------------------------------
              AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


  DAILY AVERAGE HEAD ON TOP OF LAYER  3
  -------------------------------------
    AVERAGES                 0.0000    0.0008    0.0014    0.0048    0.0000    0.0000
                             0.0000    0.0000    0.0006    0.0007    0.0002    0.0020

    STD. DEVIATIONS          0.0000    0.0017    0.0019    0.0006    0.0000    0.0000
                             0.0000    0.0000    0.0013    0.0017    0.0003    0.0030

*******************************************************************************


*******************************************************************************

    AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1974 THROUGH 1978
-------------------------------------------------------------------------------
                                      INCHES            CU. FEET       PERCENT
                                -------------------  -------------  ---------
 PRECIPITATION                   38.09     (   6.079)    380273.2      100.00

 RUNOFF                           9.415    (  2.7640)     93983.17      24.715

 EVAPOTRANSPIRATION              25.524    (  3.0119)    254794.33      67.003

 LATERAL DRAINAGE COLLECTED       3.21533 (  1.67813)     32097.053     8.44052
   FROM LAYER  2

 PERCOLATION/LEAKAGE THROUGH      0.00000 (  0.00000)         0.001     0.00000
   LAYER  4

 AVERAGE HEAD ON TOP              0.001 (     0.000)
   OF LAYER  3

 CHANGE IN WATER STORAGE         -0.065    (  0.2713)      -653.35      -0.172
*******************************************************************************
```

```
*******************************************************************************

               PEAK DAILY VALUES FOR YEARS 1974 THROUGH 1978
------------------------------------------------------------------------
                                                 (INCHES)      (CU. FT.)
                                                ----------    -------------
  PRECIPITATION                                   2.29         22859.924

  RUNOFF                                          3.382        33763.5625

  DRAINAGE COLLECTED FROM LAYER  2                0.30542       3048.86572

  PERCOLATION/LEAKAGE THROUGH LAYER  4            0.000000         0.00005

  AVERAGE HEAD ON TOP OF LAYER  3                 0.030

  MAXIMUM HEAD ON TOP OF LAYER  3                 0.015

  LOCATION OF MAXIMUM HEAD IN LAYER  2
        (DISTANCE FROM DRAIN)                     0.0 FEET

  SNOW WATER                                      3.44         34298.0781


  MAXIMUM VEG. SOIL WATER (VOL/VOL)                       0.4469

  MINIMUM VEG. SOIL WATER (VOL/VOL)                       0.2030


   ***  Maximum heads are computed using McEnroe's equations.  ***

        Reference:  Maximum Saturated Depth over Landfill Liner
                    by Bruce M. McEnroe, University of Kansas
                    ASCE Journal of Environmental Engineering
                    Vol. 119, No. 2, March 1993, pp. 262-270.

*******************************************************************************
```

```
******************************************************************************

           FINAL WATER STORAGE AT END OF YEAR 1978
    ----------------------------------------------------------------------
             LAYER        (INCHES)       (VOL/VOL)
             -----        --------       ---------
               1            9.4346         0.3931

               2            0.0080         0.0320

               3            0.0000         0.0000

               4            0.1875         0.7500

           SNOW WATER       0.000

******************************************************************************
******************************************************************************
```

Technical Notes

ADS

Technical Note 2.109

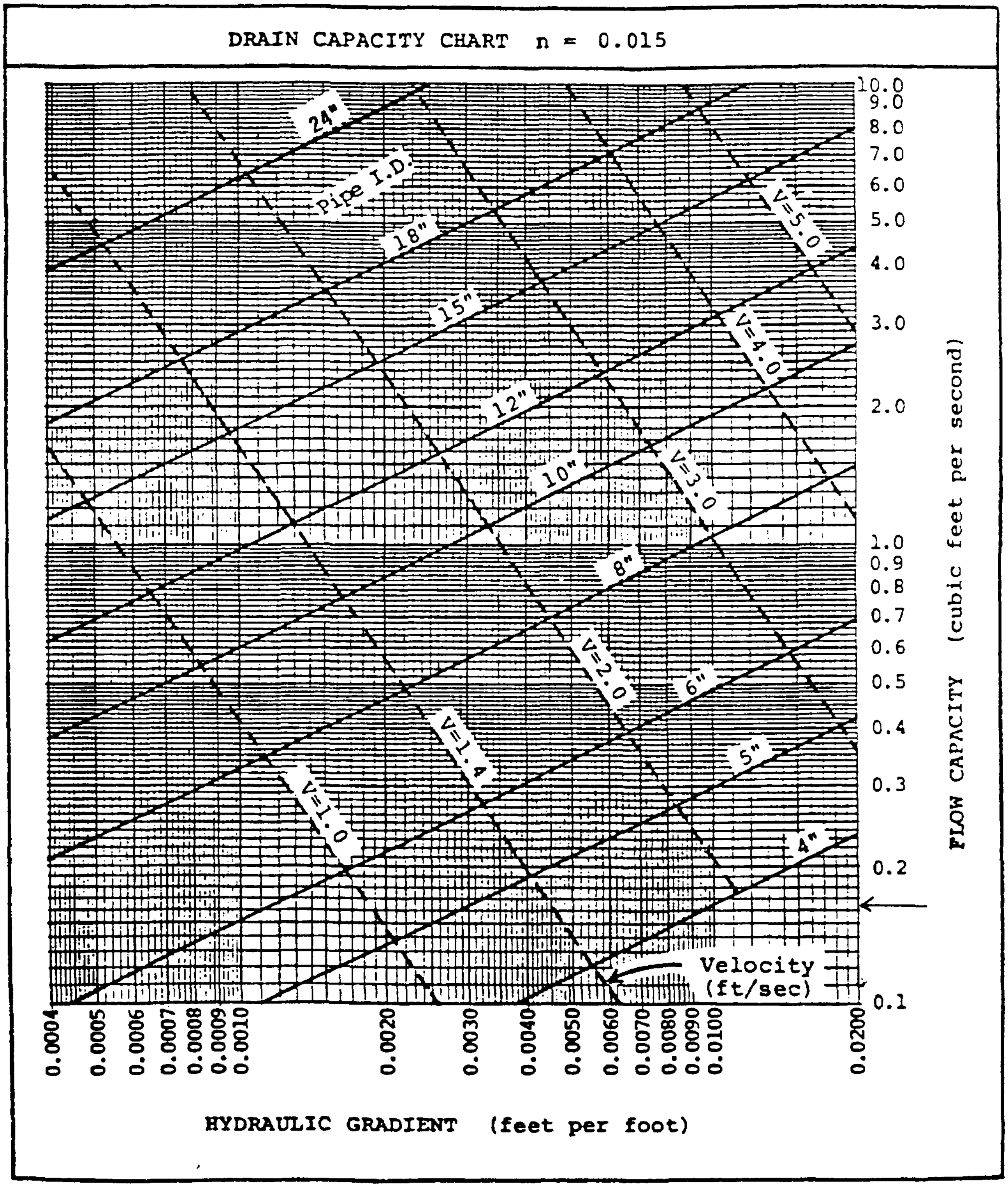
Re: Flow Capacity
Date: March 1, 1995

It is the intent of this Technical Note to provide current hydraulic performance data for use by the engineering community. A bibliography is included for the engineer's use if further information or guidance is needed.

Manning's "n" values are offered for design purposes based on the best available data assembled from a variety of sources as indicated. Table 1 presents the Manning's "n" values recommended by the A.D.S. engineering staff for use in design.

Table 1
Manning's "n" Value For Design
(Storm & Sanitary Sewer and Culverts)

Pipe Type	"n"
A.D.S. Corrugated Polyethylene Pipe	
3" - 6" Diameter	0.015
8" Diameter	0.016
10" Diameter	0.017
12" - 15" Diameter	0.018
18" - 36" Diameter	0.020
A.D.S. N-12	0.012
Concrete Pipe	0.013
Corrugated Metal Pipe (2 2/3" x 1/2" corrugation)	
Annular	
Plain	0.024
Paved Invert	0.020
Fully Paved (smooth lined)	0.013
Helical	
Plain 15" Diameter	0.013
Plain 18" Diameter	0.015
Plain 24" Diameter	0.018
Plain 36" Diameter	0.021
Spiral-Rib	0.012
Plastic Pipe (SDR, S&D, Etc.)	0.011
Vitrified Clay	0.013



DRAIN CAPACITY CHART n = 0.015

Figure 5

Soil Loss Calculations

Subject Landfill Soil Loss Calculation

By DCH Date 1.2.01 Checked [illegible] Date 1/3/01

Project Name Morgantown Project Number 457302 Sheet No. 1 of 1

Objective:

To determine the amount of soil lost from the landfill cover.

Reference:

1. "RUSLE: User Guide and Software", version 1.04. Soil and Water Conservation Society. May, 1995.

Given:

1. Soil loss was calculated for the steepest slope (approximately 25%).
2. Soil loss was calculated per year starting with the time the soil is vegetated with indigenous grasses.

Calculations:

The following factors were used to calculate soil loss:

Scenario	R	K	LS	C	P	A
Fully vegetated (25% slope)	155	0.34	6.24	0.004	1.0	**1.2**

where: R = Erosivity Factor (default value for Pittsburgh, PA)
K = Soil Erodibility Factor
LS = Slope Length Factor
C = Cover Management Factor
P = Support Practices Factor
A = Soil Loss (tons per acre-year)

Conclusions:

The RUSLE software package calculates the rate of erosion for a vegetated cap. For the fully vegetated condition that will be established, RUSLE calculates this value to be **1.2 tons per acre year**. This number is based upon a 25 % slope that will only be present at a very small percentage of the overall cap. The remainder of the cap will be a much shallower grade resulting in a smaller amount of total soil loss. During construction of the cap, silt erosion control measures, such as silt fencing, will be installed to keep the sediment from leaving the site.

Landfill Gas Calculations

Subject Morgantown Landfill Gas Calculation

By DCH Date 1.02.01 Checked GCR Date 1/3/01

Project Name Morgantown Project Number 457302 Sheet No. 1 of 5

Objective:

To determine the necessity of a gas vent system at the Morgantown, WV landfill, using the Scholl Canyon Model for quantifying Methane (CH_4) generation.

Reference:

1. "Landfill Off-Gas Collection and Treatment Systems". Engineering Technical Letter No. 1110-1-160. U.S. Army Corps of Engineers. Washington, DC. 1995.

Background:

Landfill gas (LFG) emissions are a result of the biological degradation of products contained within the landfill. As such, they are highly site-specific, leading to difficulty in accurately predicting the rate of LFG production from a landfill. The current approach to modeling the gas generation is to employ a simplified model, consistent with sound principals [1]. Several models exist for estimating LFG emission based upon site specific input parameters.

The landfill at Morgantown, WV was in operation from 1942-1962. It is comprised of approximately 2.75 acres of mostly industrial waste piled an average of 15 feet in depth across the landfill area. The absence of a large amount of municipal waste indicates that there will be less CH_4 production because of the decreased amount of cellulose content within a standard industrial waste. This implies that the theoretical value of CH_4 production later elaborated upon may never be reached. As such, this approach provides a conservative estimate of a worst-case scenario.

Model and Theory:

The Scholl Canyon Model is a LFG model that assumes CH_4 generation can be based on first-order kinetics. This model ignores the acclimation and growth stages of bacterial activity, and bases it's prediction on observed characteristics of substrate-limited bacterial growth [1]. The equation is given as:

$$Q_{CH4} = L_0 * R\ (e^{-kc} - e^{-kt})$$

Where:

Q_{CH4} = CH_4 generation rate at time t, m^3/yr

L_0 = potential CH_4 generation capacity of the waste, m^3/Mg

R = average annual acceptance rate of waste, Mg/yr

k = CH_4 generation rate constant, yr^{-1}

c = time since landfill closure, yr

t = time since initial waste placement, yr

The gas production rate is assumed to be at it's highest at initial placement of the waste and then decrease exponentially as the organic matter within the landfill is decomposed. This assumption bypasses the negligible (relative to life of the landfill) lag-time that anaerobic conditions are being established as aerobic bacteria consume all present oxygen.

Model Input:

The following table provides a description and source or justification/assumption rationale for the selection of each of the input parameters.

Parameter	Model Input	Source/ Rationale
L_0	7,400 ft^3/ton	Conservatively based on ETL municipal landfill example; can vary greatly with waste composition.
R	24,200 tons	Calculated using known volume of landfill, years of operation, and assumed density of 800 lbs/yd^3
K	0.08 yr^{-1}	Taken from ETL municipal landfill example; affected by temperature, moisture content, availability of nutrients, and pH.
C	38 years	Based on known closure date.
T	58 years	Based on known first date of operation.
ρ	800 lbs/yd^3	Based on ETL municipal landfill example

Calculations:

Landfill volume:

2.75 acres * 15 ft depth = 41.25 ac-ft

41.25 acre-ft * 43,560 ft^2/acre = 1,796,850 ft^3

1,796,850 ft^3 * 1 yd^3/ 27 ft^3 = 66,550 yd^3

Tonnage of waste in landfill:

66,550 yd^3 * 800 lbs/yd^3 = 5.32 x 10^7 lbs

5.32 x 10^7 lbs * ton/2000 lbs = 26,620 tons

Average Acceptance Rate (R):

$26{,}620 \text{ lbs} * 20 \text{ yrs}^{-1}$ = 1,331 tons/year

Estimated CH_4 Production (Q):

$7{,}400 \text{ ft}^3/\text{ton} * 1{,}331 \text{ tons/yr} * (e^{(-0.08 * 38)} - e^{(-0.08 * 58)})$ = $376{,}009 \text{ ft}^3/\text{yr}$

$376{,}009 \text{ ft}^3/\text{yr} * 525{,}960 \text{ min/yr}$ = $\underline{0.7149 \text{ ft}^3/\text{min}}$

Conclusions:

While the total amount of CH_4 produced is very small, the fact that there is gas being produced indicates the need for a gas venting system due to the potential damage to the cap system from long term gas build-up. Again, due to the very small volume, an active venting system is not warranted as a passive system will be adequate to vent the gas that is generated. Additionally, as stated in the background section, the Morgantown landfill should generate much less than even the small amount of gas predicted by this model. This is due to the fact that much of the waste contained in the landfill is non-biodegradable industrial waste, rather than the municipal waste used as a guideline in the calculations.

Excerpt From Reference 1

Arleta and Scholl Canyon models. The Palos Verdes and Sheldon Arleta will not be discussed in this ETL. Details on these models can be found elsewhere[5]. There are other models such as the Theoretical model and the GTLEACH-I model. The GTLEACH-I treats the landfill as a fixed-film microbial treatment process operating in batch-wise configuration with a continuous dilution and wash out. However, the GTLEACH-I model requires extensive input data which include numerous initial concentrations, moisture content, and leachate flow rate (4). Due to complicated input data requirements, the GTLEACH-I model will not be discussed in this ETL.

2.7.1 Scholl Canyon Model

The Scholl Canyon Model is a model which assumes that CH_4 generation is a function of first-order kinetics. This model ignores the first two stages of bacterial activity and is simply based on the observed characteristics of substrate-limited bacterial growth. The parameters of this model are empirically determined by fitting the empirical data to the model to account for variations in the refuse moisture content and other landfill conditions. The gas production rate is assumed to be at its peak upon initial placement after a negligible lag time during which anaerobic conditions are established and decreases exponentially (first-order decay) as the organic content of the waste is consumed. Average annual placement rates are used, and the time measurements are in years. The model equation takes the form:

$$Q_{CH4} = L_0 * R\ (e^{-kc} - e^{-kt}) \qquad (2\text{-}8)$$

Where:

Q_{CH4} = CH4 generation rate at time t, m^3/yr

L_0 = potential CH_4 generation capacity of the waste, m^3/Mg

R = average annual acceptance rate of waste, Mg/yr

k = CH_4 generation rate constant, 1/yr k' 2/years

c = time since landfill closure, yr (c=0 for active landfill)

t = time since initial waste placement, yr.

[illegible]

Excerpt from Reference 1

APPENDIX E
DESIGN EXAMPLES

The following hypothetical example illustrates the approach and procedure used for the calculation and design of a landfill gas collection system for a 12-acre municipal landfill. This model can be used for mixed and hazardous waste landfills, however, consideration for the composition of the refuse must be factored into the calculations for gas production potential as well as the handling of off-gas.

The following example is hypothetical. The following parameters for the hypothetical site were selected:

Site Characteristics

- Landfill Footprint: 12 acres
- Maximum Depth at Center point: 70 feet
- Landfill Side Slope: 3:1 horizontal:vertical
- Landfill Top Slope: 5 %
- Landfill cover area: 620,000 ft^2

Refuse Characteristics

- Ratio of Refuse/Cover Material: 4:1
- Age of Refuse: 20 years
- In-Place Refuse Density: 800 #/yd^3
- Capping Material: 40 mil HDPE
- Refuse Void Ratio: 4 %

Gas Characteristics

- Gas Constant: 0.08 yr^{-1}
- Gas Production Potential: 7400 ft^3/ton
- Concentration of Methane in Gas: 50 %
- Radius of Influence/Well: 200 ft
- Vacuum Pressure at Wellhead: 10 in wc
- Temperature of Landfill Gas: 110 ^{0}F
- Landfill Gas Viscosity: 2.8E-7 lbs.sec/ft^2
- Landfill Gas Density: 7.6E-2 lbs/ft^3

Figure E-1 illustrates the Model Landfill Base Grade Plan.

Ditch Sizing Calculations

Subject Ditch Sizing Calculation

By DCH Date 1.02 01 Checked CEF Date 1/3/01

Project Name Morgantown Project Number 457302 Sheet No. 1 of 8

Objective:

To determine adequate sizes for the drainage ditch that surrounds the cap area. The ditch must be capable of containing the peak flow from a 100-year, 24-hour storm event.

Reference:

1. "Pondpac™ (software), v 7.5". Haestad Methods. Waterbury, CT. 2000.

2. "Technical Release 55: Urban Hydrology for Small Watersheds, 2nd Edition". Soil Conservation Service. USDA. Washington, DC. June, 1986.

3. White, Frank M. Fluid Mechanics, 3rd edition. McGraw-Hill. 1994

Given:

1. The ditch will drain an area composed of an approximately 2.75 acre cap and an additional 1.75 acre area surrounding the cap area, for a total drainage basin of 4.5 acres.

2. The ditch will be trapezoidal in shape. It will be 1 feet deep, the bottom will have a width of 3 feet, and the side slopes shall be constructed with a grade of 2 horizontal feet to each vertical foot.

3. The minimum slope of the ditch shall be no less than a 1.0 % grade.

Calculations:

1. Manning's equation was used to size the ditch as shown below. The flow contained by the above referenced ditch dimensions is calculated from the following equation:

$$V = 1.49 * (R_h{}^{0.67}) * (S_o{}^{0.5}) * (n^{-1})$$

where: V = velocity
R_h = hydraulic radius
S_o = slope
n = Manning's coefficient of roughness

Recognize:

$V = Q/A$

where:

Q = peak flow

A = cross-sectional area of ditch

$$Q/A = 1.49 * (R_h{}^{0.67}) * (S_o{}^{0.5}) * (n^{-1})$$

Therefore:

$$Q = [1.49 * (R_h{}^{0.67}) * (S_o{}^{0.5}) * (n^{-1})] * A$$

Substitute in the following values:

R_h = (flow area)/(wetted perimeter)
= 5 / 7.47
= 0.67

S_o = 0.01

n = 0.03 (grass channel)

A = 7.47 ft^2

$$Q = [(1.49) * (0.67^{0.67}) * (0.01^{0.5}) * (0.03^{-1})] * 5$$

= **<u>18.97 cfs</u>**

Conclusions:

A drainage ditch constructed with the dimensions given will be able to adequately contain a peak discharge of **18.97 cfs**. Pondpac™ calculates the peak discharge from a 100-year, 24-hour storm event for the drainage basin to be **18.04 cfs**. Since **18.97** > **18.04**, the ditch constructed within the given parameters will adequately convey all expected runoff from the cap and surrounding area.

```
                      MASTER DESIGN STORM SUMMARY


 Default Network Design Storm File, ID MORGANTO.RNQ  100 yr


                    Total
                    Depth     Rainfall
  Return Event       in         Type          RNF File      RNF ID
  ------------     ------   ----------------  --------  ----------------
     50yr          4.9500   Synthetic Curve   SCSTYPES  TypeII  24hr
    100yr          5.7000   Synthetic Curve   SCSTYPES  TypeII  24hr

                       MASTER NETWORK SUMMARY
                     SCS Unit Hydrograph Method

                   (*Node=Outfall; +Node=Diversion;)
     (Trun= HYG Truncation: Blank=None; L=Left; R=Rt; LR=Left&Rt)


                                                                         Max
                          Return   HYG Vol         Qpeak     Qpeak   Max WSEL  Pond
Storage
 Node ID             Type Event     ac-ft   Trun    hrs       cfs       ft       ac-ft
 ----------------- ---- ------  ---------- --  ---------  --------  --------  ----------
-
 *DISCHARGE        JCT      50       .779        11.9500     14.08
 *DISCHARGE        JCT     100       .997        11.9500     18.04

  LANDFILL CAP     AREA     50       .779        11.9500     14.08
  LANDFILL CAP     AREA    100       .997        11.9500     18.04
```

```
File.... C:\HAESTAD\PPKW\SAMPLE\PROJECT1.PPW

 :::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
 TIME OF CONCENTRATION CALCULATOR
 :::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::


 -------------------------------------------------------------------------


 Segment #1:  Tc: Kerby/Hathaway

 Hydraulic Length   975.00 ft
 Mannings n          .0300
 Slope             .250000 ft/ft

 Avg.Velocity         2.91 ft/sec

                                          Segment #1 Time:      .0932 hrs
 -------------------------------------------------------------------------

                                                ==========================
                                                 Total Tc:      .0932 hrs
                                                ==========================
```

```
File.... C:\HAESTAD\PPKW\SAMPLE\PROJECT1.PPW

 --------------------------------------------------------------------------
 Tc Equations used...
 --------------------------------------------------------------------------


 ==== Kerby / Hathaway =====================================================

      Tc = 0.01377 * (Lf**0.47) * (n**0.47)* (Sf**-0.235)

      Where:  Tc = Time of concentration, hrs
              Lf = Flow length, ft
              n  = Mannings n
              Sf = Slope, ft/ft
```

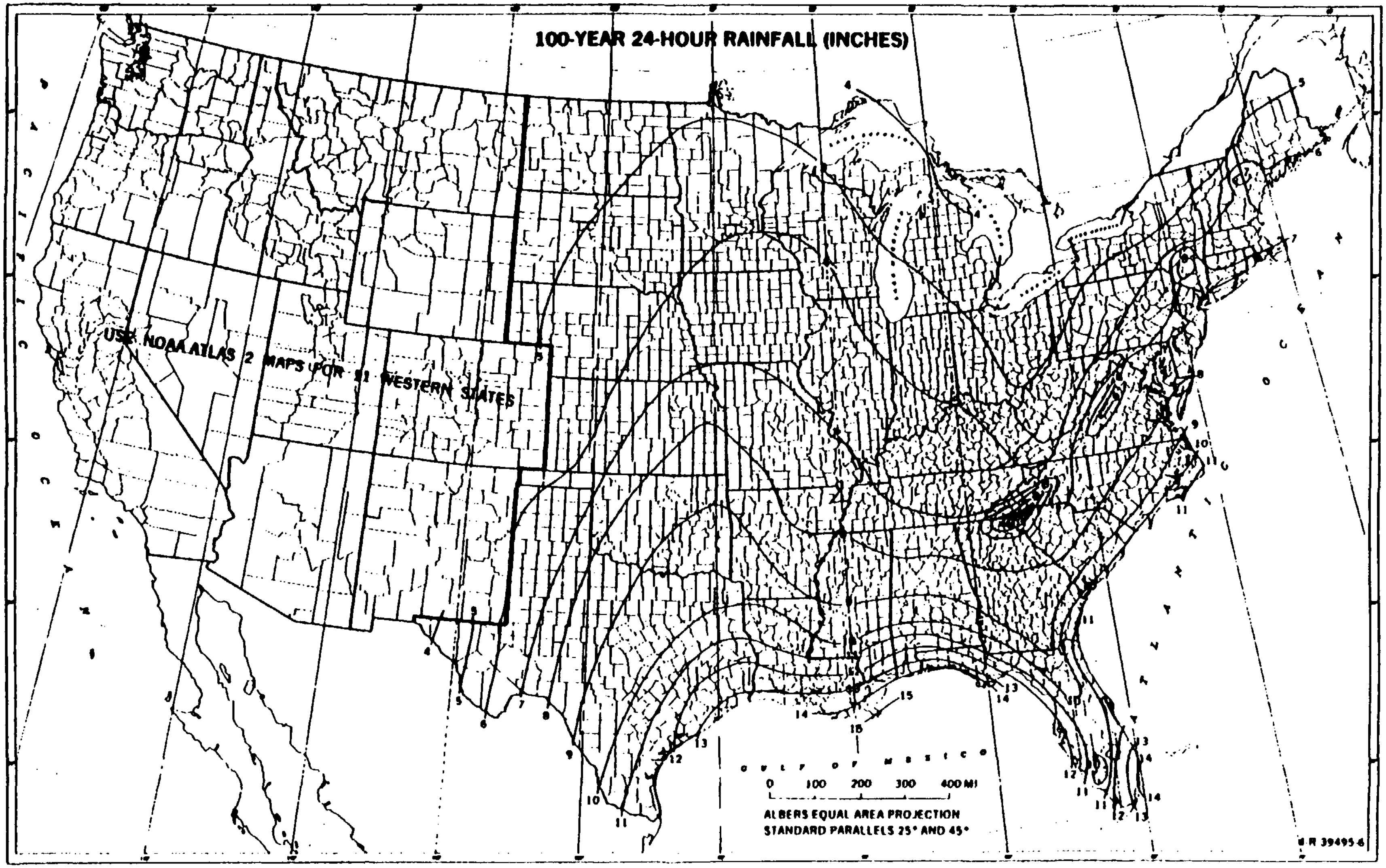


Figure B-8.—One-hundred-year, 24-hour rainfall.

For a given channel shape and bottom roughness, the quantity $(8g/f)^{1/2}$ is constant and can be denoted by C. Equation (10.13) becomes

$$V_0 = C(R_h S_0)^{1/2} \qquad Q = CA(R_h S_0)^{1/2} \tag{10.14}$$

These are called the *Chézy formulas*, first developed by the French engineer Antoine Chézy in conjunction with his experiments on the Seine River and the Courpalet Canal in 1769. The quantity C, called the *Chézy coefficient*, varies from about 60 $\text{ft}^{1/2}/\text{s}$ for small rough channels to 160 $\text{ft}^{1/2}/\text{s}$ for large smooth channels (30 to 90 $\text{m}^{1/2}/\text{s}$ in SI units).

Over the past century a great deal of hydraulics research [11] has been devoted to the correlation of the Chézy coefficient with the roughness, shape, and slope of various open channels. Correlations are due to Ganguillet and Kutter in 1869, Manning in 1889, Bazin in 1897, and Powell in 1950 [11]. All these formulations are discussed in delicious detail in Ref. 3, chap. 5. Here we confine our treatment to Manning's correlation, the most popular.

The Manning Roughness Correlation

It is reasonably accurate, and physically correct, to attack the Chézy uniform-flow formula, Eq. (10.13), by using values of f from the Moody chart (Fig. 6.13). Since typical channels are large and rough, they are usually in the fully rough turbulent-flow regime, and Eq. (6.64) reduces to

Fully rough flow:
$$f \approx \left(2.0 \log \frac{3.7D_h}{\epsilon}\right)^{-2} \tag{10.15}$$

where ϵ is the average wall roughness height. In practice, however, engineers prefer to use a simple correlation published in 1891 by Robert Manning [12], an Irish engineer. In tests with real channels, Manning found that the Chézy coefficient C increased approximately as the sixth root of the channel size. He proposed the simple formula

$$C = \left(\frac{8g}{f}\right)^{1/2} \approx \alpha \frac{R_h^{1/6}}{n} \tag{10.16}$$

where n is a roughness parameter. Since the formula is clearly not dimensionally consistent, it requires a conversion factor α which changes with the system of units used:

$$\alpha = 1.0 \quad \text{SI units} \qquad \alpha = 1.486 \quad \text{BG units} \tag{10.17}$$

Recall that we warned about this awkwardness in Example 1.4. You may verify that α is the cube root of the conversion factor between the meter and your chosen length scale: In BG units, $\alpha = (3.2808 \text{ ft/m})^{1/3} = 1.486$.*

The Manning formula for uniform-flow velocity is thus

$$\begin{aligned} V_0\ (\text{m/s}) &\approx \frac{1.0}{n}[R_h(\text{m})]^{2/3} S_0^{1/2} \\ V_0\ (\text{ft/s}) &\approx \frac{1.486}{n}[R_h(\text{ft})]^{2/3} S_0^{1/2} \end{aligned} \tag{10.18}$$

---

* An interesting discussion of the history and "dimensionality" of Manning's formula is given in Ref. 3, pp. 98–99.

The channel slope S_0 is dimensionless, and n is taken to be the same in both systems. The volume flow rate simply multiplies this result by the area:

Uniform flow: $$Q = V_0 A \approx \frac{\alpha}{n} A R_h^{2/3} S_0^{1/2} \qquad (10.19)$$

Experimental values of n (and the corresponding roughness height) are listed in Table 10.1 for various channel surfaces. There is a factor-of-15 variation from a smooth glass surface ($n \approx 0.01$) to a tree-lined floodplain ($n \approx 0.15$). Due to the irregularity of typical channel shapes and roughness, the scatter bands in Table 10.1 should be taken seriously.

Since Manning's sixth-root size variation is not exact, real channels can have a variable n depending upon the water depth. The Mississippi River near Memphis, Tennessee, has $n \approx 0.032$ at 40-ft flood depth, 0.030 at normal 20-ft depth, and 0.040 at 5-ft low-stage depth. Seasonal vegetative growth and factors such as bottom erosion can also affect the value of n.

Table 10.1 Experimental Values of Manning's n Factor*

		Average roughness height ϵ	
	n	**ft**	**mm**
Artificial lined channels:			
Glass	0.010 ± 0.002	0.0011	0.3
Brass	0.011 ± 0.002	0.0019	0.6
Steel, smooth	0.012 ± 0.002	0.0032	1.0
Painted	0.014 ± 0.003	0.0080	2.4
Riveted	0.015 ± 0.002	0.012	3.7
Cast iron	0.013 ± 0.003	0.0051	1.6
Cement, finished	0.012 ± 0.002	0.0032	1.0
Unfinished	0.014 ± 0.002	0.0080	2.4
Planed wood	0.012 ± 0.002	0.0032	1.0
Clay tile	0.014 ± 0.003	0.0080	2.4
Brickwork	0.015 ± 0.002	0.012	3.7
Asphalt	0.016 ± 0.003	0.018	5.4
Corrugated metal	0.022 ± 0.005	0.12	37
Rubble masonry	0.025 ± 0.005	0.26	80
Excavated earth channels:			
Clean	0.022 ± 0.004	0.12	37
Gravelly	0.025 ± 0.005	0.26	80
Weedy	0.030 ± 0.005	0.8	240
Stony, cobbles	0.035 ± 0.010	1.5	500
Natural channels:			
Clean and straight	0.030 ± 0.005	0.8	240
Sluggish, deep pools	0.040 ± 0.010	3	900
Major rivers	0.035 ± 0.010	1.5	500
Floodplains:			
Pasture, farmland	0.035 ± 0.010	1.5	500
Light brush	0.05 ± 0.02	6	2000
Heavy brush	0.075 ± 0.025	15	5000
Trees	0.15 ± 0.05	?	?

* A more complete list is given in Ref. 3, pp. 110–113.

Subject velocity in ditch for peak discharge / 13% grade
By DCH **Date** 3/8/01 **Checked** GER **Date** 3/14/01
Project Name Morgantown **Project Number** 457302 **Sheet No.** 1 **of** 3

Objective:

To determine the velocity associated with the maximum slope present in the drainage ditch that surrounds the Morgantown landfill cap.

Reference:

1. "Pondpac™ (software), v 7.5". Haestad Methods. Waterbury, CT. 2000.
2. "Technical Release 55: Urban Hydrology for Small Watersheds, 2nd Edition". Soil Conservation Service. USDA. Washington, DC. June, 1986.
3. White, Frank M. Fluid Mechanics, 3rd edition. McGraw-Hill. 1994

Given:

1. Peak discharge from the cap area for 100-year and 25-year, 24-hour storm events have been determined to be 18.04 cubic feet per second (cfs) and 12.54 cfs, respectively.
2. The ditch is trapezoidal in shape with a bottom width of 3 feet and equal side slopes of 2 horizontal feet to each vertical foot.
3. The maximum slope of the ditch is a 13% grade.

Calculations:

Manning's equation relates velocity to channel characteristics in the following manner:

$$V = 1.49 * (R_h{}^{0.67}) * (S_o{}^{0.5}) * (n^{-1}) \qquad (1)$$

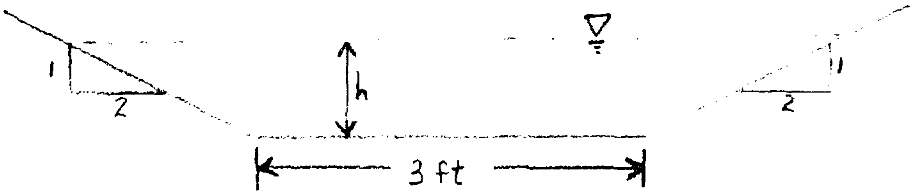
where:
V = velocity
R_h = hydraulic radius
S_o = slope
n = Manning's coefficient of roughness

Velocity is also given as:

$$V = Q / A \qquad (2)$$

where:
A = area
Q = flow

Recognize that area and wetted perimeter (part of hydraulic radius term) are unknown, as the flow height at a given volume is unknown. Using the following drawing get area and wetted perimeter (wp) in the same terms of height (h):



Therefore: $A = 5 * h$ (3)

$wp = 3 + 2 (5h)^{0.5}$ (4)

Substituting eq. (1) into eq. (2):

$$Q/A = 1.49 * (R_h^{0.67}) * (S_o^{0.5}) * (n^{-1})$$

$$Q = [1.49 * (R_h^{0.67}) * (S_o^{0.5}) * (n^{-1})] * A \quad (5)$$

Substituting eqs. (3) & (4) into eq. (5):

$$Q = [1.49 * \{(5h)/(3 + 2(5h)^{0.5})\}^{0.67} * (S_o^{0.5}) * (n^{-1})] * 5h$$

Solve for h with a known Q of 18.04 cfs:

$h = 0.3571$ ft

Substitute into eq. (3):

$A = 1.7855\ ft^2$

Solve eq. (2):

$V = 18.04\ ft^3/sec / 1.7855\ ft^2$

= **10.10 ft/sec**

Following the same calculation pattern for the 25-year, 24-hour storm event yields the following results:

$Q = 12.54\ ft^3/sec$

$h = 0.2836$ ft

$A = 1.418$ ft

V = **8.84 ft/sec**

Conclusions:

The drainage channel surrounding the Morgantown landfill has been sized to adequately contain and convey the peak discharge from a 100-year, 24-hour storm event. However, the expected life of the cap itself is expected to be approximately 25 years. As such, the materials used in the construction of the channel are picked to provide a reasonable amount of security in their capability to withstand 25 years of use. This includes lining the channel with a continuous stand of grass. The expected top velocity accompanying the peak discharge from a 25-year, 24-hour storm event is **8.84 ft/sec**. Any damage occurring to the grass-lined channel associated with high water velocities is included in the regular maintenance plan for the cap.

Appendix B - Technical Specifications

ENVIRONMENTAL STRATEGIES CORPORATION
Four Penn Center West • Suite 315 • Pittsburgh, Pennsylvania 15276 • (412) 787-5100 • Fax (412) 787-8065

FINAL
TECHNICAL SPECIFICATIONS

OU-1 MORGANTOWN ORDNANCE WORKS
MORGANTOWN, WEST VIRGINIA

PREPARED

BY

ENVIRONMENTAL STRATEGIES CORPORATION

APRIL 3, 2002

Morgantown/457302/Tar and Soil WP/Final Submittal/Final techspek.doc

Contents

No. of Pages

Division 1 - General Requirements

Division 2 - Site Work

DIVISION 1 - GENERAL REQUIREMENTS

Section 01010 - Summary of Project

Part 1 - General

1.1 Section Includes

A. This section gives a general description of the scope and extent of work necessary for this project.

B. Detailed requirements and extent of work are stated in the applicable sections of these Specifications and are shown on the Construction Drawings (Drawings). The Construction Drawings and Technical Specifications package must be on site during construction.

C. The Contractor shall, except as otherwise specifically stated herein or in any applicable part of these Specifications or Contract Documents, provide the labor, materials, equipment, tools, construction equipment, and other facilities and services inclusive of all taxes necessary for the proper execution, testing, and completion of the work for this project.

D. The work associated with the installation and construction of the landfill cap system shall include the following.

- Installation of Erosion and Sedimentation Controls (E&SC)
- Tar-like material excavation, segregation, and offsite thermal treatment (by others)
- Soil excavation and consolidation (by others)
- Sediment excavation and consolidation
- Swale, backfilling, contouring, seeding, and mulching
- Grading of onsite and imported material to produce appropriate subgrade
- Wetland restoration (by others)
- Placement of a geosynthetic clay liner
- Placement of a 40 mil High Density Polyethylene Flexible Membrane Liner (HDPE FML) and composite drainage net
- Placement of a soil cover capable of sustaining vegetation with a minimum finished thickness of 24 inches measured perpendicular to the groundsurface
- Construction of Surface Water Controls
- Seeding and mulching all disturbed areas

1.2 Codes and Standards

Section 1.2 lists the general category of Codes and Standards that may apply to the project work. Specific governing and applicable codes and standards, as they specifically relate to the project work, are included in the specific sections of these Specifications.

A. EPA Regulations
B. ACI Standards
C. AISC Standards
D. ANSI Standards
E. ASTM Standards
F. OSHA Standards
G. Other state and local governing codes and standards
H. DOT Regulations

1.3 Owner and Engineer

A. Use of the term "Owner" in these Specifications refers to Olin Corporation and the U.S. Army Corps. Of Engineers.

B. Use of the term "Engineer" in these Specifications refers to Environmental Strategies Corporation.

C. Use of the term EPA in these specifications refers to the United States Environmental Protection Agency and West Virginia Division of Environmental Protection.

Part 2 - Products

A. The Contractor shall furnish and install the materials and equipment as specified in these Specifications and as shown on the Construction Drawings. The materials and equipment shall be clean uncontaminated earthen materials and new products.

Part 3 - Execution

3.1 Examination of the Site

A. The Contractor shall familiarize himself with the site, surface, subsurface, and groundwater conditions at the site.

B. No contract adjustment will be made because of the failure of the Contractor to review and understand all existing site data.

3.2 List of Drawings

A. The Drawings include the following:

- Title Sheet (457302-D40)
- Sheet 1 - Existing Conditions (457302-D41)
- Sheet 2 - Sediment Excavation Plan (457302-D42)
- Sheet 3 - Cap Subgrade and Silt Fence Location Plan (457302-D43)
- Sheet 4 - Details
- Sheet 5 - Leachate Collection and Conveyance System (457302-D45)
- Sheet 6 - Wetlands Delineation (457302-D46)
- Sheet 7 - Security Fence Relocation Plan (457302-D47)

Part 4 - Special Requirements

4.1 Health and Safety Protection

A. U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) regulations (29 Code of Federal Regulations (CFR) 1910.120) specify worker health and safety protection requirements applicable to work at the site.

B. Contractor shall conduct his work in strict accordance with the site Health and Safety Plan (HASP) prepared by the Contractor to meet applicable OSHA regulations. Dust and ambient air monitoring and sampling must be included as a component to the HASP. Other provisions of the site HASP that will apply to the Contractor will include but not be limited to the following:

- Attendance at on-site safety briefing(s)
- Observation of site access restrictions
- Observation of personal hygiene rules
- Use of personal protective equipment (PPE; as required)
- Record keeping and reporting.

The Contractor will supply an adequate number of copies of the HASP to workers before initiation of work. Contractor shall provide onsite training to all Contractor workers and subcontractors relative to the site HASP requirements.

4.2 Contractor Quality Assurance/Quality Control

A. Quality workmanship and performance are essential in this project. Contractor shall also fully support and cooperate with the Engineer in the implementation of the overall project quality control. The Contractor will be required to furnish documentation of materials supplied to the project, calibration of measuring equipment used, as-built items, and similar equipment items.

Part 5 - Measurement and Payment

A. No separate measurement or payment shall be made for the work or materials associated with this technical specification. The costs associated with this technical specification shall be considered incidental to other work items.

END OF SECTION

Section 01300 - Submittals

Part 1 - General

1.1 Section Includes:

A. Submittal Procedures.
B. Construction progress schedules.
C. Proposed projects lists.
D. Shop drawings.
E. Product data.
F. Samples.
G. Manufacturer's instructions.
H. Manufacturer's certificates.
I. Testing data sheets.

1.2 Submittal Procedures

A. Transmit each submittal using a form that has been pre-approved by the Engineer.

B. Sequentially number the transmittal forms.

C. Identify the project number, Contractor, Subcontractor, or supplier; pertinent Drawing sheet (s) and detail number (s), and specification Section number (s), as appropriate.

D. Schedule submittals to expedite the Project, and deliver to the Engineer.

E. Identify any variations/deviations from the Drawings and Specifications which may be detrimental to the successful performance of the completed Work.

F. Revise and resubmit submittals as required, identify all changes made since the previous submittal.

G. Distribute copies of reviewed submittals to concerned parties. Instruct parties to promptly report any inability to comply with provisions. Final submittals concerning critical project components shall be forwarded to the EPA for review, as necessary.

1.3 Construction Progress Schedules

A. Submit initial progress schedule in duplicate within two weeks after Notice to Proceed has been received for Engineer review.

B. Revise and resubmit as required.

C. Submit a horizontal bar chart with separate line for each major section of Work or operation, identifying the first work day of each week.

D. Indicate estimated percentage of completion for each item of Work at each submission.

1.4 Proposed Products List

A. Within two weeks after date of Notice to Proceed, submit a complete list of major equipment and materials proposed for use, with name of manufacturer, trade name, and model number of each major piece of equipment to Engineer for review and approval.

1.5 Shop Drawings (if applicable)

A. Submit three copies of shop drawings to the Engineer for review and approval.

1.6 Equipment/Product Data

A. Submit three copies of equipment data to the Engineer.

1.7 Samples

A. Submit color, equipment, and/or material samples to illustrate functional and aesthetic characteristics of the equipment, to the extent possible.

B. Include identification on each sample, with pertinent information supplied.

1.8 Manufacturer's Instructions

A. When specified in individual specification Sections, submit manufacturer's printed instructions for delivery, storage, assembly, installation, start-up, adjusting, and finishing of the various major equipment prices.

1.9 Manufacturer Certificates

A. When specified in theses Specifications, submit manufacturers' certified equipment information to the Engineer for review.

1.10 Testing Data Sheets

A. Testing data sheets will be submitted with the test results.

Part 2 - Measurement and Payment

A. No separate measurement or payment shall be made for the work or materials associated with this technical specification. The costs associated with this technical specification shall be considered incidental to other work items.

END OF SECTION

Section 01488 - Survey Requirements

Part 1 - General

1.1 Section Includes

A. The Contractor shall establish benchmarks as required to perform the work to the lines and grades indicated on the Drawings. The benchmarks shall be tied into U.S. Geologic Survey (USGS) datum.

B. References shall be set and measurements taken using standard accepted surveying methods and equipment. The Contractor shall use only West Virginia registered professional surveyors for surveying activities. Copies of original surveyor field notes shall be given to the Engineer as part of the project record documents.

C. The accuracy of the survey layout data shall be ±0.20 foot horizontal and vertical or as approved by the Engineer. The accuracy of quantity survey data, if required, shall be ± 0.10 foot horizontal and vertical.

Part 2 - Products

2.1 Equipment

A. The Contractor or surveyor shall supply the appropriate surveying equipment required to perform the work to the lines and grades indicated on the Drawings.

Part 3 - Execution

A. The Contractor shall make the measurements and define the locations required for the proper execution of the work detailed in the Specifications and Drawings.

B. Three permanent third order benchmarks will be installed at the site for use as survey control.

Part 4 - Measurement and Payment

A. Payment shall be made based on Lump Sum unit price for the surveying requirements associated with this project. The cost shall be inclusive of survey work required to allow proper construction, survey data for payment purposes, and a final topographical and site features "as-built" survey. Survey work for payment purposes must be performed by an independent surveyor (i.e., not an employee or subsidiary of the contractor). Payment shall be full compensation for all labor, materials, tools, equipment, and other incidentals necessary for providing the survey requirements. Payment will be made in monthly payments prorated according to efforts performed. Final payment for surveying requirements will be made after engineer receipt and approval of the as-built survey information.

END OF SECTION

Section 01500 - Construction Facilities and Temporary Controls

Part 1 - General

1.1 Section Includes:

A. Temporary Utilities: Electricity, lighting, heat, air conditioning, ventilation, telephone service, water, and sanitary facilities.

B. Temporary Controls: Barriers, enclosures and fencing, protection of the Work, and water control.

C. Construction Facilities: Access Roads, parking, site housekeeping, and temporary buildings.

1.2 Temporary Electricity

A. Provide and maintain temporary power service via generators and/or power drops.

B. Provide adequate distribution equipment, wiring, and outlets to provide single-phase branch circuits for the power and lighting.

1.3 Temporary Lighting

A. Provide and maintain incandescent lighting as necessary, for construction operations.

B. Provide and maintain lighting to interior work areas after dark for security purposes.

1.4 Temporary Heat and Air Conditioning

A. Provide heat and air conditioning devices as required to maintain appropriate conditions for field offices.

B. Prior to operation of permanent equipment for temporary heating purposes, verify that installation is approved for operation, equipment is lubricated and filters are in place.

1.5 Temporary Ventilation

A. Ventilate enclosed areas to assist cure of materials, to dissipate humidity, and to prevent accumulation of dust, fumes, vapors, or gases.

1.6 Telephone Service

A. Provide and maintain telephone service to field office at time of project mobilization. Coordinate telephone service with the local telephone company.

1.7 Temporary Water Service

A. The Contractor shall provide and maintain suitable quality water service to the Site.

1.8 Temporary Sanitary Facilities

A. Provide and maintain required facilities and enclosures.

1.9 Barriers

A. Provide barriers (i.e., temporary fencing, locked gates, flagging) to prevent inadvertent unauthorized entry to construction areas and to protect existing facilities and adjacent properties from damage from construction operations.

B. Provide barricades as required by excavations made for the installation of pipelines, electrical conduit/wiring, and any other excavation(s) that may pose a hazard/damage to the public or on-site construction personnel.

C. Provide protective covers/plates over any excavation or area where vehicular and/or pedestrian traffic may pass, or as directed by the Engineer.

D. Provide protection (e.g., temporary fencing, signs, flagging) in those on-site areas that are not to be disturbed by construction activities or where trees or plant life is to be protected including those areas that are not to have materials stockpiled or placed.

1.10 Water Control

A. Grade site to drain. Maintain excavations free of water. Provide, operate, and maintain pumping equipment, if necessary.

B. Protect site from puddling or running water. Provide water barriers as required to protect site from soil erosion.

1.11 Protection of Installed Work

A. Protect installed Work and provide special protection where specified in individual specification Sections.

B. Provide temporary and removable protection for installed products. Control activity in immediate work area to minimize damage.

1.12 Security

A. Provide security to protect the equipment and work from unauthorized entry, vandalism, or theft.

1.13 Access Roads

A. Construct and maintain temporary roads accessing public thoroughfares to serve construction area if required by the Engineer.

B. Extend and relocate as Work progress requires. Provide detours necessary for unimpeded traffic flow.

1.14 Parking

A. Provide temporary surface parking areas to accommodate construction personnel and site visitors.

1.15 Site Housekeeping

A. Maintain areas free of waste materials, debris, and rubbish. Maintain site in a clean and orderly condition.

B. Broom and vacuum clean interior areas to eliminate dust, as needed.

C. Remove waste materials, debris, and rubbish from site periodically or as directed by the Engineer and dispose off-site.

1.16 Field Offices and Sheds

A. Office: Weather-tight with lighting, electrical outlets, heating, cooling and ventilating equipment, and equipped with sturdy furniture, desk, filing cabinet, drawing rack and drawing display table. Also, supply fax machine, phone (including usage), copy machine, and answering machine.

B. Provide space for project meetings with table and chairs to accommodate 10 persons.

C. Provide two separate private offices, similarly equipped and furnished, for use of Engineer and USEPA (minimum 200 square feet).

D. Locate offices and sheds a minimum distance of 30 feet from existing and new structures.

1.17 Removal of utilities, facilities, and controls

A. Remove temporary above-grade or buried utilities, equipment, facilities, and materials upon project completion or as directed by the Engineer.

B. Clean and repair damage caused by installation or use of temporary work.

C. Restore existing facilities used during construction to original condition. Restore permanent facilities used during construction to specified condition.

Part 2 - Measurement and Payment

Payment for Construction Facilities and Temporary Controls shall be based on lump sum basis, including all labor, material, equipment, utilities, and taxes. This item will be paid in two amounts, half with the first invoice after field offices are fully functional and half with the last invoice for the project.

END OF SECTION

Section 01520 - Decontamination and Disposal

Part 1 - General

1.1 Section Includes

A. The Contractor shall furnish the labor, water, materials, and equipment necessary for decontamination of equipment and personnel and disposal of wash water following decontamination.

Part 2 - Products

A. The Contractor shall construct a temporary decontamination area with a sump for the decontamination of equipment.

B. The Contractor shall provide an area for personnel decontamination and for collection of personal protective equipment and wastewater following decontamination activities.

Part 3 - Execution

A. The Contractor shall decontaminate equipment, vehicles, and personnel that come into contact with the Exclusion Zone. Decontamination of equipment shall consist of a pressure wash.

B. Wastewater from decontamination procedures shall be collected and sampled prior to disposal.

C. Personal protective equipment shall be disposed in accordance with applicable EPA and West Virginia regulations.

D. Soil materials remaining from equipment decontamination shall be relocated for ultimate capping within the landfill.

E. The Contractor's personnel decontamination procedures shall be in accordance with the site-specific health and safety plan.

Part 4 - Measurement and Payment

Payment of Decontamination and Disposal shall be based on lump sum basis, including all labor, material, analytical work, equipment, taxes, and wastewater disposal. The decontamination water may be pumped to the temporary water treatment system. This item will be paid monthly prorated over the length of construction.

END OF SECTION

Section 01540 - Security

Part 1 - General

1.1 Section Includes

A. Security Program.

B. Entry Control.

C. Personnel Identification.

D. Material Security

1.2 Security Program

A. Protect Work and existing premises from theft, vandalism, and unauthorized entry.

B. Initiate the security program at job mobilization.

C. Maintain program throughout construction period until acceptance precludes the need for Contractor security.

1.3 Entry Control

A. Allow entrance to the construction area only to authorized persons with proper identification.

B. Maintain log of workmen and visitors.

1.4 Personnel Identification

A. The Contractor shall maintain a list of his authorized persons and submit a copy to the Engineer on request.

B. These personnel shall be persons to whom the Contractor has authorized access to the site and which have been credited or assigned to various site construction responsibilities. These persons shall be directly involved in the day-to-day construction activities or those activities that are directly ancillary to the construction work. Those personnel shall include, but not be limited to, personnel who have a leading role in the overall construction work, including labor and supervisory personnel, or managers or principals responsible for the successful performance of the work.

1.5 Material Security

A. Precautions shall be taken to prevent accidental ignition of ignitable or reactive material. The material shall be separated and protected from sources of ignition or reaction including: open flames, smoking, cutting, and welding. "No Smoking" signs must be conspicuously placed at locations where there is a hazard from ignitable or reactive material.

Part 2 - Measurement and Payment

A. No separate measurement or payment shall be made for the work or materials associated with this technical specification. The costs associated with this technical specification shall be considered incidental to other work items.

END OF SECTION

Section 01560 - Environmental Controls

Part 1 - General

1.1 Section Includes

A. This section discusses the Contractor's responsibilities for installing and maintaining controls to minimize air and water pollution resulting from site activities.

B. Erosion and sedimentation controls.

C. Dust control.

D. Vapor control. (when applicable)

E. Land disturbance.

F. Disposal of generated wastes and wastewater. (when applicable)

1.2 Erosion and Sedimentation Controls

A. Contractor shall install and maintain controls to avoid excess soil erosion and downstream sedimentation as a result of site work. The work shall comply with the construction drawings and West Virginia's Handbook for Erosion and Sediment Control for Developing Areas, May 1993.

1.3 Dust Control

A. Contractor shall conduct site operations in a manner that will minimize and/or control the generation of airborne dust. As necessary, Contractor will apply approved dust control agents as allowed by the local air control district.

1.4 Vapor and Emissions Control

A. Contractor shall maintain vapor and emissions controls such that air quality standards listed in the HASP are not exceeded.

B. Contractor shall maintain vapor and emissions controls to prevent, to the extent possible, the release of any nuisance odors from the property.

C. Controls shall be maintained on soil storage trailers, roll-off boxes, and storage tanks, if present, as well as all exposed/inactive portions of excavations and fill areas.

D. Contractor shall have water and other control agents onsite to immediately apply in the event an action level is exceeded at any monitoring location.

1.5 Land Disturbance

A. Contractor shall minimize the area of land disturbance for his work and in no case shall remove vegetation, excavate soil, or conduct any other activities in areas outside that needed for safe and proper conduct of his work. The Contractor shall adhere to the limits of excavation defined in the Construction Drawings unless approved by the Engineer.

1.6 Disposal of Site Generated Waste and Wastewater

A. The Contractor shall dispose of site-generated waste and wastewater in accordance with applicable federal, state, and local laws, rules, regulations, and ordinances.

Part 2 - Products

2.1 Silt Fence

A. Silt fencing shall be approved by the Engineer.

2.2 Dust Control Agents

A. Any dust control agents to be used by the Contractor (other than potable water) shall be approved by the Engineer prior to such use. Oils shall not be used for dust control.

2.3 Waste Containers

A. Any containers used for the temporary accumulation of wastes generated at the Site shall comply with applicable regulations and be approved by the Engineer.

Part 3 - Execution

3.1 Erosion and Sedimentation Controls

A. Contractor shall erect silt fencing in accordance with manufacturer's recommendations along the downslope perimeter of the work area as shown on construction drawings and as required to control erosion. Such installation shall be approved by the Engineer.

B. Contractor shall maintain the silt fence throughout the duration of the work until vegetation is fully established.

C. Contractor shall remove the silt fence at the completion of the work, unless otherwise directed by the Engineer.

3.2 Dust Control

A. Contractor shall implement dust control program which includes, but is not limited to, the following.

- Application of water (and/or other approved constituent) when dust is a result of weather conditions (i.e., dry, windy).
- If dust levels exceed the action level specified by the HASP, additional dust suppression techniques will be implemented at the work area.

3.3 Noise Control

A. Contractor shall maintain his equipment in good operating condition so as to avoid unnecessary construction noise.

B. For any work performed between the hours of 6:00 p.m. and 7:00 a.m., Contractor shall, to the maximum extent possible, avoid activities that produce high noise levels.

C. In the event of complaints concerning construction noise, Contractor will monitor noise levels at the site perimeter to ensure compliance with the following maximum noise levels (15-minute time-weighted average).

- Day time (7:00 a.m. to 6:00 p.m.) - 80 dbA
- Night time (6:00 p.m. to 7:00 a.m.) - 50 dbA.
- If the maximum noise levels exceed these criteria, the Contractor to modify his operations as required to achieve compliance.

3.4 Vapor and Emissions Control (if applicable)

A. Contractor shall implement vapor controls that will include:

- Monitoring during all active excavations, using equipment required by the HASP.
- Covering tanks, if any.
- Covering trailers and roll-off boxes, if any, holding waste material excavated from contaminated areas.
- Covering exposed tar and contaminated soils deemed for offsite disposal, if any, at the end of each day's activity.

Part 4 - Measurement and Payment

A. Payment for the Erosion and Sediment Control measures shall be Lump Sum unit price for the maintenance of the Erosion and Sediment Controls. Payment shall be unit price per linear feet of silt fence installed. The lump sum costs shall include sufficient resources to perform maintenance until the permanent vegetation is fully established. Payment shall be full compensation for all labor, materials, tools, equipment and other incidentals necessary to provide, install, and maintain all erosion and sediment control measures. Payments will be made after initial installation of devices based on the measured linear footage of silt fence installed and with the final invoice after vegetation is fully established for the lump sum maintenance activities. In addition, the retainage applied to this project invoicing will be held until vegetation is fully established and site conditions are approved by the Engineer and USEPA. Other activities described in this specification shall be considered incidental to other work items.

END OF SECTION

DIVISION 2 - SITE WORK

Section 02120 – High Density Polyethylene Geomembrane

Part 1 – General

A. This section includes specifications and guidelines for manufacturing and installing the 40 mil textured high-density polyethylene geomembrane component of the multi-layer cover system.

Part 2 – Codes and Standards

2.1 Test Methods

A. Note: Test equipment and procedures are used which enable effective and economical confirmation that the product will conform to specifications based on the noted procedures. Some test procedures have been modified for application to geosynthetics.

B. American Society for Testing and Materials (ASTM)

1. D 638 Standard Test Method for Tensile Properties of Plastics
2. D 792 Standard Test Method for Specific Gravity and Density of Plastics by Displacement
3. D 1004 Test Method for Initial Tear Resistance of Plastic Film and Sheeting
4. D 1204 Test Method for Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature
5. D 1238 Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer
6. D 1505 Test Method for Density of Plastics by the Density-Gradient Technique
7. D 1593 Specification for Nonrigid Vinyl Chloride Plastic Sheeting
8. D 1603 Test Method for Carbon Black in Olefin Plastics
9. D 1693 Test Method for Environmental Stress-Cracking of Ethylene Plastics
10. D 3015 Standard Practice for Microscopical Examination of Pigment Dispersion in Plastic Compounds
11. D 4437 Practice for Determining Integrity of Field Seams Used in Joining Flexible Polymeric Sheet Geomembranes

C. Federal Test Method Standards - 101 Puncture Resistance

D. NSF International - Standard 54 Flexible Membrane Liners

Part 3 - Definitions

3.1 Definitions

A. Lot: A quantity of resin (usually the capacity of one rail car) used in the manufacture of polyethylene geomembrane rolls. The finished roll will be identified by a roll number traceable to the resin lot used.

B. Geomembrane Manufacturer: The party responsible for manufacturing the geomembrane rolls.

C. Installer: The party responsible for field handling, transporting, storing, deploying, seaming, seam testing.

D. Panel: The unit area of geomembrane that will be seamed in the field. A panel is identified as a roll or portion of a roll that is larger than 100 square feet.

E. Subgrade Surface: The soil layer surface which immediately underlies the geosynthetic material(s).

Part 4 – Submittals Post-Award

4.1 Furnish the following product data, in writing, to the Engineer prior to installation of the geomembrane material

A. Certify that geomembrane manufacturer is listed by NSF International.

B. Resin Data shall include the following:

Certification stating that the resin meets the specification requirements (see Section 9.2)
Certification stating all resin is from the same Manufacturer (see Section 9.2)
Copy of Quality Assurance/Quality Control certificates issued by Geomembrane Manufacturer and resin supplier shall be submitted

C. Geomembrane Roll

Certification stating that the resin meets the specification requirements (see Section 9.2)
Statement certifying no reclaimed polymer is added to resin (see Section 9.2)
Copy of quality assurance certificates issued by Geomembrane Manufacturer shall be furnished (see Section 9.2)

D. Extrudate resins and/or rod shall be certified that all extrudate is from one Manufacturer, is the same resin type, and was obtained from the same resin supplier as the resin used to manufacture the geomembrane rolls.

4.2 Furnish the Following Information to the Engineer Prior to Installation

A. Installation layout drawings-Submit drawings showing proposed panel layout including field seams and details. These drawings shall be approved prior to installing the geomembrane. This approval will be for concept only and actual panel placement will be determined by site conditions.

B. Installer's geosynthetic Field Installation Quality Assurance Plan

4.3 Submittals on a Daily Basis During Installation

A. Subgrade Acceptance Forms

B. All QC Documentation and Field Testing Results (Destructive & Non-Destructive Test Results)

4.4 Submit the Following to the Engineer Upon Completion of Installation

A. Certificate stating the geomembrane has been installed in accordance with the Contract Documents

B. Material and installation warranties

C. As-built drawings showing actual Geomembrane panel placement and seams including typical anchor trench

Part 5 – Quality Assurance

5.1 Inspections

A. Quality assurance inspections will be performed by the engineer in accordance with this specification and the Construction Quality Assurance Plan for this project.

B. Interface shear testing (ASTM D – 6342) shall be performed on the interfaces of the GCL/HDPE liner and the HDPE/drainage net for both dry and hydrated conditions. Actual samples of the material proposed for full scale application shall be used for the test. The peak interface friction angle must be 18 degrees (minimum). Laboratory data must be submitted and approved by the engineer before deployment of material will be accepted.

Part 6 - Qualifications

6.1 Geomembrane Manufacturer

A. The manufacturer shall have manufactured a minimum of 5,000,000 square feet of HDPE geomembrane during the last year.

6.2. Installer

A. The Installer shall have installed a minimum of 1,000,000 square feet of HDPE geomembrane during the last 2 years.

B. The Installation Supervisor shall have worked in a similar capacity on at least two projects similar in size and complexity to the project described in the Contract Documents during the past 5 years.

C. The Master Welder shall have completed a minimum of 1,000,000 square feet of geomembrane seaming work using the type of seaming apparatus proposed for use on this Project.

Part 7 – Material Labeling, Delivery, Storage and Handling

7.1 Labeling

A. Each roll of geomembrane delivered to the site shall be labeled by the manufacturer. The label shall clearly state the manufacturer's name, product identification, thickness, length, width and roll number. The label shall be found on either of the endcaps, an inside edge of the core, or outside the core.

7.2 Delivery

A. The rolls of liner shall be packaged and shipped by appropriate means to prevent damage to the material and to facilitate off-loading.

7.3 Storage

A. The onsite storage location for geomembrane material should be level, smooth, elevated and dry (not wooden pallets). The storage place should be protected from theft and vandalism, and should be adjacent to the area to be lined. The Contractor shall provide a suitable storage site which will protect the geomembrane from punctures, abrasions, excessive moisture and dirt.

7.4 Handling

A. The materials are to be handled so as to prevent damage. Instructions for moving geomembrane rolls shall be provided by the Manufacturer upon request.

Part 8 - Warranty

8.1 Manufacturer

A. The material shall be warranted, on a pro-rata basis against manufacturer's defects for a period of 5 years from the date of geomembrane installation.

8.2 Installer

A. The installation shall be warranted against defects in workmanship for a period of 1 year from the date of geomembrane completion.

Part 9 - Geomembrane

9.1 Liner

A. The material shall be 40 mil textured polyethylene geomembrane as shown on the drawings.

9.2 Resin

A. Resin shall be new, first quality, compounded and manufactured specifically for producing geomembrane.

B. Do not intermix resin types.

C. Natural resin (without carbon black) shall meet the following additional requirements.

Property	Test Method[1]	HDPE Resin
Density (g/cm^3)	ASTM D 792 (B) or D 1505	0.932 - 0.940
Oxidative Induction Time (minutes)	ASTM D 3895 (1 atm, 200 °C)	>100

[1] All procedures and values are subject to change without prior notification.

9.3 Geomembrane Rolls

A. Do not exceed a combined maximum total of 1 percent by weight of additives other than carbon black.

B. Geomembrane shall be free of holes, pinholes, bubbles, blisters, excessive contamination by foreign matter, and nicks and cuts on roll edges.

C. Geomembrane material is to be supplied in roll form. Each roll is to be identified with labels indicating both number, thickness, length, width and Manufacturer.

D. All liner sheets produced at the factory shall be inspected prior to shipment for compliance with the physical appearance requirements listed in previous section and be tested by an acceptable method of inspecting for pinholes. If pinholes are located, identified and indicated during manufacturing, these pinholes may be corrected during installation.

9.4 Textured Liner-Requirements

A. Textured surfaced geomembrane shall meet the minimum requirements shown in Table 1.

9.5 Extrudate Rod or Bead-Requirements

A. Extrudate material shall be made from same type resin as the geomembrane.

A. Additives shall be thoroughly dispersed.

B. Shall be free of contamination by moisture or foreign matter.

Part 10 - Equipment

10.1 Welding Equipment and Accessories-Requirements

A. Gauges showing temperatures in apparatus (extrusion welder) or wedge (wedge welder) shall be present.

B. An adequate number of welding apparati shall be available to avoid delaying work.

C. Power source capable of providing constant voltage under combined line load shall be used.

Part 11 - Deployment

11.1 Coding System

A. Assign each panel a simple and logical identifying code. The coding system shall be subject to approval and shall be determined at the job site.

11.2 Inspections

A. Visually inspect the geomembrane during deployment for imperfections and mark faulty or suspect areas.

11.3 Deployment of the Geomembrane Panels-Requirements

A. Unroll geomembrane panels using methods that will not damage geomembrane and will protect underlying surface from damage (i.e., spreader bar - protected equipment bucket).

B. Place ballast (commonly sandbags) on geomembrane which will not damage geomembrane to prevent wind uplift.

C. Personnel walking on geomembrane shall not engage in activities or wear shoes that could damage the geomembrane. Smoking will not be permitted on the geomembrane.

D. Do not allow heavy vehicular traffic directly on geomembrane. Rubber-tired ATV's and trucks are acceptable if wheel contact is less than 6 psi.

E. Protect geomembrane in areas of heavy traffic by placing protective cover over the geomembrane.

11.4 Expansion and Contraction

A. The membrane must be kept as flat as possible to prevent creasing of the membrane during placement of fill.

Part 12 – Field Seaming

12.1 Seams-Requirements

A. To the maximum extent possible, orient seams parallel to line of slope, i.e., down and not across slope.

B. Minimize number of field seams in corners, odd-shaped geometric locations and outside corners.

C. Slope seams (panels) shall extend a minimum of five-feet beyond the grade break into the flat area.

D. Use a sequential seam numbering system compatible with panel numbering system that is agreeable to the Engineer and Installer.

12.2 Welding Operations

A. Provide at least one Master Welder who shall provide direct supervision over other welders if necessary.

12.3 Extrusion Welding

A. Hot-air bond adjacent pieces together using procedures that do not damage geomembrane.

B. Purge welding apparatus of heat-degraded extrudate before welding.

C. Clean geomembrane surfaces by disc grinder or equivalent.

12.4 Hot Wedge Welding

A. Welding apparatus shall be a self-propelled device equipped with an electronic controller (same as Section 10.1) which displays applicable temperatures.

B. Protect against moisture build-up between sheets.

C. Clean seam area of dust, mud, moisture and debris immediately ahead of the hot wedge welder.

12.5 Trial Welds

A. Perform trial welds on geomembrane samples to verify welding equipment is operating properly.

B. No welding equipment or welder shall be allowed to perform production welds until equipment and welders have successfully completed trial weld.

C. Trial welds will be made with each seaming apparatus prior to use and every four hours per day thereafter.

D. Make trial welds under the same surface and environmental conditions as the production welds, i.e., in contact with subgrade and similar ambient temperature.

E. Cut four, one-inch wide by six-inch long test strips from the trial weld. Quantitatively test specimens for peel adhesion, and then for bonded seam strength (shear).

F. A trial weld specimen shall pass when the results shown in Table 2 are achieved in both peel and shear test.

1. The break, when peel testing, occurs in the liner material itself, not through peel separation (FTB)
2. The break is ductile

G. Repeat the trial weld, in its entirety, when any of the trial weld samples fail in either peel or shear.

12.6 Seaming

A. Seaming shall not proceed when ambient air temperature or adverse weather conditions jeopardize the integrity of the liner installation. Installer shall demonstrate that acceptable seaming can be performed by completing acceptable trial welds.

12.7 Defects and Repairs

A. Examine all seams and non-seam areas of the geomembrane for defects, holes, blister, undispersed raw materials, and any sign of contamination by foreign matter.

B. Repair and non-destructively test each suspect location in both seam and non-seam areas. Do not cover geomembrane at locations which have been repaired until test results with passing values are available.

Part 13 – Field Quality Assurance

13.1 Field Testing

A. Non-destructively test all field seams over their full length using a vacuum test unit, air pressure (for double fusion seams only), or other approved methods. Non-destructive testing may be carried out as the seaming progresses or at completion of all field seaming.

B. Vacuum Testing:

1. The equipment shall consist of the following: 1) A vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft gasket attached to the bottom, or valve assembly, and a vacuum gauge, 2) A vacuum pump assembly, and 3) A soapy solution.

2. Test Procedure is performed as follows: 1) Apply soapy solution to the seam. 2) Place vacuum box over the entire wetted seam area, 3) Ensure that a leak-tight seal is created, 4) Apply a vacuum of at least 5 psig, 5) Examine the geomembrane through the viewing window for the presence of soap bubbles for not fewer than ten seconds, and 6) All areas where soap bubbles appear shall be marked and repaired.

C. Air Pressure Testing (for double seam air channel)

1. The equipment shall consist of the following: 1) An air pump or tank equipped with pressure gauge capable of generating and sustaining pressure over 30 psi, 2) A sharp, hollow needle, or other approved pressure feed device equipped with a pressure gauge, and 3) A hot air gun or other device to seal the ends of the air channel.

2. Test Procedure is performed as follows: 1) Seal both ends of seam to be tested, insert air needle into the air channel, and pressurize to at least 25 psi, 2) If pressure loss exceeds 4 psi or does not stabilize after 5 minutes, locate faulty area and repair, 3) Puncture opposite end of seam to release air. If blockage is present, locate and test seam on both sides of blockage. A pressure gauge at both ends of the seam will also be acceptable, and 4) Remove needle or other approved pressure feed device and seal penetration holes by extrusion welding.

D. Destructive Testing (performed by Engineer with assistance from Installer)

1. Location and Frequency of Testing: 1) Collect destructive test samples at a frequency of one every 500 feet of seamed length and 2) Test locations will be determined after seaming.

2. Sampling Procedures are performed as follows: 1) Installer shall cut samples at locations designated by the Engineer as the seaming progresses in order to obtain laboratory test results before the geomembrane is covered, and 2) Consultant will number each sample and mark sample number and location on the installation layout drawing.

3. Installer shall repair all holes in the geomembrane resulting from destructive sampling. Repair and test the continuity of the repair in accordance with these Specifications.

4. Samples shall be twelve (12) inches wide by minimal length with the seam centered lengthwise. Cut a 2-inch wide strip from each end of the sample for field testing. Cut the remaining sample into two parts for distribution as follows: 1) One portion for the Installer: 12 inches by 12 inches, 2) One portion for Owner's Third Party laboratory testing: 12 inches by 18 inches (maximum), and 3) Additional Samples may be obtained if required.

5. Testing: 1) Test the 10 strips specified in above paragraph in peel (5 each) and shear (5 each), 2) Test strips shall meet minimum peel and shear value requirements, 3) If any field test sample fails, follow procedures outlined in Section 13.3 below, and 4) For double wedge seam samples, the outside (top) weld is considered to be the primary weld and shall be the weld tested.

13.2 Failed Seam Procedures

A. The following procedure shall be used when there is a destructive test failure.

1. The Installer shall follow one of two options: 1) Reconstruct the seam between any two passed test locations or 2) Trace the weld to an intermediate location at least 10 feet minimum or to where seam ends, in both directions from the location of the failed test. Check next seam welded using same welding device if required to obtain additional sample, i.e., if one side of the seam is fewer than 10 feet long.

2. Obtain four, one-inch samples at both locations for an additional field test.

3. If the samples pass, then the seam shall be reconstructed or capped between the test sample locations.

4. If any sample fails, the process shall be repeated to establish the zone in which the seam shall be reconstructed.

B. Acceptable seams shall be bounded by two locations from which samples have passed destructive tests.

Part 14 – Repair Procedures

A. Remove damaged geomembrane and replace with acceptable geomembrane materials if damage cannot be satisfactorily repaired.

B. Repair any portion of unsatisfactory geomembrane or seam area failing a destructive or non-destructive test. Installer shall be responsible for repair of damaged or defective areas. Agreement upon the appropriate repair method shall be decided between the Engineer and the Installer. Procedures available include the following.

1. Patching - Used to repair large holes, tears, undispersed raw materials, and contamination by foreign matter
2. Abrading and Re-welding - Used to repair small seam sections
3. Spot Welding - Used to repair pinholes or other minor, localized flaws or where geomembrane thickness has been reduced
4. Capping - Used to repair large lengths of failed seams
5. Flap Welding - Used to extrusion weld the flap (excess outer portion) of a fusion weld in lieu of a full cap
6. Removing the unacceptable seam and replace with new material

C. In addition, the following procedures shall be observed.

1. Surfaces of the polyethylene which are to be repaired by extrusion welds shall be lightly abraded to assure cleanliness.
2. All geomembrane surfaces shall be clean and dry at the time of repair.
3. Extend patches or caps at least 6 inches for extrusion weld and 4 inches for wedge weld beyond the edge of the defect, and round all corners of patch material.

D. Repair Verification

1. Number and log each patch repair
2. Non-destructively test each repair using methods specified in this Specification

Part 15 – Measurement and Payment

A. Payment for geomembrane installation will be as per contract unit price per square foot, as measured parallel to liner surface, including designed anchor trench material and is based upon net lined area. Net lined area is defined to be the true area of all surfaces to be lined including designed burial in all anchor trenches (i.e., overlaps are not included). Prices shall include full compensation for furnishing all labor, material, tools, equipment, and incidentals. Prices also include doing all the work involved in performing geomembrane installation completely as shown on the drawing, as specified herein, and as directed by the Engineer.

Table 1: Minimum Values for Coextruded Textured HDPE Geomembranes

Property	Test Method	30	40	60	80	100
Minimum Thickness [mil]	ASTM D 751, D 1593, D 5199 or GRI GM8	27	36	54	72	90
Density [g/cm^3]	ASTM D 792 (B) or D 1505	0.940	0.940	0.940	0.940	0.940
Carbon Black Content [%]	ASTM D 1603, modified	2.0	2.0	2.0	2.0	2.0
Carbon Black Dispersion	ASTM D 3015	A2	A2	A2	A2	A2
Tensile Properties: (each direction)[1]	ASTM D 638 Type IV, 2 ipm					
Strength at Yield [lb/in]	NSF 54 modified	65	86	130	173	216
Strength at Break [lb/in]		38	50	75	100	125
Elongation at Yield [%]	(1.3” gauge length)	13	13	13	13	13
Elongation at Break [%]	(2.5” gauge length)	120	120	120	120	120
Tear Resistance [lb]	ASTM D 1004	22	30	45	60	75
Puncture Resistance [lb]	FTMS 101, Method 2065	39	52	80	105	130
ESCR [hours][2]	ASTM D 1693 (B)	1500	1500	1500	1500	1500
Dimensional Stability [% change]	ASTM D 1204 (1 hr. at 100 °C)	± 2	± 2	± 2	± 2	± 2

[1] The combination of stress concentrations due to coextrusion texture geometry and the small specimen size results in large variation of test results. Therefore, these tensile properties are minimum average roll values.

[2] Environmental Stress Crack Resistance (ESCR) for coextruded textured material is conducted on representative smooth membrane samples.

Table 2: Minimum Weld Values for Coextruded Textured HDPE Geomembranes (GSE HD Textured™)

Property	Test Method	30	40	60	80	100	120
Peel strength (fusion), ppi	ASTM D 4437	44	60	88	115	143	175
Peel strength (extrusion), ppi	ASTM D 4437	31	42	63	84	105	130
Shear strength (fusion & ext.), ppi	ASTM D 4437	56	76	113	151	189	226

END OF SECTION

Section 02121 - Geonet

Part 1 - General

1.1 Section Includes

A. Work in this section defines the technical requirements and includes the procedures for placement of the Geonet drainage material.

B. The Contractor must furnish all labor, equipment, appliances, and material in performing operations in connection with the Geonet.

1.2 Codes and Standards

A. *ASTM D 1505 – Density of Plastics by the Density Gradient Technique*

B. ASTM D 1603 – Carbon Black in Olefin Plastics

C. ASTM D 1682 – Standard Test Methods for Breaking Load and Elongation of Textile Fabrics

D. ASTM D 3776 – Mass Per Unit Area (Weight) of Woven Fabric

E. ASTM D 3786 – Hydraulic Bursting Strength of Knitted Goods and Nonwoven Fabrics

F. ASTM D 4491 – Water Permeability of Geotextiles by Permittivity

G. ASTM D 4533 – Trapezoid Tearing Strength of Geotextiles

H. ASTM D 4716 – Constant Head Hydraulic Transmissivity (In-Plane Flow) of Geotextiles and Geotextile related products

I. ASTM D 4751 – Apparent Opening Size of a Geotextile

J. ASTM D 4833 – Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products

Part 2 - Products

2.1 General

A. The Geonet specified in this specification shall be manufactured of new, first quality materials designed for long-term exposure to weather. The Geonet shall be free of defects such as holes, tears, blisters, defective seams, undispersed raw materials, and inclusion of foreign materials or any other irregularities.

B. A Certificate of Compliance for each lot of Geonet shall be provided giving details of the tests described in this specification.

2.2 Geonet

A. The Geonet used shall be a constituent of a composite geotextile/Geonet drainage blanket. The Geonet shall have the following physical characteristics:

Property	**ASTM**	**Value (Typical)**
Specific gravity, min (g/cm^3)	D-1505	0.94
Carbon black content, min (%)	D-1603	2
Transmissivity, min. (m^2/sec) (1.0 gradient) at 4,000 psf compressive load	D-4716	1 x 10^{-3}
Tensile strength machine direction (lb/in)	D-1682	32 minimum

B. The geotextile shall be heat bonded both sides of the Geonet drainage media and shall be a needle-punched, nonwoven geotextile. The geotextile shall have the following physical characteristics:

Property	**ASTM**	**Value (Typical)**
Fabric weight, minimum (ounce/yd^2)	D-3776	6
Puncture resistance (lb)	D-4833	95
Permittivity (gpm/ft^2)	D-4491	110
Apparent Opening Size (AOS)	D-4751	≥ No. 70 sieve

C. Interface shear testing (ASTM D-6342) shall be performed on the interfaces of the HDPE liner/drainage net and drainage net/cover soil. Actual samples of the material proposed for full scale application shall be used for the test. The peak interface friction angle must be 18 degrees (minimum) for both dry and hydrated conditions. Laboratory data must be submitted and approved by the engineer before deployment of material will be accepted.

Part 3 - Execution

3.1 Geonet Installation

A. The Geonet shall terminate in a perimeter anchor trench at locations shown on the Drawings and in accordance with manufacturer's recommended details.

B. Panels (rolls or roll segments) shall be butted together and joined using plastic cable ties at a frequency of one every 5 feet on center along the length of the panel. End-to-end joining of panels on slopes shall be minimized, but when necessary, the panels shall be joined by using plastic cable ties at a frequency of one every 12 inches on center.

C. The Geonet shall not be attached to the geomembrane.

D. Any material placed on top of the Geonet shall be done in such a manner as not to damage the Geonet or any underlying materials.

Part 4 - Measurement and Payment

A. Payment for Geonet shall be as per contract unit price per square foot, as measured parallel to the liner surface, including designed anchor trench material and is based upon net lined area. Net lined area is defined to be the true area of all surfaces to be lined including designed burial in all anchor trenches (i.e., overlaps are not included). Payment shall be full compensation for all labor, materials, tools, equipment, other incidentals necessary for Geonet installation.

END OF SECTION

Section 02205 - Soil Materials

Part 1 - General

1.1 Section Includes

A. Work under this Section includes the provision of soil materials that shall be used primarily as the cover soil component of the cap and backfill for excavations, including the swales.

Part 2 - Products

2.1 Soil Materials

A. Materials that are to be used in the work shall be subject to approval by the Engineer.

B. The cover soil shall fall within the United States Department of Agriculture Textural Classes of sandy loam, loam, sandy clay loam, silty clay loam, loamy sand and silt loam as defined in the Soil Survey Manual published by the United States Department of Agriculture, Soil Conservation Service

C. The cover may not include rocks that are greater than 6 inches in diameter.

D. The layer of cover soil shall be at least 2 feet in thickness.

E. The grade of final slopes shall be designed, installed and maintained to accomplish the following:

(1) Ensure permanent stability.
(2) Control erosion due to rapid water velocity and other factors.
(3) Allow compaction, seeding and revegetation of cover material placed on the slopes.
(4) Ensure minimal infiltration and percolation of precipitation, surface water run-on.

F. Unless the Engineer authorizes a different slope design, slopes shall be designed, installed and maintained as follows:

(1) The grade of the final surface of the facility may not be less than 3%.
(2) The grade of the final surface of the facility may not be more than 25%:

G. The cover soil layer shall meet the following performance standards. The layer shall:

(1) Prevent vectors, odors, blowing litter and other nuisances
(2) Be capable of allowing loaded vehicles to successfully maneuver over it after placement.
(3) Be noncombustible.
(4) Be capable of supporting the germination and propagation of vegetative cover as required.

H. Samples of unclassified fill material and test results shall be provided to the Engineer five days prior to anticipated date of use.

I. The Contractor shall provide at a minimum one set of analytical test results per 5,000 cubic yards of material furnished per borrow source. The material furnished shall be tested for the parameters on the Target Compound List (TCL), which includes volatile organic compounds, semi-volatile organic compounds, and the target analyte list metals. Testing shall be performed by an independent laboratory in accordance with the SW-846 procedures. Testing shall be incidental to providing soil material. The Engineer may direct the Contractor to provide additional set(s) of these analyses if there is a change in the nature or character of the borrow material indicative of contamination. These additional tests shall be performed by the Contractor at no additional expense to the Owner. The Owner reserves the right to reject the material based on results of the tests. Six (6) samples were collected from this area by the Engineer. The results will be provided to the successful Contractor upon contract award. These samples represent analytical data for 30,000 cubic yards of soil for this area. Any volume over 30,000 cubic yards will require additional analytical data at no additional expense to the Owner.

J. Regardless of the source of the soil material, it shall remain the responsibility of the Contractor to provide the materials required for this work in adequate quantity and quality. Only clean fill shall be used for soil cover and excavation backfill. All excavated contaminated soil and sediment shall be placed beneath the cap.

M. The Contractor shall retain the services of an independent geotechnical testing laboratory to perform all testing of the soil material required by this section. Results of all testing shall be submitted to the Engineer. Costs for the laboratory services and the testing shall be separate from the appropriate unit price for payment of the soil material.

Part 3 - Execution

3.1 Stockpiling of Soil Materials

A. Stockpile materials on site at the locations approved by the Engineer.

B. Stockpile materials in sufficient quantities to meet project schedule and requirements.

C. Separate differing materials with dividers or stockpile apart to prevent mixing.

D. Direct surface water away from stockpile site to prevent erosion or deterioration of materials.

E. Cover soil stockpiles to prevent erosion.

3.2 Stockpile Cleanup

A. Remove stockpile, leave area in a clean and neat condition. Grade site surface to prevent free-standing surface water and vegetate the disturbed area.

3.3 Construction

A. The soil material shall be placed in lifts that are parallel to the final surface. Materials placed by dumping in piles or windrows shall be spread uniformly before being compacted. The loose lift thickness shall not exceed 12 inches. The placement of material to be hand compacted, including material compacted by manually directed power trampers, shall not exceed four inch loose lifts.

B. Compaction shall be accomplished by use of the equipment (i.e., dozer) constructing the lifts. Compaction tests are not required for the soil cover. A minimum of three passes per lift is required.

C. Landfill debris (metal, wood, masonry, other) must be covered by a minimum thickness of 24 inches of subgrade soil (i.e., a 24 inch soil barrier must be maintained between debris and the cap).

Part 4 - Testing and Inspection

4.1 Cover soil shall be tested for grain-size and soil classification in accordance with ASTM D422 and ASTM D2487. One set of tests shall be provided for each borrow source.

Part 5 - Measurement and Payment

A. Payment for cover soil shall be based on unit cost per cubic yard of material installed as cover for the cap and backfill for other areas. Measurement for payment will be calculated by multiplying 24 inches by the surveyed area (measured parallel to the ground surface) of the limits of the unclassified fill that has shown by excavation and inspection to meet or exceed 24 inches in thickness. Excavation and thickness measurements will be performed at a frequency of 5 per acre at locations designated by the engineer. The void will be repaired by hand tamping the exhumed cover soil and placing in four inch loose lifts. Payment shall be full compensation for all labor, materials, tools, equipment, and other incidentals necessary for unclassified fill, provided, in place, and accepted.

END OF SECTION

Section 02206 – Geosynthetic Clay Liner

Part 1 - General

1.1 Section Includes

A. This section applies to the furnishing and installation of a pre-manufactured geosynthetic clay liner over the landfill as shown on the Construction Drawings.

B. Sufficient material shall be furnished to cover the lined areas shown on the Construction Drawings, including overlaps for field seams and anchor trenches.

1.2 Related Sections

A. Section 02211 - Grading.

1.3 Submittals

A. The Contractor shall submit to the Engineer for approval shop drawings and a proposed liner layout to cover the lined area shown in the Construction Drawings. Details shall be included to show the termination of the liner at the perimeter of lined areas, the methods of sealing around penetrations, if any, and methods of anchoring. The manufacturer, on behalf of the Contractor, shall provide to the Engineer its written approval of the Contractor's shop drawings, layout, and plan.

B. The Contractor shall submit to the Engineer a physical sample of the geosynthetic clay liner material. The samples shall be labeled with manufacturer's name, product identification, lot number, and roll number.

C. The Contractor shall submit to the Engineer inventory tickets, roll numbers or batch identifications, packing papers, and invoices for the geosynthetic clay liner.

D. Prior to installation of the geosynthetic clay liner, the fabricator shall provide the Engineer with certification signed by an authorized employee of the manufacturer indicating that the material meets the required specifications.

1.4 Codes and Standards

A. ASTM Standards

1.5 Qualifications

A. The installer of the geosynthetic clay liner shall be experienced in the installation of a minimum of 1,000,000 ft^2 of liner.

Part 2 - Products

A. Acceptable products are Bentomat® DN, as manufactured by CETCO or an engineer-approved equal. The geosynthetic clay liner shall consist of a pre-manufactured three-layer composite material as follows:

MATERIAL PROPERTY	TEST METHOD	TEST FREQUENCY, ft^2 (m^2)	REQUIRED VALUES
Bentonite Swell Index[1]	ASTM D 5890	1 per 50 tonnes	24mL/2g min.
Bentonite Fluid Loss[1]	ASTM D 5891	1 per 50 tonnes	18 mL max.
Bentonite Mass/Area[2]	ASTM D 5993	40,000 ft^2 (4,000 m^2)	0.75 lb/ft^2 (3.6 kg/m^2)
GCL Grab Strength[3]	ASTM D 4632	200,000 ft^2 (20,000 m^2)	150 lbs (660 N)
GCL Peel Strength[3]	ASTM D 4632	40,000 ft^2 (4,000 m^2)	15 lbs (65 N)
GCL Index Flux[4]	ASTM D 5887	Weekly	1 x 10^{-8} m^3/m^2/sec
GCL Permeability[4]	ASTM D 5084	Weekly	5 x 10^{-9} cm/sec
GCL Hydrated Internal Shear Strength[5]	ASTM D 5321	Periodic	500 psf (24 kPa) typical

Notes:

1 Bentonite property tests performed at CETCO's bentonite processing facility before shipment to CETCO's GCL production facilities.

2 Bentonite mass/area reported at 0 percent moisture content.

3 All tensile testing is performed in the machine direction, with results as minimum average roll values unless otherwise indicated.

4 Index flux and permeability testing with deaired distilled/deionized water at 80 psi (551 kPa) cell pressure, 77 psi (531 kPa) headwater pressure and 75 psi (517 kPa) tailwater pressure. Reported value is equivalent to 925 gal/acre/day. This flux value is equivalent to a permeability of 5x10^{-9} cm/sec for typical GCL thickness. This flux value should not be used for equivalency calculations unless the gradients used represent field conditions. A flux test using gradients that represent field conditions must be performed to determine equivalency. The last 20 weekly values prior the end of the production date of the supplied GCL may be provided.

5 Peak value measured at 200 psf (30 kPa) normal stress. Site-specific materials, GCL products, and test conditions must be used to verify internal and interface strength of the proposed design.

Part 3 - Execution

3.1 Packaging and Storage

A. The geosynthetic clay liner shall be supplied in rolls, marked and tagged with the following information:

1. Manufacturer's name
2. Product identification
3. Lot number
4. Roll number
5. Roll dimensions

Liners that have been delivered to the project site shall be stored in their original, unopened wrapping in a dry area and protected from precipitation and the direct heat of the sun, especially when stored for a long period of time. The materials shall be stored above the ground surface and beneath a roof or other protective covering.

Care shall be taken to keep the liner clean and free from debris prior to installation.

3.2 Subgrade Preparation

A. Liner installation shall not begin until a proper base has been prepared to accept the liner. Base material shall be free from roots, grass, and vegetation. Foreign materials and protrusions shall be removed, cracks and voids shall be filled and the surface made uniformly sloping as indicated on the Construction Drawings. The prepared surface shall be free from loose earth, rubble, and other foreign matter. The subgrade shall be uniformly compacted as specified in Section 02205 to ensure against settlement and rutting under wheel loads.

B. The surface on which the liner is to be placed shall be maintained in a firm, clean, dry, and smooth condition during liner installation.

3.3 Liner Installation

A. The geosynthetic clay liner shall be handled, stored, and installed in accordance with the manufacturing protocols.

B. The liner shall be placed over the prepared surface in such a manner as to assure minimum handling. Anchor trench excavation should be completed before liner installation begins. The sheets shall be of such lengths and widths and shall be placed in such a manner as to minimize seams. Horizontal seams shall be minimized and shall never occur on slopes.

The liner shall not be rolled out using rope or chain through the core.

C. The liner shall not be installed in standing water or during rain. Liner must be dry when installed and must be dry when covered.

D. In areas where wind is prevalent, liner installation shall be started at the upwind side of the project and proceed downwind. The leading edge of the liner shall be secured with sandbags or other means sufficient to hold it down during high winds.

E. Sandbags or rubber tires may be used as required to hold the liner in position during installation. Materials, equipment, or other items dragged across the surface of the liner or allowed to slide down slopes on the liner shall be minimized.

F. The liner shall be installed in a relaxed condition and shall be free of tension or stress upon completion of the installation. Stretching of the liner to fit will not be allowed. The liner shall be pulled tight to smooth out creases or irregularities in the "runs".

G. Vehicles shall not be allowed to drive directly on the GCL.

3.4 Seaming

A. The first and succeeding rolls of liner must be pulled tight to smooth out creases or irregularities in the "runs". Once the first "run" has been laid, adjoining "runs" shall be laid, with a 6-inch overlap on each side. Dirt shall be removed from the overlap area of the mat.

B. Supplemental bentonite is required for reinforced liner as specified herein. Bentonite-enhanced seams are constructed between the overlapping adjacent panels. The underlying edge of the longitudinal overlap is exposed and then a continuous bead of granular sodium bentonite is applied along a zone defined by the edge of the underlying panel and the 6-inch line on the panel. A similar bead of granular sodium bentonite is applied at the end-of-roll overlap. The granular bentonite shall be applied at a minimum application rate of one quarter pound per lineal foot.

C. "Runs" shall be continuous from crest to toe of slopes. The free end at the crest shall be locked into a properly designed anchor trench. No horizontal seams will be allowed within 5 feet of the anchor trench and all horizontal seams shall have a minimum overlap of 3 feet.

D. In hot, arid conditions, when temperatures are higher than 85°F and humidity is low, shrinkage may occur soon after placement when no confining cover is placed. To account for the possibility of shrinkage under these conditions, the longitudinal seam overlap shall be increased to 12 inches and the lateral overlaps increased to 4% of the run length plus 6 inches.

3.5 Patching

A. Small (less than 6 inches) irregular shapes, cuts, or tears in the installed bentonite liner shall be covered with sufficient liner to provide a 6-inch overlap on adjoining liner. Large rips or tears shall be repaired by completely exposing the affected area, removing all foreign objects or soil, and by then placing a patch over the damage, with a minimum overlap of 12 inches on edges. Accessory bentonite should be placed between the patch and the repaired material at a rate of ¼ pound per lineal foot of edge, spread in a 6-inch width.

The above procedures should also be implemented if a rip or tear occurs on a sloped surface. In this instance, the edges of the patch shall be fastened to the repaired liner with construction adhesive, in addition to the bentonite-enhanced seam.

Part 4 - Testing and Inspection

A. Verify that the geosynthetic clay liner meets the minimum criteria requirements specified herein through the documentation of manufacture certifications.

B. As the liner is installed, overlapping of the bentonite liner shall be inspected to ensure that a minimum 6-inch overlap exists. In addition, the liner shall be inspected for any tears or punctures and repaired or replaced as deemed necessary by the Engineer.

C. Any damage to the material due to penetration by foreign objects or distress from rough subgrade shall, as directed by the Engineer, be replaced or covered with an additional layer of bentonite liner of the proper size.

D. The Contractor shall submit to the Engineer a written certification indicating that the bentonite liner was installed in an acceptable manner per the manufacturer's approval.

E. Interface shear testing (ASTM D-6342) shall be performed on the interface of the GCL/soil subgrade. Actual samples of the material proposed for full scale application shall be used for the test. The peak interface friction angle must be 18 degrees (minimum) for both dry and hydrated conditions. Laboratory data must be submitted and approved by the engineer before deployment of material will be accepted.

Part 5 - Measurement and Payment

A. Payment for Geosynthetic Clay Liner shall be as per contract unit price per square foot, as measured parallel to the liner surface, including designed anchor trench material and is based upon net lined area (not inclusive of overlaps). Payment shall be full compensation for all labor, materials, tools, equipment, other incidentals necessary for Geosynthetic Clay Liner installation.

END OF SECTION

Section 02207 – Aggregate Materials

Part 1 - General

1.1 Section Includes

A. Work under this section includes stone needed for the construction of the leachate conveyance system as described herein or as shown on the Drawings.

1.2 Codes and Standards

A. AASHTO - M147 - Materials for Aggregate and Soil-Aggregate.

Part 2 - Products

2.1 Aggregate Materials

A. Aggregate materials for the leachate conveyance system and pipe bedding material shall consist of crushed gravel meeting the requirements of AASHTO M147 Gradation 57. Limestone is not an acceptable source of aggregate material.

Part 3 - Execution

3.1 Stockpiling

A. Stockpile materials onsite at the locations designated by the Engineer.

B. Stockpile in sufficient quantities to meet project schedule and requirements.

C. Separate differing materials with dividers or stockpile apart to prevent mixing.

D. Direct surface water away from stockpile site so as to prevent erosion or deterioration of materials

3.2 Placement

A. Aggregate material must be placed in horizontal lifts not to exceed 12 inches in thickness. Each lift must be tamped by hand prior to placement of the next lift.

3.3 Stockpile Cleanup

A. Remove stockpile, leave area in a clean and neat condition. Grade site surface to prevent free-standing surface water.

Part 4 - Measurement and Payment

A. Payment for aggregate (stone) shall be based on unit price per ton of stone delivered and in place. Payment shall be full compensation for all labor, materials, tools, equipment, and other incidentals necessary for stone placement for the job. Measurement will be based on weight tickets from the supplier.

END OF SECTION

Section 02210 – Jute Mat

Part 1 – General

1.1 Section Includes

A. Work covered by this section consists of furnishing, placing, and maintaining the jute mat on the finished grades of the designated drainage ditches and 5 percent or greater slopes of the cap. If jute mat is unattainable, the Contractor may select an approved substitute in accordance with the requirements of this Specification.

Part 2 - Products

2.1 Jute Mat

A. Jute Mat: Jute mat shall consist of undyed yarn woven into a uniform open plain weave mesh with approximately 1 inch square openings, and weighing not less than 90 pounds per 100 square yards.

B. Staples: Staples for anchoring the jute mat shall be made of No. 8 gage steel wire, bent U-shaped with a throat width of 1 to 2 inches, and with an effective driving depth of not less than 6 inches.

C. Substitutes: Wood excelsior blanket, erosion control netting or nylon erosion control mat meeting the requirements of this section and as approved by the Engineer shall be considered an approved substitute for jute mat.

Part 3 – Execution

3.1 Placement

A. After the area has been graded and seeded, the jute mat shall be unrolled parallel to the direction of flow, without stretching, and anchored as specified. The upstream end of each roll shall be buried a minimum of 6 inches in a vertical slot which shall be backfilled and tamped and shall be overlapped 12 inches by any up stream section. If 2 or more widths of jute mat are placed side by side, the upper mat shall overlap the lower by not less than 4 inches, and shall be stapled along the overlap at 3 foot intervals. The unlapped edge of the mat shall be stapled at 6-foot intervals.

Part 4 - Measurement and Payment

Payment for Jute Mat shall be as per contract unit price per square foot, as measured parallel to the ground surface, and is based upon net lined area (not inclusive of overlaps). Payments shall be full compensation for all labor, materials, tools, equipment, other incidentals necessary.

END OF SECTION

Section 02211 - Grading

Part 1 - General

1.1 Section Includes

A. Work in this section shall include the earthmoving required to bring the landfill subgrade and excavated areas to proper contours using on site material and imported material, if necessary. Final subgrade, as required, shall be smooth and free from irregular surface changes.

B. This section applies to the stockpiled soil and sediment located within the footprint of the landfill.

Part 2 - Products

2.1 Materials

A. Existing soil and sediment excavated to achieve prescribed cleanup goals.

Part 3 - Execution

3.1 Examination

A. Verify the existing site conditions based on meetings and site visits.

B. Lines and grades for the work shall be as shown on the Construction Drawings or as approved by the Engineer. The lines and grades shown are intended to be the final surfaces after compaction and any settlement during construction.

C. The Contractor shall establish benchmarks and/or horizontal control monuments. Survey control during the work shall be the responsibility of the Contractor.

D. The Contractor shall provide adequate water trucks or other equipment for dust control at the construction site.

3.2 Preparation

A. Identify required lines, levels, contours, and datum.

B. Stake and flag locations of known utilities.

C. Locate, identify, and protect existing utilities from damage during construction procedures.

D. Notify and obtain all identified permits required from local companies if any utility is to be removed and/or relocated.

E. Protect above- and below-grade utilities that remain.

F. Protect benchmarks, existing structures, fences, sidewalks, paving, and curbs if any from excavating equipment and vehicular traffic.

3.3 Landfill Grading/Excavation

A. Excavate landfill material from marked areas to contours and elevations shown on construction drawings.

B. Spread surface debris into thin lift and cover with subgrade soil. **All tires must be disposed of at an appropriate offsite location.**

3.4 Filling and Compaction

A. Fill areas to contours and elevations with specified materials.

B. Place fill materials in horizontal 12-inch (maximum) loose lift continuous layers and compact. Compaction shall be accomplished by use of the equipment (i.e., dozer) constructing the lifts. In addition, a minimum of three passes with a vibratory drum roller is required for compaction. Compaction tests are not required for the subgrade of the landfill.

3.5 Tolerances

A. Top surface of subgrade shall be as approved by the Engineer. This requirement will allow for flexibility because the final volume of soil/sediment requiring excavation is not known at this time.

B. Compaction shall be accomplished by use of equipment constructing lifts and vibratory drum roller.

Part 4 - Measurement and Payment

A. Payment for Grading shall be based on the unit price per cubic yard of excavated material placed to produce the subgrade. Payment for grading shall also be based on lump sum for debris relocation activities. Payment shall be full compensation for all labor, materials, tools, equipment, and other incidentals necessary for grading provided, in place, and accepted. Measurement will be based on a comparison survey before and after grading or excavating.

END OF SECTION

Section 02225 - Trenching

Part 1 - General

1.1 Section Includes

A. Work in this section includes the trenching for the leachate conveyance system, cap liner anchor, trenches, temporary pipe/conduit, and any other trenching as directed by the Engineer.

Part 2 - Execution

2.1 Preparation

A. Identify required lines, levels, contours, and datum.

B. Protect benchmarks, existing structures, fences, sidewalks, paving, and curbs from excavation equipment and vehicular traffic.

C. Maintain and protect above- and below-grade utilities that are to remain.

D. All work shall be conducted in accordance with OSHA regulations. All trenches shall be properly braced to protect workers.

2.2 Excavation

A. Excavate subsoil required for the trenches as shown on the Construction Drawings.

B. Cut trenches sufficiently wide to enable installation, and allow inspection.

C. Remove lumped subsoil, boulders, and rocks from excavation.

2.3 Pipe Trench Excavation

A. Pipe trench excavations shall be to the uniform width for the particular size pipe to be installed and sufficiently wide to provide ample working room. Excavate trenches to the depth indicated on the Drawings or as required. Carry the depth of trenches for piping to establish the indicated flow directions and invert elevations, if necessary. Excavations for piping shall be made from the surface to a minimum depth of 4 inches below the pipe laying grade, except as shown on the Drawings or as directed by the Engineer. Pipe trench excavation shall be halted upon encountering rock with adjustments being performed to maintain the proper backfill requirements in accordance with this Specification.

2.4 Trench Bottom Preparation

A. The bottoms of trenches shall be graded to provide uniform bearing and support for the bottom quadrant of each section of the pipe.

2.5 Removal of Soft Material

A. Where soft, yielding, unstable material is encountered at the bottom of the excavation, such material shall be removed to the depth directed by the Engineer and replaced to the proper grade in accordance with Section 02211, or as directed by the Engineer.

Part 3 – Measurement and Payment

Payment for Trenching shall be unit pricing per linear foot of cap liner anchor trench and per linear foot of temporary pipe/conduit trench. Payment for the leachate conveyance system shall be based on lump sum pricing. Payment shall be in full compensation for all labor, tools, materials, equipment, and other incidentals including pipe bedding, backfilling, and compaction of the trench.

END OF SECTION

Section 02230 - Clearing and Grubbing

Part 1 - General

1.1 Definitions

1.1.1 Clearing

Clearing shall consist of the felling, trimming, and cutting of trees into sections and the satisfactory stockpiling of the trees and other vegetation designated for removal, including down timber, snags, brush, and rubbish occurring in the areas to be cleared.

1.1.2 Grubbing

Grubbing shall consist of the removal and disposal of stumps, roots larger than 3 inches in diameter, and matted roots from the designated grubbing areas.

Part 2 - Execution

2.1 Clearing

Trees, stumps, roots, brush, and other vegetation in areas to be cleared shall be cut off flush with or below the original ground surface, except such trees and vegetation as may be indicated or directed to be left standing. Trees and vegetation to be left standing shall be protected from damage incident to clearing, grubbing, and construction operations by the erection of barriers or by such other means as the circumstances require. Clearing shall also include the removal and disposal of structures that obtrude, encroach upon, or otherwise obstruct the work.

2.2 Grubbing

Material to be grubbed, together with logs and other organic or metallic debris not suitable for foundation purposes, shall be removed to a depth of not less than 12 inches below the original surface level of the ground in areas indicated to be grubbed.

2.3 Tree Removal

Where indicated or directed, trees and stumps that are designated as trees shall be removed from areas outside those areas designated for clearing and grubbing. This work shall include the felling of such trees and the removal of their stumps and roots, if necessary.

2.4 Disposal of Materials

Root, stumps, and other material collected from grubbing efforts shall be ground into chips and transferred to the landfill area for ultimate placement beneath the cap system. A minimum 2 foot cover (e.g., soil, sediment) must be maintained between debris and the GCL.

Trees and brush collected from all cleared efforts shall be stockpiled or chipped onsite at a location designated by the Engineer.

Part 3 - Measurement and Payment

Clearing and grubbing shall be measured in acres of clearing and grubbing actually performed.

Payment for clearing and grubbing will be made at the contract unit price per acre for clearing and grubbing, and this price shall constitute full compensation for all labor, equipment, tools, and incidentals necessary to complete the work specified herein.

END OF SECTION

Section 02235 - Dewatering and Treatment

Part 1 - General

1.1 Section Includes

A. Work in this section consists of performing the work necessary to remove standing and inflowing water within the limits of operations to (lower and control water levels and hydrostatic pressures) so that excavation and construction work conducted under this Contract can be performed. Dewatering work shall also include the mobilization, analytical testing, disposal, supply, installation, operation, maintenance, supervision, and final dismantling and removal from the site of the dewatering and treatment equipment.

Part 2 - Execution

2.1 Examination of the Site

A. The Contractor shall familiarize himself with the site, subsurface, and surface water conditions.

2.2 Contractor's Responsibilities

A. The Contractor shall provide adequate pumps, hoses, strainers, and other appurtenances including fuel, power, trenching drains, sumps, and sheeting required in connection with dewatering as well as the labor and maintenance. The Contractor shall select and install a system of dewatering to accomplish water control as herein specified, take measures to prevent damage to properties, buildings or structures, sewers, any piping/utility installation, pavement, sidewalks, and the work during dewatering. The Contractor shall modify the system if, after installation and while in operation, the system causes or threatens to cause damage to existing buildings, structures, pipelines, utilities, or facilities.

2.3 Dewatering Requirements

A. The Contractor shall be responsible for the arrangement, location, and depth of the system necessary to accomplish the work of dewatering.

B. Water shall not be allowed to stand in excavated areas. Water that accumulates in excavated areas shall be removed by the Contractor with pumps or other approved means. The Contractor shall provide pumps or sufficient capacity to remove accumulated water.

C. The Contractor shall route water that is generated during the construction activities to temporary storage tanks or as directed by the Engineer.

D. The Contractor shall have the collected water sampled and analyzed, in order to dispose of the water in such a manner as will not endanger public health or property and portions of the work under construction or completed. Disposal shall be conducted in accordance with all local, state, and federal regulations. Disposal may include discharge to the local wastewater treatment plant, treatment onsite and discharge, or offsite disposal at a facility approved by the Engineer.

E. Surface water runoff shall be directed away from dewatering areas to minimize the generation of construction-related water.

2.4 Onsite Treatment Performance Criteria

A. If onsite treatment is the option chosen, the following criteria apply:

The following table provides the performance criteria for the temporary storm water treatment system at the Morgantown Ordnance Works. The criteria are based on the applicable Category B1 (warm water fishery stream) water quality criteria for the protection of aquatic life per Section 6.3(a) of Title 46 Series 1 Requirements Governing Water Quality Standards. The table includes parameters based on discussions with the West Virginia Office of Water Resources and selected parameters based on their detection above water quality evaluation criteria in the current leachate samples. The laboratory should be certified by the Office of Water Resources of West Virginia (http://www.dep.state.wv.us/wr/OWR_Website/index.htm). The PQL and MDL will be laboratory specific, and should be less than the discharge limitations. The analytical methods listed in the table are relevant to the Clean Water Act NPDES program and were selected based on discussions with West Virginia Office of Water Resources.

Parameter	**Discharge Limitations (μg/l)**	**Monitoring Frequency**	**Method**
COD	NC	1/week	EPA 410
TOC	NC	1/week	EPA 415.1
TSS	NC	1/week	EPA 160.2
pH	> 6.0, < 9.0	1/week	EPA 150.1
Total phenols	2,560	1/week	EPA 420
Copper Total	$e^{(0.8545[\ln(hardness)]-1.465)}$	1/week	EPA 200.7
Copper Dissolved	$e^{(0.8545[\ln(hardness)]-1.465)}$ x 0.960	1/week	EPA 200.7
Iron Total	1,500	1/week	EPA 200 AA
PAHs	NC	1/week	EPA 625
Cyanide Total	NC	1/week	EPA 335.2
Cyanide Free ($HCN+CN^-$)	5.0	1/week	EPA 335.2
Zinc Total	$e^{(0.8473[\ln(hardness)]+0.7614)}$	1/week	EPA 200.7
Zinc Dissolved	$e^{(0.8473[\ln(hardness)]+0.7614)}$ x 0.986	1/week	EPA 200.7

Hardness in the above equations is as calcium carbonate (mg/l) measured from the discharge. The minimum hardness allowed for use in these equations shall not be less than 25 mg/l, even if the actual ambient hardness is less than 25 mg/l. The maximum hardness value for use in this equation shall not exceed 400 mg/l even if the actual ambient hardness is greater than 400 mg/l.

NC = No Category B1 Water Quality Standard per Title 46 Series 1 Requirements Governing Water Quality Standards

Part 4 - Measurement and Payment

A. Payment for Dewatering shall be based on the contract lump sum for dewatering and treatment. Payment shall be full compensation for all labor, tools, materials, equipment, and other incidentals including tanks, hoses and pumps. Payments will be made monthly prorated accordingly for the level of effort.

END OF SECTION

Section 02610 - Monitoring Well Abandonment

Part 1 - General

1.1 Section Includes

Work in this section includes the labor, materials, and procedures for sealing and abandoning monitoring wells DGW-02, DGW-03, and DGW-04, and any other monitoring wells requiring abandoning during construction, as directed by the Engineer.

Part 2 - Products

2.1 Grout Materials

A. Portland Cement: ANSI/ASTM C150, Type I, unless otherwise acceptable to the Engineer. Use the same brand throughout the project.

B. Bentonite: Bentonite powder, brand to be approved by the Engineer. Use the same brand throughout the project.

C. Water: Potable.

2.2 Related Materials

A. Grout mixer/pump.

B. Tremie hose/rods.

C. Mobile potable water supply.

Part 3 - Execution

3.1 Preparation

A. All work shall be performed in accordance with West Virginia regulations (Title 47, Series 60 Monitoring Well Design Standards [§47-60-19 Abandonment Requirements]) for sealing monitoring wells. All work shall be conducted by a West Virginia certified monitoring well driller.

B. The Contractor must obtain any necessary permits required to abandon wells from the State of West Virginia.

C. Any downhole equipment will be decontaminated prior to and between grouting each monitoring well. Decontamination shall consist of pressure washing the equipment.

D. Each monitoring well will be inspected for total depth to ensure no obstructions are present.

E. Grout will consist of 5 pounds of bentonite powder and 94 pounds of cement per 6 gallons of potable water. The site Engineer will inspect and approve the grout prior to use.

3.2 Sealing Bedrock Wells

A. A grout pump and tremie rod will be used to place the grout under pressure within each monitoring well to be abandoned.

B. The grout will be placed within the casing and open borehole in rock of each monitoring well by placing grout from the bottom to the top of the wells. Contractor will exercise caution to ensure bridging of grouting materials does not occur. The tremie pipe shall be lowered to within 5 feet of the bottom of the hole to begin grouting. The end of the tremie pipe shall be kept submerged below the top of the grout at all times during grout placement. Grout shall be pumped through the tremie until undiluted grout flows from the well at the surface.

C. The steel protective casing (if present) will be removed and the riser casing will be removed to a minimum depth of 3 feet below the ground surface. The resulting surface void shall then be backfilled with clean soil material.

D. Contractor will record and document the amount of materials used to seal each monitoring well in a log book. The volume of the seal material used must be equal to or greater than the volume of the monitoring well riser. Copies of this information will be provided to the Engineer.

E. All monitoring well abandonments shall be reported to the appropriate groundwater regulatory agency within 60 days of the abandonment using the appropriate forms. In addition to the information required on the form, the person performing the abandonment shall report any decontamination procedures used between well abandonments. A copy of the reports should be provided to the Engineer.

Part 4 - Measurement and Payment

A. Payment shall be made based on linear feet unit price for monitoring well abandonment. The diagrams for the wells requiring abandonment have been included with the bid documents. Payment shall be full compensation for all labor, materials, tools, equipment, other incidentals necessary for monitoring well abandonment.

END OF SECTION

Section 02715 – Pipe

Part 1 – General

1.1 Section Includes

A. Provide pipe and fittings as shown on the Drawings and specified herein.

1.2 Applicability

A. Perforated, butt-fused HDPE pipe (SDR-11) shall be used for collection and transportation of water in the leachate collection system to the wetlands treatment system.

B. Perforated, corrugated PE pipe shall be used for collection of surface water infiltration within the liner anchor trench. Non-perforated, corrugated PE pipe shall be used to discharge water from the anchor trench to the surface water control system as shown on construction drawings.

1.3 Codes and Standards

A. ASTM F405 – Specification for Corrugated Polyethylene Tubing and Fittings.

B. ASTM D2412 – Test Method for External Loading Properties of Plastic Pipe by Parallel – Plate Loading.

C. ASTM D1248 – Specification for Polyethylene Plastics Molding and Extrusion Materials.

1.4 Submittals

A. The Contractor shall submit product data and manufacturer's affidavit indicating compliance with the requirements of this section.

Part 2 – Products

2.1 Materials

A. Compounds used in the manufacture of corrugated PE drainage pipe and fittings shall conform with the requirements of Grade P14 Class C, Grade P23 Class C, Grade P33 Class C, or Grade P34 Class C, as defined and described in ASTM D1248.

B. The butt-fused HDPE pipe (SDR-11) shall be as manufactured by DRISCOPIPE or an approved equivalent.

C. All piping must be shown to be appropriate for the intended use herein. Crush strength data from the manufacturer must be provided to the Engineer prior to use.

2.2 Fittings

A. The fittings shall not reduce or impair the overall integrity or function of the tubing line.

B. Common corrugated fittings shall include in-line joint fittings, such as couplings and reducers. These fittings shall be installed using approved methods, such as snap-on, screw-on, or wrap-around.

2.3 Perforations

A. PE pipe perforations shall be slot-type. Width of slots shall not exceed 1/8-inch. The length of individual slots shall not exceed 1-1/4-inch on 3-inch diameter tubing; 10% of the tubing inside nominal circumference on 4- through 8-inch diameter tubing. Slots shall be centered in the valleys of the corrugations.

Part 3 – Testing

A. Random samples of tubing and fittings from the supplier stock shall conform to the test methods outlined in ASTM F405.

Part 4 – Measurement and Payment

A. Payment for the perforated, corrugated PE pipe used in the anchor trench shall be unit price per linear foot of pipe. Payment shall be full compensation for all labor (including trenching and backfilling [not including stone]), materials, tools, equipment, and other incidentals necessary to complete the installation of the perforated, corrugated PE pipe. Measurement will be based upon the measured length of pipe.

B. Payment for the non-perforated, corrugated PE pipe used to discharge water from the anchor trench to the surface water control system shall be unit price per linear foot of pipe. Payment shall be full compensation for all labor and backfilling), materials, tools, equipment, and other incidentals necessary to complete the installation of the non-perforated, corrugated PE pipe. Measurement will be based upon the measured length of pipe.

C. Payment for the non-perforated and perforated HDPE pipe used to collect and convey leachate to the wetlands shall be included as part of the lump sum item - leachate collection system. Payment shall be compensation for all labor (including trenching), materials, tools, equipment, and other incidentals necessary to complete the installation of the HDPE pipe.

END OF SECTION

Section 02831 – Chain Link Fences and Gates

Part 1 – General

1.1 Section Includes

A. Work covered under this section includes the furnishings of all labor, equipment, and materials needed to dismantle and dispose of the existing security fence and install the new security fence as directed by the Engineer. The actual location of the new fence will be determined in the field.

Part 2 – Products

2.1 Materials and Components

A. The fence shall be Aluminum-Coated Class II Chain Link per ASTM A491, No. 9 gauge woven in 2" mesh, top and bottom selvage to have a barbed finish. The fence shall be 6 feet in height. The wire pickets shall have a minimum tensile strength of 80,000 psi. Fabric shall be connected to line posts with 6 gauge wire clips every 14"; to top rail with 9 gauge ties every 24"; to terminal, corner, and gate posts by integrally weaving into the post or by using 1/4" x 3/4" tension bars tied to the post every 14" with 11 gauge 1" wide steel bands and 3/8" diameter bolts and nuts; to tension wire with 11 gauge hog rings every 24".

B. Top Rail and Bottom Rail: Top and bottom rails shall be 1-1/4" (1.66" O.D.) Standard Schedule 40 pipe or 1-5/8" x 1-1/4" roll-formed sections for 6-foot fence. Top rail shall pass through line post tops and form a continuous brace within each stretch of fence and be securely fastened to terminal posts.

C. Braces: Braces shall be the same material as the top rail and trussed from the line post back to the terminal posts with 3/8" galvanized rod complete with truss tightener.

D. Line Posts: Line posts shall be Standard Galvanized H-Column, weight 2.72 pounds per foot (lbs/ft) or 2-3/8" O.D. Standard Schedule 40 pipe, weight 3.65 lbs/ft for 6-foot fence. Posts shall be spaced on centers not to exceed 10 feet.

E. Terminal Posts: End, corner, and pull posts shall be 3" O.D. Standard Schedule 40 pipe weight 5.79 lbs/ft or 3-1/2" x 3-1/2" roll-formed sections with integral fabric loops, weight 5.14 lbs/ft. Posts for swing gates shall be 3-1/2" x 3-1/2" rolled section, weight 5.14 lbs/ft, or 2-7/8" O.D. Schedule 40 pipe, weight 5.79 lbs/ft.

F. Gates: Gate frames shall be 2" O.D. Pipe connected with pressed steel or malleable iron corner ells riveted with 4 rivets per corner. Each frame shall have 3/8" diameter adjustable truss rods. Gates shall have positive-type latching devices with provisions for padlocking, and drive gates shall have a center plunger rod, catch, and semi-automatic outer catches.

G. Posts, rails, and appurtenances shall be hot-dipped zinc-coated steel per ASTM A120, A123, or A153, whichever is applicable. Pipe posts shall have tops which exclude moisture.

H. Barbed wire: The fence shall be installed with 3 strands of standard gauge barbed wire strung along the top.

2.2 Tolerance

A. Standard mill tolerances on all framework and chain link shall apply.

Part 3 - Execution

3.1 Installation

A. Fence is to be installed by skilled and experienced fence erectors and on lines and grades furnished by the Engineer. Each post shall be set in a concrete foundation with a minimum compressive strength of 2,500 psi and having a minimum diameter of 12" for 6-foot high fence and be 36" deep.

Part 4 - Measurement and Payment

A. Measurement and payment for removing and disposing of the existing fence shall be based on lump sum. The fence shall be dismantled and transported and disposed of at a facility approved by the Engineer and Owner. Payment shall be full compensation for all labor, materials, tools, equipment, and other incidentals necessary.

B. Measurement and payment for the new security fence shall be as per contract unit price per linear foot installed and approved by the Engineer. Payment shall be full compensation for all labor, materials, tools, equipment, and other incidentals necessary. For bid purposes, assume 2,200 linear feet, 1 vehicle gate, and 2 man-gates are required for the project.

END OF SECTION

Section 02936 - Seeding and Mulching

Part 1 - General

1.1 Section Includes

A. The scope covered in these Specifications covers the installation of seeding and mulching. The specified seed varieties and quantities shall be uniformly distributed over disturbed ground areas, including grading, soil stockpiling, and soil excavation, and not otherwise surfaced. Seeding will be performed in such manner that will produce an even stand of grass over the entire area seeded. The Contractor shall notify the Engineer at least 10 days prior to seeding operation. The Contractor shall furnish all labor, materials, equipment, and incidentals required to accomplish the activity.

1.2 Codes and Standards

A. "West Virginia Erosion and Sediment Control Handbook for Developing Areas", United States Department of Agriculture, Soil Conservation Service, Revised May 1993.

B. Federal Specified (Fed. Spec.) O-F-241D - Fertilizer, Mixed, Commercial.

C. U.S. Department of Agriculture - Federal Seed Act of 9 August 1939 (53 Stat. 1275).

Part 2 - Products

2.1 Seed

A. Seed shall be state-certified seed of the latest season's crop and shall be delivered in original sealed packages bearing the producer's guaranteed analysis for percentages of mixtures, purity, germination, weed-seed content, and inert material. Labels shall conform with USDA Federal Seed Act, Rules and Regulations and applicable state seed laws. Wet, moldy, or otherwise damaged seed will be rejected.

2.2 Fertilizer

A. Fertilizer shall be controlled-release, commercial grade, granular free flowing, uniform in composition, delivered in fully labeled sealed containers, and shall conform to applicable state and federal regulations. Fertilizer shall bear the manufacturer's guaranteed statement of analysis.

Part 3 - Execution

3.1 Dates for Seeding

A. Field Seeding: The Contractor shall prepare the seedbed and perform field seeding as specified in paragraph: Seed between the dates of March 1 to June 15 or August 15 to October 15. No seeding will be performed when soil is frozen or muddy.

3.2 Delivery and Storage

A. Delivery: Seed shall be inspected upon arrival at the job site, and unacceptable material shall be removed from the job.

  1. During delivery, seed shall be protected from any drying or contamination by detrimental material.

  2. Fertilizer shall be delivered to the site in the original, unopened containers bearing the manufacturer's guaranteed chemical analysis, name, trade name, trademark, and conformance to state and federal law.

B. Storage:

  1. Seed fertilizer shall be stored in cool, dry locations away from contaminants.

  2. Material shall be stored in areas designated or as approved by the Engineer.

3.3 Preparation of Seedbed

A. General: The Contractor shall place soil and established finished grades in accordance with this section and the Section 02211 - Grading. Any eroded finished grades shall be repaired in accordance with these Technical Specifications.

B. Tillage: Subsequent to grading, the areas to be seeded shall be thoroughly scarified by approved means to a depth of at least 6 inches by plowing, discing, harrowing, or rototilling. The work shall be performed only during periods when beneficial results are likely to be obtained. When conditions are such, by reason of drought, excessive moisture, or other factors, that satisfactory results are not likely to be obtained, the work will be stopped by the Engineer and shall be resumed only when directed. The soil shall be leveled to meet finished grade requirements before seeding. Seedbed preparation shall be performed on the contour to reduce soil loss.

3.4 Application and Rates of Lime and Fertilizer

A. The application of lime and fertilizer shall be based solely on the results of a soil agronomy test (routine and diagnostic) to determine the suitability of the cover soil for the specified seeding mix (native warm-season grasses [NWSG]). The routine and diagnostic soil test will provide information on fertility soil, pH, lime requirements, fertilizer requirements and cation balance and levels of micronutrients or metals and possible phytotoxic characteristics.

B. The soil agronomy test should be specified for the planting of NWSG and the liming and fertilization rates should be calculated based on the following factors:

- Lime (agricultural limestone) should not be applied if the soil pH is greater than 5.5 (pH of 5.5 to 6.0 is preferable for establishing NWSG to allow a competitive advantage) and should only be applied (calculated) to achieve this soil pH range if the soil test determines that the cover soil has a pH of less than 5.5.
- The preferred C-4 (warm-season) grasses are more competitive at low fertility, but lack the root symbionts for the uptake of phosphorus (P_2O_5). Therefore, fertilizer applied should only be applied as phosphorus based on P_2O_5 lbs/acre determination on soil test or at a rate of 200 lbs/acre (0-200-0).
- Any required lime and fertilizer (P_2O_5 only) should be incorporated into the soil to a depth of 6-inches during seedbed preparation.

3.5 Application of Seeding

A. The specified seeding mixture specifications consist of two mixes. Mixture 1 is specified for the landfill cover and Mixture 2 is specified for swales (wet and dry).

B. Mixture 1 (for landfill cover) plant species and seeding rates:

Common Name/Scientific Name[1]	**Variety**[5]	**Seeding Rate**
Big Bluestem/*Andropogen gerardi*	'Niagana'	4 lbs/acre pure live seed
Indian Grass/*Sorghastrum nutans*	'Rumsey'	6 lbs/acre pure live seed
Little Bluestem/*Schizachyrium scoparium*	'Aldous'	6 lbs/acre pure live seed
Sideoats Grama/*Bouteloua curtipendula*	'El Reno'	4 lbs/acre pure live seed
Chewings (Red) Fescue/ *Festuca rubra var commutata*[2]	'Banner II', 'Center', 'Dover', 'Longfellow'	25 lbs/acre pure live seed
Birdsfoot Trefoil/*Lotus corniculatus*[3]	'Leo', 'Empire', 'Norcen'	6 lbs/acre pure live seed
Virginia Bush-clover/*Lespedeza virginica*[4]	'Common Seed'	2 lbs/acre pure live seed

Notes:

1- The recommended seed mixture contains a composite of commonly used NWSG that should provide adequate growth and cover during the first year of growth with increased vigor during the second year of growth when root systems are established.

2- Chewings fescue is an exotic, cool-season, turf grass that is a fine-leaved, upright growing form of red fescue. This cool-season grass is less competitive than other C-3 grasses with the NWSG and will provide a long-term nurse crop until the NWSG are established.

3- Birdsfoot Trefoil is an introduced legume that is very compatible with NWSG specified. Low-growing varieties have been specified that provide nitrogen (fixation) and a long-term nurse cover. Birdsfoot trefoil must be inoculated with the root-nodule bacteria specified for that legume. This legume should be inoculated with the proper strain of inoculant at a rate five times higher than recommended on the inoculant package just prior to seeding.

4- Virginia bush-clover or slender lespedeza is a native legume that has been added to the mixture to add diversity (it is a perennial).

5- The varieties or cultivars for NWSG and other herbaceous perennials specified represent cultivars that are adapted for the project site location and other varieties should not be used.

6- The seeding rates specified are PLS (pure live seed) for the NWSG. PLS is the product of the percentage of pure live seed times germination divided by 100 to secure the actual planting rate for each NWSG (PLS percentage shown on seed tag or calculated).

C. Mixture 2 (for drainage swales) plant species and seeding rates:

Common Name/Scientific Name	Variety	Seeding Rate
Redtop/*Agrostis alba*	'common seed'	3 lbs/acre
Deer-tongue Witchgrass/*Panicum clandestinum*	'Tioga'	10 lbs/acre
Switchgrass/*Panicum virgatum*	'Shelter'	15 lbs/acre pure live seed[1]

1- The seeding rate for switchgrass requires PLS (pure live seed) similar to other selected NWSG.

3.6 Planting Seed

A. Prior to seeding, any previously prepared seedbed areas compacted or damaged by interim rains, traffic, or other cause shall be reworked to restore the ground to the specified condition. Seed shall be planted at the rate specified herein.

3.7 Seeding Methods

A. Seed must be planted by a conventional or rangeland seed drill. Seed drills are usually available for rental by local Soil Conservation Districts or the Natural Resources Conservation Service. In lieu of drilled application, the seed can be broadcast using a rotary spreader. Ensure that seed mixture is premixed before it is allotted to the drill hoppers or rotary spreader.

- The drill should be equipped with a cultipacker to firm the seedbed after planting
- The drill must be set to plant seed at a depth of at least one-quarter inch and no greater than one-half inch.

B. If the drill is not used (upon approval by the Engineer), seed can be broadcast using a rotary spreader.

- The required seed should be divided into two lots. The second lot should be broadcast at right angles to the first lot.
- Immediately after broadcast seeding, the seed bed should be dragged to ensure planted seeds are covered to a depth of at least one-quarter inch and no deeper than one-half inch. The seedbed should be firmed by packing or rolling after seedbed is dragged.

3.8 Vegetative Mulching

A. The Contractor shall perform vegetative mulching on the same day as planting seed.

B. Applying Mulch: Straw mulch shall be spread uniformly in a continuous blanket over the seeded areas, using 2 tons of material per acre. The mulch shall be spread in such manner as to prevent bunching.

3.9 Straw Mulch Anchoring Methods

A. Mechanical: A disk, crimper, or similar type tool shall be set straight to punch or anchor the mulch material into the soil. Straw mechanically anchored shall not be finely chopped but, generally, be left longer that 6 inches.

B. Mulch Nettings: Nettings shall be used according to the manufacturer's recommendations. Netting may be necessary to hold mulch in place in areas of concentrated runoff and on critical slopes.

C. Synthetic Binders: Synthetic binders such as Acrylic DLR (Agri-Tac), DCA-70, Petroset, Terra Tack or equal may be used at rates recommended by the manufacturer.

D. Wood Cellulose Fiber: Wood cellulose fiber binder shall be applied at a net dry weight of 750 lb./ac. The Wood cellulose fiber shall be mixed with water and the mixture shall contain a maximum of 50 lb./100 gal. of wood cellulose fiber.

3.10 Soil Preparation for Ditches and Slopes

A. The surfaces of ditches and slopes to receive soil erosion control material shall be finished, tilled, fertilized, and seeded in accordance with these Technical Specifications.

3.11 Protection and Cleanup

A. After seeding and mulching operations have been completed, barricades or approved warning signs shall be erected by the Contractor as required to provide protection against traffic and trespass. Excess material from seeding and mulching operations, and debris, shall be cleaned up and disposed of off the site.

3.12 Final Acceptance

A. Final inspection and acceptance will be performed by the Engineer prior to the termination of the Contract. Acceptance will be based upon material, performance and completion of those items of work specified for Seeding.

Part 4 - Measurement and Payment

A. Payment for Seeding and Mulching shall be based on the unit price per acre to satisfy the requirements in the Specifications. Complete payment will not be made until vegetation is fully established and approval from the Engineer is received. Payment shall be full compensation for all labor, materials (including seed, lime, fertilizer and mulch), tools, equipment, and other incidentals necessary to complete seeding and mulching, contingent upon the approval of the Engineer. A ten percent retainage relative to the total project dollar amount will be held until vegetation is fully established as approved by the Engineer. Measurement will be based on the survey of the total acreage seeded and mulched. The persistent nurse crop (chewings fescue and birdsfoot trefoil) should cover at least 85 percent of the area after one growing season. The NWSGs should have at least one viable stem per square foot after one growing season.

END OF SECTION

Appendix C - Construction Quality Assurance Plan

ESC

ENVIRONMENTAL STRATEGIES CORPORATION

Four Penn Center West • Suite 315 • Pittsburgh, Pennsylvania 15276 • (412) 787-5100 • Fax (412) 787-8065

FINAL
CONSTRUCTION QUALITY ASSURANCE PLAN
MORGANTOWN ORDNANCE WORKS
OPERABLE UNIT NO. 1
MORGANTOWN, WEST VIRGINIA

PREPARED

BY

ENVIRONMENTAL STRATEGIES CORPORATION

APRIL 3, 2002

Morgantown\457302\Tar and Soil WP\ Final Submittal\MOWCQAP.doc

Contents

Contents
(continued)

List of Tables:

List of Attachments:

1.0 Introduction

This Construction Quality Assurance Plan (CQAP) provides the methodologies to monitor major construction procedures and practices associated with implementation of cap construction activities and other ancillary components of remediation for the Morgantown Ordnance Works (MOW) Operable Unit No. 1 (OU-1) site in Monongalia County, West Virginia. This CQAP has been prepared to assure compliance with Construction Drawings and Technical Specifications developed by Environmental Strategies Corporation (ESC) and Ecological Restoration, Inc. (ERI) for the implementation of the remediation as approved by the United States Environmental Protection Agency (USEPA) and West Virginia Department of Environmental Protection (WVDEP). ERI has been subcontracted by ESC to prepare the wetlands mitigation and constructed wetlands treatment designs. The CQAP was prepared by ESC on behalf of the respondents[1] to the MOW OU-1 Administrative Order and U.S. Army Corps of Engineers, Omaha District (the OU-1 Group).

Components of the closure consist primarily of the following:

- installation of erosion and sedimentation controls
- excavation of sediment
- preparation of the cap subgrade
- construction of the capping system
- establishment of vegetative growth over disturbed areas
- replacement of wetlands and restoration of stream beds
- construction of a constructed wetlands treatment system

The CQAP addresses these components and provides the means to document that work conforms to the Construction Drawings and Technical Specifications through inspection, testing, and monitoring. The CQAP also includes the means for identifying, documenting, and obtaining acceptance for field changes from Construction Drawings and Technical Specifications.

---

[1] Named respondents are Rockwell International Corporation, Olin Corporation, General Electric Company, and Morgantown Industrial Park Associates, Limited Partnership.

The CQAP uses the requirements and format set forth in the EPA technical guidance document entitled, "Quality Assurance Quality Control for Waste Containment Facilities" (EPA/600/R-93/182). The CQAP contains the following information:

- responsibilities and authorities of personnel associated with project implementation
- Construction Quality Assurance (CQA) personnel qualifications
- inspection activities to provide controls and documentation to demonstrate that the work conforms to the Construction Drawings and Technical Specifications
- sampling strategies to provide confidence that the proper materials and workmanship are used in performing the closure
- documentation and reporting requirements associated with CQAP activities

Contractors and subcontractors performing work on this project will be required to comply with the final CQAP as approved by the USEPA and WVDEP. Changes significantly affecting the approved Construction Drawings, Technical Specifications, or the schedule for completion will be brought promptly to USEPA's and WVDEP's attention. Work found to be out of compliance with Construction Drawings and Technical Specifications will be reviewed and halted, if necessary, until a satisfactory resolution is achieved. Conflicts between the CQAP and other project documents will be brought to the immediate attention of the CQA Officer, OU-1 Group, USEPA, and WVDEP so the conflict may be resolved. Necessary field changes and non-compliance issues will be resolved through the Field Change Request process or documented using Non-Conformance Reports, as applicable.

2.0 Responsibility and Authority

The principal organizations involved in implementing the remediation at the MOW site include USEPA, WVDEP, the OU-1 Group, and ESC. Specific responsibilities and authority are delineated below to establish the lines of communication required to produce an effective decision-making process during implementation of the CQAP.

2.1 Regulatory Agency

The lead regulatory agency involved with this project is the USEPA. In this capacity, the USEPA will review the Construction Drawings and Technical Specifications for conformance to applicable requirements. The USEPA has the authority to review and accept or reject design revisions or requests for variances that are submitted after the remedial design documents have been approved. The USEPA also has the authority and responsibility to review CQAP documentation to confirm that the CQAP was effectively implemented. The WVDEP supports the USEPA with these efforts.

2.2 OU-1 Group

The OU-1 Group is ultimately responsible for the proper permitting, design, and construction of the project. The OU-1 Group has retained ESC as the project engineer and quality assurance team. The Construction Contractor(s) will be hired following approval of the Construction Drawings and Technical Specifications. The OU-1 Group has the authority to dismiss all non-regulatory organizations involved in design, CQA, and construction. It is the OU-1 Group's ultimate responsibility to provide assurance to the regulatory agencies that the construction is conducted in accordance with the final Construction Drawings and Technical Specifications.

2.3 Environmental Strategies Corporation (ESC)

ESC will function as Project Engineer and will provide CQA personnel. ESC's responsibilities under these separate functions are defined below.

2.3.1 Engineer

As the Project Engineer, ESC's primary responsibilities will be to provide engineering technical support for the OU-1 Group during construction. In this capacity, ESC will be responsible for monitoring of construction work and providing the contractor feedback from questions regarding the Construction Drawings and Technical Specifications. In addition, ESC will be responsible for identifying, documenting, and correcting deviations from these documents.

The Director of Engineering of ESC, Mr. Steve Kretschman has the responsibility to review proposed design revisions associated with field changes from the Construction Drawings and Technical Specifications. The Director of Engineering has the authority to approve the revisions on behalf of ESC and submit the proposed revisions to the OU-1 Group and USEPA for approval. All field changes will be processed in accordance with established procedures (Attachment A).

2.3.2 Construction Quality Assurance Personnel

ESC will provide CQA personnel during implementation of the remediation activities. The responsibilities of the CQA personnel are to perform the verification activities specified in the CQAP to provide confidence that closure is performed in accordance with the Construction Drawings and Technical Specifications. The CQA personnel for this project will consist of a CQA Officer and between one and three QA Inspectors, as needed for particular tasks. The CQA Officer, Mr. Glen Rieger has the responsibility and authority to halt any remediation activity or work that is not in conformance with the approved Construction Drawings and Technical Specifications. Site-assigned CQA Inspectors performing verification activities report directly to the CQA Officer and have the responsibility to notify the CQA Officer of any deviation from the Construction Drawings and Technical Specifications. The CQA Inspectors have the responsibility to report and the authority to investigate all deviations and nonconforming conditions to determine the source or root cause. The CQA Officer's responsibilities include:

- reviewing Construction Drawings and Technical Specifications for clarity and completeness so that the CQAP can be implemented in a timely fashion
- educating CQA personnel onsite
- scheduling and coordinating CQA inspection activities

- verifying and documenting that the test equipment used is of the appropriate type and has been properly calibrated
- confirming that the test data, inspection, and monitoring activities have been properly documented and confirming that their results meet with the Construction Drawings and Technical Specifications
- providing the OU-1 Group with CQA updates, identifying deficient work, and providing recommended corrective action measures
- ensuring that any changes in testing equipment, personnel, or procedures do not adversely impact the inspection process
- CQA audit implementation

CQA Inspector responsibilities include:

- performing onsite inspections of the remediation to ensure compliance with Construction Drawings and Technical Specifications
- verifying tests as specified herein, including the submitting of test samples (if required) to qualified laboratories for acquiring test results
- documenting the results of all inspection, test, and monitoring activities
- reporting nonconforming conditions in accordance with the procedures explained in Attachment B as well as other deviations from the Construction Drawings and Technical Specifications to the CQA Officer, the OU-1 Group, and USEPA
- verifying the implementation of any corrective action measures.

2.3.3 Contractor

The Contractor's responsibility is to perform the work in accordance with the Construction Drawings and Technical Specifications. Construction personnel, including the Contractor's Project Manager, will coordinate their work with the ESC CQA Officer and CQA inspectors.

2.4 Project Construction and Quality Assurance Meetings

Periodic (a minimum of once per week frequency) CQA meetings will be held during the implementation of the construction. Meeting attendees will include the Contractor Project Manager and ESC's CQA Officer and/or Inspector. Representatives of the regulatory agencies and representatives of the OU-1 Group may also attend, as necessary.

Additional CQA meetings may be held at the site or via a telephone conference and will be used to discuss the project progress, construction issues and unanticipated site conditions, and deviations from the Construction Drawings and Technical Specifications. Each meeting will be documented by the CQA Officer or one of the CQA Inspectors.

2.4.1 Initial Construction Quality Assurance Meeting

The initial CQA meeting will be conducted onsite prior to initiating work. Subjects proposed to be covered during this meeting include:

- providing appropriate parties with the finalized CQAP
- reviewing the responsibilities and authority of each party
- reviewing lines of authority and communication
- resolving identified conflicts between the CQAP and the Construction Drawings and Technical Specifications
- reviewing the procedures and requirements for the tests and inspections to be performed
- reviewing methods for documenting and reporting inspection data
- reviewing storage of documents
- reviewing procedures for identifying and correcting deviations from the Construction Drawings and Technical Specifications
- discussing proper storage requirements for construction materials
- reviewing the site health and safety plan as needed
- conducting a site walk to review and discuss work issues
- reviewing methods for documenting and reporting inspection data
- schedule for the upcoming two weeks
- reporting of key submittals to the USEPA (if any)

2.4.2 Weekly Construction Quality Assurance Meetings

At the beginning of each work week, the CQA Inspectors will communicate with the CQA Officer to discuss upcoming project activities. Discussion topics will include:

- previous week's activities and progress
- current week's planned activities
- anticipated or potential construction issues
- review of testing procedures, submittals, or inspection activities required for the current week's work
- coordination of CQA monitoring and inspection activities with the Contractor Project Manager.

The weekly meetings/telephone conferences will be documented by a CQA Inspector. The documentation will be included in the appropriate CQA Inspector's daily report.

3.0 Construction Quality Assurance Personnel Qualifications

CQA personnel provided for this project will include one CQA Officer and as many as three CQA Inspectors. These personnel have been selected to perform the verification activities outlined in this CQAP and carry out the responsibilities listed in Section 2.3.2, Construction Quality Assurance Personnel. Resumes for CQA personnel are presented as Attachment C to this CQAP. A description of the personnel qualifications is presented in this chapter.

3.1 Construction Quality Assurance Officer

The CQA Officer for this project is Mr. Glen Rieger. The CQA Officer will perform at least one site visit per calendar month during construction.

3.2 Construction Quality Assurance Inspection Personnel

In addition to the CQA Officer, additional CQA inspection personnel will be assigned, as dictated by the demands of the remedial action effort. The additional CQA inspection personnel identified for this project are Mr. Cheyne Gross, Mr. Don Haddox, or other similarly experienced individuals. They will perform CQA inspection activities under the supervision of the CQA Officer. ESC may submit additional CQA inspection personnel for this project subject to the approval of the OU-1 Group.

4.0 Inspection Activities

Inspection activities required to provide confidence that materials and construction methods meet the intent of the Construction Drawings and Technical Specifications are provided in this chapter.

4.1 Landfill Capping System Construction

A low-permeability landfill capping system will be constructed over the landfill. The capping system will consist of several components presented in order from the lowest layer to the upper layer.

- subgrade preparation
- Geosynthetic Clay Liner (GCL)
- high density polyethylene (HDPE) flexible membrane liner
- geosynthetic composite drainage net
- protective soil layer (24 inches minimum of uniform soil material capable of supporting vegetation).
- grass vegetation

4.1.1 Subgrade Preparation

Inspection activities to be performed during the subgrade preparation include:

- inspections to ensure all erosion and sediment controls are in place and maintained
- survey data to demonstrate that the existing surface had been graded to the proposed contours or as approved by the Project Engineer
- inspections to verify that the surface of the subgrade has been compacted

4.1.2 Geosynthetic Clay Liner

Inspection activities to be performed during final placement include verifying and documenting the following items:

- GCL material meets specifications
- subgrade layer is inspected for objects that may cause damage to the GCL

- inspection to demonstrate proper seam installation
- obtain panel layout information
- inspect and verify anchor trench dimensions

4.1.3 High-Density Polyethylene Flexible Membrane Liner

Inspection activities to be performed during final placement include verifying and documenting the following items:

- geomembrane material meets specifications.
- GCL layer is inspected for objects that may cause damage to the liner.
- testing to demonstrate seam integrity.
- obtain panel layout information.
- inspect and verify anchor trench dimensions.

4.1.4 Drainage Net

Inspection activities to be performed during double composite geosynthetic drainage net placement include verifying and documenting the following items:

- Geonet meets specifications
- inspect and verify anchor trench dimensions
- verify proper joining of geonet panels and cable tie frequencies
- verify that geonet placement is not damaging the liner

4.1.5 Protective Soil Layer (24 inches uniform soil material)

Inspection activities to be performed during the construction of the protective earth layer include verifying and documenting the following items:

- observations that the soils materials are free from rocks greater than 6 inches in any dimension, undesirable organic material, excessive moisture, and other deleterious substances
- placement of material in the specified lift thickness and measurement of the total protective layer thickness is as specified

- measurements to verify that the final grades are as specified on the Construction Drawings or as approved by the Engineer
- observations that seeding and mulching are applied according to the Technical Specifications
- observation that after final grading, low spots that could potentially trap precipitation are not in evidence
- as-built survey is conducted to ensure that final slopes are within the specified ranges or as approved by the Engineer and USEPA
- measurements to verify that the soil is compacted to satisfy the Technical Specifications

4.2 Surface Water Controls

Surface water controls will be constructed to reduce shallow subsurface flow to the cap area, to divert upgradient storm water runoff from the cap area, and to convey storm water runoff from the capped area to the existing surface water control system (Swales 2 and 3). Surface water controls will consist of drainage ditches.

Locations for the drainage ditches are shown on the Construction Drawings. Inspection activities to be performed during surface water controls construction include verifying and documenting the following items:

- drainage ditch construction does not damage the capping system
- materials used in drainage ditch construction are in accordance with the Technical Specifications and Construction Drawings
- drainage ditch construction is to the lines and grades shown on the Construction Drawings or as approved by the Engineer
- Cross-sectional ditch dimensions are in accordance with the Construction Drawings. Dimensions in excess, wider and deeper, are acceptable, provided that the slope is maintained and no pooling occurs.

4.3 Constructed Wetlands Treatment System

A constructed wetlands treatment system will be installed to remove constituents of concern from the landfill leachate. It is expected that this system will be temporary. After the cap is in place, the leachate flow rate is anticipated to dissipate and eventually disappear.

Inspection activities to be performed during the wetland treatment system construction include verifying and documenting the following items:

- the construction is performed in accordance with ERI's design
- the components of the wetland treatment system are installed at the specified elevations
- planting scheme is followed

4.4 Wetlands Mitigation

During sediment excavation activities, approximately 1 acre of existing wetlands will be excavated and removed. As required, these wetlands will be replaced at a ratio of 1.5 to 1 ratio. Thus, 1.5 acres of wetlands will be replaced. The new wetlands will be constructed within the flood plain of the Monongahela River. Inspection activities to be performed during the wetland replacement activities include verifying and documenting the following items:

- the construction is performed in accordance with ERI's design
- the wetlands are constructed at the specified elevations
- the planting scheme is followed

4.5 Sediment Excavation

Sediment from swales 1, 2, and 3 will be excavated and relocated within the landfill limits for ultimate placement beneath the cap. Excavation will start at the beginning (highest elevations) of the swales and continue downstream until the first railroad right-of-way is encountered for Swales 2 and 3. Swale 1 excavation will continue until the rock liner is encountered (see construction drawings). Inspection activities to be performed during the sediment excavation activities include verifying and documenting the following:

- excavation was advanced to the specified depths
- sediment was stabilized with additives, as necessary, to allow handling with conventional earthmoving equipment
- swales were restored as specified by the design documents

5.0 Sampling Strategies

Representative sampling and testing of the materials used during remediation will provide an indicator of the overall project quality. This CQAP, in conjunction with the Construction Drawings and Technical Specifications, provides the sampling and testing required to document that the construction proceeds as specified. Minimum criteria that will be addressed with the sampling strategies include:

- component being tested
- test method
- sample frequency
- acceptance/rejection criteria
- type of test
- corrective measures.

5.1 Construction Sampling Strategies

Materials submittals and representative sampling and testing provide the majority of the information verifying that materials and construction procedures comply with the Construction Drawings and Technical Specifications. The materials submittals will be reviewed by an ESC CQA Inspector for Specification compliance before the materials are used onsite. Materials not in compliance with the Technical Specifications will be rejected. Material submittals acquired will be included in the final Certification report for documentation of Technical Specification compliance.

Representative sampling and testing will be performed in accordance with Tables 1 and 2 and documented in accordance with the CQA checklists provided in Attachment D. In addition, to clarify the verification of representative sampling and material testing, the CQAP tables will be used in conjunction with the CQA checklists as applicable.

6.0 Documentation

The effectiveness of the CQAP will be determined by providing information to verify that the CQA inspection activities and sampling strategies are employed. This information is provided mainly by documentation. Daily reports, data sheets, test results, inspection reports, monitoring reports, and completed checklists prepared by ESC CQA Inspectors will create a project history and provide confidence that the required CQAP activities were performed as discussed herein.

6.1 Daily Reports

Daily reports (including field sketches) are required by all personnel involved in QA inspection activities (e.g., CQA Inspectors). The CQA Officer is responsible for timely review of all daily reports to remedy inconsistencies or other problems detected. CQA Inspectors will maintain a field log for quick reference and notes, but will also be required to prepare reports at the end of each working day. At the project's completion, field logs will become part of the permanent records, along with the daily reports.

The daily reports, at a minimum, will contain the following information:

- date, project name, ESC project number, and CQA Inspector preparing report
- weather conditions
- reports on meetings held
- construction activities
- equipment and personnel used
- description of materials delivered
- calibration of test equipment
- nonconformances and corrective measures
- Field Change Requests
- specific QA construction activities
- approved changes to Construction Drawings and Technical Specifications
- signature of the CQA Inspector

Daily reports will be maintained onsite (copies) and will be summarized in monthly reports to be submitted to the USEPA and WVDEP.

6.2 CQA Inspection Reports

CQA Inspection Reports will be issued for all CQA verification activities. These activities shall be documented within Daily Reports for routine activities, on preplanned checklists for more detailed specific activities, and within narrative reports for other than preplanned activities. Each CQA Inspection Report shall include the following items:

- identification of the items or materials inspected
- references to applicable procedures and acceptance criteria including Technical Specifications and Construction Drawings
- a description of the verification activity and the results, including corrective action measures
- location of activity
- date and signature of the inspector

Inspection checklists for this project are provided in Attachment D. Information within the checklists will be compared with individual Technical Specifications to verify consistency and completeness. Review of the checklists will be covered during the daily CQA meetings.

6.3 Photographs

Photographs will be taken to visually document construction activities each day that work occurs. At least two copies of each photograph will be produced, one for the onsite working file and one retained in the project file maintained in the ESC office in Pittsburgh, Pennsylvania.

Photographs will be stored in a protective file and become part of the final project record.

6.4 Field Change Requests

Revisions required or requested during work will require formal approval following the procedures in Attachment A. USEPA will be notified of pending revisions to the Construction Drawings and/or Technical Specifications through the field change request process.

6.5 Field Change Requests and Nonconformance Reporting

Modifications to the final (approved) Construction Drawings and Technical Specifications will be formally requested and documented using the procedures in Attachment A.

Work that does not conform to the final (approved) Construction Drawings and Technical Specifications will be formally documented, reported, and resolved using the procedures in Attachment B.

6.6 Final Documentation

At the completion of construction, a final report will be prepared and submitted to the USEPA. CQA document control will be maintained throughout construction. This documentation will be incorporated into the final report. The final report will contain copies of relevant documents to demonstrate that the CQAP was instituted and executed properly. The final report will also contain any deviations and associated corrections performed and will include a set of as-built drawings, including a final survey. ESC will certify that the activities described in the final report have been completed in accordance with the Final Construction Drawings and Technical Specifications, or approved changes.

6.7 Documentation Storage

Originals of the field records, Construction Drawings and Technical Specification, CQA documentation, and the final documentation (or copies in the event that the originals are misplaced or destroyed) will be maintained by ESC. Copies of the field records or other documentation will be made available for review upon request of USEPA. The CQA Officer will be responsible for accumulating and storing ESC's project CQA documentation.

Tables

Table 1

Material Control Testing (Prior to Placement) (a)
Morgantown Ordnance Works, OU-1 Group
Morgantown , West Virginia

Property Test	Test Method	Minimum Testing Frequency
Protective Soil Layer		
Grain Size Distribution	ASTM D422	1 test per source
Classification	ASTM D2487	1 test per source
Chemical Analysis (TCL)	SW-846	1 test per 5,000 cubic yards
Stone		
Grain Size Distribution	ASTM D422	1 test per source
Composite Drainage Net		
Net:		
Specific Gravity	ASTM D1505	Manufacturer minimum requirements
Transmissivity	ASTM D4716	Manufacturer minimum requirements
Tensile Strength	ASTM D1682	Manufacturer minimum requirements
Fabric:		
Weight	ASTM D3776	Manufacturer minimum requirements
Puncture Resistance	ASTM D4833	Manufacturer minimum requirements
Apparent Opening Size	ASTM D4751	Manufacturer minimum requirements
Interface Friction Angle (FML/Drainage Net and Drainage Net/Soil Cover Interfaces)	ASTM D6342	1 test per interface per source of material (minimum interface friction angle of 18 degrees)
High-density Polyethylene Flexible Membrane Liner		
Thickness	ASTM D751	Manufacturer minimum requirements
	ASTM D1593	Manufacturer minimum requirements
	ASTM D5199	Manufacturer minimum requirements
Resin Density	ASTM D792	Manufacturer minimum requirements
	ASTM D1505	Manufacturer minimum requirements
Tensile Strength at Yield	ASTM D638	Manufacturer minimum requirements
Tensile Strength at Break	ASTM D638	Manufacturer minimum requirements
Elongation at Yield	ASTM D638	Manufacturer minimum requirements
Elongation at Break	ASTM D638	Manufacturer minimum requirements
Geosynthetic Clay Liner		
Permeability	ASTM D5084	Manufacturer minimum requirements
Interface Friction Angle (Landfill Subgrade/GCL and GCL/FML Interfaces)	ASTM D6342	1 test per interface per source of material (minimum interface friction angle of 18 degrees required)
Geotextile:		
Grab Tensile	ASTM D4632	Manufacturer minimum requirements
Burst Strength	ASTM D3786	Manufacturer minimum requirements
Bentonite:		
Water Adsorption	ASTM E946	Manufacturer minimum requirements
Free Swell	USP-NF-XVII	Manufacturer minimum requirements

---

a/ See individual Technical Specifications for additional details and testing requirements.

Table 2

In Situ Testing Requirements *(a)*
Morgantown Ordnance Works, OU-1 Group
Morgantown , West Virginia

Property Test	Test Method	Minimum Testing Frequency	Minimum Criteria Specification
Subgrade			
Compaction	Visual Inspection	Continuously Inspected	Three passes with dozer and roller - 12 inch loose lift thickness
Protective Soil Layer			
Total Layer Thickness	Excavate small area	5 tests/acre	
Stone			
Hand Tamp	Visual Inspection	Continuously Inspected	
Geosynthetic Clay Liner			
Visual Inspection	Observe	Continuous	No Damages, (holes, punctures, tears) seams properly overlapped
Composite Drainage Net			
Inspection	NA	Continuous	Seams butted together
Inspection	NA	Continuous	Plastic ties installed every 5 linear feet along length of panel and every 1 foot along width of panel.
High-density Polyethylene Flexible Membrane Liner			
Visual Inspection	Observe	Continuous	No Damages, (holes, punctures, tears)
Non-Destructive Field Testing:			
Vacuum Testing of Extrusion Seams	NA	All extrusions welded seams	No air bubbles present
Air Pressure Testing	ASTM D4437	All double welded seams	Pressure loss less than 4 psi
Destructive Field Testing:			
Peel Strength	ASTM D4437	1 per 500 feet of seamed length	60 ppi lb/in
Shear Strength	ASTM D4437	1 per 500 feet of seamed length	76 lb/in

---

a/ See individual Technical Specifications for additional details and testing requirements.

Attachment A - Field Change Request Procedures

Field Change Request (FCR)

FCR No. ________

PART 1 (Contractor completes Part 1) **ESC Project No. 457302**

Project: Morgantown Ordnance Works - Operable Unit No. 1

Location: Morgantown, West Virginia

Reference(s): Technical Specification No.: ________
Construction Drawing No.: ________

Description of Change Requested:

____

____

____

Reason for Change:

____

____

____

____
Originator's Signature

PART 2 (ESC completes Part 2)

Disposition:
[ ] Accepted as minor change [ ] Rejected
[ ] Major FCR, accepted, requires USEPA approval before implementation

Remarks:

____

____

____

Reviewed By: ________ CQA Officer ________ Date

Dispositioned By: ________ Director of Engineering or designee ________ Date

Distribution: ________

Attachment A -1

1.0 Purpose

The purpose of this procedure is to describe the method for requesting acceptance for the implementation of field changes to design, specifications, drawings, and procedures applicable to the Morgantown Ordnance Works, Operable Unit No. 1 remedial action.

A Field Change Request (FCR) is a document used to request and acquire the necessary reviews and acceptance for implementing a field change involving design, process, or method.

2.0 Discussion

During the course of field activities, conditions may be encountered that necessitate a change in requirements affecting design, processes, or methods.

These changes may be necessary to correct or revise a design, institute an additional requirement, or request approval for relief from an existing requirement with suitable justification. Field changes may also be requested to address and acquire guidance for unforeseen or unanticipated conditions, or to acquire acceptance for alternate methods or processes to be employed.

To provide a mechanism for controlling these changes, ESC has established a FCR system which documents a complete description of the change, acquires the necessary acceptance, and provides disposition of the request and affected documents.

3.0 Responsibilities

The Contractor initiating the field change request will complete Part 1 - Initiation of the FCR form (Attachment A-1) and submit each FCR to the Engineer for processing and acceptance.

The Director of Engineering of ESC, or designee, will be responsible for acquiring all necessary reviews and disposition(s) for each FCR. The Director of Engineering of ESC will ensure that the use of the FCR is not in conflict with contractual requirements and shall also determine (1) if the change requires approval by the OU-1 Group due to additional costs or (2) if the requested change is rejected and will not be implemented. The disposition of each FCR will address the need for changes to any affected documents.

The Director of Engineering, or designee shall review all FCRs involving design, specifications, plans, drawings, or procedures for compliance with regulatory requirements and protocols, as requested by the CQA Officer.

4.0 Procedure

4.1 General

When conditions are encountered in the field that require either a change in specified design or the need for procedural deviation in method process, a FCR may be initiated by the contractor and submitted for review and disposition.

FCRs will be reviewed by ESC and USEPA and accepted prior to implementing any field change.

4.2 Preparation

The FCR is a two (2) part form which identifies the details of the requested change and provides the disposition for the request.

Part 1 to be completed by the originator consists of the following information:

- project (title description)
- location
- FCR Number (sequential number)
- date of issue
- ESC Project Number
- description of the requested change including referenced requirements and documents affected by the change
- justification with an explanation of the basis or reason for the change
- signature of the originator

On completing Part 1 of the FCR, the form is to be submitted to the Director of Engineering of ESC, or designee, for review, disposition, and acceptance.

4.3 FCR Processing, Review, and Acceptance

Once the FCR has been submitted to the Director of Engineering of ESC, the Director of Engineering of ESC or designee will review the FCR and determine the initial basis or justification for the change to be implemented.

If the FCR is rejected, no further review processing will be performed and the FCR will be returned to the originator.

The Director of Engineering of ESC, or designee, will review all provided input and recommendations and acknowledge the disposition recorded in Part 2 of the FCR original by signature and date.

The disposition of each FCR should provide sufficient instruction to implement the requested change and address subsequent actions to be performed involving the need to revise affected documents such as procedures, reports, drawings, etc.

All FCRs that are to be implemented will be submitted to USEPA before construction for USEPA concurrence.

Distribution of the completed FCR, with supportive documentation, will be shown on the FCR form (Attachment A).

USEPA approvals will be provided on separate letter responses for each affected FCR.

5.0 Records

Each project-related FCR will be filed and maintained in the project files in accordance with the CQAP.

Attachment B - Nonconformance Reporting Procedure

Nonconformance Report

NCR No. ________

PART 1

ESC Project No. 457302

Project: Morgantown Ordnance Works - Operable Unit No. 1

Location: Morgantown, West Virginia

Reference(s):
Technical Specification No.: ____________________
Construction Drawing No.: ____________________

Nonconformance Description:

____

____

____

____
Originator's Signature

PART 2

Disposition:

[ ] Accepted as is

[ ] Rework/reperform work to satisfy intent of the specifications and drawings

Remarks:

____

____

____

Reviewed By:

________________________ ____________
Engineering Date

________________________ ____________
Environmental Compliance Date

________________________ ____________
Other Date

Dispositioned By:

________________________ ____________
Director of Engineering or designee Date

Distribution: ________________________________

Attachment B-1

1.0 Purpose

The purpose of this procedure is to establish and provide a system for identifying, reporting, evaluating, and dispositioning nonconforming items to prevent their inadvertent use or installation.

2.0 Scope

This procedure applies to permanent installations and items of hardware or materials which are procured, constructed, installed, or used in conjunction with remedial activities. This procedure does not apply to expendable tools, supplies, or temporary equipment, items or materials.

3.0 Definition

3.1 Nonconformance

A nonconformance is a deficiency in characteristic, documentation, or procedure that renders the quality of an item or material unacceptable or indeterminate.

3.2 Disposition

A disposition is a written order to correct or place a nonconforming condition into a conclusive form. Acceptable dispositions may require nonconforming conditions to be either repaired, reworked, scrapped, or used-as-is with suitable justification.

4.0 Discussion

This procedure for the control of nonconforming items and materials has been established by ESC to ensure that such conditions are properly identified, reported, evaluated, and dispositioned. The application of this procedure is intended to augment the requirements of the applicable Construction Quality Assurance Plan (CQAP). Any conflicts between the requirements of this procedure and the CQAP shall be brought to the immediate attention of the CQA Officer for resolution.

5.0 Responsibilities

The CQA Inspector initiating the Nonconformance Report (NCR) (Attachment B-1) will provide a detailed description of the nonconforming condition(s), including any reference(s) to drawings, specifications, or procedures which may provide acceptance criteria for the item or material being reported.

The Inspector will acquire a nonconformance report number from the CQA Nonconformance Report Log and shall submit the report to the Director of Engineering at ESC who is responsible for acquiring the disposition.

The CQA Officer, or designee, will maintain a log of NCRs which shall reflect the current status of each report.

The Director of Engineering at ESC will be responsible for receipt and review of the initiated NCR. The Director of Engineering at ESC shall also be responsible for providing the recommended disposition.

The CQA Inspector assigned to verify the performance of the disposition and any corrective action measures will verify and attest to the completion of such measures by signature and date on the NCR form.

6.0 Procedure

6.1 General

Any Contractor or ESC employee engaged in project work who discovers a nonconforming condition shall immediately notify the CQA inspector. The CQA inspector will in turn immediately notify the CQA Officer via submittal of a formal NCR.

Any nonconforming conditions that can be immediately corrected within the contractor's scope of work may not require the initiation of an NCR. However, in all cases, a NCR will be issued for:

- nonconforming conditions that are required to be documented in accordance with contractual requirements
- nonconforming items or materials, supplied by others, which are not with the Contractor's scope of work, or responsibility, for repair or rework
- nonconforming conditions that may require extensive repair or rework, engineering evaluation, or significant corrective action measures
- nonconforming conditions that are repetitive
- nonconforming conditions, items, or materials whose failure could attribute to undue risks to the health and safety of personnel.

6.2 Preparing and Processing the Nonconformance Report

Once the condition has been determined to be nonconforming, a NCR will be initiated in accordance with this procedure.

Each nonconforming condition will be brought to the immediate attention of the CQA Officer. The CQA Inspector initiating the report will log the NCR, acquiring a sequential number from the CQA Nonconformance Log and shall complete the initiation (i.e., upper) portion of the report.

The original NCR will be immediately submitted to the CQA Officer with a copy submitted to the Director of Engineering and the contractor.

Nonconforming items or materials will be identified and/or segregated in accordance with Section 6.3 of this procedure.

The Director of Engineering of ESC will evaluate the nonconforming condition and provide a recommended disposition (repair/rework, reject, or accept as-is).

If the disposition must be prepared by someone other than the Director of Engineering of ESC, the Director of Engineering of ESC will submit the NCR to that responsible party and acquire a disposition in a timely manner.

Once the disposition and any steps for corrective action have been determined, they will be reviewed by the Contractor who shall sign and date the "accepted by" line in the disposition portion of the NCR.

The Director of Engineering of ESC will send the original NCR to the Contractor for performance of the disposition. A copy will also be sent to the CQA Officer.

Once the disposition has been performed, verification shall be documented by signature and date of the CQA Inspector performing the verification.

The completed NCR original will be sent by the CQA Inspector to the Director of Engineering of ESC with a copy submitted to the contractor and the CQA Officer.

The Director of Engineering of ESC will process the original NCR to the project central file and shall be responsible for any required distribution prior to filing.

If the NCR prompts any change, USEPA must approve of the change prior to implementation.

6.3 Tagging and Segregation

The site-assigned CQA Inspector will identify the nonconforming item(s) or material(s) by affixing a "hold tag", which will reflect the NCR Number, date of the report and name of the inspector and a brief description of the nonconformity (i.e., material not per specification, incorrectly installed, damaged, or failed required test(s), etc.).

When the use of hold tags is considered impractical, item(s) or material(s) should be segregated to prevent inadvertent use.

All hold tags will be removed from items or materials upon completion of disposition activities.

7.0 Records

Each completed NCR will be maintained on file in accordance with the Construction Quality Assurance Plan (CQAP).

Attachment C - Construction Quality Assurance Personnel Resumes

STEPHEN J. KRETSCHMAN, P.E.
DIRECTOR OF ENGINEERING

SUMMARY OF EXPERIENCE

REMEDIAL EVALUATION, SELECTION & DESIGN

Mr. Kretschman has wide ranging experience in the design and application of engineering processes for environmental remediation and regulatory compliance. He conducts and directs the engineering and design of ESC projects from the Pittsburgh office. His specific skills relate to remedial design, civil engineering, process engineering, and construction management.

Mr. Kretschman's expertise and direct experience is related to the detailed design of sitework and processes for environmental controls and site remediation. He is directly involved in the preparation of plans and technical specifications for closure and remediation of over 50 sites, including CERCLA remedial actions, RCRA corrective actions, landfill and mine site closures, and UST removals. He has prepared a corrective action plan to address 270 UST sites at a military base in North Carolina. The plan included decision trees for technology selection and design aids for implementation of the appropriate technology for corrective action. He has prepared the guidance documents for remedy selection and evaluation under the voluntary remediation program in West Virginia.

Mr. Kretschman's direct experience is as a designer, project engineer and manager of soil and groundwater remediation, wastewater minimization and treatment, and solid and hazardous waste facility construction projects. He has obtained this expertise through the management and execution of projects for our clients in the chemical, glass, pulp and paper, metals, and waste management industries. He has applied his engineering expertise to the implementation of projects under CERCLA, RCRA, and TSCA.

GROUNDWATER/ WASTEWATER ENGINEERING

Mr. Kretschman evaluates treatment technologies and designed treatment systems for industrial wastewater and contaminated groundwater. His experiences include ammonia stripping, carbon adsorption, chemical oxidation, chrome reduction, dissolved air flotation, ion exchange, sand filtration and ultrafiltration, and UV oxidation. Mr. Kretschman's expertise in the preparation of performance-based specifications for environmental processes was used to prepare a guide specification and standard operating procedure for use in remedial action contracts placed by the Department of the Navy in North Carolina and Virginia. He evaluates wastewater treatment plant operations for the steel and chemical industries and designs modifications and improvements to meet more stringent effluent criteria.

Mr. Kretschman's engineering practice includes a broad spectrum of civil and geotechnical engineering projects. He performs hydrologic analysis and hydraulic design of storm water runoff from industrial and hazardous waste sites. He has performed sediment loading calculations and pond design for mine closures. His experience includes foundation designs and the analysis and design of sheet piling for excavation bracing and groundwater barriers.

CERCLA

On behalf of a client, Mr. Kretschman designed groundwater treatment systems for an NPL site in North Carolina containing mixed solvents; managed a removal action for buried drums and soil containing volatile organic compounds at a CERCLA-regulated remedial action in Virginia; provided operation and maintenance assistance and demonstrated hydraulic capture for a groundwater extraction and treatment system at an NPL site in Maryland; and conducted feasibility studies for hazardous waste sites in Tennessee, Puerto Rico, and the District of Columbia.

CHEMICAL INDUSTRY EXPERIENCE

Mr. Kretschman is involved with the design of environmental controls at chemical plants in Pennsylvania, New Jersey, Ohio, West Virginia, Indiana, and South Carolina. His experience at chemical facilities includes NPDES compliance services for storm water and process wastewater segregation, evaluation and design of wastewater treatment facilities, and implementation and monitoring of soil and groundwater corrective measures. Mr. Kretschman's experience in the operation of chemical plants provides insights during the treatment system design process that lead to cost savings for ESC's clients.

STEEL INDUSTRY EXPERIENCE

Mr. Kretschman's experience with environmental issues at primary metals mills is diverse. His experience includes evaluating systems for treatment or recycling of acid rinse, caustic rinse, and oily wastewaters from sheet and tin finishing operations. He has designed modifications for a leachate treatment system for an on-site residual waste landfill at a steel mill. His experience also includes the design of wastewater pretreatment modifications for strong and weak ammonia liquor at the by-products department of a coke plant.

SOLID WASTE INDUSTRY EXPERIENCE

Mr. Kretschman has experience with the solid waste industry, providing design services for landfills and transfer stations in New Jersey, New York, and Pennsylvania. He selected equipment and prepared plans and technical specifications for the installation of a system to collect and treat a leachate seep combined with acid mine drainage discharging iron and manganese in excess of NPDES-permitted limits for a landfill in Pennsylvania.

APPLICATION OF INNOVATIVE TECHNOLOGIES

Examples of Mr. Kretschman's ability to apply innovative technologies includes the preparation of a pilot test plan for conducting *in-situ* reduction of hexavalent chrome in unsaturated soils as part of a RCRA corrective measures study. The plan includes the injection of ferrous sulfate into pre-acidified soil, and pre- and post-injection monitoring of soil and groundwater chrome concentrations. Mr. Kretschman applied an innovative approach to soil sampling that led to the acceptance by the regulatory agency of an alternative cleanup level for nickel. The ACL reduced the volume of soil requiring stabilization from 20,000 cubic yards to less than 100 cubic yards, saving the client over $800,000.

EDUCATION

Pennsylvania State University University Park, Pennsylvania
Civil Engineering, B.S.

AFFILIATIONS & PROFESSIONAL CREDENTIALS

- Professional Engineer: Pennsylvania, District of Columbia
- American Society of Civil Engineers

GLEN E. RIEGER, P.E.
PROJECT DIRECTOR

SUMMARY OF EXPERIENCE

ENVIRONMENTAL MANAGEMENT

Mr. Rieger is a civil engineer with design, costing, and engineering experience in the hazardous waste remediation field. He has experience in and is currently managing environmental projects including initial site characterization, remedial investigations, feasibility studies, remedial design, construction oversight, remedial actions, and Phase I assessments. He provides remedial design and engineering expertise on environmental projects, performs construction management during remedial actions, and aids in the expansion of the engineering services throughout ESC, providing technical support as needed. His specific skills relate to civil engineering, conceptual and detailed remedial design, and construction management.

REMEDIAL DESIGN

On behalf of ESC's clients, Mr. Rieger combines construction experience with conceptual design ideas to create effective and affordable alternatives for the cleanup of contaminated sites under RCRA, CERCLA, state lead, and voluntary cleanup programs. Selected examples of Mr. Rieger's remedial design projects are provided below.

Mr. Rieger developed a closure plan for a 20-acre neutralized pickle liquor sludge lagoon. The closure consisted of constructing a soil cover. Because the sludge varied in depth, moisture content, and strength, differential settlement was a concern. Mr. Rieger's calculations of the estimated consolidation settlement were incorporated into the construction aspects of the closure.

Mr. Rieger participated in the design of a groundwater collection and treatment system for a hillside landfill in western Pennsylvania. The design involved a braced-cut excavation which exceeded 20 feet in depth and was several hundred feet in length. The support provided by the braced-cut permitted the cost effective installation of a "french drain" groundwater collection system.

Mr. Rieger assisted in the development of a remedial design to remediate an industrial complex containing a wide range of hazardous constituents. Components of this remediation included a 16-acre low permeability synthetic cap, groundwater collection and treatment system with discharge to a nearby river, low permeability slurry wall, slope stabilization, and river sediment dredging.

Mr. Rieger was the lead design engineer for a dual-phase vapor collection and treatment system for a former chemical distribution facility. Mr. Rieger identified significant operational cost savings through the use of an onsite regenerative carbon system. The final design included positive displacement blowers for soil vapor and groundwater collection, an air stripper for groundwater treatment, onsite regenerative carbon for soil vapor treatment, and telemetric monitoring capabilities.

CONSTRUCTION OVERSIGHT

Mr. Rieger provided civil and geotechnical engineering support and construction oversight for the remediation of a CERCLA site. The remediation components included a groundwater collection system (extraction wells, "french drain" using a biopolymer slurry and shallow seep collection drains), a groundwater pretreatment system (solids/metals removal and air stripping with off-gas carbon treatment), a low permeability capping system (gas venting layer, geosynthetic clay liner, polyethylene flexible membrane liner, horizontal drainage layer, and protective soil cover), a surface water control system (fabric formed concrete ditchwork, grass lined drainage swales, and a storm water retention basin), and slope stabilization.

REMEDIATION

Mr. Rieger was assistant project manager and field engineer for a CERCLA remedial action involving the construction of a solid waste containment cell, excavation and treatment of lead- and arsenic-contaminated soils to render them non-hazardous, and placement of the treated material into the containment cell. The soil treatment saved the client significant long-term monitoring costs associated with maintaining a hazardous waste containment cell.

CERCLA

Mr. Rieger has successfully managed a CERCLA "time-critical" removal action and feasibility study preparation for a former barrel recycling facility. The removal action involved bulk waste characterization, segregation, consolidation, and offsite disposal; aboveground and underground storage tank removal; process equipment decontamination; and building decontamination and demolition activities. The removal action, from work plan preparation through completion of the removal activities, took approximately 4 months.

RCRA

Mr. Rieger actively managed the design and construction of a multi-layer cap system for a 10-acre foundry sand pile in Ohio. Technical components of the design included a slope stability analysis, storm water management, leachate collection, and erosion control. This multi-million dollar project was designed and constructed within budget and in accordance with the project schedule. Design and construction took less than one calendar year to complete.

EDUCATION

University of Pittsburgh — Pittsburgh, Pennsylvania
Civil Engineering, B.S.

AFFILIATIONS & PROFESSIONAL CREDENTIALS

- Registered Professional Engineer in Pennsylvania, Ohio, and New Jersey
- OSHA 40-hour health and safety training with current 8-hour refresher training

PUBLICATIONS

Rieger, G.E. and T.E. Scott. 1997. Emerging Technical Developments – Phytoremediation. Environmental Claims Journal. Winter 1998, Volume 10, Number 2, pp. 171-180.

CHEYNE P. GROSS, P.E.
SENIOR ENGINEER

SUMMARY OF EXPERIENCE

GENERAL	Mr. Gross is a civil engineer with design and engineering experience in the hazardous waste remediation field. He helps ESC's clients engineer remediation solutions through effective and cost efficient technical design and engineering, on-site field engineering, project quality control, and construction quality assurance. Mr. Gross manages numerous remediation projects on behalf of our clients, conducts site meetings and provides on-site construction management services including development and management of field change requests.
GENERAL	Mr. Gross develops various remedial action plans including construction drawings, technical specifications, design reports, operations and maintenance manuals, project completion reports, and health and safety plans. Additionally, he prepares permit applications and his engineering and design experience includes dual vapor extraction systems, including pipe flow calculations, well spacing, groundwater flow calculations, and piping and equipment sizing and landfill caps, including slope stability calculations, surface water infiltration calculations, soil loss calculations, grading plans, and erosion and sediment controls.
SOIL VAPOR EXTRACTION DESIGN AND INSTALLATION	For a chemical manufacturer, Mr. Gross designed and installed an air sparging and soil vapor extraction system in the state of Ohio to remediate volatile organic compounds in soil and groundwater. For another client, Mr. Gross designed a dual phase vacuum extraction system in the state of Ohio and performed oversight and operation at several other soil vapor extraction sites.
PILOT STUDIES	Mr. Gross is designing and performing several pilot studies for air sparging, soil vapor extraction, and dual vapor extraction in the states of Florida, Tennessee, Kentucky, Michigan, and Indiana.
LANDFILL CAP DESIGN	Mr. Gross designed and performed construction management and oversight for a 10-acre RCRA cap in the state of Ohio. The design included a leachate collection system and a permanent sedimentation pond. Mr. Gross has prepared landfill cap designs for sites in New Jersey, California, and Pennsylvania.
OPERATION AND MAINTENANCE	Mr. Gross manages operation and maintenance activities of a groundwater pump and treat system in the state of Tennessee.
FEASIBILITY STUDIES	Mr. Gross prepared a feasibility study for CERCLA site in the state of New York.
PILOT STUDIES	Mr. Gross performed oversight of a chemical oxidation pilot study in the state of Florida. The pilot study was performed using peroxide injection to oxidize volatile organic compounds.
GROUNDWATER CONTAINMENT DESIGN	Mr. Gross designed an air sparging curtain for the containment of volatile organic compounds at a site in the state of Florida.

GROUNDWATER BARRIER DESIGN AND INSTALLATION	Mr. Gross performs design and oversight of vertical barrier walls using slurry wall construction techniques He has completed these activities at several RCRA sites in the State of Ohio
REMOVAL ACTION	Mr. Gross served as the site supervisor for a time critical removal action at an NPL site. The project included characterization, sampling, and disposal of approximately 300 drums of unknown material. In addition, underground and aboveground tanks were removed and decontaminated, several pieces of large equipment were decontaminated and disposed, and buildings were decontaminated and demolished. Mr. Gross prepared the completion report that was submitted to the EPA.
CONSTRUCTION OVERSIGHT	Mr. Gross provided project management and oversight for a project that included the demolition of a 252,000-gallon aboveground storage tank and excavation of 4,500 tons of crude oil-contaminated soil. Removal and reconstruction of two railroad spurs were performed.
CONSTRUCTION OVERSIGHT	Mr. Gross provided oversight and project management support for a soil remediation project in the Province of Ontario that included the excavation of approximately 4,000 tons of regulated soil. He coordinated the disposal and treatment of various waste streams.
CONSTRUCTION OVERSIGHT	Mr. Gross provides various construction oversight activities. Specifically, he provided oversight for the installation of a dual phase extraction system which included the use of submersible groundwater pumps in conjunction with pneumatic skimmer pumps for the collection of LNAPL. Mr. Gross prepared the operations and maintenance manual for the system. He has also overseen and managed several underground tank removals in a number of states. He installs LNAPL collection systems and coordinates the disposal of LNAPL.
SITE INVESTIGATION	Mr. Gross performed site characterization and sampling activities at an active steel mill as part of a RCRA facility investigation. Activities included test pit excavations, stream sediment sampling, monitoring well installation, and groundwater sampling.

EDUCATION

Carnegie Mellon University Pittsburgh, Pennsylvania
Civil Engineering and Engineering and Public Policy, B.S.

AFFILIATIONS & PROFESSIONAL CREDENTIALS

- Licensed Professional Engineer in the Commonwealth of Pennsylvania

DON C. HADDOX
ENVIRONMENTAL ENGINEER

SUMMARY OF EXPERIENCE

GENERAL

Mr. Haddox is an environmental engineer with experience in design, development, operation and maintenance, cost estimation, and engineering calculation for a variey of environmental issues. He helps ESC's clients engineer remediation solutions through effective and cost efficient technical design and engineering, on-site field engineering, project quality control, and construction quality assurance.

Mr. Haddox's experience has been largely focussed on the remediation of polycyclic aromatic hydrocarbons (PAHs) at hazardous waste sites, including several publications in refereed journals and conference proceedings as well as international presentations. He also has experience with remediation of other waste site constituents. Both academically and professionally, Mr. Haddox has studied and assisted in the development of biological treatment systems, including bioremediation and phytoremediation; soil vapor extraction (SVE) systems, and capping designs for these and other environmentally impacted areas. His work experience also has included acting as liaison between client and government agencies to ensure proper permitting and compliance with environmental regulations.

LANDFILL CAP DESIGN

Mr. Haddox ensured the engineering accuracy of technical drawings for a CERCLA landfill in Puerto Rico. This task additionally entailed comparison of proposed storm water diversion channels to engineered site conditions for final design. Mr. Haddox also provided the final check of all technical drawings before submittal to the regulatory agency.

Mr. Haddox assisted in the final design of a landfill site in California utilizing a geomembrane cap design. This included developing depth zones for individual component layers based on drainage factors and proposed topography. Mr. Haddox also compiled cost estimates for the overall design of the project.

Mr. Haddox is currently designing detention ponds to handle cap runoff and stream flow for a former mine site in the state of Kansas. This application includes the use of the computer-modeling program Pondpac© to determine maximum storm returns and development of suitable ponds based on this data. Additionally, Mr. Haddox is involved in the overall waste quantity determination for tailing piles and streams within the site.

SOIL VAPOR EXTRACTION SYSTEMS

Mr. Haddox was in charge of data analysis, system evaluation, requisition of maintenance parts, and communication liaison between the client and field personnel for several government operated SVE systems on the east coast. Mr. Haddox prepared weekly reports for the U.S. Navy detailing remedial activities and summarizing data analysis.

Mr. Haddox provided cost estimating for an SVE/AS piping design for a site in Muskegon, MI.

Mr. Haddox acquired air permit exemptions from the appropriate state offices for SVE pilot tests in West Virginia and North Carolina. Mr. Haddox additionally assisted in the completion of the pilot test in West Virginia.

CONSTRUCTION OVERSIGHT

Mr. Haddox provided construction oversight in accordance with a U.S. EPA Corrective Measures Implementation Work Plan for the installation of a groundwater interceptor trench in Ohio. The site was a former chemical distribution facility and was currently impacted by a variety of volatile organic compounds. Mr. Haddox was responsible for assuring compliance with construction drawings, approving any field changes, as well as serving as site safety and health officer. Following completion of the installation, Mr Haddox was responsible for preparing the Construction Completion report for submittal to the U.S. EPA

OPERATION AND MAINTENANCE

Mr. Haddox served as the task manager for a groundwater remediation system operation for a former wood-treating site in Illinois. Mr. Haddox assisted with the day-to-day activities associated with unit operations, which included a biological reactor, oil/water separator, and activated carbon units. Additionally, Mr. Haddox tabulated and monitored bi-weekly analytical results for Illinois EPA records.

FEASIBILITY STUDIES

Mr. Haddox developed an attached growth reactor for the treatment of PAH contaminated river sediment. The process included selection of appropriate microorganisms, growth and maintenance of the bacterial culture, sampling of sediment for laboratory analysis, high performance liquid chromatography analysis (HPLC) of contamination, and evaluation of data.

SAMPLING EXPERIENCE

Mr. Haddox completed a delineation study for arsenic in soil and groundwater for a client in New Jersey. The task included taking soil samples from hand-bored holes as well as sampling groundwater from established monitoring wells. Mr. Haddox has sampled monitoring wells for groundwater contamination for clients in Pennsylvania and New Jersey. He also has experience in sampling river sediment in Ohio.

EDUCATION & TRAINING

University of Akron — Akron, Ohio
M.S.C.E., Civil Engineering, Environmental Specialization

University of Akron — Akron, Ohio
B.S. Bridge-up, Civil Engineering, Environmental Specialization

Hiram College — Hiram, Ohio
B.A., Psychology,

Haestad Methods- Urban Stormwater Management and Detention Pond Design

Beginning and Intermediate Visual Basic Computer Programming

AFFILIATIONS & PROFESSIONAL CREDENTIALS

- Tau Beta Pi

PUBLICATIONS & CONFERENCE PRESENTATIONS

Haddox, D.C., and Cutright, T.J. "Evaluation of Two Bacterial Delivery Systems for the In-Situ Remediation of PAH Contaminated Sediments". 17th International Symposium on Polycyclic Aromatic Hydrocarbons. Bordeaux, France. 1999.

Haddox, D., Sauer, N., Cutright, T. "Preliminary Respirometer Studies for the Bioremediation of PAH Contaminated Soils". Global Environmental Biotechnology. Kluwer Academic Press. 1997

Srivastava, R., Haddox, D., Cutright, T. "Development of a Preliminary Kinetic Model for In-Situ PAH Bioremediation". ACS Emergent Technologies and Hazardous Waste Management. VIII. Birmingham, AL. 1996.

Attachment D - Quality Assurance Checklists

Checklist Implementation

The checklists in this Attachment have been prepared to provide the OU-1 Group, ESC, and USEPA confidence that construction activities will be performed, verified, and documented.

Checklists associated with major remedial action components have been identified for:

- General Requirements
- Site Work

Checklists for individual/applicable Technical Specification sections will be provided sequentially to allow construction and Quality Assurance Inspections to verify that design requirements have been met. ESC recognizes that certain Specification section checklists will be used only once, while others will be used frequently to accommodate in-progress activities or final completion. Should USEPA indicate that the frequency of use of an individual checklist needs to be increased, ESC will adjust its use of that checklist accordingly.

Completed checklists may be supplemented with attached sketches, photographs, and other documents that assist in describing the verification performed.

Any item or activity found to be unacceptable or not in accordance with the applicable requirements will be indicated as rejected on the checklist and brought to the immediate attention of the Contractor for corrective action.

If the item or activity cannot be brought into compliance with existing procedures or specification requirements, the condition shall be documented on a Nonconformance Report. The Nonconformance Report number will be identified on the checklist in the space provided for Remarks.

Completed CQA Checklists will be signed and dated by the CQA Inspector and submitted to the CQA Officer for review. Copies will be maintained within Site project files for review and reference.

Each CQA Inspector will maintain a field logbook for keeping notes that are applicable to site activities. The Inspector's logbook will not be used in place of formal checklists or data sheets. Each logbook will be individually numbered, bound with hard cover, and assigned to the Inspector. All entries will be dated. All corrections will include striking a line through the incorrect data, adding the corrected entry in close proximity, with initials of the individual making the correction, and the date that the correction was made.

Contents

Summary of Project
Section 01010

	Accept	Reject	N/A
1. General Requirements			
– Health and Safety Plan onsite	☐	☐	☐
– Final Design Report onsite	☐	☐	☐
– Final Specifications and Drawings onsite	☐	☐	☐
2. Verifications			
– Contractor confirmed site personnel have received the HASP training (certificates provided)	☐	☐	☐
– HASP requirements followed	☐	☐	☐
3. Additional Requirements			
– OSHA regulations and posters onsite	☐	☐	☐
– Contractor maintains and updates health and safety documents	☐	☐	☐

4. Remarks ____

____

Inspector ______________________ Date ______________________

Reviewed By ______________________ Date ______________________

Submittals
Section 01300

	Accept	Reject	N/A
1. General Requirements			
– Submittal register onsite	☐	☐	☐
– General submittal procedure being followed	☐	☐	☐
2. Verifications			
– Submittal forms properly filled out	☐	☐	☐
– Submittals sequentially numbered	☐	☐	☐
– Construction schedule submission up to date	☐	☐	☐
– Appropriate certifications provided	☐	☐	☐
3. Additional Requirements			
– Submittal process performed to expedite the construction schedule	☐	☐	☐
– Schedule requirements satisfied	☐	☐	☐

4. Remarks ____

____

Inspector ______________________ Date ______________________

Reviewed By ______________________ Date ______________________

Survey Requirements
Section 01488

	Accept	Reject	N/A
1. Survey Requirements			
– Establish benchmarks	☐	☐	☐
– Perform work to established lines and grades	☐	☐	☐
2. Verifications			
– Benchmark tied to USGS datum or other required plant datum	☐	☐	☐
– Surveyor registered in West Virginia	☐	☐	☐
3. Additional Requirements			
– Survey layout data accurate 0.20 foot horizontal and vertical	☐	☐	☐
– Survey for quantity/payment purposes accurate 0.10 foot horizontal and vertical	☐	☐	☐
– Thickness grid (or other acceptable procedure) should be used to verify the volume of material excavated and placed to create the subgrade	☐	☐	☐
– As-built drawings/surveying performed to document construction	☐	☐	☐
4. Approximate Location			
– Per Drawings ________	☐	☐	☐

5. Remarks ____

____

Inspector ______________________________ Date ______________________

Reviewed By ____________________________ Date ______________________

Construction Facilities and Temporary Controls
Section 01500

	Accept	Reject	N/A
1. General Requirements			
– Temporary utilities adequate	☐	☐	☐
– Protect the work area with barriers	☐	☐	☐
– Sanitary facilities adequate	☐	☐	☐
2. Verifications			
– Field offices satisfy specification	☐	☐	☐
– Housekeeping activities in place	☐	☐	☐
– Remove temporary utilities at project completion	☐	☐	☐
– Restore any damaged areas	☐	☐	☐

3. Remarks ____

____

Inspector ______________________ Date ______________________

Reviewed By ______________________ Date ______________________

Decontamination and Disposal
Section 01520

	Accept	Reject	N/A
1. General Requirements			
– Appropriate decontamination facilities established	☐	☐	☐
2. Verifications			
– Decontamination pad lined and suitable for water collection	☐	☐	☐
– Wastewater sampled prior to disposal	☐	☐	☐
– HASP followed for personnel decontamination	☐	☐	☐
3. Additional Requirements			
– Equipment and personnel exiting the exclusion zone pass through the decontamination area	☐	☐	☐
– Pressure wash equipment	☐	☐	☐
– Soil material residue transferred to landfill area for placement beneath the cap	☐	☐	☐

4. Remarks ____

____

Inspector ______________________ Date ______________________

Reviewed By ______________________ Date ______________________

Security
Section 01540

	Accept	Reject	N/A
1. Security Requirements			
– Security program initiated and maintained	☐	☐	☐
2. Verifications			
– Only authorized persons have access to site	☐	☐	☐
3. Additional Requirements			
– Only authorized persons have access to Exclusion Zone	☐	☐	☐
– Visitors log maintained	☐	☐	☐
– Security surveillance	☐	☐	☐
– Material security and safety procedures taken	☐	☐	☐
4. Approximate Location			
– Per Drawings ________	☐	☐	☐

5. Remarks ____

____

Inspector ____________________________ Date ______________________

Reviewed By __________________________ Date ______________________

Environmental Controls
Section 01560

	Accept	Reject	N/A
1. Environmental Control Requirements			
– Controls minimize air and water pollution	☐	☐	☐
– Erosion and sedimentation controls installed and maintained	☐	☐	☐
2. Verifications			
– Erosion and sedimentation minimized	☐	☐	☐
– Dust controlled (vehicle speed, water application)	☐	☐	☐
– Noise controlled (comply with maximum noise levels)	☐	☐	☐
– Land disturbance minimized	☐	☐	☐
– Silt fence in place	☐	☐	☐
3. Additional Requirements			
– Wetland areas protected (if applicable)			
– Wildlife access limited and animals protected	☐	☐	☐
– Dust control agents applied	☐	☐	☐
– Disposal of site waste according to regulations	☐	☐	☐
4. Approximate Location			
– Per Drawings ________	☐	☐	☐

5. Remarks ____

____

Inspector ______________________________ Date ______________________

Reviewed By ____________________________ Date ______________________

High Density Polyethylene Geomembrane
Section 02120

	Accept	Reject	N/A
1. Submittals – Post Award (prior to installation)			
– Geomembrane Manufacturer listed by NSF International	☐	☐	☐
– Resin Data meets specifications	☐	☐	☐
– Geomembrane roll meets specifications	☐	☐	☐
– Installation layout drawings	☐	☐	☐
– Field Installation Quality Assurance Plan	☐	☐	☐
– Interface Shear Test Results	☐	☐	☐
2. Submittals – Daily Basis (during installation)			
– Subgrade acceptance forms	☐	☐	☐
– All QC Documentation and Field Testing Results	☐	☐	☐
3. Submittals – (upon completion of installation)			
– Installation in accordance with contract	☐	☐	☐
– Material and installation warranties	☐	☐	☐
– As-built drawings	☐	☐	☐
4. Quality Assurance			
– Daily inspection completed	☐	☐	☐
5. Correct Location			
– Per Drawings ________	☐	☐	☐

6. Remarks____

____

Inspector ________________________________ Date ________________________

Reviewed By ______________________________ Date ________________________

Geonet
Section 02121

	Accept	Reject	N/A
1. Submittals – Post Award (prior to installation)			
– Geonet meets specifications	☐	☐	☐
– Geotextile meets specifications	☐	☐	☐
– Field Installation Quality Assurance Plan	☐	☐	☐
– Interface Shear Test Results	☐	☐	☐
2. Installation Quality Assurance			
– Daily inspection completed	☐	☐	☐
3. Correct Location			
– Per Drawings ________	☐	☐	☐

4. Remarks ____

____

Inspector ______________________ Date ______________________

Reviewed By ______________________ Date ______________________

Soil Materials
Section 02205

	Accept	Reject	N/A
1. Storage Requirements (prior to use)			
– Stockpiled materials are segregated	☐	☐	☐
– Surface water directed away from stockpile	☐	☐	☐
2. Verifications			
– Area used for stockpile returned to clean (no free standing surface water)	☐	☐	☐
– Analytical data	☐	☐	☐
3. Additional Requirements			
– Soil material - free of rock > 6" in any dimension, debris, waste, perishable materials, frozen materials, vegetation and/or root matter; other deleterious material	☐	☐	☐
– Spreading loose lifts of 12 inches or less	☐	☐	☐
– Minimum three passes with dozer for compaction	☐	☐	☐
4. Correct Location			
– Per Drawings ________	☐	☐	☐

5. Remarks ____

____

Inspector ______________________ Date ______________________

Reviewed By ______________________ Date ______________________

Geosynthetic Clay Liner
Section 02206

	Accept	Reject	N/A
1. Submittals			
– Product data meets specifications	☐	☐	☐
– Shop drawings	☐	☐	☐
– Proposed liner layout	☐	☐	☐
– Physical sample	☐	☐	☐
– Manufacturer affidavit	☐	☐	☐
– Interface shear test results	☐	☐	☐
2. Qualifications			
– Installer experience $\geq$ 1.000.000 ft^2 of liner	☐	☐	☐
3. Quality Assurance			
– Daily inspection completed	☐	☐	☐
4. Current Location			
– Per Drawings ________	☐	☐	☐
– Per proposed liner layout	☐	☐	☐

5. Remarks ____

____

Inspector ______________________________ Date ______________________

Reviewed By ______________________________ Date ______________________

Aggregate Materials
Section 02207

	Accept	Reject	N/A
1. Storage Requirements (prior to use)			
– Stockpiled aggregate are segregated and placed at designated locations	☐	☐	☐
– Surface water directed away from aggregate stockpile	☐	☐	☐
2. Verifications			
– Aggregate meet gradation requirements	☐	☐	☐
– Area used for stockpile returned to clean (no free standing surface water)	☐	☐	☐
– Verify material is free of unwanted debris that would prevent it from functioning as intended	☐	☐	☐
3. Additional Requirements			
– Aggregate - free of lumps, balls of clay, foreign or other objectionable material	☐	☐	☐
4. Approximate Location			
– Per Drawings ________	☐	☐	☐

5. Remarks ____

____

Inspector ______________________ Date ______________________

Reviewed By ______________________ Date ______________________

Jute Mat
Section 02210

	Accept	Reject	N/A
1. Submittals			
– Product meets specification	☐	☐	☐
2. Verifications			
– Mat installed parallel to the direction of flow	☐	☐	☐
– Appropriate overlaps	☐	☐	☐
– Staples appropriately sized	☐	☐	☐
3. Approximate Location			
– Per Drawings ________	☐	☐	☐

4. Remarks ____

____

Inspector ______________________________ Date ______________________

Reviewed By ____________________________ Date ______________________

Grading
Section 02211

	Accept	Reject	N/A
1. Grading Requirements			
– Rough grading to subgrade elevations shown or as directed	☐	☐	☐
– Survey control by Contractor	☐	☐	☐
– Benchmarks and control monuments established	☐	☐	☐
2. Grading Verifications			
– Grading is to the lines and grades as approved by the engineer	☐	☐	☐
– Filling done in continuous layers	☐	☐	☐
– Entire surface tracked by dozer	☐	☐	☐
– Compaction of fill material shall be accomplished by minimum of three passes with the dozer and roller	☐	☐	☐
3. Additional Requirements			
– Grade changes gradual (no abrupt changes)	☐	☐	☐
4. Approximate Location			
– Per Drawings ________	☐	☐	☐

5. Remarks ____

____

Inspector ______________________ Date ______________________

Reviewed By ______________________ Date ______________________

Trenching
Section 02225

	Accept	Reject	N/A
1. Verifications			
– All utilities and structures protected	☐	☐	☐
– Trenching completed as shown on Drawings	☐	☐	☐
2. Approximate Location			
– Per Drawings ________	☐	☐	☐

3. Remarks ____

____

Inspector ______________________________ Date ______________________

Reviewed By ______________________________ Date ______________________

Clearing and Grubbing
Section 02230

	Accept	Reject	N/A
1. General			
– Only areas designated by the engineer are cleared and grubbed	☐	☐	☐
2. Verifications			
– Trees stockpiled onsite	☐	☐	☐
– Roots and stumps placed beneath landfill cap	☐	☐	☐

3. Remarks ____

____

Inspector ______________________ Date ______________________

Reviewed By ______________________ Date ______________________

Dewatering and Treatment
Section 02235

	Accept	Reject	N/A
1. General Requirements			
– Standing water removed from excavations	☐	☐	☐
– Water properly disposed of or treated	☐	☐	☐
– Surface water runoff directed away from dewatering areas	☐	☐	☐
2. Verifications			
– Analytical appropriate for discharge	☐	☐	☐

3. Remarks ____

____

Inspector ______________________ Date ______________________

Reviewed By ______________________ Date ______________________

Monitoring Well Abandonment
Section 02610

	Accept	Reject	N/A
1. Monitoring Well Abandonment Requirements			
– Selected site monitoring wells sealed/abandoned	☐	☐	☐
– Monitoring wells inspected (no obstructions present)	☐	☐	☐
2. Verifications			
– Seal material mix approved	☐	☐	☐
– Log book prepared (amount of sealing materials, type of materials/methods)	☐	☐	☐
3. Additional Requirements			
– All downhole equipment is decontaminated prior to grouting each well	☐	☐	☐
– Grout pump used to place grout monitoring wells	☐	☐	☐
– Protective steel casing is removed	☐	☐	☐
– Steel casings removed from monitoring wells	☐	☐	☐
– Monitoring well casings removed at least 3' below ground surface	☐	☐	☐
– Grout plug inspected after 24 hours for settling; additional grout added, as needed	☐	☐	☐
4. Approximate Location			
– Per Drawings ________	☐	☐	☐

5. Remarks ____

____

Inspector ______________________ Date ______________________

Reviewed By ______________________ Date ______________________

Pipe
Section 02715

	Accept	Reject	N/A
1. PE Corrugated Pipe Requirements			
– PE pipe meets specifications	☐	☐	☐
– Compounds meet specifications	☐	☐	☐
– Test methods conform to ASTM F-405	☐	☐	☐
2. Butt-fused HDPE Pipe Requirements			
– Butt-fused HDPE pipe meets specifications	☐	☐	☐
– Welds are satisfactory	☐	☐	☐
3. Approximate Location			
– Per Drawings ________	☐	☐	☐

4. Remarks ____

____

Inspector ________________________________ Date ________________________

Reviewed By ______________________________ Date ________________________

Seeding and Mulching
Section 02936

	Accept	Reject	N/A
1. Seeding and Mulching Requirements			
– Seeding mixture meets specifications	☐	☐	☐
– Fertilizer meets specifications (adjusted according to agronomy test)	☐	☐	☐
– Seed and fertilizer applied at specified rates (adjusted according to agronomy test)	☐	☐	☐
– Mulching applied, if needed	☐	☐	☐
– Final acceptance approved	☐	☐	☐
2. Approximate Location			
– Per Drawings ________	☐	☐	☐

3. Remarks ____

____

Inspector ______________________________ Date ______________________

Reviewed By ______________________________ Date ______________________

Appendix D - Post Closure Plan

ESC

ENVIRONMENTAL STRATEGIES CORPORATION

Four Penn Center West • Suite 315 • Pittsburgh, Pennsylvania 15276 • (412) 787-5100 • Fax (412) 787-8065

FINAL

POST CLOSURE PLAN

MORGANTOWN ORDNANCE WORKS
OPERABLE UNIT NO. 1
MORGANTOWN, WEST VIRGINIA

PREPARED

BY

ENVIRONMENTAL STRATEGIES CORPORATION

APRIL 3, 2002

Morgantown\457302\Tar and Soil WP\Final Submittal\post-closure-plan.doc

Contents

List of Figures:

List of Attachments:

1.0 Introduction

1.1 General

This Post Closure Plan is intended to provide monitoring and maintenance personnel with the information necessary for monitoring conditions and performing routine maintenance and minor repair of the landfill cap system, replacement wetlands, and treatment wetlands installed at Operable Unit 1 (OU-1) at the Morgantown Ordnance Works facility in Morgantown, West Virginia. Monitoring and maintenance of the landfill cap system, replacement wetlands, and treatment wetlands is required as post closure care for OU-1. This plan has been developed to satisfy the requirements specified in Section XI of the Record of Decision (ROD) for the facility.

The general approach describing the remedy includes:

- excavation and offsite thermal treatment of tar and visible tar-like material
- excavation and relocation of soil and sediments of concern to the existing landfill area
- construction of a multi-layer cap over the existing landfill area and relocated soil and sediment
- restoration of the drainage swales
- replacement of disturbed wetlands
- installation of a wetlands treatment system to treat landfill leachate

For reference purposes, a copy of this Post Closure Plan as well as the following documents should be kept within possession of the entity responsible for implementing the monitoring and maintenance:

- Design Report
- As-Built Construction Drawings
- Technical Specifications
- Remedial Action Report

Unless a catastrophic failure of the landfill cap occurs, contact with OU-1 waste material will not occur while performing the maintenance and minor repair activities specified in this plan. In the event of a catastrophic event, ESC (the Engineer) should be consulted to obtain the details and requirements necessary to perform a major repair to the cap.

1.2 Cap System

The cap system for the OU-1 landfill was designed and constructed to prevent direct contact with, and inhalation of, potentially harmful dust generated from contaminated soil. The cap will also prevent offsite migration of contaminated soil and reduce the amount of precipitation which infiltrates through contaminated soil. The cap system is comprised of the following components (from top to bottom):

- vegetation
- 24 inches of protective soil cover
- a lateral drainage layer
- 40-mil textured high density polyethylene (HDPE) synthetic membrane
- a geosynthetic clay liner
- a gas vent system

1.3 Replacement Wetlands

The wetlands impacted during remediation activities will be replaced in the floodplain of the Monongahela River between Swale 1 and 3. A total of 0.7 acres of wetlands will be impacted in the sediment excavation plan. The replacement wetlands will be constructed to attain a 1.5:1 replacement ratio (1.05 acres of replacement wetlands) utilizing a single enhanced system that will be hydrologically connected to the Monongahela River.

1.4 Treatment Wetlands

The residual leachate from the landfill will be treated utilizing wetlands treatment at the toe (eastside) of the cap system. The design of the wetlands system will allow passive treatment of the leachate without the need for electricity at the site. The system will also have the ability to adapt to various flows, chemical loads, and weather conditions. The wetlands system will use a subsurface flow design to minimize surface exposure to the leachate, and will use selected vegetation to avoid creating an attractive nuisance for wildlife.

The construction drawings outline the limits of the cap, the replacement wetlands, and the treatment wetlands, and provide detailed information pertaining to the closure of OU-1.

2.0 Water Quality Monitoring Program

In accordance with Section XI of the ROD and sections 47CSR58 through 47CSR60 of the West Virginia Regulations, a water quality monitoring program will be implemented as part of the post closure activities at OU-1. The groundwater monitoring position of the program will include the sampling and analysis of a monitoring well system around the landfill cap that is capable of detecting potential groundwater degradation from the landfill. The surface water portion of the program will include the sampling and analysis of the effluent from the treatment wetlands. However, it is noted that the details for the water quality monitoring program are described in the following subsections.

2.1 Monitoring Point Locations and Construction Details

Three existing monitoring wells (DGW-01, DGW-05, and DGW-06) located around the OU-1 landfill will comprise the post closure water quality monitoring system (Figure 1). These monitoring wells were installed in 1987 as part of the OU-1 Remedial Investigation activities. The construction and placement of these wells is consistent with the applicable sections of 47CSR58 through 47CSR60. Lithologic logs and construction details for these monitoring wells are included in Attachment A.

Based on data presented in the Final Remedial Investigation/Feasibility Study Report (January 1988), monitoring well DGW-01 is located upgradient of the landfill cap and monitoring wells DGW-05 and DGW-06 are located hydraulically downgradient and to the east of the OU-1 landfill. The planned cap over the landfill will not extend to any of these locations, so they will remain viable post-closure monitoring points. All three monitoring wells were installed in the first continuous water bearing zone beneath OU-1.

As discussed in the Final Remedial Investigation/Feasibility Study Report (January 1988) and the Final Focused Feasibility Study Report (September 1988), attempts were made during the Remedial Investigation to install shallow wells in the unconsolidated deposits overlying bedrock beneath the site. However, no saturated zones in the soils above the bedrock were observed during the installation of the perimeter monitoring wells (i.e. DGW-01 through DGW-06). During an investigation prior to the Remedial Investigation, wells were also installed in the vicinity of the former lagoons, but these were also dry or recharge was insufficient to obtain representative samples. As such, the bedrock aquifer, in which wells DGW-01, DGW-05, and DGW-06 are completed, represents the first continuous water bearing zone beneath the OU-1 landfill. The total depths of the existing water quality monitoring wells range from 71 feet below ground surface (bgs) at DGW-06 to 120 feet bgs at DGW-01.

As required by the WVDEP, a shallow groundwater monitoring system will also be installed in an attempt to evaluate the unconsolidated unit overlaying bedrock. Well screens will be installed to monitor the interval immediately above the interface between the unconsolidated material and bedrock. The system will consist of one upgradient and three downgradient wells. One of the downgradient wells shall be located downgradient of the wetlands treatment system. A request for variance in design may be necessary depending on the thickness of the unconsolidated unit at the well locations. If the wells do not yield sufficient water for sampling after purging, the wells will be abandoned.

The effluent from the treatment wetlands will be sampled, if available, immediately downstream of the final subsurface flow treatment wetland. This wetland will provide polishing of the effluent before discharge to Swale 3. The effluent sampling will provide monitoring of the performance of the treatment wetlands. It is noted that the treatment wetlands will become fully operational within one year of installation, assuming the treatment wetlands are completed by late summer of 2002.

2.2 Sampling and Analysis

Monitoring wells DGW-01, DGW-05, and DGW-06 and new wells (MW-1S through MW-4S) will be sampled quarterly for two years for the following parameters:

- Target Compound List (TCL) Semivolatile organic compounds SVOCs by Environmental Protection Agency (EPA) SW-846 Method 8270
- Target Analyte List (TAL) Metals by EPA SW-846 Method 6010/7000 series

Depth to water measurements will be obtained during each sampling event to calculate the potentiometric surface elevations. This information will be used to prepare potentiometric surface contour maps which will be provided in the quarterly monitoring reports. ESC's standard groundwater sampling procedures are provided in Attachment B.

The effluent from the treatment wetlands will be sampled monthly during the first year of operation. After the first year, the effluent will be sampled quarterly for five years, assuming there is still production of leachate from the landfill. ESCs standard surface water sampling procedures are provided in Attachment B. The following table provides the performance criteria for the treatment wetlands. The criteria are based on the applicable Category B1 (warm water fishery stream) water quality criteria for the protection of aquatic life per Section 6.3(a) of Title 46 Series 1 Requirements Governing Water Quality Standards. The table includes parameters based on discussions with the West Virginia Office of Water Resources and selected parameters based on their detection above water quality evaluation criteria in the current leachate samples. The laboratory will be certified by the Office of Water Resources of West Virginia (http://www.dep.state.wv.us/wr/OWR_Website/index.htm). The analytical methods listed in the table are relevant to the Clean Water Act NPDES program and were selected based on discussions with West Virginia Office of Water Resources.

Parameter	**Performance Criteria (µg/l)**	**Method**
COD	NC	EPA 410
TOC	NC	EPA 415.1
TSS	NC	EPA 160.2
PH	> 6.0, < 9.0	EPA 150.1
Total phenols	2,560	EPA 420
Copper Total	$e^{(0.8545[\ln(\text{hardness})]-1.465)}$	EPA 200.7
Copper Dissolved	$e^{(0.8545[\ln(\text{hardness})]-1.465)} \text{ x } 0.960$	EPA 200.7
Iron Total	1,500	EPA 200 AA
PAHs	NC	EPA 625
Cyanide Total	NC	EPA 335.2
Cyanide Free ($HCN+CN^{-}$)	5.0	EPA 335.2
Zinc Total	$e^{(0.8473[\ln(\text{hardness})]+0.7614)}$	EPA 200.7
Zinc Dissolved	$e^{(0.8473[\ln(\text{hardness})]+0.7614)} \text{ x } 0.986$	EPA 200.7

Hardness in the above equations is as calcium carbonate (mg/l) in the discharge. The minimum hardness allowed for use in these equations shall not be less than 25 mg/l, even if the actual ambient hardness is less than 25 mg/l. The maximum hardness value for use in this equation shall not exceed 400 mg/l even if the actual ambient hardness is greater than 400 mg/l.

NC = No Category B1 Water Quality Standard per Title 46 Series 1 Requirements Governing Water Quality Standards

2.3 Data Analysis and Reporting

Within 60 days following sampling, the analytical data and potentiometric surface elevations will be submitted to USEPA and WVDEP in a letter report. The groundwater data will be analyzed by comparing the results to the applicable standards (MCLs). In the absence of MCLs, the data will be evaluated for exceedance of RBCs. If after two years of monitoring, no analytes exceed the applicable standard, a petition will be submitted to terminate or modify the OU-1 groundwater quality monitoring program. At the end of the first year of quarterly monitoring, the EPA and WVDEP will consider modification of the sampling period and/or abandonment of the shallow monitoring system.

The surface water data will be analyzed by comparing the results to the performance criteria in the table above.

In addition to groundwater and surface water data, a summary of the cap and wetlands inspection will be included in the letter report. The completed inspection checklist forms (Attachment C) will be attached to the report.

3.0 Maintenance

Maintenance and upkeep of the various components of the cap system, replacement wetlands, and treatment wetlands are important to ensure their proper function.

3.1 Cap System

Maintenance activities involve inspections of these areas for early signs of conditions that may hinder the effectiveness of the cap. A quarterly inspection checklist for the cap system is provided in Attachment B. The following is a list of general conditions which will be checked:

- Grass coverage - A thick and even vegetative cover on the cap is required to prevent erosion. An exposed soil area greater than 10 square feet or a thinly covered area (e.g., less than 70 percent coverage, characterized by clumps of grass with several inches of exposed soil between them) should be reseeded. Seeding should be performed in accordance with the appropriate technical specification.
- Lack of ponding water - The cap system was designed and constructed to promote surface water runoff. An inspection should be made to check for areas that may allow runoff to collect. Significant ponding shall be determined as an occurrence of an area larger than 100 square feet, which retains water (after a precipitation event or snow melt) exceeding a depth of 3 inches at the deepest point of the depression. Fill should be added to any low spots that develop due to protective cover soil settlement.

  Low spots should be filled with soil material. This material can be transported to the location by a pickup truck or similar vehicle. The topsoil material should be placed by manual methods (i.e., a shovel) and hand-tamped. The low spot should then be reseeded.

A detailed report of the repair shall be entered in the maintenance log book kept by the facility, and shall, at the minimum, include the exact location of the repair, the size of the affected area, the depth of the depression, the amount of material placed, and the repair procedures used to restore the original slope of the cap.

- Differential settlement - Although the cap system has been designed to withstand minor settlement, significant settlement within the waste disposal area may allow water to pond. The cap system shall be considered damaged if a depression (settlement) of the protective soil layer of more than 1.5 feet over a span of up to 20 feet has occurred. This magnitude of differential settlement indicates that the maximum allowable tensile strain of 1% (for the cap system) has been exceeded. The measurement of a depression on the surface of the cap must take into account the thickness of any soil material that was previously added in order to remedy ponding. All areas affected by significant differential settlement, based on the above standard, must be repaired immediately. A repair must include all components of the cap, must be performed in accordance with all standards used in construction of the cap, and must restore the cap to its original performance level. The repair must be fully documented, and the report must be submitted to the USEPA and WVDEP upon completion.
- Erosion on cap - Adequate soil is required to prevent damage to the cap. Inspections for erosion problems are critical to ensure the continuing integrity of the soil cover system and should be conducted on a quarterly basis. Should erosion occur, the soil material must be replaced and reseeded. Erosion scars and ruts should be repaired before the next regularly scheduled inspection.
- Soil-dwelling animals - Soil-dwelling animals can cause damage to the cap. If an animal burrow is found within the limits of the soil cover and there is evidence of occupancy (e.g., freshly excavated soil), an attempt should be made to trap the animal using conventional trapping techniques and release it alive.
- Erosion in drainage areas - Drainage layer discharge location free of erosion. The stone shall be replaced as necessary.
- Land slide or slope failures - The outslopes should be inspected quarterly for evidence of soil movement. Evidence of a slide or slope failure may include gaps or separations the in soil cover across the outslopes or sagging areas. Should slides or slope failures occur, a geotechnical inspection should occur to determine the cause of the failure. All repair work should be performed by a qualified contractor and documented in a field logbook.

In addition to quarterly inspections for the first two years, a minor amount of maintenance will be needed for the cap. The only anticipated cap maintenance activity is semi-annual grass mowing to inhibit the development of woody vegetation. Mowing should occur in late spring and summer. Mowing can be accomplished using common, motorized field mowing equipment. Woody vegetation should be removed manually; herbicides will not be allowed on the cover.

3.2 Wetlands

Replacement and treatment wetlands maintenance activities will consist of inspections by a wetland ecologist to evaluate the overall condition of the wetland systems.

- For the replacement wetlands, field observations will evaluate the retention of 80 percent of the original system (1.05 acres), and document the condition of the system in supporting the structure and function of the original system. The US Army Corps of Engineers (USCOE) requires monitoring twice a year for two years, then once per year for three years for a total of seven monitoring events over five years. Data forms (Attachment C) will be filled out for the key indicator parameters - vegetation, hydrology, and soils. The predominance of desirable, nuisance, and native hydrophytes will be evaluated. If 80 percent coverage is not attained or maintained for the desirable hydrophytes (and native hydrophytes that are not evasive), a plan for correction will be implemented typically after the first four monitoring events. Additional performance measures that will be evaluated may include proportions of facultative, facultative wet, and obligate species; and the percent dominant species. The extent of erosion or sedimentation in the mitigation wetlands will be evaluated; and if required, corrective measures will be implemented.
- For the treatment wetlands, field observations will record wildlife occurrence within the wetland habitat and the potential for exposure to residual leachate, and the condition of the system in supporting the structural and functional condition of the wetlands with regards to the design of the original system. Monitoring inspections will be conducted monthly during the growing season for one year, then twice a year for the next year, then yearly for the next three years. Data forms (Attachment C) filled out for the key indicator parameters that include vegetation, hydrology, and soils. The predominance of desirable, nuisance, and native hydrophytes will be evaluated. If 80 percent

coverage is not attained or maintained for the desirable hydrophytes (and native hydrophytes that are not evasive), a plan for correction will be implemented typically after the first four monitoring events. Additional performance measures that will be evaluated may include proportions of facultative, facultative wet, and obligate species; and the percent dominant species. The extent of erosion or sedimentation in the mitigation wetlands will be evaluated; and if required, corrective measures will be implemented.

4.0 Document Control

4.1 Required Documents

The records required to document maintenance and monitoring activities performed in accordance with this Post Closure Plan include the quarterly inspection logs presented in Attachment C.

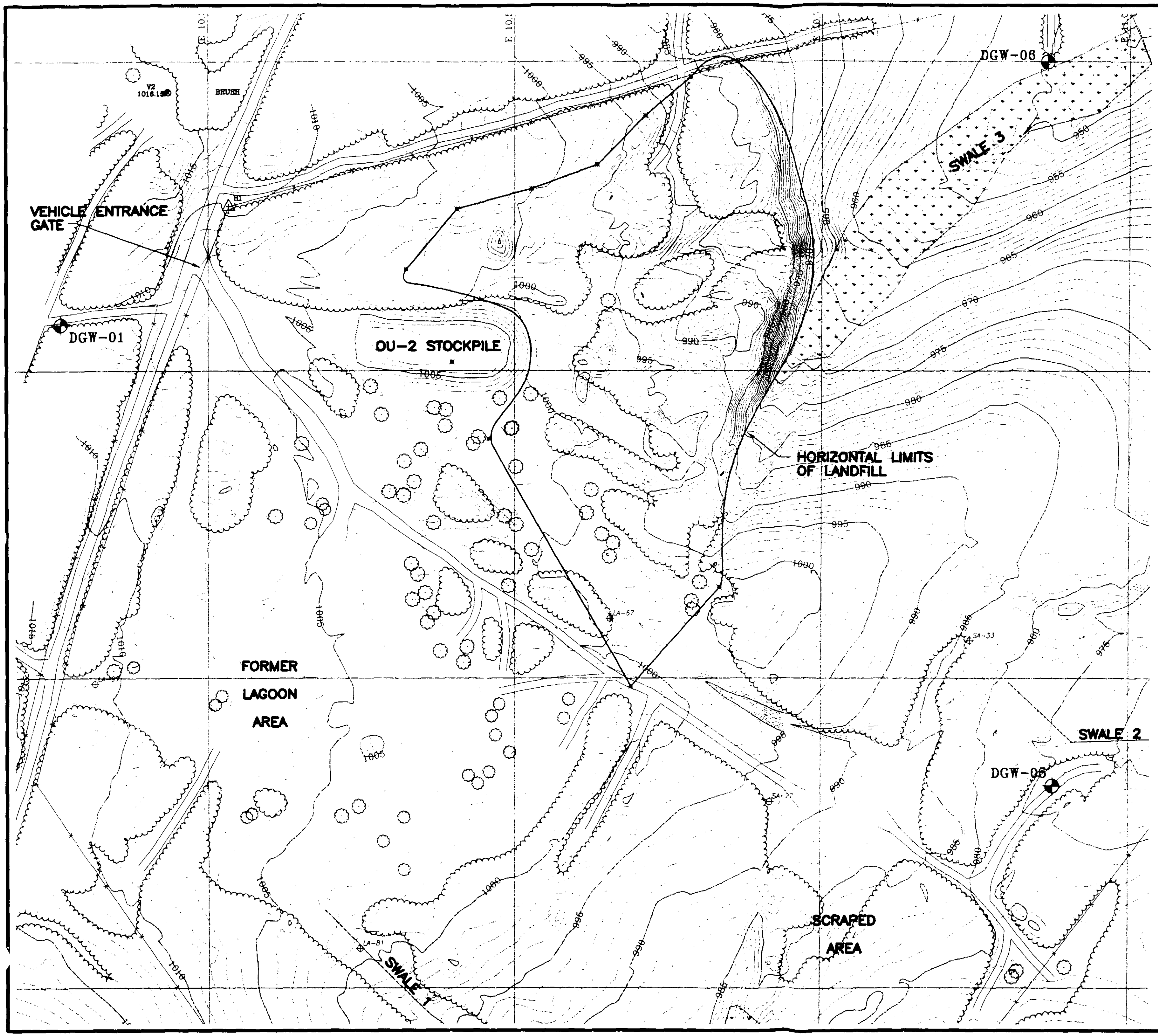
Each item requiring inspection under this Post Closure Plan is listed on the quarterly inspection logs contained in Attachment C. The inspector is encouraged to supplement these logs with brief descriptions of required maintenance or other abnormalities. After completing routine maintenance activities, a brief summary should be prepared on separate sheets of paper (signed and dated). The completed inspection logs and supplemental information shall be maintained in a logbook and kept on file at the facility.

5.0 References

Law Engineering and Environmental Services, Inc. "Final Focused Feasibility Study Report for the Morgantown Ordnance Works Site, Operable Unit One, Morgantown, West Virginia, Revision 2". September 1998.

Roy F. Weston, Inc and Clement Associates, Inc. "Final Remedial Investigation/Feasibility Study Report for the Ordnance Works Site, Morgantown, West Virginia, Volume 1". January 1988

Figures



LEGEND

⊕ LOCATION OF EXISTING DEEP GROUNDWATER MONITORING WELL

FENCE LINE

EDGE OF ROAD

LANDFILL PERIMETER

DESIGNATED WETLAND

NOTES:

1. HORIZONTAL AND VERTICAL CONTROL AND TOPOGRAPHIC MAPPING PROVIDED BY SHEFFLER AND COMPANY, INC. CORAOPOLIS, PA.
2. LANDFILL LIMITS WERE CONFIRMED VIA TEST PIT EXCAVATION AND VISUAL INSPECTION DURING THE PRE-DESIGN INVESTIGATION ACTIVITIES.

SCALE, FEET
0 40 80 160

ENVIRONMENTAL
STRATEGIES CORPORATION
Four Penn Center West, Suite 315
Pittsburgh, Pennsylvania 15276
(412) 787-5100

Figure 1

MONITORING WELL
LOCATIONS

OU-1, MORGANTOWN
ORDNANCE WORKS
MORGANTOWN, WEST VIRGINIA
PREPARED FOR
OPERABLE UNIT 1 GROUP

Drawn By: TMB 3-28-01
Checked:
Approved:
Drawing Number: 457302-B03

D: \450\457302 Morg\457302B03.dwg, 05/31/2001 09:19:20 AM, raz

Attachment A - Monitoring Well Lithologic and Construction Logs

Location

WELL LOG

Page 1 of 2

Well No. ORD-DGW-01 Drill Company Duncan Bros. Log By J. Vann

Client CDM (ORD) Driller Jim White Field Book No.

Job No. 192-RI1 -SIGRW Date Began 2/19/86 End 2/20/86 Log Date 2/19 - 2/20

Drilling Method Air Rotary Rig Davey

Sampling Method Cuttings Examined No Samples

Casing Size and Type 6-5/8" OD Steel Screen Size N/A Joint Type Screw Pipe Length 32'

Type of Pack N/A

Emplacement Method N/A

Interval N/A

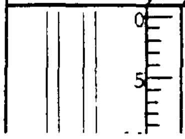
Type of Seal Portland Cement Grout (I/II) 5 bag 25 gal pump to bottom of annulus

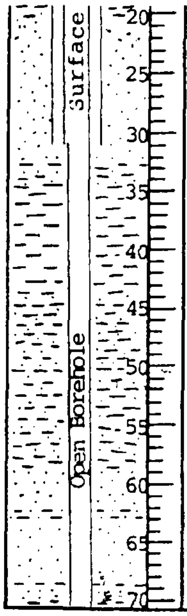
Emplacement Method through tremie pipe

Interval 0-30' (2' stickup)

Development Method Flush with air for 1 hr. Gallons Removed ~ 300

Comments





Lithology and Well Construction	Depth	Sample No.	Interval	Recovery	Blow Counts		Description	Remarks
							1': Dark brown topsoil.	
							10': Reddish silty to sandy clay	
							grey soft shale. Dry.	
							20': Tan sandstone (driller reported increase in hardness)	
							25': Slight increase in moisture.	
							30': Set 6-5/8" steel casing 0-30 feet.	Grouted annulus Left to set 18
							32.5': Dark grey silty shale, dry.	OVA rdg: 1ppm GCA miniram: 0.11
							34': Reddish shale. Dry.	
							44': Grey fine sandy shale .	
							52': Dark green-grey hard sandy shale. dry.	
							59': Dark grey fine grained sandstone .	
							61': Streak of sandy shale. Dry.	
							62': Dark grey fine sandstone. Dry .	
							64': Slight amt of water (1gpm)	
							68.5': Sandstone as above with laminations of shale. Dry.	

WELL LOG

Page 2 of 2

Well No. ORD-DGW-01 Client CDM (ORD) Job No. 192-RI1-SIGRW Log By J. Vann

Lithology and Well Construction	Depth	Sample No.	Interval	Recovery	Blow Counts		Description	Remarks
Open Borehole	70						70': Slight increase in moisture. Med. grey med to coarse sandstone .	
	75							
	80							
	85							
	90							
	95						95': Slight increase in moisture .	
	100							
	105							
	110						110': Increase in moisture .	
	115						115': Water. Approx. 5 gpm .	
	120						120': Bottom of Well .	

WELL LOG

Location

Page 1 of 2

Well No. ORD-DGW-0 2 Drill Company Duncan Bros. Log By J. Vann

Client CDM (ORD) Driller Jim White Field Book No.

Job No. 192-RI1 -SIGRW Date Began 2/25/86 End 2/26/86 Log Date

Drilling Method Air Rotary Rig Davey

Sampling Method Cuttings Examined No Samples

Casing Size and Type 6-5/8" OD Steel Screen Size N/A Joint Type Screw Pipe Length 29' ~~16 gal.~~/

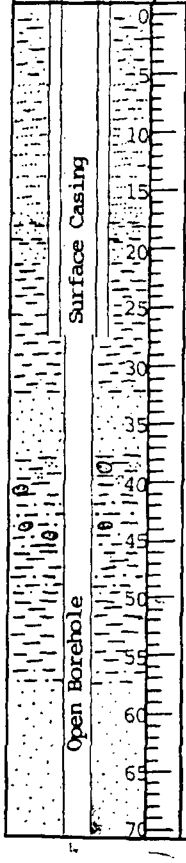
Type of Pack N/A Type of Seal Portland Cement Grout (I/II) 3 bags

Emplacement Method N/A Emplacement Method Annulus filled via tremie pipe

Interval N/A Interval 0-27' (2' stickup)

Development Method Flush with air for 75 min. Gallons Removed ~ 135

Comments

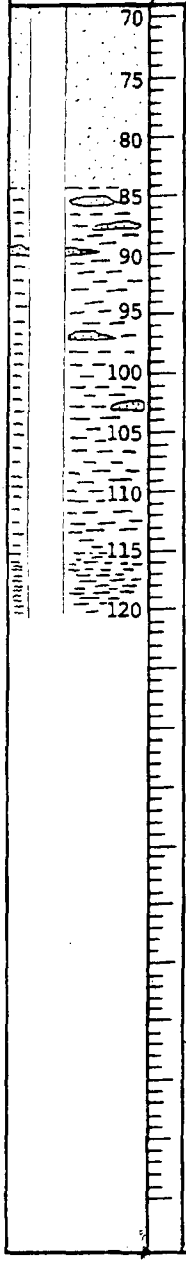


Lithology and Well Construction	Depth (ft)	Sample No.	Interval	Recovery	Blow Counts		Description	Remarks
							3':Brown clayey silt.	
							5':Orange brown friable siltstone.	
							17':Grey sandstone, interbedded with brown shale.	
							21':Grey shale.	
							27':Set 6-5/8" steel casing 0-27'.	grouted annulus. left to set for 15.5 hrs.
							32':Dark grey med grained hard sandstone stained red. possible iron.	
							37':Red claystone/shale, little sandstone.	
							41':Med grey hard, silty shale, trace of dark red, fine sandstone Dry.	
							46':Grey med. hard shale, Some brown claystone. Dry .	
							47':Red, silty shale. Dry .	
							49.5': Dark grey shale and brown claystone. Dry.	Clay content decreases with depth.
							55':Dk grey, silty, hard shale and brown claystone. Damp.	
							57':Dk grey fine sandstone, some water.	

WELL LOG

Page 2 of 2

Well No. ORD-DGW-C2 Client CDM (ORD) Job No. 192-RI1-SIGRW Log By J. Vann



Lithology and Well Construction	Depth (ft)	Sample No.	Interval	Recovery	Blow Counts		Description	Remarks
							62': Dk grey, coarse, brittle sandstone, some clay stone. 84': Grey shale and weakly cemented sandstone. 115': Black soft shale. 120': Bottom of well.	

Location

WELL LOG

Page 1 of 2

Well No. ORD-DGW-03 Drill Company Duncan Bros. Log By J. Vann

Client CDM (ORD) Driller Jim White Field Book No.

Job No. 192-RI1-SIGRW Date Began 2/20/86 End 2/21/86 Log Date

Drilling Method Air Rotary Rig Davey

Sampling Method Cuttings Examined No Samples

Casing Size and Type 6-5/8" OD Steel Screen Size N/A Joint Type Screw Pipe Length 30' 30 ga.

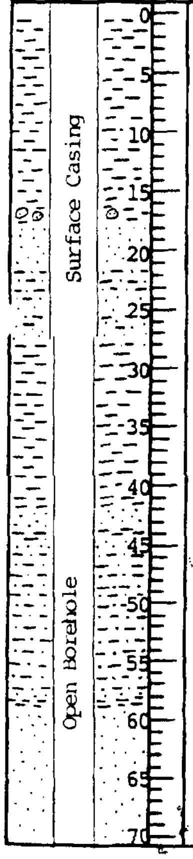
Type of Pack N/A Type of Seal Portland Cement Grout (I/II) 5 bags

Emplacement Method N/A Emplacement Method Filled annulus via Tremie Pipe

Interval N/A Interval 0-28' (2' stickup)

Development Method Flush with air for 50 min. Gallons Removed ~ 400

Comments



Lithology and Well Construction	Depth (ft)	Sample No.	Interval	Recovery	Blow Counts		Description	Remarks
							5': Yellow brn sticky clay.	
							10': Reddish clay.	
							17': Reddish sandy clay, green grey sandstone frags. Dry.	
							18': Green-grey sandstone.	
							19.5': Grey, soft siltstone.	
							21': Reddish soft clay/siltstone. Dry.	
							27': Grey, hard, med. coarse sandstone, some green soft shale.	
							28': 6-5/8" steel casing set 0-28'.	Grouted annu Left to set 15 hrs.
							32': Light green hard shale, some moisture.	
							42': Light green fine sandstone and water (~1gpm).	Interbedded sandstone and shale.
							43': Green shale.	
							44': Green sandstone.	
							45': Grey hard silty shale. Dry.	
							50': Grey soft sandy shale. Dry.	
							58': Lamination of brown clay, then grey, med to coarse brittle sandstone.	
							65': Dark grey, coarse, very hard sandstone with mica.	

WELL LOG

03

Page 2 of 2

Well No. ORD-DGW-01 Client CDM (ORD) Job No. 192-RI1-SIGRW Log By J. Vann

Lithology and Well Construction	Depth	Sample No.	Interval	Recovery	Blow Counts		Description	Remarks
Open Borehole	70						74': Slight increase in moisture.	
	75							
	80							
	85							
	90							
	95							
	100						103': Water, Approx. 8 gpm.	Black, silty insoluble subst in flushed wate Possible coal dust
	105						104.5': Bottom of well.	
	110							
	115							
	120							

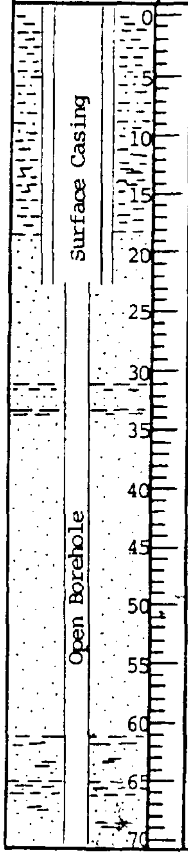
WESTON

WELL LOG

Page 1 of 2

Location

Well No. ORD-DGW-04 Drill Company Duncan Bros. Log By J. Vann
Client CDM (ORD) Driller Jim White Field Book No.
Job No. 192-RI1-SIGRW Date Began 2/21/86 End 2/23/86 Log Date
Drilling Method Air Rotary Rig Davey
Sampling Method Cuttings Examined No Samples
Casing Size and Type 6-5/8" OD Steel Screen Size N/A Joint Type Screw Pipe Length 23'
Type of Pack N/A Type of Seal Portland Cement Grout (I/II) 3 bags 16 gal/
Emplacement Method N/A Emplacement Method Filled annulus via tremie pipe
Interval N/A Interval 0-21'
Development Method Flush with air for 68 minutes Gallons Removed ~ 136
Comments

Lithology and Well Construction	Depth	Sample No.	Interval	Recovery	Blow Counts		Description	Remarks
							5': Yellow-brn soft clay.	
							8': Reddish sandy clay.	
							9.5': Dark grey soft shale, dry.	
							13' Dk grey, med-hard fractured shale. Dry.	Sand content increasing
							17.5:Dk grey,hard fine sandstone Dry.	
							19':Sandstone increasing in particle size to med grained with mica. Dry.	
							21.5':Set 6-5/8 steel casing 0-21.5'.	Grouted annulus Left to set for 21.5 hrs.
							31':Dk grey, coarse hard sandstone. A lamination of brn claystone.	
							33':Lamination of grey claystone in sandstone. Brn claystone.	
							35':Very coarse (+) to med. grained sandstone. Stained brn, prob. from claystone. Dry.	Clay diminished with depth. S.St. weakly cemented
							45':Dk grey, med to coarse grained hard sandstone. Dry.	
							51':Brn stained weak sandstone, some dk grey coarse hard sandstone.	
							54':Increase in moisture.	
							61':Brn claystone and brn stained coarse weak sandstone with shale fragments.	

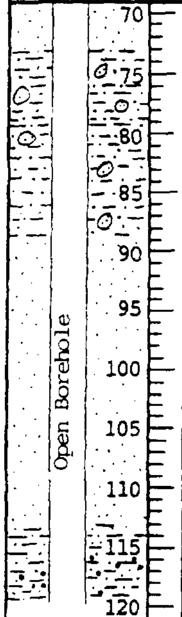
WESTON

WELL LOG

D4

Page 2 of 2

Well No. ORD-DGW-02✓ Client CDM (ORD) Job No. 192-RI1-SIGRW Log By J. Vann



Depth	Sample No.	Interval	Recovery	Blow Counts	Description	Remarks
					62': Brittle black silty shale some brn, coarse sandstone.	
					63': Water (2gpm).	
					65': Dk green-grey, med. grained sandstone.	
					73': Dk grey, silty shale. Some coarse, weak sandstone.	Sand increases with depth
					80': Chunks of sandstone in shale.	
					90': Grey, med. to coarse soft sandstone. Dry.	
					114': Med. grey, soft silty shale some coarse sandstone.	Encountered no further water
					119': Well bottom.	

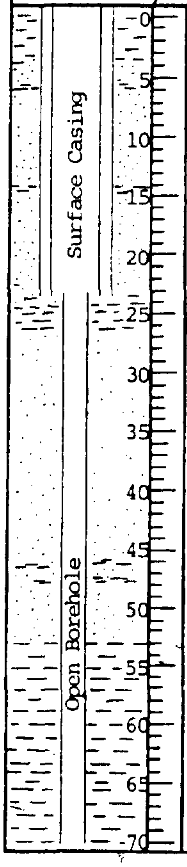
DEP 00792

WELL LOG

Page 1 of 2

Location

Well No. ORD-DGW-0 6 Drill Company Duncan Bros. Log By J. Vann
Client CDM (ORD) Driller Jim White Field Book No.
Job No. 192-RI1-SIGRW Date Began 2/24/86 End 2/25/86 Log Date
Drilling Method Air Rotary Rig Davey
Sampling Method Cuttings Examined No Samples
Casing Size and Type 6-5/8" OD Steel Screen Size N/A Joint Type Screw Pipe Length 23½'
Type of Pack N/A Type of Seal Portland Cement Grout (I/II)
Emplacement Method N/A Emplacement Method Annulus filled via tremie pipe
Interval N/A Interval 0-21½'
Development Method Flush with air for 45 minutes Gallons Removed
Comments

Lithology and Well Construction	Depth	Sample No.	Interval	Recovery	Blow Counts		Description	Remarks
							3': Yellow-brn clay-topsoil.	
							3.5': Blk-grey, med. grained sandstone with mica-brittle. Lesser yellow brn claystone.	
							6.5': Med. grey, brittle, soft med grained sandstone, w/frags. of harder black sandstone. Dry.	
							14': Brn claystone lamination, sandstone.	
							17': Grey-blk sandstone with mica, trace red-yellow staining.	
							19.5': Drk grey fine, brittle sandstone. Dry. Some brn-stained drk grey, coarse sandstone.	Stain prob. du to clay
							21.5': Set 6-5/8" steel casing 0-21.5'.	Grouted annulus left to set 17
							24.5: Brown claystone.	
							26': Sandstone.	
							30': Grey, silty, sandstone. Damp.	
							46': Brownish grey sandstone, some claystone. Damp.	
							47': Grey sandstone.	
							50': Olive grey, med. grained sandstone. Damp.	
							51': Water.	
							53': Saturated, dk grey, soft shale.	Black, insoluble dust

WELL LOG

Page 1 of 2

Well No. ORD-DGW-05 Drill Company Duncan Bros. Log By J. Vann

Client CDM (ORD) Driller Jim White Field Book No.

Job No. 192-RI1-SIGRW Date Began 2/23/86 End 2/24/86 Log Date

Drilling Method Air Rotary Rig Davey

Sampling Method Cuttings Examined No Samples

Casing Size and Type 6-5/8" OD Steel Screen Size N/A Joint Type Screw Pipe Length 23'6" 16 gal.

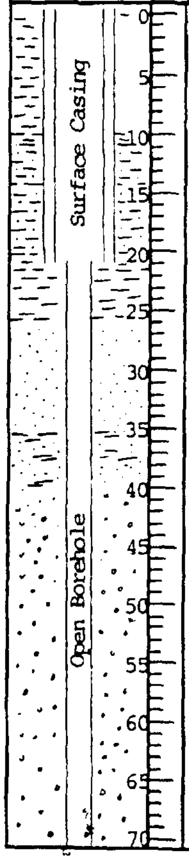
Type of Pack N/A Type of Seal Portland Cement Grout (I/II)3 bags

Emplacement Method N/A Emplacement Method Filling annulus via tremi pipe

Interval N/A Interval 0-21'

Development Method Flush with air for 70 minutes Gallons Removed

Comments



Lithology and Well Construction	Depth	Sample No.	Interval	Recovery	Blow Counts		Description	Remarks
							5':Brn clay topsoil.	
							10': Yellow-brn claystone .	
							11': Green-grey, silty, soft shale some yellow-brn claystone. Dry.	
							14': Green-grey shale, some red silty shale. Dry .	
							15.5': Drk green, soft, silty shale, little hard brn claystone.	
							16.5': Red stained, silty shale and claystone.	
							20': Soft green-grey shale, trace yellow-brn claystone .	
							21.5': Set 6-5/8" steel casing 0-21.5'.	Grouted annulus left to set 16
							25': Green-grey, med. grained sandstone. Dry .	
							35': Drk grey sandstone, some hard green shale.	
							40-41': Brn-stained coarse sandstone. Brittle & Dry.	Brn stain appears to be from clay
							45': Increase in moisture .	
							55': Dry sandstone, as above .	
							64': Water	HNU rdg: < 1ppm above backgrou

WESTON

WELL LOG

Page 2 of 2

Well No. ORD-DGW-06 Client CDM (ORD) Job No. 192-RI1-SIGRW Log By J. Vann

Lithology and Well Construction	Depth	Sample No.	Interval	Recovery	Blow Counts		Description	Remarks
	70						71':Dark grey shale, some olive grey sandstone. 71':Bottom of well.	
	75							
	80							
	85							
	90							
	95							
	100							
	105							
	110							
	115							
	120							

Attachment B - Sampling Standard Operating Procedures

Standard Operating Procedure – 1

Note Taking and Log Book Entries

Materials:

Permanently bound log book (no spiral-bound log books)
Black or blue ballpoint pen (waterproof ink)

Procedure:

1. Use black or blue ballpoint pen with waterproof ink. Felt-tip pens should not be used.
2. Reserve the inside front cover for business cards from key personnel who visit the site (including the person in charge of the log book).
3. On the first page of the log book, place a return for reward notice, ESC's phone number, and the project manager's name.
4. Enter the following on the second page of the log book: project name, project number, project manager's name, onsite contacts, onsite telephone number and address, telephone numbers for all key personnel, and emergency fire and medical telephone numbers.
5. Number each page, initial each page, and put the date at the top of each page. Start a new page for each day. At the end of a day, summarize the day's activities, sign the page, and put a slash through the rest of the blank lines. Start the next day on a new page.
6. Enter the time (in military time, e.g., 0830) in the left column of each page when an entry is recorded in the field notebook.
7. If a mistake is made in an entry, cross out the mistake with one line and initial the end of the line.
8. At all times, maintain the chain of custody on the field log book.

Content:

1. Be sure that log book entries are LEGIBLE and contain accurate and inclusive documentation of project field activities.
2. Provide sufficient detail to enable others to reconstruct the activities observed.
3. Thoroughly describe all field activities while onsite. Be objective, factual, and thorough. Language should be free of personal feelings or other terminology that might prove inappropriate.
4. Describe problems, delays, and any unusual occurrences such as wrong equipment or breakdowns along with the resolutions and recommendations that resulted.
5. Fully document any deviations from or changes in the workplan.

6. Describe the weather and changes in the weather, particularly during sampling events.

7. Sketch a map of the facility or areas onsite where activities are occurring, especially the location of sampling points.

8. During sampling activities, record all information pertaining to the sampling event. Include descriptive locations and diagrams of the sample locations, time, sample media, analysis, sampling procedure, equipment used, sizes and types of containers, preservation and any resulting reactions, sampling identification (especially for duplicate samples), shipping procedures (record airbill numbers), and addresses.

9. Note decontamination or disposal procedures for all equipment, samples, and protective clothing and how effectively each is performed.

10. If possible, photograph all sample locations and areas of interest. Maintain a photographic log in the field log book and include:

    Date, time, photographer, name of site, general direction faced, description of the subject taken, and sequential number of the photograph and the roll number.

11. Record the names and affiliations of key personnel onsite each day.

12. List all field equipment used and record field measurements, including distances, monitoring and testing instrument readings (e.g., photoionization detector (PID), organic vapor analyzer (OVA), pH, conductivity, model numbers, etc.), and calibration activities.

13. Record proposed work schedules and changes in current schedules in the log book.

14. Describe site security measures.

15. Include drum inventory for all investigation-derived waste (IDW) materials generated during site activities. Provide information on how IDW material was labeled.

Standard Operating Procedure - 2

Sample Container, Preservatives, & Holding Times

Scope:

This operating procedure describes the ways and means of selecting the appropriate sampling containers for environmental sampling.

Application:

The purpose of this procedure is to assure that sample volumes and preservatives are sufficient for analytical services required under EPA-approved protocols.

Materials:

Sample containers
Sample container labels
Indelible (waterproof) markers or pens
Clear tape

Procedures:

1. Refer to Table 1 for minimum sample volume and glassware types required for sampling a particular matrix and compound class.

2. Select the appropriate glassware (i.e., bottles or jars) from those provided by the analytical laboratory. Verify that the analytical laboratory has provided the correct number of sample containers and the correct preservatives for the project per the sampling plan requirements.

3. The analytical laboratory should always provide extra sample containers for all analytical parameters in case of breakage or other problems encountered in the field. This is particularly true for VOC sample containers (i.e., 40-ml vials).

4. Report any discrepancies or non-receipt of specific types of sample containers to the Quality Assurance Officer immediately. Arrangements should be made with the laboratory to immediately ship the missing or additional sampling containers to the project site.

5. Apply ESC sample labels to the sample containers.

6. Information on the sample labels should contain the following data:

   Site/Project name
   Project/Task number
   Unique sample identification number
   Sample date
   Time of sample collection (military system, e.g., 0000 to 2400 hours)
   Analytical parameters
   Preservative
   Sampling personnel

7. Once sample containers are properly labeled, the sample labels should be wrapped with clear tape to prevent deterioration of sample label.

8. Proceed with the sample collection per the sampling plan requirements.

9. Collected samples should be immediately placed in an iced cooler to maintain as close as possible a 4°C atmosphere for shipment to the analytical laboratory. Follow sample shipping procedures detailed in Sample Shipping Standard Operating Procedures.

10. Recommended order of sample collection:

    In-situ measurements (e.g., temperature, pH, specific conductance)
    Volatile organic analytes (VOA)
    Purgeable organic carbon (POC)
    Purgeable organic halogens (POX)
    Total organic halogens (TOX)
    Total organic carbon (TOC)
    Extractable organics
    Total petroleum hydrocarbons (TPH)
    Total metals
    Dissolved metals
    Microbiologicals
    Phenols
    Cyanide
    Sulfate and chloride
    Turbidity
    Nitrate and ammonia
    Radionuclides

Standard Operating Procedure - 3

Groundwater Sampling

Materials:

Bound sampling notebook
Groundwater monitoring data log forms
Well key
Adjustable wrench or manhole wrench
Plastic sheeting
Photoionization detector (PID)
Flashlight or mirror
Electronic water level indicator or interface probe
Bailer (bottom loading)
Pump (for purging)
Nylon or polyethylene rope
Temperature, pH, and conductivity meters
Other field meters, as appropriate (i.e., turbidity meter, DO meter, etc.)
Sample bottles, labels, indelible markers, and clear tape
Peristaltic pump
0.45-micron filter
Teflon tubing
Polyethylene tubing
Pocket knife or scissors
Saranex or Tyvek suit (if required by Health & Safety Plan)
Nitrile gloves
Vinyl gloves

Note: To sample using a low flow submersible pump, see SOP-3b.

Procedure:

1. Verify locations of wells, media to be sampled, and parameters to be analyzed for as specified in the sampling plan.

2. Prepare field log book with description of site, weather, participants, and other relevant observations, including all sampling data necessary to complete the groundwater monitoring data log (Refer to SOP-1). Inspect the well for soundness of protective casing and surface ground seal.

3. With the field personnel in Level C personal protective equipment, unless historical data warrants downgrading to Level D protective equipment, survey around the base of the well and wellhead with a PID; remove well cap, place probe of PID in wellhead, and record PID response in field book. Survey breathing zone to ensure that the level of personal protection is appropriate. Note observations on the groundwater monitoring data log.

4. Check for floating product layer (LNAPLs) and sinking free product layer (DNAPLs). Measure thickness with an oil/water interface probe in accordance with EPA or state guidance documents or requirements. (If NAPL sampling is required, see the sampling procedures in SOP-3a).

5. Measure the casing inside diameter (CID) and record in inches. From the top of the casing, measure the depth (in feet) to water (DTW) with an electronic water level indicator and record in the field log book. Static water level measurements must be recorded from the surveyor's mark at the top of the casing, if present. If no mark is present, mark a location with a metal file or indelible marker on the casing for future reference. Measure and record the total depth (in feet) (TD) of the well.

6. Monitoring wells should be sampled by starting with the upgradient (or clean wells) and proceeding downgradient (in the order from most to least contaminated wells) for the remaining monitoring wells.

7. Calculate the length of the water column in the well casing:

   length = (TD - DTW)

   Calculate the volume of water in gallons in one well casing:

   For a 2-inch well: or $vol=0.041\ d^2h$

   vol = [(TD - DTW) * 0.16] where: h = TD-DTW

   For a 4-inch well: d = diameter of well

   vol = [(TD - DTW) * 0.65]

   For a 6-inch well:

   vol = [(TD - DTW) * 1.47]

   or calculate the volume using the formula:

   $vol = (TD - DTW)(CID)^2(0.041)$ CID=casing inside diameter in inches

9. Remove a minimum of three well volumes before sampling. To determine the number of gallons required to purge the well, multiply the number of gallons in one well volume (calculations above) by three. Record the minimum purge volume in the field log book. Record water color, suspended particulates, discoloration of casing, casing diameter and material, any unusual occurrences during sampling, and any pertinent weather details in the field log book.

10. Place plastic sheeting around the well before beginning purging process. Once plastic is around well, the purging process may begin. Do not allow the bailer rope to come into contact with the ground surface (i.e., keep the rope on the plastic). Keep the plastic as clean as possible.

11. Carefully lower the bailer attached to bailer cord into the well and allow the bottom to sink 1 foot below the water surface to capture surficial water only. Remove bailer and inspect it for LNAPL. If any are found, or if sampling plan requires, secure samples of the LNAPL in accordance with SOP-3a for analysis if sufficient volume is present. Place collected samples on ice. DO NOT PURGE OR SAMPLE GROUNDWATER IN WELL CONTAINING LNAPL.

12. During the purging process, geochemical measurements (e.g., pH, conductivity, turbidity, and temperature) should be collected a minimum of four times (i.e., before purging and after the removal of each well volume). Record these data in the field log book.

13. Continue bailing at a uniform rate. Each time, empty the bailer into a calibrated container for measurement. Dispose of the contents in an appropriate container for later disposal in compliance with federal and state laws.

14. A decontaminated submersible pump may be used in place of a bailer to purge wells when the diameter of the well is large or the purge volume is large. Refer to SOP-16 for submersible pump decontamination procedures.

15. If well is bailed dry before removing three well volumes, allow well to recharge and proceed to sample. Wells shall not be bailed dry if doing so will cause recharge water to enter the well in a cascading fashion but instead will be bailed at a rate which will minimize the agitation of recharged water. If full recovery exceeds 2 hours, sample as soon as sufficient volume is available within 3 hours of purging.

16. After the minimum purge volume has been removed, review the geochemical measurements to ensure that readings have stabilized. Readings should be within 10% of the previous reading. If the geochemical measurements have not stabilized, continue to purge the well until the monitoring parameters do not vary more than 10 percent between two successive well volumes removed.

17. Affix a sample label to each sample container and complete all required information (sample no., date, time, sampler's initials, analysis, preservatives). Place clear tape over the label. Record sample number, well number, date, time, and the sampler's initials in the field book.

18. Collect the groundwater samples after purging is complete. While collecting samples, lower the bailer slowly to avoid agitating the water. Sample first for VOCs, taking care to remove all air bubbles from the vial and minimize agitation. Collect remaining organic samples then inorganic samples.

    The recommended order of sample collection is as follows:

    In field measurements (e.g., temperature, pH, specific conductance, turbidity, dissolved oxygen)
    Volatile organic compounds (VOCs)
    Purgeable organic carbon (POC)
    Purgeable organic halogens (POX)
    Total organic halons (TOX)
    Total organic carbon (TOC)
    Extractable organics
    Total metals
    Dissolved metals
    Phenols
    Cyanide
    Sulfate and chloride
    Turbidity
    Nitrate and ammonia

Radionuclides

19. Thoroughly decontaminate all equipment used before proceeding to the next well. Discard used bailer cord, plastic sheeting, towels, gloves, etc., in a plastic bag.

20. Complete chain-of-custody forms with appropriate sampling information.

21. Complete both front and back of the groundwater monitoring data log (attachment) for each monitoring well or sampling point upon return from the field, using data from the field log book.

Filtering of Metal Samples:

1. Assemble peristaltic pump per operating manual instructions, which accompany pump.

2. At the pump intake, attach polyethylene tubing to the tubing at the head of the peristaltic pump. The polyethylene tubing should be long enough to extend to the bottom of the bailer. At the pump discharge end, attach a clean 0.45-micron filter (or appropriate sized filter) to the Teflon tubing.

3. Turn on the pump and draw the water from the bailer, through the pump and filter, and into the sample container.

4. Disassemble the pump head and discard the polyethylene and Teflon tubing and filter in a plastic bag.

Attachment 1 – Groundwater Monitoring Data Log

Found on next page

May 2000

Groundwater Monitoring Data Log

Well No./Designation ____________________ Date: ____________________

Site Data

Site Name: ____________________ ESC Sampling Team ____________________

Site Address: ____________________ ESC project No.: ____________________

Weather Conditions: ____________________

Well Description

Well Location: ____________________

Well Security: ____________________

Casing Material: Inner ____________________ Outer ____________________

Organic Vapors (PID, OVA, TIP): Wellhead ____________________ ppm

Breathing Zone ____________________ ppm

Nonaqueous Phase (thickness): ____________________

Reference Point (e.g., top of PVC casing): ____________________

Purge Data

Purge Method: ____________________

(Note: Allow water level to equilibrate after removing well cap)

Total Well Depth (TD): ____________________ ft Depth to Water (DTW): ____________________

Casing Inner Diameter (CID): ____________________ inches

To calculate well volume: Well Vol.(gal)=$(CID)^2(0.04)(TD-DTW)$

Well Volume: _______________ gal x 3=Purge Volume _______________ gal

Purge Time: Begin _______________ End _______________

Prepurge Data: Temp _______ pH _______ Spec. Cond.______________Turb. ____________Other ________

Volume 1: Temp _______ pH _______ Spec. Cond.______________Turb. ____________Other ________

Volume 2: Temp _______ pH _______ Spec. Cond.______________Turb. ____________Other ________

Volume 3: Temp _______ pH _______ Spec. Cond.______________Turb. ____________Other ________

Volume 4: Temp _______ pH _______ Spec. Cond.______________Turb. ____________Other ________

Volume 5: Temp _______ pH _______ Spec. Cond.______________Turb. ____________Other ________

Volume Purged: ______________________ Purged Dry: Yes No

Disposal Method for Purgewater: ____

Water Description

Odor: Prepurge ______________________________ Postpurge ______________________________

Color: Prepurge ______________________________ Postpurge ______________________________

Sampling Data

Sampling Method: ____

Sampling Time: Begin ____________________________ End ______________________________

Analytical Parameters (circle appropriate parameters):

VOCs BNA BNE Total (Unfiltered) Metals

Dissolved (Filtered) Metals TPH PCB Cyanide

Other: ____

____

Comments: ____

____

____

May 2000

Standard Operating Procedure - 4

Surface Water and Sediment Sampling (using hand trowel)

Surface Water Sampling

Materials:

Nitrile gloves
Saranex or Tyvek suit
Vinyl gloves
Bulldog boots
Hip-waders
Sample containers
Sample labels and indelible marker
Bound field log book

Procedure:

1. Collection of surface water samples should be completed before collection of the stream sediment samples from the same location. This procedure will eliminate the introduction of sediment and turbulence in the surface water that is to be sampled.

2. The sampler should wear hip-waders or rubber boots and gloves, or Saranex or Tyvek sleeves duct taped onto nitrile gloves, to avoid dermal contact with the surface water.

3. Extreme caution should be exercised when wading into the stream at the sampling location to minimize disturbance of the fine sediments.

4. Because of possible unseen water hazards, two people should be present during the collection of surface water samples.

5. If collecting several surface water samples from the same surface water body, start sampling at the downstream location and progressively move upstream. The sampler should always face upstream (i.e., upcurrent) when collecting the surface water sample.

6. The surface water sample container should be placed into the flowing water and the sample should be collected from just beneath the stream surface.

7. The sample container should be labeled before sample collection. After the sample is collected, the container should be sealed, and placed into a cooler for shipment to the analytical laboratory.

8. The sampling location should be described, including width of stream, depth of stream, water color, and approximate surface flow (e.g., slow, fast moving, etc.).

9. Sampling locations should be marked with a stake or flagged for future reference. Locations should be recorded with respect to a permanent feature, if available.

10. Complete chain of custody form with appropriate sampling information.

11. If collecting sediment samples, proceed to collect the sample from this location.

Sediment Sampling

Materials:

Hand trowels (stainless steel or Teflon)
Nitrile gloves
Vinyl gloves
Tray, mixing pans, Ziploc® plastic bags
Stainless steel or Teflon spoons
Aluminum foil
Saranex or Tyvek suit
Hip-waders of rubber boots
Sample containers
Sample labels and indelible marker
Bound field log book

Procedure:

1. The hand trowel can be used to sample shallow stream bottom sediments, where the depth of water does not exceed 1 foot, using the same procedures specified in the Standard Operating Procedures for Collection of Soils Samples Using a Hand Trowel. The sediment corer or other appropriate sampling device should be used in water deeper than 1 foot (see SOP-6).

2. The sampler should wear hip-waders or rubber boots and gloves, or Saranex or Tyvek sleeves duct taped onto nitrile gloves, to avoid dermal contact with the water.

3. Extreme caution should be exercised when wading into the stream at the sampling location to minimize disturbance of the fine sediments.

4. If collecting several sediment samples from the stream, start sampling at the downstream location and progressively move upstream. The sampler should always face upstream (into the current) when collecting the sediment sample.

5. Insert the trowel into the sediment bed and retrieve sediment. Carefully remove the trowel from the water to avoid washing sediment from the blade. The trowel blade should be tilted at a slight angle, if necessary, to drain excess water from the blade before placing the sediment in the mixing tray.

6. If more sediment is needed to provide sufficient sample volume, reinsert trowel at the sample location and retrieve as before.

7. Examine contents of tray. For volatile organic compound (VOC) samples, do not mix the sediment sample in the tray. Transfer sediment directly into sample containers, choosing your sample from various portions of the tray to simulate homogeneity.

8. After the collection of VOC samples and before filling other sample containers, mix the contents of the tray so a homogeneous texture remains.

9. Transfer the tray contents to the sample containers.

10. The sample container should be labeled before sample collection. After the sample is collected, the container should be sealed, wiped clean of excess sediment material, and placed in a cooler with ice or freezer packs for shipment to the analytical laboratory. Complete chain-of-custody form with appropriate sampling information.

11. The sampling location should be described, including width of stream, depth of stream, water color, and approximate surface flow (e.g., slow, fast moving, etc.).

12. Sampling locations should be marked with a stake or flagged for future reference. Locations should be recorded with respect to a permanent feature, if available.

Attachment C - Inspection Checklist Logs

Inspection Checklist
Operable Unit 1
Morgantown Ordnance Works Site
Morgantown, West Virginia

DATE:________**TIME:**________ **INSPECTOR:**____________**WEATHER CONDITIONS:**______________________________

Item	OK	Requires Maintenance	Comments
Cap System – Quarterly			
Adequate grass coverage on all portions of soil cover system			
Soil cover areas are free of ponding surface water			
Soil cover system does not have areas of significant differential settlement			
No woody plants developing on soil cover			
Protective soil cover layers are free from erosion ruts caused by surface water runoff			
No evidence of soil-dwelling animals disturbing the protective soil cover layers			
Grass cover has been mowed (twice per year)			Date mowed last: by:
All areas of slope remain stable with no apparent slides or slope failures			
Site fence extends to within 6 inches of ground surface with no large gaps caused by erosion or animals			
Site fence and barbed wire are completely intact and upright with no damage from tree limbs or soil erosion			

Item	OK	Requires Maintenance	Comments
Wetlands - (see Section 3.2 for inspection frequency)			
Retention of 80 percent of the original wetland replacement system (1.05 acres) and 80 percent of desirable species			
Current condition supports structure and function of the original wetland replacement system			
Predominance of desirable, nuisance, and native hydrophytes within acceptable range.			
Occurrence of wildlife and potential for exposure to residual leachate in treatment wetland system			
Erosion or sedimentation within acceptable limits.			

Appendix E – Conceptual Design Passive Leachate Treatment System

FINAL

CONCEPTUAL DESIGN
PASSIVE LEACHATE TREATMENT SYSTEM

MORGANTOWN ORDNANCE WORKS, OPERABLE UNIT 1

Morgantown, Monongalia County, West Virginia

Prepared For:

Environmental Strategies Corporation
Four Penn Center West, Suite 315
Pittsburgh, PA 15276

Prepared By:

David C. Hails, Robert Hedin, Ph.D and Joel Toso, Ph.D, P.E.
Ecological Restoration, Inc.
Administrative Office
311 Crooks Drive
Apollo, PA 15613

July 6, 2001

Mow\457302\Wetlands Report\Morgantown Treatment Wetland Design.doc

Table of Contents

Figures

Tables

Attachments

1.0 Introduction

A final Design Report is required to implement the selected remedial action pursuant to the Record of Decision (ROD) for the Morgantown Ordnance Works (MOW), Operable Unit 1 (OU-1), located in Monongalia County, West Virginia (see Figure 1). Previous Remedial Investigations (RI) conducted for OU-1 indicated that metals and polynuclear aromatic hydrocarbons (PAHs) were the primary constituents of concern at the site. Currently, leachate from an onsite landfill is discharging to Swale 3, that ultimately discharges to the Monongahela River. The onsite landfill will be capped with an impermeable liner. Although the new cap system should eliminate the leachate by diverting the water and preventing it from infiltrating into the landfill, there will be an unknown period until the water flow from the toe is eliminated. As a result, the current cap design has a provision for a drain system to avoid any geotechnical failures of the cap due to water buildup along the toe. That water will be collected and will need to be treated before discharge to Swale 3.

Ecological Restoration, Inc. (ERI) was contracted to develop a system to passively treat any water collected by the drain system at OU-1. A passive treatment system is recommended as an alternative to conventional pump and treat systems at the OU-1 facility. Passive treatment incorporates a more natural approach and does not require electrical service or significant maintenance. Initial costs for construction of the passive system may be similar to conventional systems, but the operational and maintenance costs will be much lower. Figure 2 shows the proposed location for the passive treatment system. This report contains the results of the evaluation of the site data, and the development of a treatment strategy and conceptual design for a passive treatment system.

Passive treatment systems have proven effective as both primary and secondary treatment for metals in surface water. The systems are specifically designed on a site-specific basis. Because no two sites are the same and the technology is relatively new, these systems are still considered experimental. Best management practices were used in developing this innovative technology based on a review of the current literature (Gusek, 1998; Dvorak et al, 1992;, Jarvis and Younger, 2001; and, Nuttall, 2000). Dr. Robert Hedin, a member of the design team, was instrumental in developing the technology during work he conducted for the U.S. Bureau of Mines and is considered a expert on the subject of passive water treatment. Dr. Hedin designed the system that is proposed for OU-1 using knowledge of how the various constituents interact with treatment media, their synergistic effects, the uptake potential of the system, and other factors. The design is based on flow and concentrations of the constituents of concern. These systems are designed to require minimal maintenance, but are not maintenance free.

In addition to Dr. Hedin, who developed the treatment strategy and the calculation of its functional parameters, other design team members provided input to the conceptual design. Dr. Joel Toso P.E./P.H. and an expert hydrologist, fit the system into the existing and proposed topography and prepared pertinent design drawings based on Dr. Hedin's strategy and calculations. Dave Hails, a Certified Ecologist, selected the appropriate plant species to use, provided general construction recommendations, and coordinated the preparation of this report. Resumes of the project team are provided as Attachment 2.

2.0 Water Characteristics of the Leachate

Until the landfill is capped, the water chemistry and flow of leachate only can be estimated for the design of the passive treatment system. For the purpose of the evaluation, samples were collected in January, 2001 in Swale 3. Swale 3 is located immediately downgradient of the proposed leachate pipe and currently receives leachate from the landfill. The treatment strategy was based on these data. However, once the cap is installed, there should be a significant reduction in infiltrating water that would result in a decrease in leachate production from contact with the constituents of concern. Flow rates are also difficult to predict, but are expected to be minimal once the cap is installed (elimination of water infiltration from rain events). A rate of five gallons per minute (gpm) was used as the design standard for this system based on professional engineering judgement and existing hydrological conditions.

Based on a comparison to water quality criteria, the constituents of concern include aluminum, iron, manganese, copper and zinc.. The water quality criteria used for comparison are based on applicable Category B1 (warm water fishery stream) criteria for the protection of aquatic life per Section 6.3(a) of Title 46 Series 1 Requirements Governing Water Quality Standards. Criteria of 0.087 mg/L aluminum, 1.5 mg/L iron, 0.080 mg/L manganese, 0.0416 mg/L copper, and 0.369 mg/L zinc were used to determine the constituents of concern for this waste stream. The criteria listed above for copper and zinc are calculated based on the hardness of the sample, which should range from 25 mg/L to 400 mg/L. The average hardness of the samples collected at the MOW site was 436 mg/L. The equations for calculating total copper and zinc criteria are as follows:

$$\text{Total Copper} = e^{(0.8545[\ln(\text{hardness})]-1.465)}$$

$$\text{Total Zinc} = e^{(0.8473[\ln(\text{hardness})]+0.7614)}$$

The data from four samples collected in January, 2001 from Swale 3 are provided in Table 1 These samples were designated fence, middle, toe, and upper (from downstream to upstream). Toe and upper were duplicate samples that were taken at the same location. Figure 3 shows the sampling locations. All samples were found to be alkaline and contained elevated concentrations of zinc, iron and manganese. Copper concentrations were elevated in the toe and upper samples and at or near detection limits for the middle and fence samples. Slightly elevated concentrations of aluminum in the toe sample are likely due to solids within the sample and are not of concern. Under the existing alkaline conditions, aluminum is highly insoluble. The upper/toe samples are likely the most representative of the proposed leachate to be treated with the passive system. These samples are nearest the proposed leachate discharge. The other samples are within the existing wetland. It is possible that the existing wetland is currently functioning as a filter and reflects the elevated concentrations of constituents at these locations. These do not appear representative of what we can expect from the leachate, thus the design was based on the samples represented by the upper/toe locations. For example, 10 mg/L of zinc (rounded up from the 7.2 and 8.2 mg/L readings from the upper and toe samples, respectively) was used in the evaluation of treatment strategies and not 35 mg/L of zinc. Trace constituents such as mercury, lead, nickel, arsenic and chromium may also be polished by the proposed passive treatment system.

3.0 Treatment Strategies

A constructed wetland system was chosen to treat the landfill leachate at the MOW site for a number of reasons. These systems can reduce metals to low levels, are reliable and relatively inexpensive to operate, and they minimize the amount of toxic waste that requires final disposal.

The recommended treatment strategies contained in this design report are based on studies of existing systems treating waste streams containing elevated metals concentrations. Specifically, systems in the Appalachian coal fields constructed to treat mine drainage contaminated with iron and aluminum (extensively evaluated and published by Hedin et al., (1994) for mine drainage), were used as models for this design. Other systems designed by ERI and reported in various publications show that the technology is effective for decreasing numerous trace metal concentrations including cobalt, copper, nickel and zinc to levels below ambient water quality criteria standards.

General Performance

Constructed wetland systems have been studied to determine their ability to remove metals from a variety of waste streams. Several of these studies and ERI's experiences with similar systems are discussed below. Although the sites included in these studies do not have identical characteristics to the MOW site, the data obtained from these studies can provide justification for the design of the MOW system.

Design Comparisons

The design of the MOW treatment system includes three components. The waste stream first enters a subsurface constructed wetland for pretreatment, flows into a vertical flow pond for metals removal, then is polished by a final subsurface flow constructed wetland.

The iron and solids present in the waste stream are expected to precipitate in the first constructed wetland component of the system. Under anaerobic conditions, ferric iron, or Fe (III) is reduced to soluble ferrous iron, or Fe (II). This soluble form of iron is expected to enter the wetland where it will combine with sulfide (sulfate is present in the substrate or produced by microorganisms), forming relatively insoluble ferrous sulfide. Although ferrous iron is expected to be the predominant species of iron, ferric iron may also be present in the waste. Bacteria that derive their energy from the oxidation of reduced iron, producing ferric hydroxide and removing iron from the waste stream, may be present in the wetland. These bacteria inhabit the region of the wetland where the surface waters and reduced sediments meet (Kadlec and Knight, 1996). Since the iron treatment efficiency of constructed wetlands was found to correlate directly with the area of a treatment wetland and inversely with wetland depth, this component of the treatment system will be a shallow wetland (Kadlec and Knight, 1996). The design of the vertical flow pond includes an organic substrate underlain by a layer of crushed limestone, commonly used to introduce alkalinity into waste streams. To ensure that the system functions properly, the drain must be anoxic to prevent clogging by metals that will precipitate in the presence of oxygen (CDPHE, 2000). Under these anaerobic conditions, sulfate-reducing bacteria will use carbon and sulfates to produce sulfides. The sulfides then combine with heavy metals to form metal sulfides, which are relatively insoluble (CDPHE, 2000). Metals bound to sulfides are often not bio-available and remain buried in the sediments unless disturbed (EPA, 2000). Metals will also adsorb to the substrate to form insoluble complexes with organic material. It should be noted that these treatment systems should be constructed in unpopulated areas since excess hydrogen sulfide may be produced, causing undesirable odors. Copper and zinc will be removed from the waste stream in this component of the system. Following treatment in the pond, the waste will enter the polishing wetland where any remaining metals will precipitate. These metals may precipitate under aerobic conditions, near the surface of the wetland and surrounding the plant roots, or in the anaerobic zones depending on the type and species of the metal. This second polishing wetland was also designed to remove BOD from the waste stream. The substrate present in the system may initially contribute BOD to the waste stream. After the initial start-up of the system, the effluent BOD concentrations are expected to be minimal.

Aquatic Macrophyte Selection

Cattails, or *Typha,* will be planted in the two subsurface flow wetlands for the MOW system. Research conducted by Lan et al. (1992) found that *Typha* appears to possess a resistance to high concentrations of zinc in wastewater. However, the authors also state that concentrations of zinc greater than 1.6 mg/L would affect plant growth. In practice, ERI has found that cattails have the ability to acclimate to relatively high concentrations of metals, especially when the wetlands are planted with cattails and heavily seeded.

Zinc Reduction Data

In general, studies show that metals are often easily sequestered in wetland sediments and biota (Mitch and Gosselink, 1993). The zinc retained in wetlands is typically transferred to soils or wetland substrates (80 %) and fine roots (17%) (Kadlec and Knight, 1996). A study by Dvorak et al., (1992) indicates that bacterial activity and physical removal processes reduced influent zinc concentrations of 317 mg/L to 0.3 mg/L in anaerobic reactors filled with spent mushroom compost. Similar results have been obtained using full-scale treatment systems. Table 2 summarizes the ability of several wetland systems to remove zinc from waste influents. The systems listed in this table received influent waste streams containing between 0.8 mg/L and 34 mg/l zinc.

Toxicity Data

A study completed by Gillespie et al. (2000) noted that the removal of zinc in their treatment wetlands included the transformation of toxic soluble forms of zinc to less soluble nontoxic forms. This transformation reduced the zinc toxicity by 54-73% between the wetland inflow and outflow. The authors noted that although the zinc removal efficiencies of their system was less than other reported reductions (additional studies report zinc removals in excess of 75%), the zinc toxicity of the wastewater was significantly reduced.

ERI Experience

Members of the ERI design team have experience designing and constructing treatment wetland systems with operational requirements similar to the system designed for the MOW site. Dr. Hedin has been involved in the construction of numerous treatment systems consisting of constructed wetlands and vertical flow ponds used to treat waste streams containing zinc. ERI also has experience with a similar system, located in Shasta County, California, designed to treat metal-contaminated discharge from copper mines. This system was built in 2000 and consists of a constructed wetland and vertical flow pond (Hails, 1999). Another treatment wetland, located in Pennsylvania, was designed and constructed by ERI to treat acid mind drainage. This system, consisting of a 7,500 ft^2 vertical flow pond followed by a 5,400 ft^2 constructed wetland, is similar to the second and third components of the system designed for the MOW site. Although zinc was not the primary constituent of concern for this waste stream, consistent zinc concentration reductions of 96% were found in the vertical flow pond component of this site. A summary of data collected at this site is provided as Attachment 2 (Hedin, 1997).

Seasonal Performance

In general, studies have shown that constructed wetland treatment system's functionality may slightly decrease as temperature decreases during the winter. Although the functionality may decrease, reactions taking place in the wetland substrate will continue during all seasons since decomposition and microbial activity generate heat, keeping the substrate from freezing (USDA-NRCS and US EPA).

Specifically, Buttersworth et al. (1999), found that the removal of zinc by constructed wetlands may not be sensitive to temperature changes for several reasons. Due to the small fraction (about 1%) of zinc that will be absorbed by wetland plants, the seasonal cycle of plant growth and senescence will have little effect on zinc removal by the wetland. The authors also found that although the level of microbial activity in the wetland was directly related to seasonal temperature fluctuations, the zinc removal was unaffected by the change. This study (Buttersworth et al., 1999) revealed that during the warmer months, zinc reduction occurred by sulfide precipitation mediated by the microorganisms in the system and during the colder months, zinc reduction occurred through adsorption and exchange with the wetland substrate. Although the processes occurring in the wetland may change seasonally, zinc removal efficiencies are expected to remain relatively consistent.

Wildlife Health

The system designed for the MOW has an open water component and two subsurface flow wetlands. As the waste passes through each component of the system, the concentration of the contaminants will decrease. Wildlife will not have direct access to the waste stream in the subsurface flow wetlands after adequate plant cover has been established. Metals are expected to adsorb to the sediments in the wetland and to a lesser degree be incorporated into the biomass of wetland macrophytes. However, the concentration of metals absorbed by the plants depends on the metal species and the plant type (EPA, 2000). As stated above, the plants will assimilate only a fraction (17%) of the zinc present in the waste. Additionally, the zinc contained in the biomass of the plants is typically located in the below ground portions of the plants (Mulamotil et al., 1999). Although wildlife may have access to the shoots of the plants, the metals concentration in the plants is expected to be minimal (Buttersworth et al., 1999; Mulamoottil et al., 1999.; Kadlec and Knight, 1996). Additionally, zinc does not appear to biomagnify in the food chain (Kadlec and Knight, 1996). The only direct access to the waste stream will be in the vertical flow pond component of the system. The total concentrations and the toxicity of zinc are expected to decrease significantly in this component of the system.

Wildlife Nuisance

In some cases, mechanical protection may be needed to prevent significant damage to newly established wetland plants by animals such as Canada geese, deer, blackbirds and muskrats (USDA-NRCS and US EPA). In ERI's experience, damage to cattail shoots and seedlings have not been a significant problem since cattails are a large and aggressive plant species.

4.0 Conceptual Design

The recommended passive system is based on an assumed flow of five gpm containing 10 mg/L zinc, 8 mg/L iron, 1 mg/L copper, and 1 mg/L manganese. Lower metal loadings will decrease the size of the system in an approximate linear fashion. Because of the difficulty in modifying the size of an installed passive treatment system, it is recommended that the design assumptions utilize the above conditions, which represent the best available information on the current leachate quality.

The system should discharge water with iron, zinc, manganese and copper at concentrations less than 1 mg/L. During the first 1-2 months of operation, the system may discharge discolored water due to the initial flooding of the organic substrate. It is also common for iron and manganese removal to increase after the initial 1-2 month start-up period.

The conceptual design for the passive treatment system is based on stormwater bypassing the system for optimal system operation. Figure 4 shows a plan view of the system. Individual components of the treatment system are discussed in the following sections.

Primary Treatment, Subsurface Flow Wetland

The purpose of the first constructed wetland is to precipitate all solids that require only retention. Iron, the principal target, will readily oxidize and precipitate as iron oxyhydroxide when present in an alkaline environment.

$$Fe^{2+} + \frac{1}{4}O_2 + 2HCO_3^- \rightarrow FeOOH + \frac{1}{2}H_2O + 2CO_2$$

At moderate concentrations of iron (as exist at OU-1), 24 hours of retention in a shallow water wetland environment is recommended. Assuming a flow rate of five gallons per minute, the total volume of leachate discharged per day was calculated to be 973 ft^3 waste/day. The volume of leachate was then divided by the depth of the wetland (6 inches), to yield a surface area of 1925 ft^2. However, based on a porosity of 50 percent, it is necessary to double this surface area to account for the plants and substrate present in the wetland. The calculated surface area of 3850 ft^2 was increased to 4,000 ft^2 adding a safety factor to the design.

Water from the leachate collection system will be discharged directly into a subsurface gravel layer of this wetland system. The design size of this wetland will be 4,000 ft^2 to incorporate a flow-variable safety factor, and will have subsurface flow through the gravel layer. All soils underlying the wetland must be thoroughly compacted on twelve-inch lifts and contain sufficient clay material to prevent the entire system failing due to leakage. Foundation fill should not include stumps or other organic debris or rocks larger than six inches in diameter. The surface will contain an organic substrate of high-quality topsoil or leaf compost, or a mixture of the two. The outlet pipe from the wetland should be adjustable to allow for the period of plant establishment. The water level should be set at the substrate surface to allow for complete saturation of the compost. Initially, some surface water may be visible, but as the plants grow, it will be less visible. A detail for the wetland treatment system is shown in Figure 5.

A mixture of *Typha latifolia* and *Typha angustifolia* (wide and narrow leaf cattails) will be used in this system. These species have proven to be most effective in other systems that ERI has built. Planting of mature plants on one-foot centers is required for establishment. Seeding is also required at a rate of two pounds per 1000 ft^2. Success of plant establishment will be evaluated during the monitoring periods. Planting and seeding should occur in early spring. At the end of the first growing season, coverage should be at 70 percent or greater. If less than 70 percent coverage is attained (density minimum two plant shoots per ft^2), seeding and planting should again occur early the next spring.

Secondary Treatment, Vertical-Flow Pond

The purpose of the vertical flow pond is to remove zinc and copper through their precipitation as sulfide and carbonate solids. Sulfide will be generated in the pond through bacterial sulfate reduction. Carbonate will be generated through bacterial activity and limestone dissolution. Bacterial sulfate reduction occurs optimally under anoxic, neutral pH conditions within a fertile organic substrate where sulfate concentrations exceed 50 mg/L. The simplified reaction is:

$$SO_4^{2-} + 2CH_2O \rightarrow H_2S + 2HCO_3^-$$

where CH_2O represents simple organic compounds. Rates of sulfate reduction in natural systems range from 50 to 300 millimole (mmol) per cubic meter (m^3) of substrate per day. The variation is generally temperature related, with the lower rates occurring at low temperature. Limestone dissolution occurs as follows:

$$CaCO_3 + H_2CO_3 \rightarrow Ca^{2+} + 2HCO_3^-$$

Dissolved zinc and copper are removed by their reaction with sulfide to form zinc sulfide and copper sulfide, and by their reaction with carbonate to form $ZnCO_3$ and $CuCO_3$.

The maximum estimated zinc and copper loading at the OU-1 is approximately 5,000 mmol per day (five gpm flow containing 35 mg/L of zinc and 1 mg/L of copper). Assuming the low range of sulfate reduction rates (50 mmol m^{-3} d^{-1}), then 100 m^3 of substrate are required. This is equivalent to 3,500 ft^3 of substrate.

This volume of material placed two feet deep has a surface area of approximately 1,750 ft^2. Assuming that the organic substrate is overlain with two feet of water, then the surface area of the vertical flow pond would be approximately 3,000 ft^2. This surface area is based on a slope of 4:1 and includes a flow-variable safety factor.

All soils underlying the vertical flow pond must be thoroughly compacted on twelve inch lifts and contain sufficient clay material to prevent failure of the system due to leakage. Foundation fill should not include stumps or other organic debris or rocks larger than six inches in diameter.

Removal of metals through the formation of carbonate solids will be promoted through the incorporation of calcitic limestone (greater than 85 percent $CaCO_3$).The underdrain system will be constructed with limestone aggregate. The organic substrate will be amended with limestone gravel to improve permeability and provide an additional source of carbonate. Therefore, the vertical flow pond consists of a flooded layer (two feet thick and equal to approximately 200 cubic yards) of alkaline organic substrate consisting of 100 percent leaf compost, and underlain by a bed of limestone (AASHTO #1) aggregate that contains a perforated pipe underdrain at the base of the system. Water flows into the pond's surface, down through the organic substrate, through the limestone aggregate, and into the underdrain collection system to the polishing wetland (see Figures 6, 7 and 8). Limestone for vertical flow pond or for mixing with the compost will have a calcium carbonate content of 85 percent or greater.

As water flows through the organic substrate, microbial reactions will decrease concentrations of zinc and copper. The vertical flow pond will require 3,000 ft^{2}of surface area and six feet of hydraulic head for the system to operate properly. The hydraulic head of six feet includes the compost and gravel layers. Thus, each of the water, compost, and gravel layers will contain two feet of hydraulic head for a total of six feet.

Although an open water component is less desirable due to the potential for attraction of wildlife, a two-foot layer of open water is necessary for the system to function properly. The purpose of the open water layer is to ensure an anoxic environment is present for removal of copper and zinc. Plants will not be present in this component of the system because oxygen releases from their roots would create small aerobic zones in the system. This open water layer is also necessary to create the pressure necessary to force the wastewater down through the anoxic sediments and limestone drain. This open water design is the least expensive in terms of construction and maintenance costs. Interaction with the atmosphere for this component is not necessary. Options for this component include covering the system with a synthetic material similar to those used at wastewater treatment facilities or using an enclosed tank. A buried tank will need a removable top in the event clean-out is necessary.

Tertiary Treatment, Polishing Wetland

This wetland will provide polishing of remaining residual metals and BOD from the system. It will also be an important component during the initial start-up of the system before the plants and microbial populations in the first two systems are established. This polishing wetland will also provide an overall safety factor for the design of the system. The polishing wetland design will be the same as the primary treatment wetland (see Figure 5), requiring 4,000 ft^2 of surface area (calculated at 3,850 ft^2 and incorporating a flow-variable safety factor) to function properly, with a 24-hour retention time.

All soils underlying this wetland must be thoroughly compacted on twelve-inch lifts and contain sufficient clay material to prevent failure of the system due to leakage. Foundation fill should not include stumps or other organic debris or rocks larger than 6 inches in diameter.

5.0 References

Butterworth, R., D. Ferlow, E. Moran, M. Aridgides and W. Hazelton. 1999. *Manufacturing Facility Meets Zinc Discharge Limits with Natural System.* Industrial Wastewater. pp. 39-44.

CDPHE (Colorado Department of Public Health and Environment). 2000. Mining nonpoint source management program. http://www.cdphe.state.co.us/op/wqcc/miningfinal.pdf

Dombeck, G. D., M. W. Perry and M. B. Anderson. 1999. *Trace metals assimilation in treatment wetland sediments. In Water Environment Federation 1999 Conference Proceedings.* New Orleans, Louisiana: October 9-13, 1999.

Dvorak, D. H., R. S. Hedin, H. M. Edenborn and P. E. McIntire. 1992. *Treatment of metal-contaminated water using bacterial sulfate reduction: results of pilot-scale reactors.* Biotechnology and Bioengineering, 40: 609-616.

EPA (Environmental Protection Agency). 2000. Constructed Wetlands Treatment of Municipal Wastewaters. Office of Research and Development. Cincinnati, Ohio. EPA/625/R-99/010.

Gillespie, W. B, W. B. Hawkins, J. H. Rodgers, M. L. Cano and P. B. Dorn. 2000. *Transfers and transformations of zinc in constructed wetlands: Mitigation of a refinery effluent.* Ecological Engineering 14:279-292.

Gusek, J. J. 1998. *Three case histories of passive treatment of metal mine drainage. In Proceedings of the 19th Annual West Virginia Surface Mine Drainage Task Force Symposium.* West Virginia University.

Hails, David C. 1999. *Conceptual Plan for a Passive Water Treatment System at the MRRC Keystone Mine Site, Shasta County, California.* Ecological Restoration, Inc. Technical Document. 37pp.

Hails, David C. 1998. *Conceptual Plan for a Passive Leachate Treatment System at a Residual Waste Landfill, Frankfort Springs, Pennsylvania.* Ecological Restoration, Inc. Technical Document. 19pp.

Hedin, R.S., R.W. Nairn and R. L. P. Kleinmann. 1994. *Passive treatment of coal mine drainage.* US Bureau of Mines IC 9389. US Department of the Interior, Pittsburgh, PA.

Kadlec, R. H. and R. L. Knight. 1996. Treatment Wetlands. CRC Press, Boca Raton, Florida.

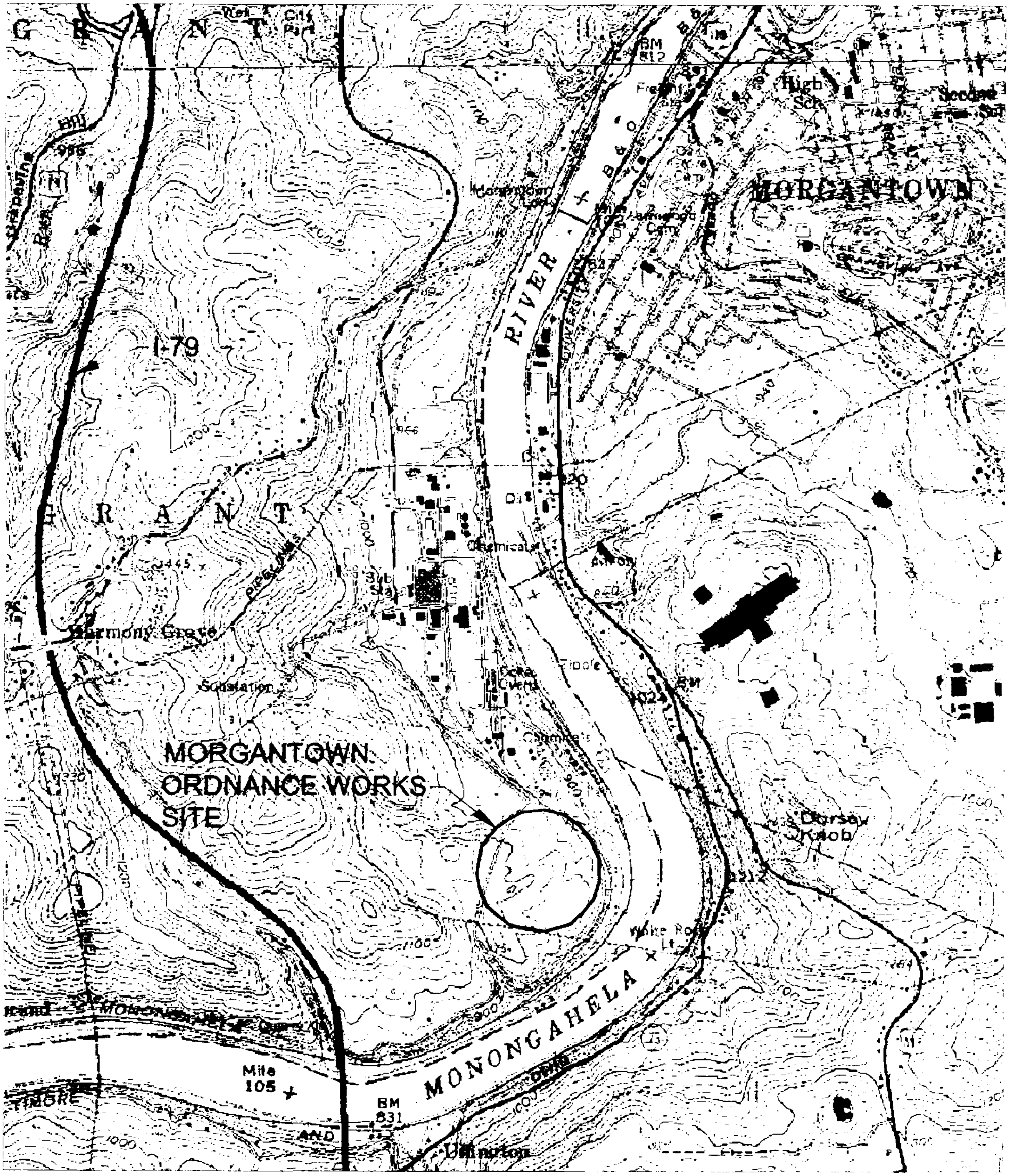
Lan, C., G. Chen, L. Li and M. H. Wong. 1992. *Use of cattails in treating wastewater from a Pb/Zn mine.* Environmental Management 16:75-80.

Mitsch, W. J. and J. G. Gosselink. 1993. Wetlands. Van Nostrand Reinhold, New York.

Mulamoottil, G., E. A. McBean and F. Rovers. 1999. Constructed wetlands for the treatment of landfill leachates. Lewis Publishers, Boca Raton.

USDA-NRCS and US EPA Region III. A handbook of constructed wetlands. http://www.epa.gov/owow/wetlands/pdf/hand.pdf

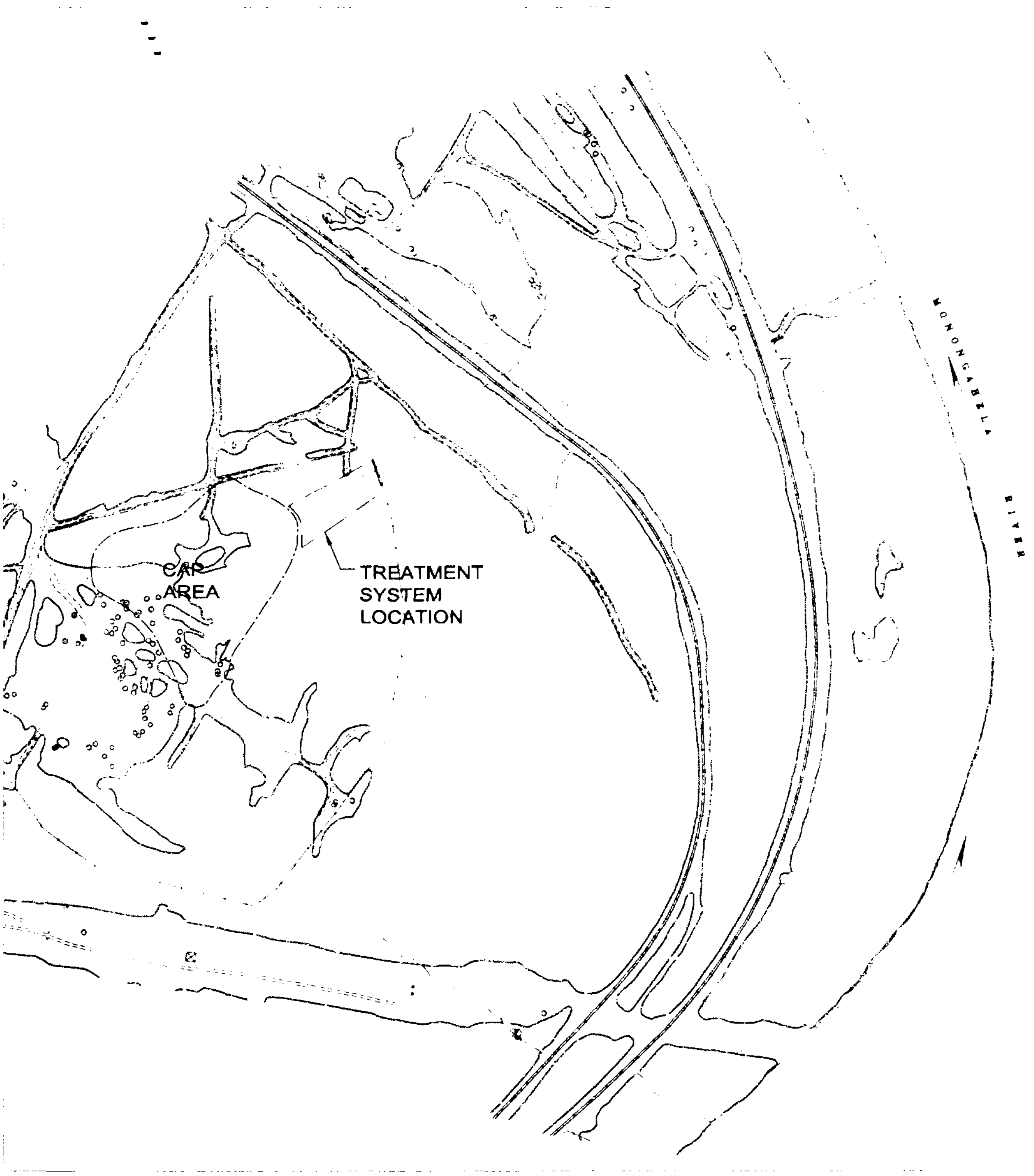
FIGURES



MORGANTOWN ORDNANCE WORKS SITE

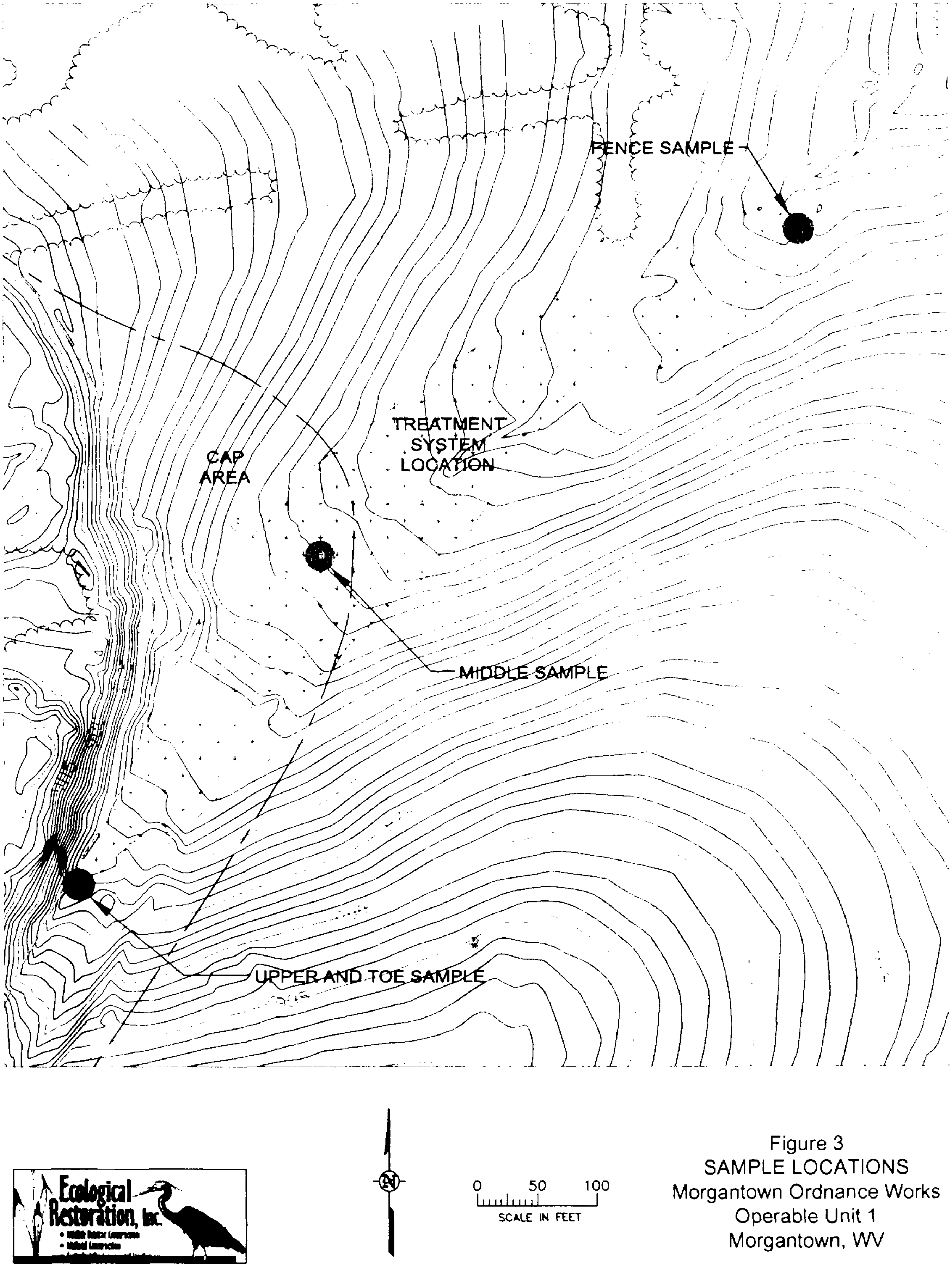
Ecological Restoration, Inc.

Figure 1
SITE LOCATION
Morgantown Ordnance Works
Operable Unit 1
Morgantown, WV



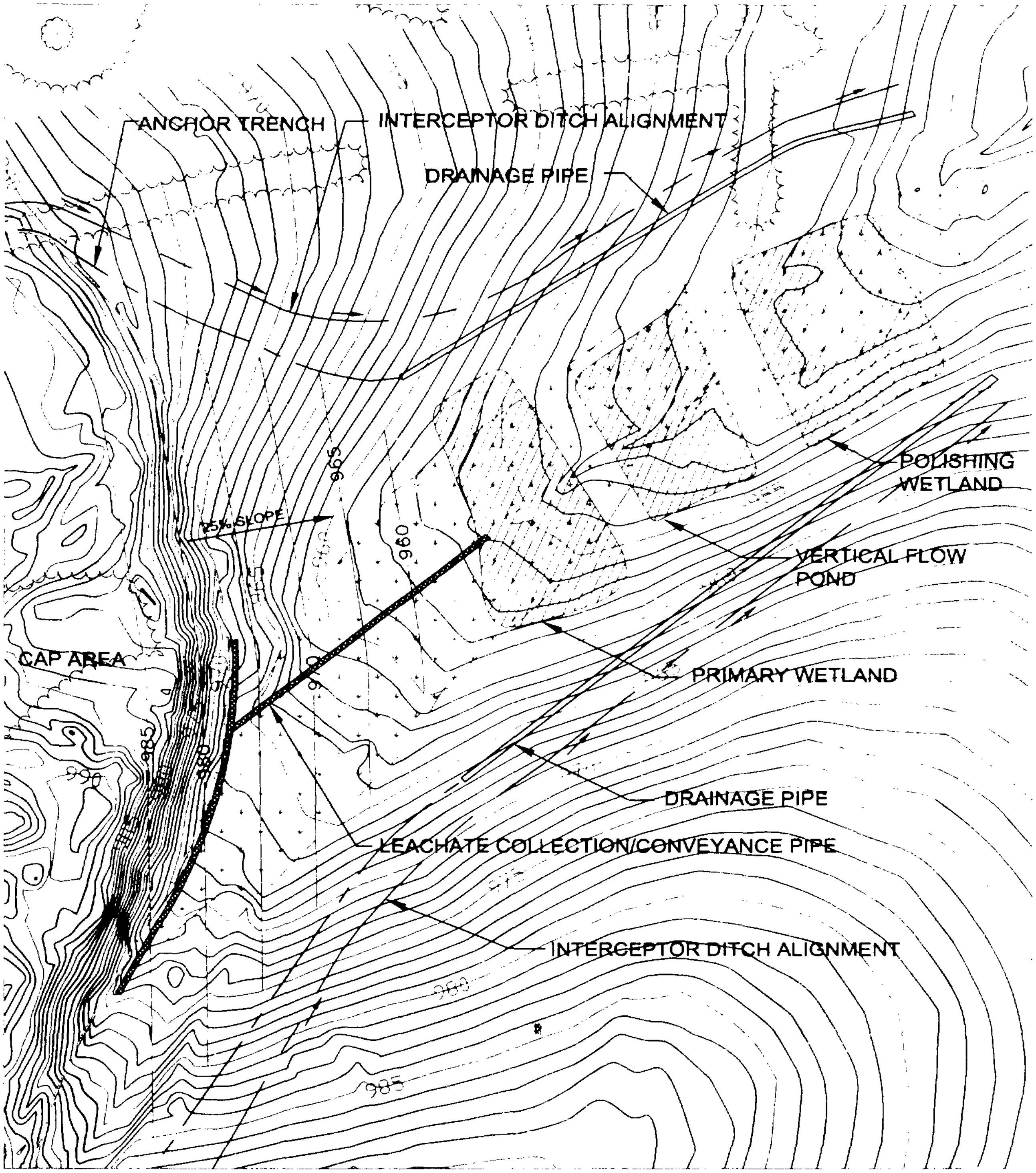
Ecological Restoration, Inc.

Figure 2
PROPOSED LOCATION FOR
TREATMENT SYSTEM
Morgantown Ordnance Works
Operable Unit 1
Morgantown, WV



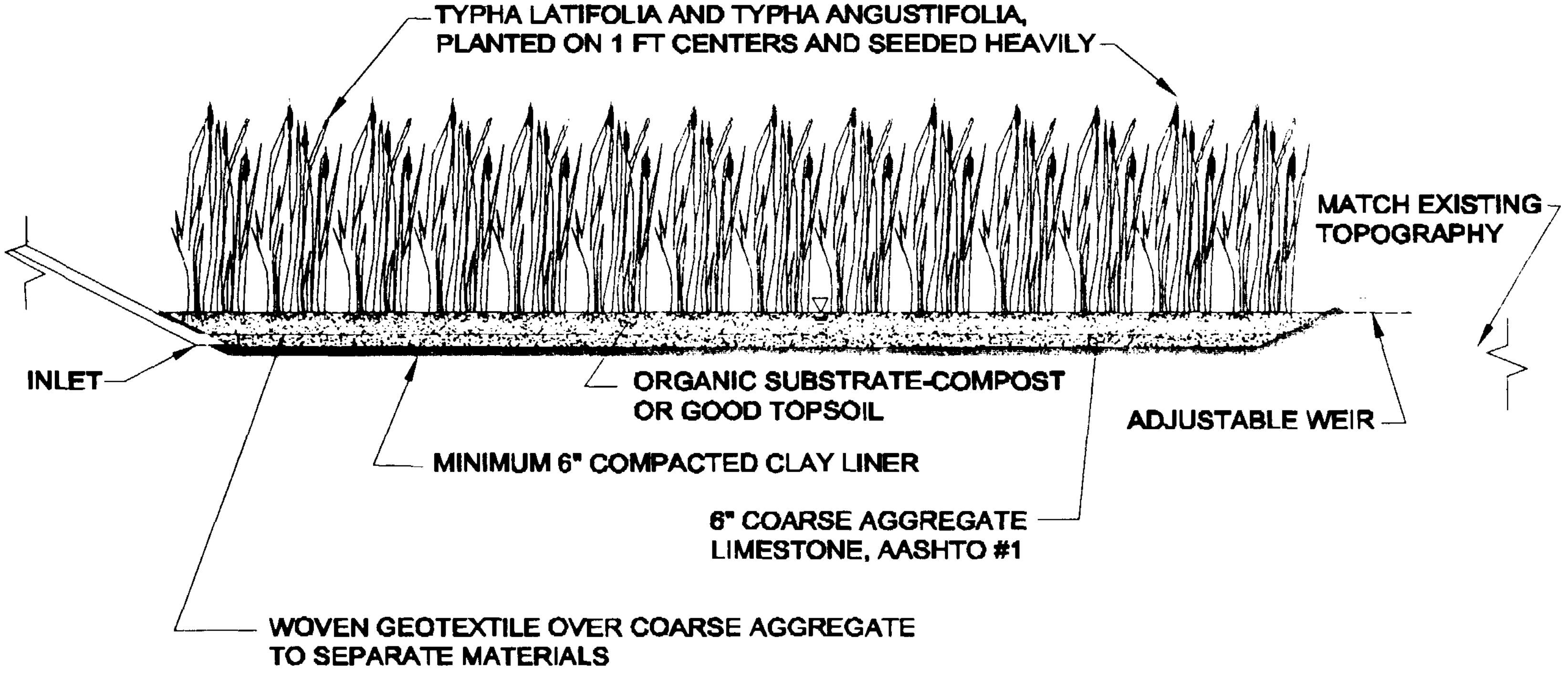
Ecological Restoration, Inc.

Figure 3
SAMPLE LOCATIONS
Morgantown Ordnance Works
Operable Unit 1
Morgantown, WV



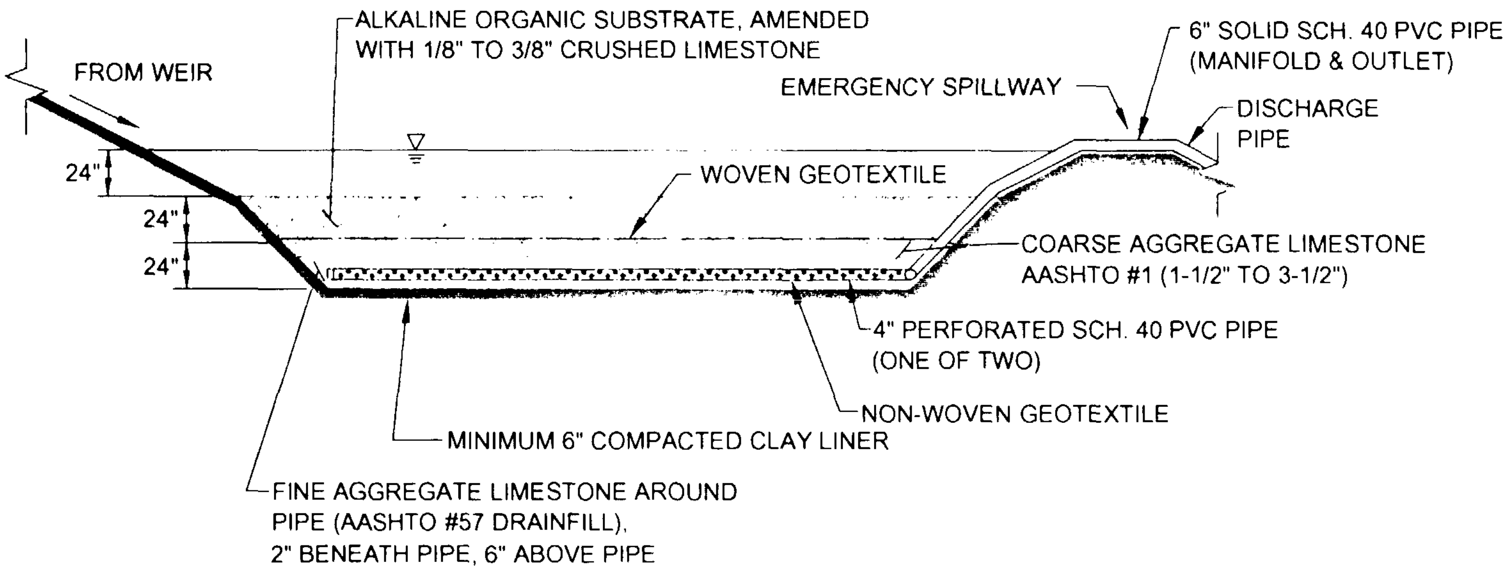
Ecological Restoration, Inc.

Figure 4
TREATEMENT SYSTEM PLAN
Morgantown Ordnance Works
Operable Unit 1
Morgantown, WV



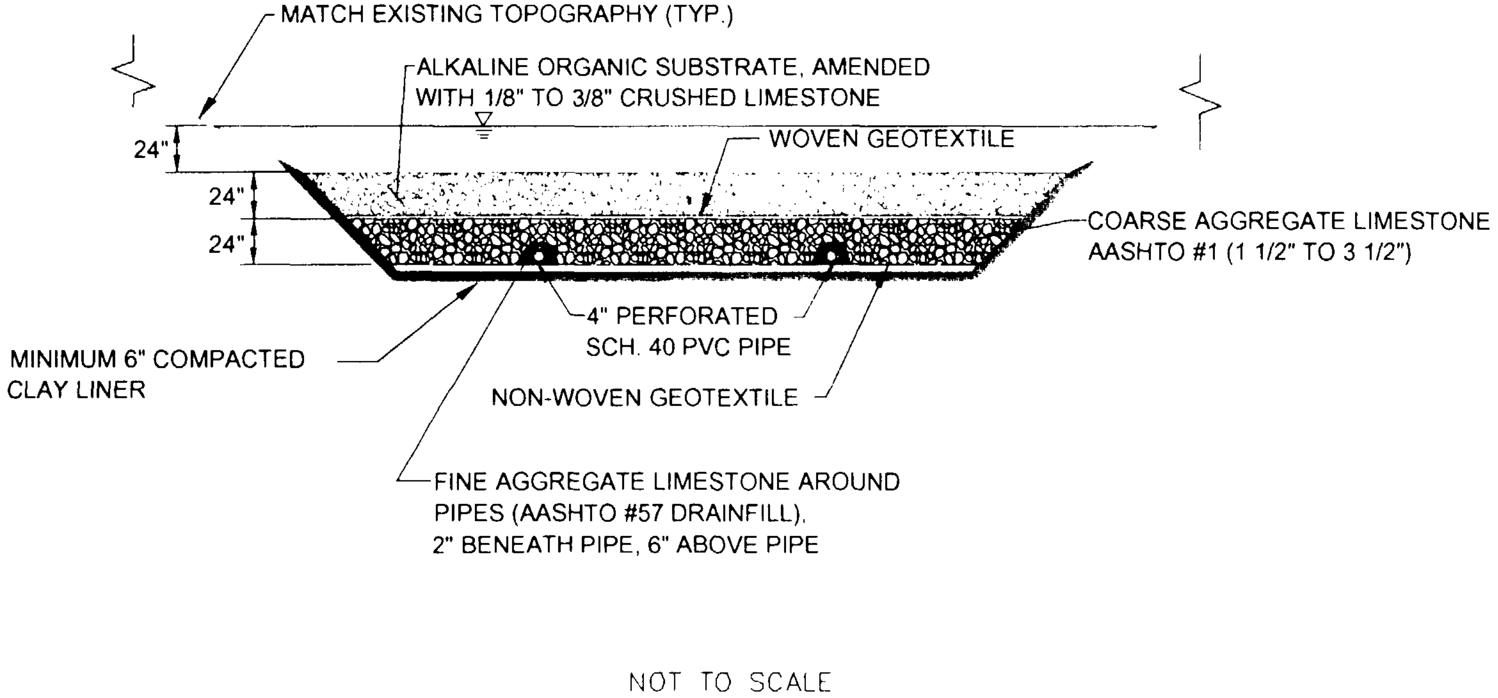
Ecological Restoration, Inc.

Figure 5
WETLAND SYSTEM PROFILE
Morgantown Ordnance Works
Operable Unit 1
Morgantown, WV



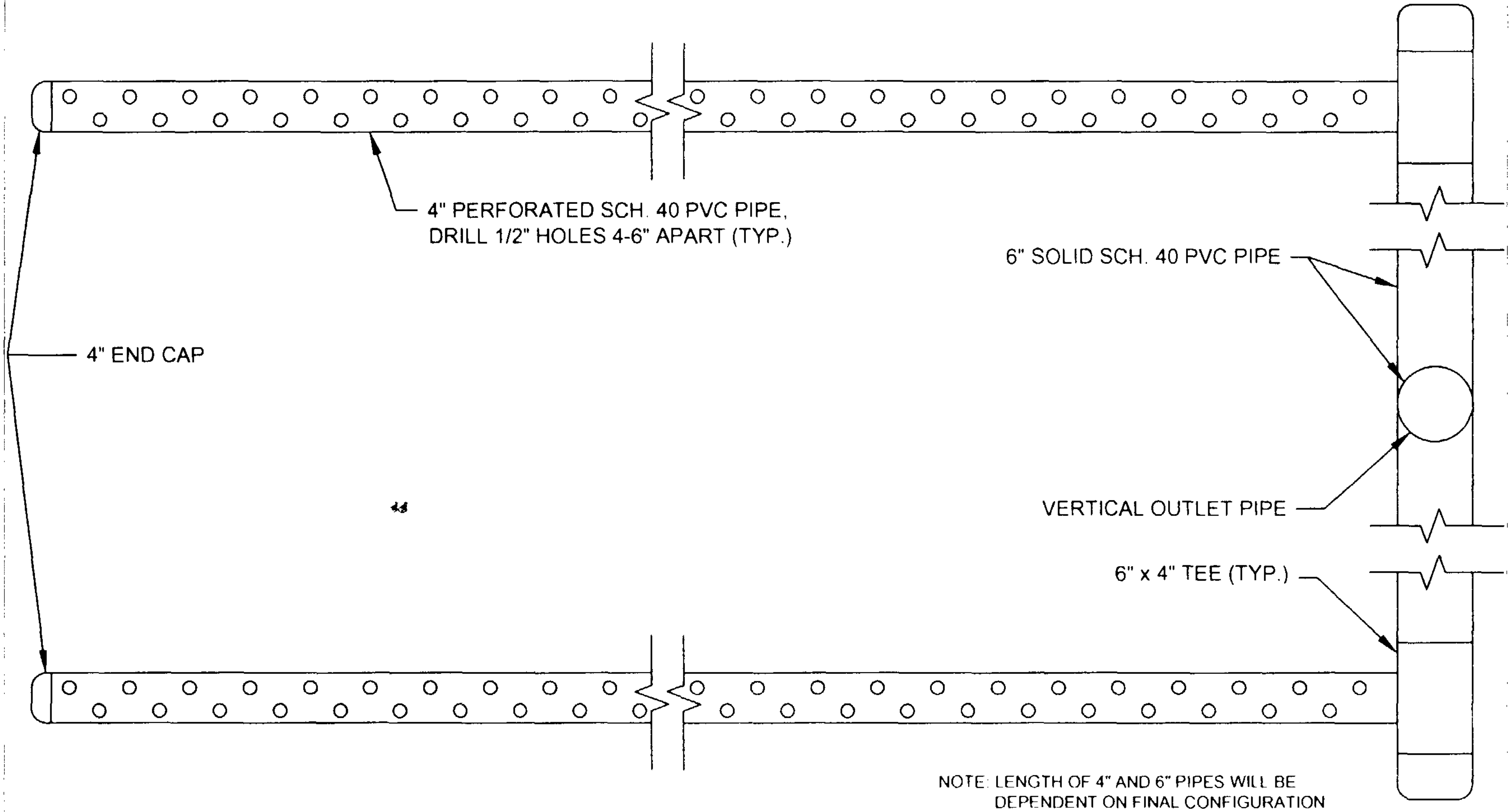
NOT TO SCALE

Figure 6
VERTICAL FLOW POND PROFILE
Morgantown Ordnance Works
Operable Unit 1
Morgantown, WV



Ecological Restoration, Inc.

Figure 7
VERTICAL FLOW POND TYPICAL
CROSS SECTION
Morgantown Ordnance Works
Operable Unit 1
Morgantown, WV



NOTE: LENGTH OF 4" AND 6" PIPES WILL BE DEPENDENT ON FINAL CONFIGURATION OF VERTICAL FLOW POND

NOT TO SCALE

Ecological Restoration, Inc.

Figure 8
VERTICAL FLOW POND
OUTLET MANIFOLD
Morgantown Ordnance Works
Operable Unit 1
Morgantown, WV

TABLES

Table 1

Water Chemistry Data
Morgantown Ordnance Works
Morgantown, West Virginia

Sample Analyte	TOE	UPPER	MIDDLE	FENCE
Inorganics (ug/L)				
Aluminum	433	< 200	63.3	< 200
Arsenic	2.7	< 10	< 10	< 10
Barium	42.7	38.1	20	17.4
Cadmium	0.64	< 5	2	0.75
Calcium	149000	153000	156000	131000
Chromium	2.4	1	3.1	< 10
Cobalt	6.5	4.9	51	3.4
Copper	768	170	40.3	6.8
Iron	8400	2790	8600	80.6
Lead	5.1	< 3	< 3	< 3
Magnesium	11200	11500	23700	20100
Manganese	866	812	11000	2150
Mercury	0.11	0.089	< 0.20	< 0.2
Nickel	56	53.2	108	54
Potassium	3990	4070	4450	3210
Selenium	< 5	< 5	< 10	< 5
Silver	< 10	< 10	1.8	< 10
Sodium	6830	6980	7330	7140
Vanadium	< 50	3.1	4.1	< 50
Zinc	8200	7180	34900	13900
Conventionals (mg/L)				
Alkalinity	339	388	167	174
Chloride	3.4	3.3	3.6	3.4
Phosphate as P, ortho	< 0.5	< 0.5	< 0.5	< 0.5
Sulfate	101	99.5	422	280
TSS	43.2	10.8	25.6	28.8

Table 2

Metals Removal Efficiencies of Treatment Wetland Systems
Morgantown Ordnance Works
Morgantown, West Virginia

System Location	Constituents	Mass Removal Efficiency	Type of System	Reference
Sacramento Sanitation District, Elk Grove, CA	Silver Mercury Lead Zinc	Consistently greater than 70%	Surface-flow, native soil substrate, planted with native vegetation	Dombeck et al., 1999
Shell Norco refinery in St. Charles Parish, LA	Zinc	Removed 38% of total recoverable zinc and 65 % soluble zinc	Surface-flow, alluvial flood plain sediment substrate, planted with *Scirpus californicus*	Gillespie et al., 2000
Constructed meadow, marsh, pond, Brookhaven, NY	Zinc	89.5%	Details not provided	Kadlec and Knight, 1996
Minnesota	Zinc	96% 90% 96%	Surface-flow, planted with *Carex*	Kadlec and Knight, 1996
Northern Australia	Zinc	96% 98%	Surface-flow, planted with *Typha*	Kadlec and Knight, 1996
PB/Zn mine at Shaoguan, Guangdon Province, China	Zinc	95%	Purification pond and an aquatic macrophyte system, planted with *Typha latifolia*	Lan et al., 1992

ATTACHMENT 1

RESUMES OF PROJECT TEAM

DAVID C. HAILS

Certified Ecologist

PROFESSIONAL HISTORY

Ecological Restoration, Inc., 1997-present *President/Senior Ecologist*
Wetland Supply Co./Wetland Restoration Nursery, 1992-present, *Owner/Nursery Manager*
EAP Environmental, 1993 - 1996, *Senior Ecologist /Manager*
Ecotoxicology Testing Services, 1993-1997, *Research Director/Owner*
Chester Environmental, Inc., 1990-1993, *Ecology Dept. Manager*
Keystone Environmental Resources, Inc., 1988-1990, *Ecology Dept. Manager*
Koppers Co., Inc., Environmental Services Division., 1986-1988, *Staff Ecologist*
RMC Environmental, Inc., 1985-1986, *Fisheries Biologist*
That Fish Place, Inc., 1984-1985, *Biological Consultant*
U.S. Department of the Interior, Office of Surface Mining, 1983, *Biological Technician*

EDUCATION

- B.S. Environmental Biology/Marine Biology, Millersville University of PA

- Three years of full time undergraduate study in Biology, Saint Vincent College, Latrobe, PA

- Additional Courses in Wetland Ecology, Oceanography, Marine Biology, Marine Ichthyology, Marine Invertebrates, and Wetland Ornithology from The Wallops Island Marine Science Consortium, VA and FL

- Additional Course in Federal Wetland Policy, Wetland Training Institute, MD

CERTIFICATIONS

Certified Ecologist, Ecological Society of America
Certified 40 Hour Training for Hazardous Waste Site Health and Safety Operations
Certified Supervisor for Hazardous Waste Site Health and Safety Operations
Certified by Red Cross for First Aid and CPR
Certified Nurseryman, Pennsylvania Department of Agriculture

AFFILIATIONS

Society of Wetland Scientists
American Society for Surface Mining Reclamation
North American Benthological Society
Ecological Society of America
Pennsylvania Water Environment Association
Western Pennsylvania Ecology Society
Water Environment Federation

TECHNICAL SPECIALTIES

* Wetlands – Delineation, Mitigation Design, Construction
* Land Use Planning Based on Ecological Parameters
* Habitat Evaluation for Hazardous Waste/Superfund Site Impact Assessment
* Ecological Risk Assessment
* Natural Resource Damage Assessment
* Streambank Restoration

LEGAL EXPERIENCE

Testified as an expert witness in aquatic ecology and wetland ecology in court on behalf of several clients.

REPRESENTATIVE PROJECT EXPERIENCE

Wetland Delineation and Land Use Analysis of 1,160 Acres of Bottomland in Harleyville, South Carolina: Senior project ecologist for a major land use study performed for a marl mining company to determine land suitable for mining that would avoid wetland impacts.

Aided in the Design and Construction of a Wastewater Treatment Facility, Frankfort Springs, Pennsylvania. Aided a client in removing metals from wastewater to reduce toxicity to aquatic organisms in the receiving stream. Designed and constructed an experinmental wetland polishing system.

Conducted a Wetland Impact Assessment at a 5 Acre Wetland Site that had been Illegally Filled near Pittsburgh, PA. Senior ecologist in charge of project.

Wetland Delineation and Habitat Evaluation of 500 Acres and Subsequent Wetland Mitigation Design and Construction and Aquatic Study near Pittsburgh, PA: Senior project ecologist and construction supervisor in charge of the entire project.

Endangered Species Survey, Wetland Delineation and Habitat Evaluation in and Adjacent to Silver Bow Creek, Butte, Montana: Senior project ecologist for a superfund site investigation where protected bird species were thought to be utilizing on site wetlands.

Wetland and Upland Habitat Assessment and Subsequent Ecological Risk Assessment at a Superfund Site in New Jersey: Senior ecologist in charge of entire assessment which included field surveys of dominant vegetation, birds, mammals, and fish; and preparation of a Preliminary Ecological Risk Assessment Report.

Conducted a Habitat Evaluation, Prepared and Implemented Wetland and Aquatic Habitat Mitigation Plans for a Superfund Site in Morrisville, North Carolina: Senior ecologist in charge of entire study and habitat construction. Study included a fish survey using electrofishing and gill netting, fish tissue analyses and an an analyses of waterfowl utilizing the site, an ecological risk assessment, preparation of a plan to mitigate the resources lost as part of the site remediation effort and construction of replacement habitats.

Conducted a Habitat Evaluation at a Superfund Site in Salisbury, Maryland: Senior ecologist in charge of a study which included an evaluation of protected raptor species utilizing the site, identification of all wetland and upland habitats, and preparation of a preliminary ecological risk assessment. Currently involved in wetland replacement efforts at the site.

Conducted a Wetland Delineation and Habitat Assessment for a Real Estate Developer in Cartaret, New Jersey on 150 Acres: Senior ecologist responsible for determining the boundaries of all wetlands on the site and to provide an analysis of the usage of these wetlands by migratory waterfowl.

Performed an Ecological Risk Assessment, Wetland Delineation and Wetland Mitigation for a Superfund Site in Armstrong County, Pennsylvania: Ultimately responsible for all ecology-related work performed on this site for a 12 year period. Studies included wetland delineation and mitigation, wildlife usage analysis, fish surveys, fish and crayfish tissue analyses, benthic macroinvertebrate investigations, and terrestrial biota studies. Currently involved in a Toxicity Identification Evaluation using bioassay.

Conducted a Wetland Delineation, Prepared and Implemented a Wetland Restoration Plan and Performed a Fish Survey and Fish Tissue Analyses for a Superfund Site in Massachusetts: Senior ecologist in charge of project for the past 8 years.

Conducted a Wetland Delineation and Habitat Evaluation at a Superfund Site in Carbondale, Illinois: Senior ecologist in charge of evaluating all habitat on the site for it's ability to support wildlife and to delineate the wetlands.

Conducted a Wetland Impact Assessment in two Wetland Areas that had been Illegally Filled Near Philadelphia, PA. Senior ecologist in charge of project.

Designed a Wetland for Municipal Wastewater Treatment, Sewickley Heights, PA: Provided professional consultation for the design of a wastewater treatment system that would treat sewage for twelve homes.

Performed an Ecological Risk Assessment at a Superfund Site in Charleston, South Carolina: Ultimately responsible for all work performed on this project for a two year period. The work included habitat evaluation, stream surveys, fish and crayfish tissue collection for analysis and preparation of an Ecological Risk Assessment Report.

Performed a Stream Survey, Fish and Crayfish Tissue Collection for Chemical Analysis, and a Wetland Delineation at a Superfund Site in Texarkana, Texas: Senior ecologist in charge of entire project.

Conducted a Habitat Evaluation at a Wood Treating Facility in Portsmouth, Virginia: Senior ecologist in charge of entire project.

Conducted a Habitat Evaluation and an Ecological Risk Assessment at a Superfund Site in Saint Paul, Minnesota: Conducted field sampling, terrestrial and aquatic toxicity tests, wetland and habitat assessments and prepared an Ecological Risk Assessment Report.

Developed a Environmentally Sensitive Area Protection Plan for a Wood Treating Facility in New Jersey: Prepared the plan for submittal to the jurisdictional Agencies.

Conducted a Land Use Study for a Coal Mining Company in Burgettstown, Pennsylvania: Conducted a wetland delineation and habitat evaluation on approximately 100 acres of land. Provided recommendations on avoiding ecologically sensitive areas.

Conducted a Habitat Evaluation at a Proposed Riverfront Park in Westmoreland County, PA: Aided in the design of a park system to avoid impact to endangered and threatened species of wildflowers and sensitive wetland areas.

Conducted a Wetland Delineation in Dolomite, Alabama for a Tar Plant: Delineated wetlands consisting mainly of bottomland hardwoods.

Prepared a Wetland Mitigation Plan and Conducted a Stream Survey for a Landfill Company in Pennsylvania: Senior Ecologist in charge of assuring habitat replacement in accordance with applicable state and federal regulations.

Conducted a Natural Resource Damage Assessment for a Municipality in Johnstown, PA: Conducted a study after a 10,000 gallon chemical spill. Study included benthic macroinvertebrate, fish and chemistry studies.

Conducted a Wetland Delineation and Prepared a Wetland Mitigation Plan for the Proposed Location for a Residual Waste Landfill in New Castle, Delaware: Senior ecologist in charge of study, currently designing wetland mitigation.

Prepared a Sampling Plan and a Preliminary Environmental Assessment for a Chemical Plant in Follansbee, WV: The preliminary assessment included a wetland, terrestrial and aquatic habitat evaluation and preparation of a detailed report.

Responsible for the Following Key Projects (performed field work and authored technical documents for all):

- *Developed and Implemented an Education Program in Which over 1000 students participated in the Construction of a 2.5 acre Habitat area which attracted hundreds of species of wildlife.*
- *Supervised onsite work for an 8 cell passive treatment wetland project to treat mine drainage at Powdermill Nature Reserve in Rector, PA.*
- *Supervised all onsite work for a 2.6 acre wetland construction project in Cranberry, PA.*
- *Supervised onsite work for an 8 acre wetland planting project in South Park Township, PA., constructed as part of the Mon/Fayette PA Turnpike Expressway.*
- *Currently manage all wastewater treatment operations at a landfill facility in Frankfort Springs, PA including preparation of monthly Discharge Monitoring Reports, design and implementation of a wetland treatment system, preparation of application for landfill expansion and permit renewal.*
- *Conducted a Wetland Delineation in the Vicinity of a Proposed Municipal Landfill in Westmoreland County, PA.*
- *Conducted a Wetland Delineation at a 20 acre site for a Proposed Housing Development for a major Home Developer in Reading, PA.*
- *Performed Surface Water and Well Sampling in Dolomite, AL as part of a RCRA Program for a Coke Plant.*
- *Performed Surface Water and Well Sampling near Little Rock, AR as part of a RCRA Program for a Wood Treating Facility.*
- *Designed and Constructed a Wastewater Treatment Plant for a Wood Treating Facility in Lumby, British Columbia. Spent over one month on site constructing the system.*

- *Conducted Proportionalized Flow Analyses for a POTW Discharge from a Chemical Facility in Oxnard, CA.*
- *Conducted Proportionalized Flow Analyses for a POTW Discharge from a Chemical Facility in Richmond, CA.*
- *Conducted Monitoring Well Sampling at a Chemical Facility in Conley, GA.*
- *Conducted Air Emissions Stack Testing for a Major Aluminum Manufacturer in Evansville, IN.*
- *Conducted RCRA Monitoring Well Sampling at a Wood Treating Facility in Guthrie, KY.*
- *Conducted RCRA Monitoring Well Sampling at a Ring and Piston Manufacturing Facility in Baltimore, MD.*
- *Conducted Radiotelemetry, Electrofishing, Floy Tag and other Fisheries Studies in the Susquehanna River and Chesapeake Bay.*
- *Conducted Hazardous Waste Sampling of over 150 Drums with Unknown Constituents at a Paint Manufacturing Facility in Newark, New Jersey.*
- *Conducted Monitoring Well Sampling at a Marine Paint Manufacturing Facility in Rockaway, NJ.*
- *Remediated the Contaminated Remnants of a Former Manufactured Gas Plant in Buffalo, NY. Spent over one month on site supervising the cleanup operations.*
- *Conducted Surface Water and Monitoring Well Sampling at a Former Tar Manufacturing Facility in Youngstown, OH.*
- *Conducted Monitoring Well Sampling at a Chemical Facility in Heath, OH.*
- *Conducted Monitoring Well Sampling at a Chemical Facility in Orrville, OH.*
- *Sampled Residue from Chemical Storage Tanks at a Pencil Pitch Plant in Portland, OR.*
- *Provided Consultation on the Design and Construction of a Wastewater Treatment Facility for a Wood Treating Plant in Eugene, OR.*
- *Conducted Outfall Sampling for Chemical Analyses at a Chemical Manufacturing Plant in Bridgeville, PA.*
- *Conducted Monitoring Well Sampling at a Superfund Site Near Weirton, WV.*
- *Conducted Monitoring Well Sampling at a Foundry in Greenville, PA.*

- *Conducted NPDES outfall Sampling at a Research Facility in Monroeville, PA.*

- *Conducted Monitoring Well, Surface Water, and Plant Outfall Sampling for Chemical Analyses; Stream Flow Studies; and Operated and Trained Plant Employees on Wastewater Treatment Plant Operations and Sampling Procedures at a Chemical Plant in Petrolia, PA.*

- *Conducted Monitoring Well Sampling for Chemical Analyses at a Wood Treating Facility in Susquehanna, PA.*

- *Conducted Sampling of Various Unknown Hazardous Waste Materials Contained in a Storage Room at Research Facility in Verona, PA.*

- *Conducted Monitoring Well Sampling for Chemical Analyses at a Chemical Plant in Wampum, PA.*

- *Performed Pump Tests and other Hydrogeological Testing at a Superfund Site in Lock Haven, PA.*

- *Conducted Surface Water and Monitoring Well Sampling in the Vicinity of a Former Chemical Plant near Houston, PA.*

- *Collected Soil Samples at a Former Coke Plant near Philadelphia for use in Treatability testing.*

- *Developed and Maintained Activated Sludge and Aeration Tank Bench Scale Systems in a Treatability Laboratory for Various Clients in the Gasoline, Wood Treating and Tar Manufacturing Industries.*

- *Aided in the Design and Construction of a Pilot-Scale Soil Washing System for use on Contaminated Soils at a Wood Treating Facility in Feather River, CA.*

- *Installed and Refurbished Full-Scale Ozone-UV Treatment Systems at Various Facilities in U.S.*

- *Aided in the Development and Construction of a Pilot Biological Wastewater Treatment System for use at a Wood Treating Facility in Portland, OR.*

- *Constructed an Emergency Wastewater Treatment System for Treating Water with high Naphthalene Content and Refurbished and Modernized an Existing Wastewater Treatment System at a Wood Treating Facility in Salem, VA. Spent over one month on site conducting these tasks.*

- *Conducted a Wetland Delineation at the proposed site of an Infectious Waste Transfer Station in Neville Island, PA.*

- *Conducted a Preliminary Wetland Assessment at the Proposed Site for a Major Chemical Plant in Butler County, PA.*

- *Conducted a Wetland Delineation for a Semiconductor Manufacturing Facility in Mountaintop, PA after an Expansion Project was Halted due to the Potential Presence of Wetlands.*

- *Conducted a Wetland Delineation and a Qualitative Stream Survey for Fish and Benthic Macroinvertebrates for a Developer in Monroeville, PA. Obtained a permit to allow the stream to be enclosed as part of the project.*

- *Conducted Corbicula (Asiatic Clam) studies at the Intakes of two Power Generating Facilities Located Along the Susquehanna River.*

- *Conducted a Wetland Delineation in the Vicinity of a Proposed Residual Waste Landfill near Williamsport, PA.*

- *Prepared a Preliminary Environmental Assessment for a Hazardous Waste Site near Monaca, PA.*

- *Conducted a Wetland Delineation in Ebensburg, PA on a 25 Acre Tract of Land for Sale by a Developer.*

- *Collected Samples using an ISCO Sampler at 9 different Municipal Wastewater Treatment plants for use in Toxicity Testing.*

- *Prepared an Environmental Assessment for a Chemical Manufacturing Facility in Newell, PA.*

- *Conducted a Benthic Macroinvertebrate Survey in Bald Eagle Creek near Lock Haven, PA for a Paper Company.*

- *Conducted a Major Stream Survey in the Clarion River for a Paper Company in Johnsonburg, PA which Included Fish Electroshocking, Benthic Macroinvertebrate Studies, a Thermal Profile of 4 miles of Stream and Sampling for Chemical Analyses of Sediment and Surface Waters. Study duration was two years.*

- *Prepared a Joint 105/404 Permit Application for a Steel Mill in Clairton, PA for Dredging Activities in the Monongahela River.*

- *Conducted a Wetland Delineation and Prepared Preliminary Wetland Mitigation Plans for a Major Land Developer in Coraopolis, PA.*

- *Conducted a Wetland Delineation for a State Penitentiary along the Ohio River.*

- *Conducted a Preliminary Ecological Impact Assessment at a Hazardous Waste Disposal Site near Petrolia, PA.*

- *Conducted a Benthic Macroinvertebrate Investigation as Background Data on two Stream Systems near the North Park Area of Pittsburgh, PA.*

- ***Prepared a Joint Permit Application for Stream Encroachment from a Proposed Sanitary Sewer Interceptor Line in Castle Shannon, PA. Study included wetlands and benthic macroinvertebrate surveys.***

- ***Prepared a Ecological Impact Study Plan for a Superfund Site in Charleston, SC.***

- ***Conducted Monitoring Well Sampling at a Tar Plant in Houston, TX.***

- ***Conducted Monitoring Well Sampling at a Wood Treating Facility in Houston, TX.***

- ***Conducted Groundwater Pump Testing and Sampling at a Superfund Site in Houston, TX.***

- ***Participated in the Closure of a Contaminated Lagoon at a Wood Treating Facility near Green Springs, WV.***

- ***Conducted Lithium Tracer Analyses for Determining the Underground Flow Scheme of a Stormwater Conduit System Underlying a Coke Plant near Weirton, WV.***

- ***Collected Groundwater and Lagoon Sediment Samples for Chemical Analyses at a Wood Treating Facility in Superior, WI.***

- ***Installed a Pump and Treat System for Contaminated Groundwater at Window Manufacturing Facility in Wausau, WI.***

- ***Aided in the Preparation of an Ecological Risk Assessment for a Major Car Manufacturing Facility in Kenosha, WI.***

- ***Performed a Preliminary Ecological Risk Assessment Investigation at a Superfund Site in Lafayette, LA.***

- ***Performed a Preliminary Ecological Risk Assessment Investigation Inc. at a Hazardous Waste Site in Elkhart, IN. Study included wetland and benthic macroinvertebrate studies.***

- ***Performed a Preliminary Ecological Risk Assessment Investigation at a Hazardous Waste Site in Ft. Wayne, IN. Study included wetland and benthic macroinvertebrate studies.***

- ***Supervised a drinking water well contamination study resulting from the release of potential toxicants, including pesticides from a nursery fire in Greensburg, PA.***

- ***Aided in the construction and planting of a wetland treatment system to treat landfill leachate at a facility in Springdale, PA.***

- ***Performed a stream restoration using coir fiber blankets and wetland plants at a superfund site in Westborough, MA.***

- *Managed the planting of a 60 acre multi-million dollar wetland mitigation project near Bridgeville, PA.*

- *Provided consulting services to a major hog farm in Evansville, IN regarding the treatment of hog waste using wetland systems.*

- *Managed an underground storage tank removal in Mckeesport, PA.*

- *Conduct yearly benthic macroinvertebrate surveys at a municipal landfill near Shippensburg, PA.*

- *Conducted yearly benthic macroinvertebrate surveys in stream systems adjacent to a municipal landfill in Leeper, PA.*

- *Supervised all onsite work on a stream channel restoration project related to the cleanup of PCB contaminated soils and sediments, Delmont, PA.*

- *Planted and seeded a 30 acre wetland and wildlife habitat constructed as part of the Mon/Fayette PA Turnpike Expressway in Smithfield, PA.*

- *Conducted a wetland delineation as part of the proposed construction of a large water pumping storage area in St. Michaels, PA.*

- *Testified as an expert witness for a paper manufacturing facility with regards to aquatic ecology concerns from a chip storage area.*

- *Conducted a benthic macroinvertebrate study as part of the siting of a building in Oakdale, PA.*

- *Supervised construction of an elaborate single-family wastewater treatment facility utilizing two septic tanks, an equalization tank, a sand filter and a chlorination tank constructed on the side of a steep hillside.*

- *Prepared a 316(a) study plan for a major paper manufacturing facility regarding thermal discharge limits. Currently implementing the study which includes conducting a detailed river survey involving computerized temperature profiles, fish surveys, benthic macroinvertebrate surveys, dissolved oxygen, pH, conductivity and flow profiles and water chemistry on a 5 mile stretch of a river.*

- *Designed a passive wastewater treatment system utilizing vertical flow pond and wetland cells to treat copper and other metals found in mine drainage, Shasta County, CA.*

- *Constructed a mitigation wetland for a major developer in Fox Chappel, PA*

- *Delineated wetlands at a Superfund Site in Horseheads, NY*

- *Designed and constructed a 15 acre tidal and nontidal wetland system at a hazardous waste site in Salisbury, MD*

Robert S. Hedin

Principal, Hedin Environmental

Years of Experience: 12

Key Qualifications

Dr. Hedin is one of the Nation's leading authorities on the characterization and treatment of contaminated mine water. As a research scientist at the US Bureau of Mines, Dr. Hedin developed a research program that defined methods to predict, characterize, and treat passively contaminated mine drainage. The results of this research program are widely referenced and are the technical basis for expanded use of passive concepts by the mining industry and recent changes in reclamation laws in several eastern States. Recently, Hedin Environmental has expanded its treatment expertise into conventional chemical systems. As a Principal of Hedin Environmental, Dr. Hedin has assisted the mining industry, stream restoration groups, Federal and State reclamation agencies with water quality assessments, treatment cost estimates, and treatment plans. Hedin Environmental has prepared discharge treatment plans that have been incorporated into consent orders, were the basis for detailed construction plans, and eventually resulted in the release of applicable bonds. Fourteen treatment systems, designed by Hedin Environmental, are currently treating mine waters contaminated with acidity, iron, aluminum and manganese. Hedin Environmental operates, under a contractual basis, a chemical treatment system in central Pennsylvania.

Recent Project Experience

Restoration of the Headwaters of Jonathan Run. *Current.* Jonathan Run, located in Center County, is degraded by acidic water flowing from fill used to construct Interstate 80 in central PA. Hedin Environmental conducting an assessment of the problem for the Beech Creek Watershed Association. HE's recommendations will be jointly implemented by BCWA and PennDOT. The project is funded by PA DEP's Growing Greeener program.

Assessment of AMD Inputs to Little Elk Run *Current.* Little Elk Run, located in Jefferson County near Punxsutawney, is polluted by acid mine drainage. Hedin Environmental is conducting an assessment of the problem so that remediation projects can be identified and prioritized. The project is funded by PA DEP's Growing Greeener program.

Little Hefren Run Restoration Project, PA Bureau of Watershed Conservation. *Current.* Hedin Environmental has been awarded a Section 319 grant to design and construct a passive mine water treatment system in Cook Forest State Park (Clarion County, PA). The passive system will treat a metal and acidity contaminated spring that degrades a high quality trout fishery. The system will be completed in the autumn of 2000.

Waste Management, Inc., Philadelphia, PA. *Current.* Hedin Environmental operates an AMD treatment system at a Waste Management site in central PA. While managing the site to assure cost-effective compliance with applicable discharge permits, Hedin Environmental is also exploring the feasibility of moving the treatment responsibilities to a location where treatment would provide significant benefits to a highly valued stream.

Trout Umlimited, Washington D.C. *Current.* Hedin Environmental is developing a watershed restoration plan for the lower portion of the Kettle Creek Watershed in northcentral PA. Kettle Creek, one of Pennsylvania's premier trout streams, is polluted by coal mine drainage. Recommendations contained in the draft plan are already being considered for implementation.

Headwaters Charitable Trust, DuBois, PA. 2000. Hedin Environmental developed a watershed remediation plan for the East Branch of the Clarion River. Recommendations in the Plan that address the remediation of polluted coal mine drainage are currently being implemented by the Trust and local parties.

Jennings Environmental Education Center, PA Bureau of Watershed Conservation, 1999. Hedin Environmental was the prime contractor for the construction of a passive treatment system at the Jennings Environmental Education Center near Slippery Rock, PA. The passive system, constructed in 1997, is currently treating a deep mine discharge contaminated with acidity, iron, aluminum and manganese. Educational programs at Jennings are being modified to incorporate the passive treatment system.

US Department of Agriculture. Washington D.C. 1999. In 1995, Hedin Environmental received a Small Business Innovation Research Award to investigate the feasibility of recovering a marketable iron product from mine water treatment systems. The project, which moved to Phase II, demonstrated the feasibility of the resource recovery concept. Subsequent grants and contracts are supporting the pilot-scale recovery of iron from a site in western PA.

Hanley Brick Company, New York City, NY. *1999.* As part of a consent decree with the Commonwealth of Pennsylvania, Hanley Brick Company is obligated to decrease mine drainage pollution to Redbank Creek in the vicinity of Summerville PA. Hedin Environmental was retained to investigate passive treatment opportunities in the Beaver Run watershed. A stream restoration plan was developed and a 3 acre passive mine water system was constructed with Hedin Environmental oversight.

Susquehanna River Basin Commission, Harrisburg, PA. *1998.* The SRBC recently assessed water quality issues in the Wiconisco Creek watershed. Hedin Environmental was retained to assist with mine water aspects of the assessment. Discharges were inspected, historic water quality and mine discharge records were reviewed, and recommendations were made regarding passive treatment opportunities. Hedin Environmental's findings and recommendations were incorporated into the final report and will become the basis for future restoration activities in the watershed.

Sequatchie Valley Coal Corporation, Dunlap, TN. *1994-98.* Hedin Environmental was retained in 1994 to assist in the evaluation and implementation of passive mine water treatment systems at a 1000 acre closed surface mine site. Passive treatment of a 700 gpm pump discharge has met compliance continually for three years. In 1995, a passive system was constructed to treat 175 gpm of acidic drainage. Dr. Hedin was instrumental in the evaluation of water chemistry, demonstrating the cost-effective potential of a passive approach, developing the system design, and follow-up analyses of the system's performance.

Utica Mutual Insurance Company. *1995.* Hedin Environmental provided a "turn-key" passive mine water treatment system as part of a bond forfeiture settlement between Utica Mutual and the Commonwealth of Pennsylvania. Two metal-contaminated discharges were treated with anoxic limestone drains and constructed wetlands that tie into existing natural wetlands. The passive systems are contributing significantly to improved water quality of the receiving stream.

Education: B.A. Environmental Studies and Economics, St. Lawrence University, 1978
Ph.D. Ecology, Rutgers University, 1987

Previous Experience

1986-1988, Research Fellow, Oak Ridge Associated Universities, Oak Ridge, TN

1988-1994, Research Biologist, US Bureau of Mines, Pittsburgh, PA

1994-present, President, Hedin Environmental, Pittsburgh, PA

Awards and Honors

Pittsburgh Research Center, Publication of the Year, 1989, 1990, 1991, 1994, 1995

U.S. Department of the Interior, 1990, Secretary's Stewardship Award for Science and Technology

Three Rivers Environmental Award, 1995

Memberships in Scientific Societies

American Society for Surface Mining and Reclamation, member since 1987,
Co-Chair of the Ecology Section, 1990-94.

Ecological Society of America, member since 1987.

Society for Ecological Restoration, member since 1988.

Technical Advisories

Monastery Run Improvement Coalition, Greensburg, Pennsylvania. Member of Steering Committee (1993-present) and chairman of the Technical Committee (1993-present).

Chartiers Creek Watershed Coalition, Scott Township, Pennsylvania. Member of Steering Committee (1994-present)

Standard Methods for the Examination of Water and Wastewater, Chairman of the Acidity Task Group for 20th Edition

Acid Drainage Technology Initiative, member of the Prediction working group (1996)

Invited Lectures

Rutgers University, Biological Sciences Program, New Brunswick, NJ
    Plant Succession on Minelands (1987)
Pennsylvania Department of Environmental Resources, Bureau of Mining and Reclamation,
    Passive Minewater Treatment (1989, 1993, 1994, 1996)
Soil Conservation Service, Passive Minewater Treatment, National Meeting of Program Managers (1990)
    West Virginia SCS (1991), Ohio SCS (1991)
West Virginia Surface Mine Drainage Task Force Symposium, Morgantown, WV; invited papers on
    Anoxic Limestone Drains (1991), Passive Mine Water Treatment (1992), Reming (1997), and
    Resource Recovery (1998)
Indiana Mining and Reclamation Task Force, Annual Meeting, Vincennes, IN
    Passive Minewater Treatment (1992, 1994)
International Symposium on the Utilization of Spent Mushroom Substrate, Philadelphia, PA
    Use of SMS in Minewater Treatment Systems (1994)
Ohio State University, Natural Resources Program, Columbus, OH
    Passive Minewater Treatment and Successional Manipulation on Minelands (1994)
International Mine Water Conference, 1994 meeting, Nottingham, UK. Invited workshop on Coal Mine Drainage
    and Passive Treatment
Institution of Water and Environmental Management, Minewater Treatment Using Wetlands, 1997, keynote speech

Publications

Harris, G. R., A. Grover, B. Hale, and R. Hedin. 1979. The role of lakeshore homeowner associations in environmental management. *Environmental Management* 3: 195-203.

Caccamise, D. F. and R. S. Hedin. 1985. An aerodynamic basis for selecting transmitter loads in birds. *Wilson Bull.* 97: 306-318.

Hedin, R. S. 1988. Volunteer revegetation processes on acid coal spoils in north western Pennsylvania. Bureau of Mines Information Circular 9184, pp. 111-118.

Hedin, R. S., D. M. Hyman and R. W. Hammack. 1988. Implication of sulfate-reduction and pyrite formation processes for water quality in a constructed wetland. Bureau of Mines Information Circular 9183, pp. 382-389.

rickson, P. M. and R. S. Hedin. 1988. Evaluation of overburden analytical methods as means to predict post-mining coal mine drainage quality. Bureau of Mines Information Circular 9183, pp. 11-21.

Robert S. Hedin (continued)

Hedin, R. S. and P. M. Erickson. 1988. Relationships between the initial geochemistry and leachate chemistry of weathering overburden samples. Bureau of Mines Information Circular 9183, pp. 21-29.

Hedin, R. S., R. W. Hammack, and D. M. Hyman. 1989. The Potential importance of sulfate reduction in wetlands constructed to treat mine drainage. *In*: D. Hammer (ed.) Constructed Wetlands for Wastewater Treatment: Municipal, Industrial, and Agricultural (Lewis Publishers, Chelsea MI), pp. 508-516.

Kleinmann, R. L. P. and R. S. Hedin. 1989. Biological treatment of mine water: an update. *In*: M. E. Chalkley, B. R. Conard, V. I. Lakshmanan and K. G. Wheeland (eds.) Tailings and Effluent Management (Pergamon Press, New York, NY), pp. 173-179.

Hedin, R. S. 1989. Treatment of coal mine drainage with constructed wetlands. *In*: S. K. Majumdar, R. P. Brooks, F. J. Brenner and J. W. Tiner, Jr. (eds.) Wetlands Ecology and Conservation: Emphasis in Pennsylvania (Pennsylvania Academy of Science, Philadelphia, PA), pp. 349-362.

Hedin, R. S. and E. R. Hedin. 1990. Stimulation of aspen establishment on unreclaimed mine spoils, *In*: D. H. Graves and R. W. DeVore (eds), 1990 National Symposium on Mining (University of Kentucky, OES Publications, Lexington, KY) pp. 85-95.

Dvorak, D. H., R. S. Hedin, H. M. Edenborn and P. E. McIntire. 1992. Treatment of metal-contaminated water using bacterial sulfate reduction: results of pilot-scale reactors. *Biotechnology and Bioengineering* 40: 609-616.

Nairn, R. W., R. S. Hedin and G. R. Watzlaf. 1992. Generation of alkalinity in an anoxic limestone drain. *In*: Achieving Land Use Potential through Reclamation (American Society for Surface Mining and Reclamation, Princeton, WV), pp. 206-220.

Watzlaf, G. R. and R. S. Hedin. 1993. A method for predicting the alkalinity generated by anoxic limestone drains. *In*: Thirteenth Annual West Virginia Surface Mine Drainage Task Force Symposium, West Virginia University, Morgantown.

Kleinmann, R. L. P. and R. S. Hedin. 1993. Treat mine water using passive methods. *Pollut. Eng.* 25:20-22.

Hedin, R. S. and R. W. Nairn. 1993. Contaminant removal capabilities of wetlands constructed to treat coal mine drainage. *In*: Moshiri, G. A. (ed.) Constructed Wetlands for Water Quality Improvement, Proceedings of an International Conference (Lewis Publishers, Chelsea, MI). pp. 187-197.

Hedin, R. S. and G. R. Watzlaf. 1994. The effects of anoxic limestone drains on mine water chemistry. *In:* Proceedings of the International Land Reclamation and Mine Drainage Conference and the Third International Conference on the Abatement of Acidic Drainage (United States Department of the Interior, Bureau of Mines Special Publication SP 06A-94, Washington DC) pp. 185-195.

Hedin, R. S., R. W. Nairn and R. L. P. Kleinmann. 1994. Passive treatment of polluted coal mine drainage. Bureau of Mines Information Circular 9389. United States Department of Interior, Washington DC.

Hedin, R. S., G. R. Watzlaf and R. W. Nairn. 1994. Passive treatment of acid mine drainage with limestone. *Journal of Environmental Quality 23:1338-1345.*

Hedin, R. S. 1996. Environmental Engineering Forum: Long-Term Effects of Wetland Treatment of Mine Drainage. *Journal of Environmental Engineering*: 83-84.

Schmidt, T. W., R. S. Hedin and P.R. Lorello. 1996. Assessment of an anoxic limestone drain for a surface mine in east central Tennessee. *In*: Proceedings of 13th Annual Meeting of the American Society for Surface Mining and Reclamation (ASSMR, Princeton, WV) pp. 384-390.

Fish, C. L., R. S. Hedin and J. Partezana. 1996. Chemical characterization of iron oxide precipitates from wetlands constructed to treat polluted mine drainage. *In*: Proceedings of 13th Annual Meeting of the American Society for Surface Mining and Reclamation (ASSMR, Princeton, WV) pp. 541-549.

Hedin, R.S., 1998. Potential recovery of iron oxides from coal mine drainage. *In*: Nineteenth Annual West Virginia Surface Mine Drainage Task Force Symposium, West Virginia University, Morgantown.

Joel W. Toso, Ph.D, P.E., P.H.

Background

Dr. Toso has twenty years of experience in hydrology and water resources engineering. Examples of his experience are presented below. Mr. Toso also serves as an instructor in hydrology and applied hydraulics at the Civil Engineering Department of the University of Minnesota.

Experience

- Prepared the surface water management plan for the remediation of a large former wood treating site in the State of Maryland. The work included modeling surface water runoff, special considerations to maximize surface water runoff and minimize percolation to the groundwater, investigating the hydrology for wetland mitigation sites, preparing grading plans and specifications and permitting documentation, erosion and sediment control plans and preparing plans for moving a creek around an mitigation area. Work with a wetland consultant/contractor to prepare grading plans for tidal and non-tidal wetland mitigation sites.

- Managed and provided technical direction for surface water management plans for the "Next Area of Growth" in Brooklyn Park, and the Battle Creek Lake watershed in Woodbury, Minnesota. These plans included: hydrology and hydraulic modeling; channel, pipe, and pond sizing; wetland delineations and considerations; recommended improvements; and cost estimates.

- Managed and provided technical direction for an investigation of a storm water geysering problem in 12-foot diameter storm drainage tunnel below Interstate 35W in downtown Minneapolis. The work consisted of reviewing data regarding the hydrology and hydraulics of various storms causing the problem including the July 1st, 1997 storm; designing an instrumentation system; and exploring various alternative solutions to the problem.

- Prepared two hydraulic design manuals for segmental retaining walls, one for installations along channels and one for along shorelines. The manual cover stream flow hydraulics, wave hydraulics, computations of water and ice forces, and related considerations for segmental retaining wall design. They are being distributed throughout the United States and portions of Canada and Australia.

- Designed a unique streambank protection method for Nine Mile Creek in Bloomington, Minnesota. Responsibilities in the S2.0 million project included: plans and specifications, an environmental assessment worksheet, coordination and cooperation in the City of Bloomington, and construction observation.

- Investigated outlet channel options for landlocked Devil's Lake in North Dakota. Work involved design and cost analysis of 13 different gravity and pumped outlet options considered for flood control. Worked on the design of alternatives for a pumped outlet for Devil's Lake. The project include design of multiple pipelines, channels, pump systems, intake and outlet considerations, hydraulic transients, groundwater infiltration/exfiltration and cost estimation.

- Managed and provided technical direction for a sediment transport study to address a sedimentation problem at an intake of a power plant along the Minnesota River near Mankato, Minnesota. Work involved using a two dimensional flow model to investigate alternatives to address the problems at the intake. The report presented the results, a cost comparison, and recommendations.

- Rewrote three Reservoir Regulation Manuals for the Mississippi River Headwaters. Prepared text and figures, compiled pertinent information, coordinated revisions with the Corps of Engineers.

- Assisted with remedial investigation of large industrial facility with soil and water contamination by coal tar derivatives in Duluth, Minnesota. Project included: mapping contamination, identifying alternative remediation measures, preparing cost estimates and report.

- Prepared revised permit reissuance report for landfill involving paper plant wastes. Project involved use of CADD to design future landfill configurations, and compute landfill capacities.

Other

During 1987-1988, Mr. Toso spent eight months as a research engineer for QIT-Fer et Titane, Inc., Madagascar Minerals Project in Montreal. The project objective was to establish a dredge-operated mine for beach sand ilmenite in Madagascar. His responsibilities included the following:

- Directed water resources study performed by consultants to predict water yield from surface and groundwater sources and to devise optimum water management schemes for mining operations.

- Managed environmental program; tasks included: coordinating on-site flora and fauna survey; preparing scope of work; reviewing proposals submitted for environmental impact assessment; and responding to correspondence from World Bank in Washington, D.C.

Education

Ph.D., University of Minnesota, 1986 (Hydraulics)
M.S., Civil Engineering, University of Minnesota, 1983 (Hydrology)
B.S., Civil Engineering, University of Minnesota, 1981

Registration

Professional Engineer (Civil): MN 19950
Professional Hydrologist: American Institute of Hydrology

ATTACHMENT 2

CASE STUDY

Passive Treatment of Acid Mine Drainage At the Jennings Environmental Education Center

Acid mine drainage flows from an abandoned underground coal mine, through existing wetlands in the Jennings Environmental Education Center (Slippery Rock, PA) and into Big Run. Both the wetlands and Big Run were degraded by the AMD. In 1997, a passive treatment system was constructed between the AMD discharge point and the existing wetlands. The system consists of a 7,500 ft^2 vertical flow pond followed by a 5,400 ft^2 constructed wetland. The reactive media consists of 300 tons of organic substrate mixed with 380 tons of limestone. It was placed on top of a pipe underdrain and then flooded with 1-2 ft. of water. The AMD is collected from the mine by a buried collection system and flows onto the surface of the vertical flow pond, down through the reactive media, and into the underdrain collection system. The collection system discharges to the constructed wetland.

The performance of the system has been monitored since its construction by Hedin Environmental, US Department of Energy (DOE), Pennsylvania Department of Environmental Protection, and Slippery Rock University. Most attention has focused on pH, acidity, alkalinity, Fe and Al. The complete system has always discharged alkaline water with pH 6-7 and concentrations of Fe and Al less than 1 mg/L. Samples collected by the DOE (and analyzed by their laboratory in Pittsburgh) have measured a wider spectrum of metals. DOE data indicate that the AMD always contains elevated concentrations of Co, Ni and Zn. Elevated concentrations of Cu were detected in July 1998. The vertical flow pond consistently decreases concentrations of these metals to <50 ug/L. Summary data for the 13-month monitoring period and individual data for the July 30, 1998 sampling are shown in the following tables.

Removal of Zn, Co, Ni, and Zn by the Jennings Vertical Flow Pond. Flows are gpm and concentrations are ug/L.

Date	flow	Co		Cu		Ni		Zn	
		in	out	in	out	in	out	in	out
9/25/97	17	280	30	<20	<20	530	30	700	30
10/15/97	17	300	50	<20	<20	570	30	750	40
10/29/97	16	330	50	<20	<20	920	40	820	20
11/20/97	16	320	60	<20	<20	610	<20	790	30
12/23/97	20	330	70	<20	<20	590	50	770	50
7/30/98	17	300	30	490	<10	610	20	1390	30
Average	17	310	48	98*	18	638	32	870	33

* detection limit used in average calculations

Performance of the Jennings passive system on July 30, 1998

Point	Flow gpm	pH	Acid mg/L	Alk mg/L	Fe mg/L	Al mg/L	Co ug/L	Cu ug/L	Ni ug/L	Zn ug/L
Raw Water	-	2.8	251	0	62	21	300	490	610	1390
VFP effluent	17	6.6	0	220	13	<1	30	<10	20	30
Wetland effluent	-	7.5	0	191	<1	<1	20	<10	20	10

The performance of the system is effected by temperature and flow rates. Variation in contaminant loading rates is primarily a function of flow. The highest flows (and loadings) occur in late winter and spring. Concurrent with the high flows are low water temperatures, which decrease microbial activity. In 1997/98, a mild wet winter in western PA, the highest flows, 30-35 gpm, occurred in April. During this period, the vertical flow system discharged 160-180 mg/L alkalinity (down from 200-250 mg/L during autumn 1997). This treatment was more than sufficient to assure a final discharge with neutral pH and low metal concentrations. During the summer and autumn of 1998, alkalinity generation rebounded to levels observed in 1997. In summary, the Jennings system currently produces the targeted effluent quality under high flow/cold temperature conditions and greatly exceeds these targets during base flow/warm temperature conditions. While not specifically targeting heavy metals, the system has also substantially decreased concentrations of Co, Cu, Ni, and Zn.

Appendix F - Wetlands Mitigation Plan

WETLAND MITIGATION PLAN

MORGANTOWN ORDNANCE WORKS, OPERABLE UNIT 1

Morgantown, Monongalia County, West Virginia

Prepared For:

Environmental Strategies Corporation
Four Penn Center West, Suite 315
Pittsburgh, PA 15276

Prepared By:

David C. Hails and Joel Toso
Ecological Restoration, Inc.
Administrative Office
311 Crooks Drive
Apollo, PA 15613

April, 2001

Morgantown\457302\Tar and Soil WP\Final Submittal\Wetlands Mitigation\Morgantown Mitigation Plan.doc

Table of Contents

Figures

Tables

1.0 Introduction

This report presents a plan for the mitigation of wetlands that are proposed to be impacted as a result of remediation efforts at the Morgantown Ordnance Works, Operable Unit OU-1. The site is located in Monongalia County, near Morgantown, West Virginia, along the Monongahela River as shown on the general location map provided in Figure 1.

A Wetland Delineation of the site was conducted by Patrick Bonislawsky and David Hails, Senior Ecologists at Ecological Restoration, Inc. in Fall and Winter of 2000. A Jurisdictional Determination by the U.S. Army Corps of Engineers verified the delineation boundaries presented by Bonislawsky and Hails. A final Wetland Delineation Report was prepared and distributed to the Agencies in February, 2001. The wetland delineation study area included the landfill footprint (fenced area) and the channels of the three drainageways (swales) that drain the landfill area from the landfill to the Monongahela River.

2.0 Description of Wetland Areas to be Impacted

From the wetlands delineated (Ecological Restoration – Wetland Delineation Report, 2000), approximately 0.70 acre of wetlands will be impacted as a result of site remedial activities. Wetlands will be replaced at a 1.5 to 1 ratio. Thus, the total wetland acreage to be replaced is 1.05 acres. Table 1 summarizes the areas of impact in the four of six delineated wetlands that will be impacted. Table 2 summarizes the prevalent plant species found in the wetlands to be impacted. Figure 2 shows the location of the wetlands to be impacted on the site.

Wetland Area No. 1 (W-1)

This wetland area is located in the southeastern portion of the scraped area and is 0.08 acre in size. This area occurs in the headwaters of Swale 1 where the hydrology is caused by accumulation of surface runoff and seasonal seepage causing somewhat poorly drained conditions. The wetland is small and does not have a diverse wetland plant community. Prevalent emergent vegetation consists of whitegrass, small-spiked false nettle, deer-tongue witchgrass, panic-grass and soft rush. All of Wetland Area No. 1 will be impacted as a result of the site activities.

Wetland Area No. 2 (W-2)

This wetland area is located in the eastern edge of the scraped area and is 0.43 acre in size. This area is the largest wetland delineated on the project site and has the highest wetland functional values. W-2 is a remnant man-made pond (identified on NWI mapping as POWZx) where deposited sediments (saturated at the surface) occur within and along the headwater area of Swale 3. A seep area at the base of the landfill maintains the wetland hydrology in this wetland for a sufficient duration.

The wetland plant community is not diverse and consists of redtop, deer-tongue witchgrass, reed canarygrass, sensitive fern, common boneset, fox sedge, Virginia bugleweed and rice cutgrass. All of Wetland Area No. 2 will be impacted as a result of the site activities. All of Wetland Area No. 2 will be impacted as a result of the site activities. Wetland Area No. 4 and No. 6 are not affected, as so are not discussed here.

Wetland Area No. 3 (W-3)

This wetland area is located on Swale 3 immediately downstream of W-2 and is 0.15 acres in size. Swale 3 is enclosed under a raised (ballast) railroad spur immediately downstream of W-2 which causes frequent overflows (flow detention) of Swale 3 channel in W-2. This periodic inundation causes somewhat poorly drained to poorly drained conditions in W-2. As with the other wetland areas on the terrace, the wetland plant community is not diverse consisting of whitegrass, small-spiked false nettle, wrinkled golden-rod, stout wood-reedgrass and water horsetail. All of Wetland Area No. 3 will be impacted as a result of the site activities.

Wetland Area No. 5 (W-5)

This wetland area is located on Swale 2, downstream of the landfill and is 0.01 acres in size. The steep gradient of Swale 2 is reduced in this area where the stream crosses an abandoned logging road. The accumulation of surface runoff in this small area causes somewhat poorly drained to temporary poorly drained conditions. The wetland plant community is not diverse and consists of whitegrass, small-spike false nettle, sensitive fern, deer-tongue witchgrass, interrupted fern and wool-grass. All of Wetland Area No. 5 will be impacted as a result of the site activities.

Table 1

Size and Classification of Wetlands to be Impacted on Project Site

Delineated Wetland Units	Area of Impact		Classification
	Sq. ft.	Acres	
W-1	3,353	0.08	PEM1A
W-2	18,942	0.43	PEM1B
W-3	6,496	0.15	PEM1A
W-5	1,525	0.04	PEM1A
TOTAL	39,108	0.70	

At a 1.5:1 replacement ratio, 0.70 acres times 1.5 = 1.05 replacement acres

Key

P = Palustrine

EM = Emergent

1 = Persistent

A = Temporary

B = Saturated

Table 2

Composite List of Prevalent Plant Species that Occur in Wetland Areas to be Impacted at Project Site

Scientific Name	**Common Name**	**Indicator Status**
Scirpus atrovirens	Green Bulrush	OBL
Verbesina alternifolia	Wingstem	FAC
Solidago rugosa	Wrinkled Goldenrod	FAC
Aster prenanthoides	Crooked-stemmed Aster	FAC
Carex vulpinoidea	Fox Sedge	OBL
Boehmeria cylindrica	Small-spiked False Nettle	FACW+
Leersia oryzoides	Rice Cutgrass	OBL
Onoclea sensibilis	Sensitive Fern	FACW
Impatiens capensis	Spotted Touch-me-not	FACW
Geum lacinatum	Rough Avens	FAC+
Phalaris arundinacea	Reed Canarygrass	FACW+
Mimulus ringens	Monkeyflower	OBL
Epilobum ciliatum	Hairy Willow-herb	FAC-
Equisetum fluviatile	Water Horsetail	OBL
Leersia virginica	Whitegrass	FACW
Scirpus cyperinus	Woolgrass	FACW

Indicator status (Based on plant species frequency of occurrence in wetlands, developed by Reed, 1988).

- UPL = Upland (probability >99% found in uplands)
- FACU = Facultative Upland (probability 67-99% found in nonwetlands, 1-33% in wetlands)
- FAC = Facultative (probability 34-66% found in wetlands)
- FACW = Facultative Wetland (probability 66-99% found in wetlands)
- OBL = Obligate Wetland Plant (probability >99% found in wetlands)

Table 3
Composite List of Plant Species Proposed for the Replacement Wetlands

Scientific Name	**Common Name**	**Indicator Status**	**Planting Zone***
Scirpus atrovirens	Green Bulrush	OBL	B
Carex vulpinoidea	Fox Sedge	OBL	B
Leersia oryzoides	Rice Cutgrass	OBL	A
Onoclea sensibilis	Sensitive Fern	FACW	C
Impatiens capensis	Spotted Touch-me-not	FACW	C
Mimulus ringens	Monkeyflower	OBL	B
Leersia virginica	Whitegrass	FACW	C
Scirpus cyperinus	Woolgrass	FACW	C
Polygonum lapathifolium	Nodding Smartweed	OBL	B
Sagittaria latifolia	Duck Potato	OBL	A
Sagittaria rigida	Deep Water Duck Potato	OBL	D
Pontederia cordata	Pickerelweed	OBL	A
Saururus cernuus	Lizard Tail	OBL	A
Carex lurida	Lurid Sedge	OBL	B
Nuphar advena	Spatterdock	OBL	D
Zizania aquatica	Wild Rice	OBL	D
Alisma plantago –aquatica	Water Plantain	OBL	A
Iris versicolor	Blue Flag	OBL	B
Carex crinita	Fringed Sedge	OBL	B
Sparganium eurycarpum	Burreed	OBL	A
Alnus serrulata	Alder	FACW	E
Salix exigua	Sandbar Willow	OBL	E
Salix amygdaloides	Peachleaf Willow	FACW	E
Viburnum lentago	Nannyberry	FAC	E
Sambucus canadensis	Elderberry	FACW	E
Aronia arbutifolia	Red Chokeberry	FACW	E
Cornus amomum	Silky Dogwood	FACW	E
Cornus foemina	Stiff Dogwood	FAC	E
Vallisneria americana	Tapegrass	OBL	D

*Refer to Figure 5 for Planting Zones

Indicator status (Based on plant species frequency of occurrence in wetlands, developed by Reed, 1988)

- UPL = Upland (probability >99% found in uplands)
- FACU = Facultative Upland (probability 67-99% found in nonwetlands, 1-33% in wetlands)
- FAC = Facultative (probability 34-66% found in wetlands)
- FACW = Facultative Wetland (probability 66-99% found in wetlands)
- OBL = Obligate Wetland Plant (probability >99% found in wetlands)

3.0 Wetland Mitigation Design

3.1 Description

The replacement wetland area is located in the floodplain of the Monongahela River as shown in Figure 2. Basic design consists of excavation and recontouring to allow for establishment of hydrology via surface runoff from upgradient acreage. Sufficient surface runoff from upgradient (nearly 100 acres of runoff is available) topography will support the wetland hydrology. By creating diversion berms (without impacting existing wetlands), water can be directed to the inlet of the proposed constructed wetland. The hydrology within the constructed wetland basin was designed to support five distinct wetland plant groups described later in this report.

Figure 3 shows the proposed grading plan. Inflow will enter from the southern portion and outflow from the north. The outlet will empty into an existing wetland (delineated Wetland Area No. 6) which in turn flows to the Monongahela River. There will be no impact to the existing wetland. Connection to Wetland Area No. 6 will be made after the wetland basin is constructed. A berm will remain until this time so that no sedimentation will leave the site. A typical cross section of the proposed wetland is provided as Figure 4.

3.2 Planting Scheme

The planting approach will be straightforward and will allow for field adjustments, if necessary. The basic approach is to reestablish vegetation in the replacement wetland that is similar to that of the wetlands to be impacted (minus invasive, non-commercially available or non-native species) with the addition of hydrologic zones that will enable the establishment of more diverse vegetation. Additional species that are indigenous to the area, but not found in abundance (or at all) on the Site will be added to increase the diversity and overall value of the wetlands.

Table 3 presents the proposed plant species and shows their planting zone (refer to Figure 5 for zonation). Five plant groupings will be established. Zone A consists of obligate wetland plants. This group will contain permanent saturation (standing water or saturated soils). Zone B will contain moderate saturation and may be inundated for periods, then reduced no standing water. This zone should have saturated soils or standing water for most of the growing season. Zone C may be periodically inundated, but may also experience periods of dry-down during summer months. Zone D is deep water and should contain permanent inundation. Zone E consists of the banks which represent a transition zone from the wetlands to uplands.

Figure 6 shows a typical cross sections of the planting areas. In each zone "stands" or beds of the individual species will be established. That is, the species will not be mixed when planted. In a given wetland, the value of a plant bed of one species is generally higher than that of mixed beds.

4.0 Construction

4.1 Sequence

The general construction sequence that will occur for each construction phase is presented below:

1. Establish construction benchmarks and baselines
2. Stake project earthwork boundary
3. Establish topsoil and excavated soil stockpile areas
4. Establish access arrangement for mobilization of equipment
5. Install erosion and sedimentation control measures
6. Mobilize excavation/grading equipment
7. Clear and grub
8. Strip and stockpile topsoil
9. Set grade stakes
10. Cut to rough grade according to typical construction section
11. Add site features (deeper water zones, etc.)
12. Complete final grade with 6 inches of topsoil
13. Construct inlet
14. Construct water diversion berms – direst towards inlet, allow site to flood
15. Seed and mulch disturbed areas outside the wetland planting zones
16. Allow hydrology to establish
17. Demobilize construction equipment
18. Establish planting zones based on stabilized hydrologic conditions.
19. Install hydrophytic emergent vegetation
20. Install bank vegetation
21. Complete site cleanup (unused materials, construction debris, etc.)

22. Return to remove temporary erosion and sedimentation control devices, after stabilization

Since woody planting material is bare root, dormant planting must occur. It may be necessary to install some material the following season if the entire wetland mitigation effort cannot be completed in one planting season. The typical planting window is between October 15 to December 15 or March 1 to May 15. Herbaceous plants can be installed at any time of the year with proper care.

4.2 Construction Specifications

4.2.1 Erosion Control

Erosion and sediment control measures will be implemented during wetland mitigation work to reduce the displacement of site soils, fill, and final cover materials. This will be accomplished by the placement of silt fence down-gradient of all areas where disturbance of the soil surface may occur. Silt fence will be placed to maintain the site soils and stockpiled materials at their respective locations and prevent their migration into surface watercourses.

Sedimentation control measures will be installed to reduce the amount of sediments that may be transported in site drainage courses and to prevent the discharge of soil particles with site runoff. This will be accomplished by using straw bail silt barriers in any drainage courses that may be affected by such sedimentation.

Erosion and sediment control measures must be implemented prior to the initiation of any other site activities. These measures will remain in place and be maintained for the duration of the construction project and until all work been accepted by the owner's representative.

4.2.2 Materials

Topsoil

Material obtained during excavation of the site that is suitable for topsoil (free of debris, garbage or contamination) shall be defined as fine-grained, weathered material, on the surface or directly below, any loose or partially decomposed organic matter in natural or undisturbed strata. Topsoil may be dark colored, fine, silty or sandy material with a high content of well decomposed organic matter. The material shall be representative of productive soils in the site area. If no suitable soils are available onsite, then soils from an offsite location shall be obtained.

Areas that are to receive topsoil, especially the sloped portions of the wetland basin, shall have the compacted subgrade soil scarified to a depth of at least 1-inch to allow bonding of the vegetative soil with the subsoil. The vegetative soil shall then be spread (6 inches minimum). Vegetative soil shall not be spread when frozen or excessively wet or dry.

Low Permeability Soil Liner

A 1-foot thick layer of low permeability soil shall be placed (if not already present) or site soils reworked as directed by the owner's representative. The wetland basin will require this liner to minimize seepage of ponded water. This low permeability soil material shall be silt or clay and be free from roots and other organic matter, trash, debris, and stones larger then six inches in any dimension. The material shall be capable of achieving a permeability of approximately 1 x 10^{-6} centimeters per second or less.

4.2.3 Outlet Construction

A rip-rap outlet channel will be constructed as part of the replacement wetland. Nonwoven filter fabric will be used as an underlayment with the rip-rap. The filter fabric will be placed directly on the prepared foundation. The edges will be overlapped by at least 12-inches and the anchor pins will be spaced every three feet along the overlap. The upper and lower ends of the cloth will be buried a minimum of 12-inches below the ground. The fabric must meet the following criteria:

ITEM	**ACCEPTABLE RANGE**
Material Type	Woven or Non-woven
E.O.S. (equivalent opening size)	0.15mm to 60mm
Open Area	4% to 36%
Thickness	20 to 60 mills
Grab Strength	90 to 120 lbs

The fabric shall conform to ASTM D-1862 or ASTM D-177.

Placement of rip-rap should follow immediately after placement of the filter fabric. Place rip-rap in an 12-inch thick layer so that it forms a dense, well-graded mass of stone with a minimum of voids. Rip-rap stone shall be hard, durable, material. The material shall consist of rock ranging in size from 7 inches to 24 inches with a median size of 12 inches. The spillway should be narrow at the top and wide at the bottom forming an apron to help dissipate water as it flows into Wetland Area No. 6.

4.2.4 Site Restoration and Demobilization

Site restoration and demobilization includes those activities performed to remove equipment, unused materials, temporary facilities, erosion and sediment control measures, and to restore the area to near original conditions after the construction work has been completed and accepted. All construction equipment, unused materials, unused supplies, temporary facilities, including erosion and sediment control measures, and garbage shall be removed from the site.

The area around the wetland mitigation construction site and any other areas disturbed during the construction operations shall be restored. The area shall be graded as needed and compacted to form a firm, even surface. Any areas that are without vegetation shall be seeded and mulched to prevent future erosion of site soils. Care should be taken to avoid inadvertently allowing upland restoration grass seed to fall within the constructed wetland basin as these species may compete with those planted for the purpose of establishing wetland species.

4.2.5 Plants and Planting

4.2.5.1 Qualifications of Planting Crew

The planting crew shall be supervised by a Certified Ecologist (The Ecological Society of America or equivalent) with a minimum of a Bachelor of Science Degree in Ecology or related field and a minimum of five years experience in wetland mitigation plantings. The crew shall consist of qualified individuals with at least one year of experience in landscape planting, wetland planting or other similar work.

4.2.5.2 Acquisition of Plant Material

Plants for use in the mitigation wetlands shall be obtained from a reputable wetland vegetation vendor. The vendor must specialize in supplying wetland vegetation for the purposes of wetland mitigation and must grow native stock from an ecotype within West Virginia or neighboring states. In no case should the wetland vegetation originate either by seed or whole plant from outside this region.

All shrub species shall arrive as bare root with well developed root systems. Shrubs shall be the minimum height specified in the planting scheme. All shrubs and trees shall be dormant when planting. Herbaceous material can be dormant or growing bare root adult material with vigorous root systems.

All plants shall be certified from the vendor to be true to species and free of diseases. A Certificate of Inspection from the State of origin's Department of Agriculture shall accompany each shipment of plants.

4.2.5.3 Delivery of Plant Materials to the Site

Plants shall be delivered to the Site after all earth moving and final grading of the wetland mitigation areas has been completed. Storage of plants on Site for more than a few days shall not be acceptable unless cold storage is available. Plants shall be planted within 2-3 days of arrival. During the 2-3 day period, dormant plants shall be stored in a cool, dark place. Boxes, bundles, trays or bags of the plants shall be identified by scientific species name with durable waterproof labels and weather resistant ink.

Special care shall be taken with plants that are sprouted, producing leaves or otherwise in a non-dormant state. These plants shall be kept moist and in a shaded area until planted. Exposure to sun and wind that could burn or dry leaves and roots shall be avoided.

Care shall be taken not to introduce non-dormant greenhouse grown plants to dormant conditions. The vendor shall be required not to entice the native wetland plants to continue growing beyond their normal growing period. In other words, they shall be allowed to go dormant just as the other naturally occurring plants of the same species. This will minimize stress when planted. Additional requirements are listed below for herbaceous and woody plants.

4.2.5.4. Specific Planting Requirements for Vegetative Zones

Vegetative species selected for planting in the mitigation wetland have been separated into five groups according to their wetness and/or other habits. Each of these groups have specific planting requirements that are listed below.

Zone A - Obligate Herbaceous Vegetation

These plants require, at a minimum, moist soils at the time of planting. Some standing water can be present, but the water shall not be over the leaves of the plants. It is most important that all roots be completely covered with soil so they will not dry out. Any leaf material that may be exposed to the air (emerged) after planting shall not be allowed to get wet during the planting. Splashing the leaves or inadvertently allowing the leaves to fall in the water during planting and then reexposing them to the air can cause stress to the plant or could cause the leaves to become sun-burned.

Zone B –Moderately Wet Herbaceous OBL and FACW Plants

These plants need moist root zones when planted. The moisture in root zones should persist for at least two weeks after planting. The area should be subject to regular flooding. These plants can tolerate standing water, but not continuously. Roots should be completely covered with soil and packed down to avoid wash-out during flooding.

Zone C – FACW Plants, Intermittently Wet

These plants can withstand dry-down periods, but soils should be wet during planting. If planted during a dry period, some watering may be required as recommended by the plant supplier or site Ecologist.

Zone D – Deepwater Areas

Standing water should be present at the time of planting. Contractor should make every effort to assure that the plants do not float. Weights or staples can be used to aid in this task.

Zone E – Wetland/Upland Fringe and Bank Shrubs

These groups can be planted in drier areas on the banks. Plenty of room shall be provided for the root systems and fertilizer may be required at planting time (depending on quality of the soil). All shrubs shall be watered at planting time unless soils are moderately wet and, depending on conditions, may require periodic waterings until the roots are established.

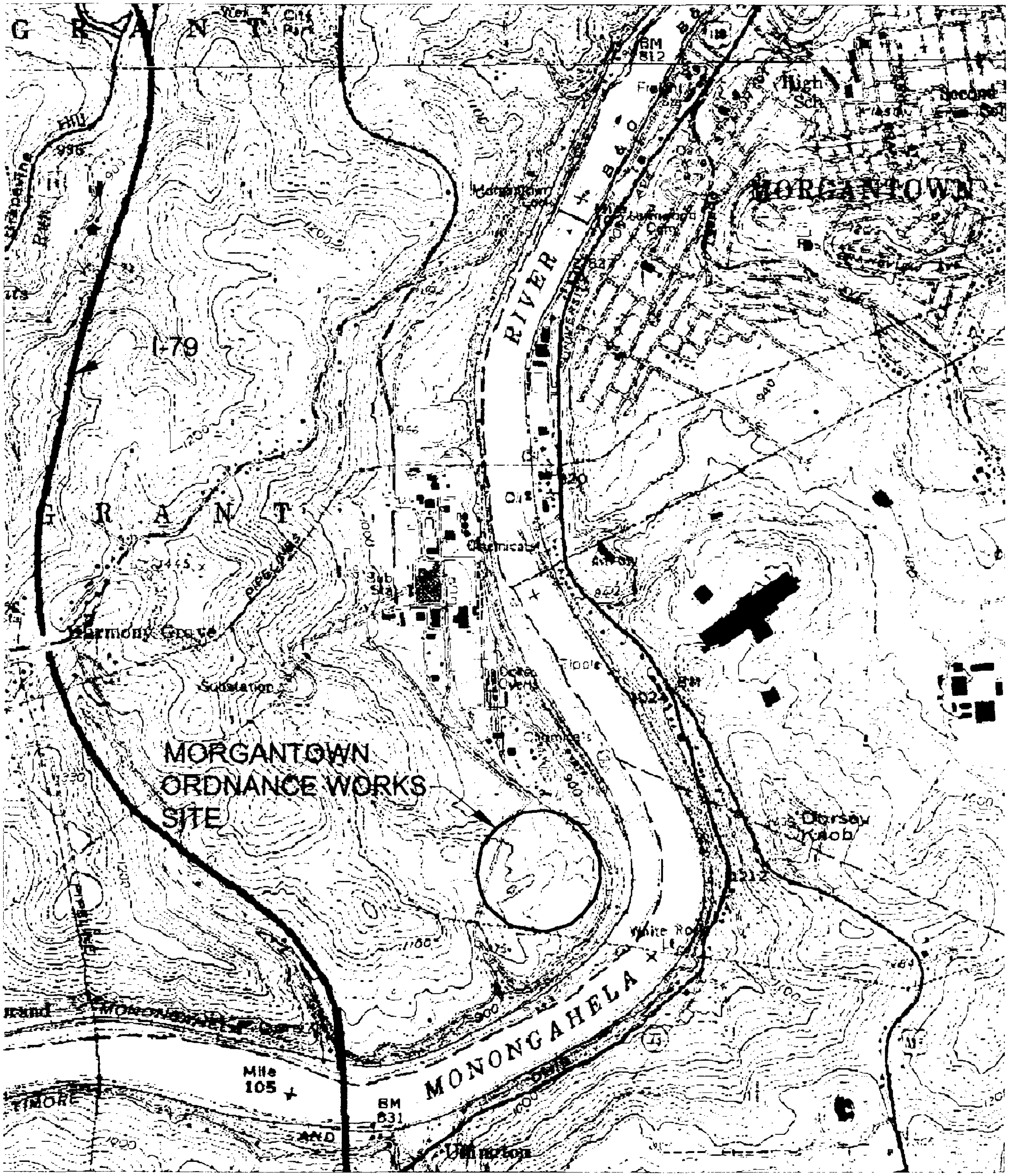
4.3 Schedule

Construction is expected to begin in summer or winter, 2001 with planting in fall, 2001 or spring, 2002, respectively.

5.0 References

ERI-2001 – Del. Report. Reed, 1988.

FIGURES



Ecological Restoration, Inc.

N

0 100 200 300
SCALE IN FEET

Figure 1
SITE LOCATION
Morgantown Ordnance Works
Operable Unit 1
Morgantown, WV

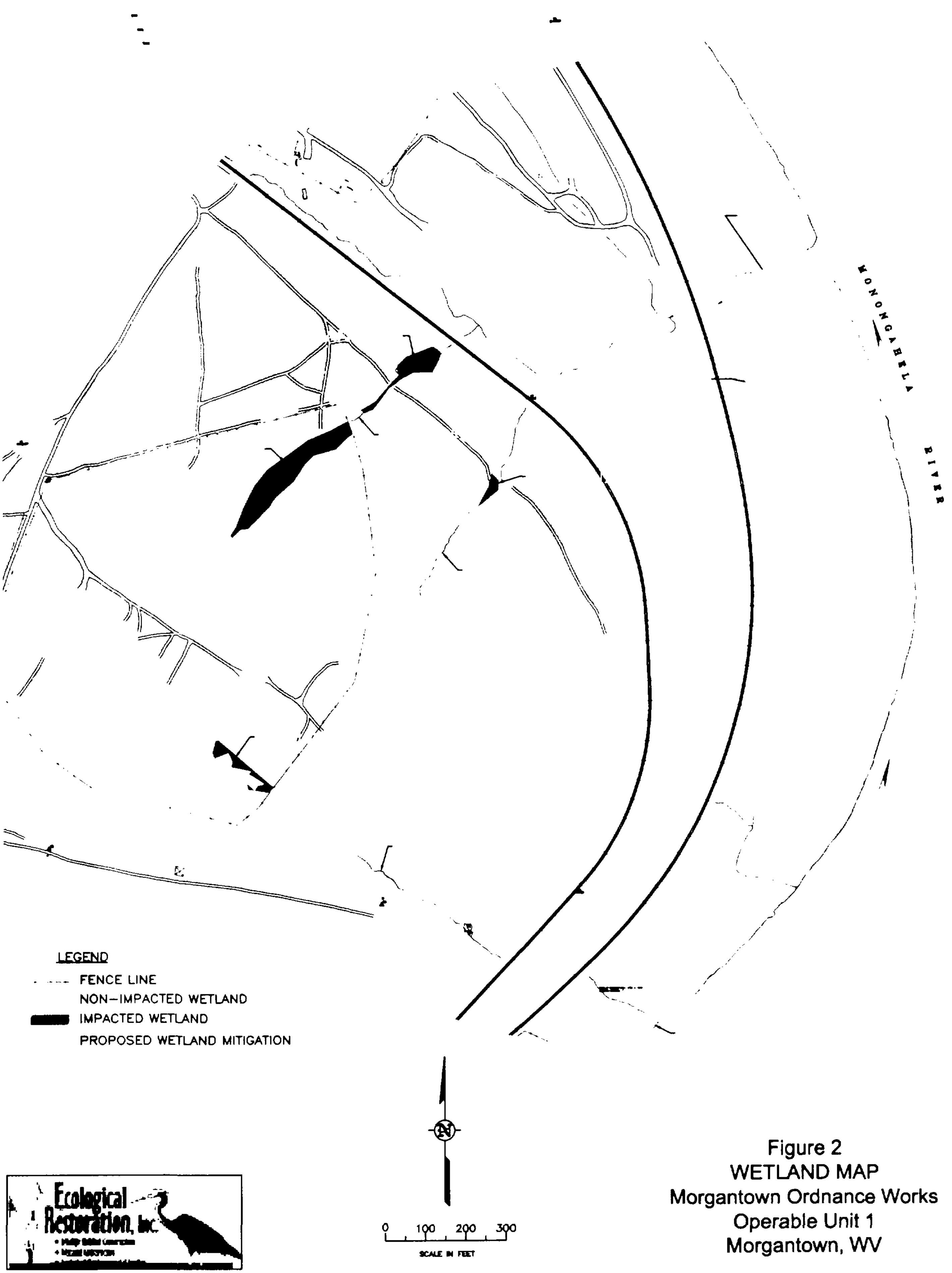
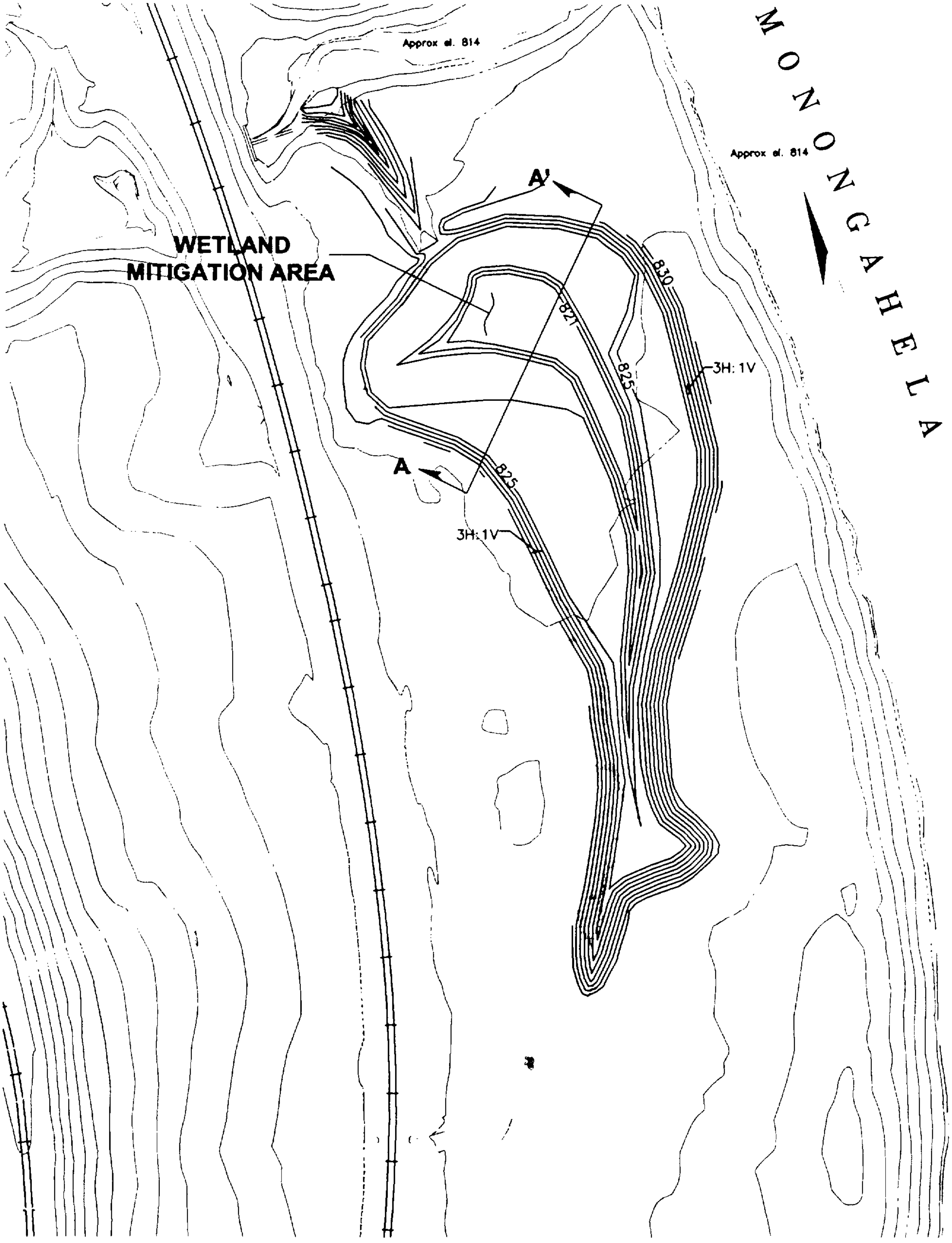


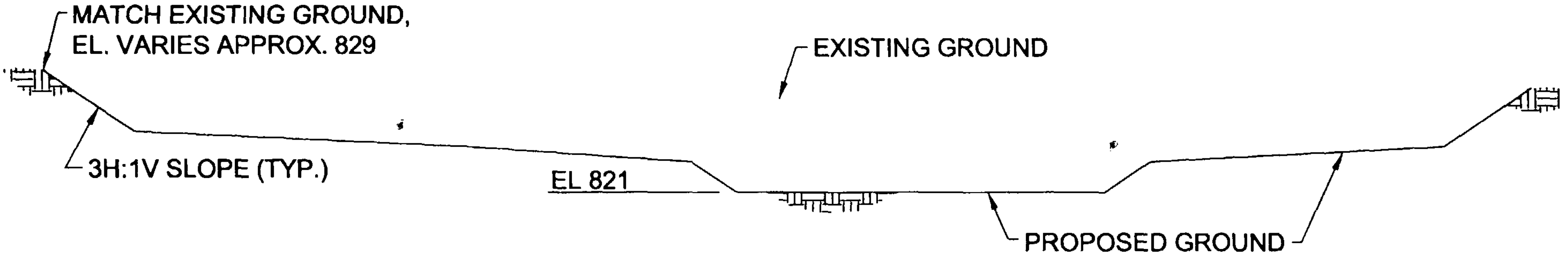
Figure 2
WETLAND MAP
Morgantown Ordnance Works
Operable Unit 1
Morgantown, WV

Ecological Restoration, Inc.

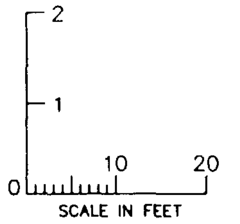


Ecological Restoration, Inc.

Figure 3
GRADING PLAN
Morgantown Ordnance Works
Operable Unit 1
Morgantown, WV



SECTION **A - A'**



Ecological Restoration, Inc.

Figure 4
TYPICAL CROSS SECTION
Morgantown Ordnance Works
Operable Unit 1
Morgantown, WV

LEGEND

☐ Zone A:
OBL Plants (wetter area)

▨ Zone B:
FACW & OBL Plants (moderate area)

☐ Zone C:
FACW Plants (drier area)

■ Zone D:
Channel and deepwater plants

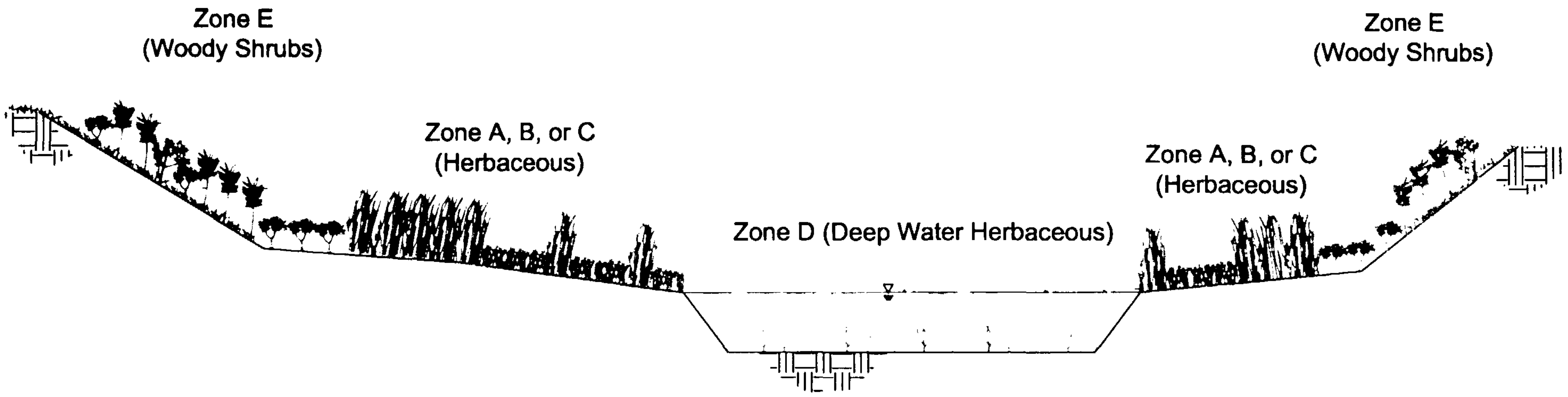
■ Zone E:
Bank shrub plants (wetland fringe)

Ecological Restoration, Inc.

N

0 50 100
SCALE IN FEET

Figure 5
PLANTING SCHEME
Morgantown Ordnance Works
Operable Unit 1
Morgantown, WV



Ecological Restoration, Inc.

Figure 6
TYPICAL PLANTING CROSS
SECTION
Morgantown Ordnance Works
Operable Unit 1
Morgantown, WV