CIVIL/SANITARY/ENVIRONMENTAL ENGINEERS
SOLID WASTE MANAGEMENT
Municipal Services
Engineering Company, P.A.
SITE PLANNING/SUBDIVISIONS
SUBSURFACE UTILITY ENGINEERING (SUE)

July 21, 2009

Mr. Zinith Barbee, Project Manager
Solid Waste Section
Division of Waste Management
North Carolina Department of Environmental and Natural Resources
401 Oberlin Road, Suite 150
Raleigh, NC 27605

Re: **Revised Corrective Action Plan**
Greene County Permit #40-02

Dear Mr. Barbee:

Enclosed please find two hard copies of a revised Corrective Action Plan (CAP) for the Greene County Landfill, Permit #40-02. This revision was prepared in response to comments and requests documented in your letter (Document ID 7536) dated June 18, 2009 which you indicated were based on your review of our previous CAP submittal in May 2009. For your convenience, a copy of your letter is included in the front pocket of the report binder.

We appreciate this opportunity to represent Greene County in this manner and feel we have addressed your concerns and issues. Please contact us at (919) 772-5393, spatrick@mesco.com or mbrown@mesco.com if you have any questions or comments regarding this submittal.

Sincerely,
MUNICIPAL ENGINEERING SERVICES CO., P.A.

Sean Patrick, P.G.
Professional Geologist

Mark Brown, LG, PG
Senior Geologist

Enclosures

Cc: David Jones – Greene County

NCDENR
North Carolina Department of Environment and Natural Resources
Division of Waste Management
Dexter R. Matthews
Director

Beverly Eaves Perdue
Governor

Dee Freeman
Secretary

June 18, 2009

Mr. David Jones
Public Works Director
Post Office Box 543
Snow Hill, North Carolina 28580

COPY

Subject: Draft Text for Corrective Action Plan
Greene County Landfill
Construction and Demolition Landfill Permit 40-02,
Doc ID 7536

Dear Mr. Jones:

The Solid Waste Section (SWS) reviewed the draft text (draft report) of the third revised Corrective Action Plan (CAP) for the Greene County Landfill. Municipal Engineering Services Company, P.A. (MESCO) submitted the draft report with its response letter, dated May 13, 2009 (Doc ID 7358), to the SWS's second technical review (Doc ID 7138). The CAP presented in the draft report replaces the CAP revised on February 25 2009 in which a remedy not presented to the public had been proposed. The current remedy has been presented in a public meeting.

Although the draft report is not approved, the SWS approves the selected remedy—Monitored Natural Attenuation (MNA)—for groundwater contamination described in the Assessment of Corrective Measures (ACM), dated August 2007. Groundwater contamination is reportedly within the SWS's relevant point of compliance. Revision of the draft report is required. More characterization of the contamination plume is necessary, and more information about financial assurance is needed. Specific revisions are listed below. The numbers correspond to the numbered sections in the draft report.

1.3 Include lead, iron, and cis-1,2-dichloroethene as constituents of concern (COC's). Lead is reported in both the ACM and CAP as "statistically significant". It is historically detected above the state groundwater quality standard in four out of six wells proposed for MNA—background well, MW-1R; compliance wells, MW-6 and MW-7; and MW-4 in the plume. Pursuant to 15A NCAC 13B .1634, lead is also identified in Appendices I and II as a constituent to be assessed. Iron is detected in MW-4 and MW-5 at more than 20 times levels detected in background and adjacent wells; therefore, appears more indicative of onsite contamination than "natural" occurrence. Sampling reports for March 2007, September 2007, and March 2008 show iron detected above the state groundwater standard. Iron is also a MNA parameter. Cis-1,2-dichloroethene is listed as a COC in the ACM and is reportedly the COC modeled for the CAP. Compliance with "the 1600 Rules" and "the 500

Rules" referred to in the response letter do not preclude compliance with state groundwater quality standards specified in 15A NCAC 2L .0202.

1.4 Two revisions are necessary. One, see comment for 1.3. Two, reconcile opposing groundwater flow directions at MW-6. In the ACM, MW-6 is downgradient of the plume; whereas, in sampling reports, it is upgradient. Provide a "site conception model" showing consistent relationship between the wells and plume.

2.1 See comment 1.3.

2.5.2 Delete the sentence in which lead and iron are reported to not be COC's.

6.2 Attach to the CAP documentation from the "Transition Plan" referenced here and in Section 2.3 in which the "Explosive Gas Control Plan" is described. Include a map of sampling points, detail of the gas vents, etc.

8.0 Show the total cost for the years during which corrective action is in effect. More information about financial assurance is at the end of this letter.

Plates

Plate 3 Show location of the relevant point of compliance.

To date the SWS has not received a revised financial assurance mechanism that includes a cost for corrective action. The SWS received a letter from the chief financial officer of Greene County, dated March 27, 2009 showing financial assurance for the costs of closure and post-closure but not for the cost of corrective action. Also, please note that in Regulation 15A NCAC 13B .1628 (d)(1)(A) is the specification that the cost estimate be adjusted for inflation. A revised financial assurance mechanism including a cost estimate for the CAP should be sent to Ms. Shawn McKee in the SWS. She can be contacted at 919-508-8512 or at: shawn.mckee@ncdenr.gov.

The revised CAP should be submitted within 30 days of the receipt of this letter. If you have questions, please contact me at 919-508-8401 or at: zinith.barbee@ncdenr.gov.

Sincerely,
Zinith Barbee

Zinith Barbee
Project Manager
Solid Waste Section

cc: Mark Poindexter	Field Operations Supervisor
Ed Mussler	Solid Waste Section
Pat Backus	SWS
Shawn McKee	SWS
Sean Patrick	Municipal Engineering Services Co., P.A.
Central Fill	

Corrective Action Plan

Prepared for

Greene County Landfill - Permit #40-02
Walstonburg, Greene County, North Carolina

MESCO Project Number: G07061.0

Completed on 2/25/2009
Revised on 7/22/2009

LICENSE NUMBER: C-0281
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EXECUTIVE SUMMARY

The report presents a proposed Corrective Action Plan (CAP) to remediate contamination detected at the Greene County Construction and Demolition (C&D) Landfill located at 105 Landfill Road (SR 1239), Walstonburg, Greene County, North Carolina. Greene County C&D landfill operates under permit #40-02. Prior to operating as a C&D landfill, the site operated as an approximate 9-acre Municipal Solid Waste (MSW) unlined sanitary landfill. The MSW unit stopped receiving waste by January 1, 1998 in accordance with the *Greene County Transition Plan* prepared for Greene County by Municipal Engineering Services Company, P.A (MESCO), April 1994. The C&D landfill is constructed and operating on top of the MSW unit and, in accordance with Solid Waste Section (Section) Guidelines, is monitored under 15A NCAC 13B.1630

As a result of elevated contaminant concentrations detected during previous groundwater sampling events, the following chemical compounds were identified in the *Assessment of Corrective Measures (ACM) for Greene County Landfill* dated August 2007 as contaminants of concern (COCs):

- Benzene, chloroethane, *cis*-1, 2-dichlorothene (*cis*-1,2-DCE), vinyl chloride, *p*-dichlorobenzene, toluene, iron, lead

Greene County selected a remedy to meet the standards listed in Rule 15A NCAC 13B.1636(b) based on the following number of factors:

- The extent of detected contamination lies within the relevant point of compliance.
- There are no potable wells observed or reported within 2,000 feet of the facility.
- A man-made diversion ditch beginning at the northwest corner of the C&D landfill extends easterly along the northern property boundary.
- Contamination is below risk exposure levels.
- Contamination appears to be limited to the unconfined, surficial aquifer.
- Natural attenuation mechanisms appear to be actively controlling groundwater contaminant movement in this area.
- Modeling suggests that *cis*-1,2-DCE and vinyl chloride might reach the relevant point of compliance in approximately 10 years.

Greene County has determined that the most cost effective and efficient system for remediation at the site is monitored natural attenuation (MNA) supplemented by phytoremediation. Institutional controls limit access to the site, public water is available to the surrounding area, and the source area has been capped to limit the infiltration. MNA will be implemented to correspond with semi-annual sampling.

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1 INTRODUCTION

1.1 Site Background

The Greene County Construction and Demolition (C&D) landfill is an approximate 9-acre tract located at 105 Landfill Road (SR 1239), Walstonburg, Greene County, North Carolina. Greene County C&D landfill operates under permit #40-02. Prior to operating as a C&D landfill, the site operated as a Municipal Solid Waste (MSW) unlined sanitary landfill. The MSW unit was closed using an 18-inch cohesive soil cap with a permeability of 1 x 10^{-5} cm/sec, and 18 inches of erosive layer. The MSW unit stopped receiving waste by January 1, 1998 in accordance with the *Greene County Transition Plan* prepared for Greene County (the County) by Municipal Engineering Services Company, P.A (MESCO), April 1994.[7] The C&D landfill is constructed and operating on top of the MSW unit and, in accordance with Solid Waste Section (Section) Guidelines, is monitored under 15A NCAC 13B.1630. A topographic map presenting the location of the site is included as **Plate 1**.

1.2 Aquifer Characteristics

The site lies within the Coastal Plain physiographic province, which is characterized by flat or gently undulating topography and dissected by drainage features with narrow to moderately sloped sides. Topographic relief across the facility is approximately 20 feet. Surface drainage across the site is generally northeast towards a tributary of Sandy Run. Sandy Run flows east towards Little Contentnea Creek, which drains into the Neuse River. A site map presenting the layout of the permitted facility is included as **Plate 2**.

The site is underlain by unconsolidated surficial deposits made up of sand, clay and gravel, which generally dip to the southeast. The surficial sediments are underlain by the Yorktown formation, which consists of an overlying confining unit of clay, silty clay, and/or sandy clay that is approximately 25 feet thick; followed by an underlying unit of fine sand, silty sand, and clayey sand.[4] Groundwater at the site is relatively shallow and typically occurs at depths of less than 20 feet below ground surface (bgs), with the shallowest depths occurring along the eastern side of the property. Groundwater static water level measurements in the monitoring wells have been generally consistent over time, and have been reported in the following depth ranges:

- ≤ 10 ft. bgs: *MW-1R, MW-6*
- 10 to 20 ft. bgs: *MW-4, MW-5, MW-7, MW-8*

Historical groundwater elevations are provided in **Table 2**. Local drainage features control primary groundwater flow dynamics. Groundwater located beneath the site appears to flow in an easterly direction away from the waste limits. A single-day potentiometric map depicting groundwater flow conditions recorded on July 15, 2009 is provided as **Plate 3**.

1.3 Contaminant Distribution

Groundwater contaminants of concern (COCs) at the site consisted of dissolved-phase volatile organic compounds (VOCs) and inorganic compounds (metals) in concentrations exceeding established 15A NCAC 2L Groundwater Standards (2L Standards). Six organic compounds (benzene, chloroethane, chloroethene (vinyl chloride), *cis*-1,2-dichloroethene, 1,4-dichlorobenzene (*p*-dichlorobenzene) and methylbenzene (toluene)) were detected at levels above their respective 2L Standards in MW-4 at the northeastern corner of the site. Inorganic constituents (metals) detected above their respective 2L Standards included cadmium, chromium, iron, lead, and manganese. Cadmium, chromium, iron, lead, vanadium, and zinc have also been detected in surface water samples at levels above the surface water standards promulgated in 15A NCAC 2B (2B Standards).

1.4 Site Conceptual Model

The site conceptual model represents, and is based on, the physical, chemical and biological processes that determine the transport of contaminants from sources through environmental media to potential receptors. Site conceptual and analytical models were developed and originally presented in the *Assessment of Corrective Measures (ACM) Greene County* prepared by MESCO in August 2007. The models consisted of conceptual cross sections and analytical modeling using MODFLOW with MT3D^{96}. The lithologic cross-sections presented in the *ACM* are provided herein on **Plate 4**.

1.5 Site Description

The site lies within the Coastal Plain physiographic province that is characterized by flat or gently undulating topography dissected by drainage features with narrow to moderately sloped sides. There is approximately 20 feet of relief across the site. Surface drainage is northeast towards a tributary of Sandy Run. Sandy Run flows east towards little Contentnea Creek and ultimately to the Neuse River.

1.5.1 Geology

The geology of the site consists of surficial sediments overlying the Pliocene Yorktown and Cretaceous Black Creek Formations. The surficial deposits are made up of sand, clay and gravel which dip to the southeast at less than 0.5 degrees and are generally less than forty feet deep. The Yorktown formation consists of an overlying confining unit of clay, silty clay, or sandy clay that is approximately 25 feet thick, followed by fine sand, silty sand, and clayey sand.[4]

According to information presented in the *ACM*, the subsurface lithology at location MW-1R consists of orange mottled silty clay to gray mottled sandy clay; the lithology at location MW-4 consists primarily of red-orange mottled clay/silty clay, to red sandy clay, to orange silty clay. The lithology at MW-5 consists of tan silty clay, gray sandy clay to orange clayey sand. Subgrade soils located at location MW-6 consist of orange, mottled gray silty clay/sandy clay. MW-7's lithology consists of mottled gray/red/orange clay, and MW-8 is located primarily in gray/red/orange-mottled clay to orange clayey sand.

1.5.2 Hydrogeology

Hydrogeologic properties of monitoring wells MW-1R, MW-4, MW-5, and MW-6 were reported in a *Water Quality Monitoring System Modifications Report* prepared by GAI Consultants. Hydraulic conductivity (K) values are summarized in **Table 3.** K values, as determined from slug testing performed by others in October 1994 [3] and by MESCO in June 2007 (after installation of monitor wells MW-7 and MW-8), reportedly ranged from 1.10 x 10^{-4} cm/sec (MW-4) to 1.14 x 10^{-3} cm/sec (MW-8), with a geometric mean of 2.07 x 10^{-4} cm/sec.

Average linear groundwater velocities (v_x) were calculated using the following equation:

$$v_x = \frac{K * i}{n_e}$$

where:

v_x represents the average linear velocity [length/time]
K represents the hydraulic conductivity [length/time]
n_e represents the effective porosity [unitless]

and

i represents the horizontal hydraulic gradient in the direction of groundwater flow, taken as the difference in head elevation between two points divided by the distance between those points [unitless, or length/length]

The hydraulic gradient was calculated graphically by first drawing a perpendicular line from each monitoring well to the closest downgradient equipotential line. The hydraulic head (*dh*) elevations were calculated by subtracting the equipotential line elevation value from the static water level elevation value measured in the corresponding piezometer. The lateral distance (*dl*) is the horizontal length of the line between the two points. *dl* values are further denoted on **Plate 3.** The hydraulic gradient at a given piezometer location was determined by dividing *dh* by *dl*. Hydraulic gradient at the site was calculated to range from 0.015 to 0.025 ft/ft. The calculated average linear velocities were found to have a median value of 33.4 ft/yr.

Porosities for MW-1R, MW-4, MW-5, and MW-6 were reported in the aforementioned *ACM*. Porosities for MW-7 and MW-8 were calculated from Shelby Tube samples collected during installation of the monitoring wells. Values of total porosity ranged from a high of 43.2% in MW-6 to a low of 36.7% in MW-1R with an average of 40.1%.

Effective porosities for MW-1R, MW-4, MW-5, and MW-6 were assumed in the *ACM* at 15%. Effective porosity for MW-7 and MW-8 were estimated using the relationship between effective porosity and grain-size distribution. Johnson (1967) compiled a number of published effective porosity values and developed a relationship between the grain size distribution and the effective porosity. Grain size distribution from monitoring wells MW-7 and MW-8 was applied to the "tri-linear graph of textural classification." Unfortunately, the grain size distribution fell into an area of no samples. The reported value of 15% does not conform with published values of silty clay or sandy clay. The published value of 7% was, therefore, used as the estimated effective porosity for the Sandy Clay [5]

1.5.3 Hydrology

1.5.3.1 Potable Sources

Municipal water is available to the surrounding area. A site reconnaissance and receptor survey performed in the area in 2007 as part of the *Transition Plan* did not identify any potable wells located within 2000 feet of the facility. A man-made diversion ditch beginning at the northwest corner of the C&D landfill extends easterly along the northern property boundary.

1.5.3.2 Groundwater Regime

Regionally the near-surface aquifer occurs in unconsolidated soils. These unconsolidated soils overlie several regional confined aquifers. In the area south of Wooten's Crossroads, the Yorktown aquifer underlies the surficial aquifer and is confined by a clay/sandy clay-confining unit.[4]

Locally, groundwater exhibits flow dynamics that are primarily controlled by the local drainage features. Groundwater elevations have been recorded during sampling events. A summary of historical groundwater elevation data is included in **Table 2**. Water elevations appear to be fairly consistent. On average, static groundwater in MW-1R and MW-6 occurs approximately five to six feet below ground surface (bgs), in MW-4 and MW-5 approximately 16 to 17 feet bgs, and in new wells MW-7 and MW-8 approximately 10 to 11 feet bgs. Groundwater flow is generally easterly A potentiometric map is provided as **Plate 3**.

1.5.3.3 Groundwater Modeling

A conceptual model of the site was developed with Visual MODFLOW designed by Waterloo Hydrogeologic, Inc. The visual MODFLOW package includes the USGS developed MODFLOW, the accompanying particle tracking program, MODPATH, as well as the contamination transport package MT3D^{96} developed by Papadopulos and Associates, Inc.

The model grid consisted of an area 1700 feet x 1200 feet divided into 60 rows, 85 columns and 5 layers. To approximate the aquifer characteristics, each layer was defined with distinct hydraulic properties.

Lithology		Hydraulic Conductivity (cm/sec)	Total Porosity	Effective Porosity
Layer 1	Orange Mottled Silty CLAY	1.15×10^{-4}	38.4	7
Layer 2	Orange/Red/Gray Sandy CLAY	4.90×10^{-4}	40.4	7
Layer 3	Gray Silty CLAY	1.15×10^{-4}	38.4	7
Layer 4	Confining Layer of Yorktown Formation	5.90×10^{-6}	37.6	9
Layer 5	Yorktown Formation	7.7×10^{-3}	51.7	20

Layer 1 and Layer 3 - Estimated from MW-1R and MW-4
Layer 2 Estimated from MW-5, MW-6 and MW-8
Layer 4 and Layer 5 estimated from published values[4]

The contaminant plume was determined from plume models created using MODFLOW (with transport package MT3D^{96}) to simulate a release. Modeling parameters assumed leakage occurred prior to installation of the CAP system. As with the development of the MODFLOW model, MT3D^{96} Transport was calibrated through a trial and adjustment procedure. The retardation coefficient and dispersion factors were calibrated to time periods 2006 and 2007. In an attempt to incorporate historical data, MESCO used 1990 as a baseline, and target step periods of 5 years (1995), 16 years (2006), 17 years (2007), 25 years (2015), 35 years (2025), and 50 years (2040) were simulated in the model. The plume contour for 2007 was manually transposed from the simulations onto **Plate 5.** Based on plume contours, groundwater impact appeared to be limited to monitoring well MW-4 and, therefore, the unconfined surficial aquifer. To date, elevated levels of target analytes have not been detected in compliance wells MW-7 and MW-8. Historically detected organic constituents are presented in **Table 4**.

1.5.4 Physical Processes

The primary mechanism promoting physical movement of the plume is advection. Retardation coefficients (R values) were calculated in the *ACM*. The following table expresses the anticipated time requirements for dissolved target analytes to reach the relevant point of compliance, excluding biological decay and dilution.

Contaminant Velocity (Presented in ACM)		
Monitoring Well	**MW-4**	**Time to relevant point of compliance (approx. 125 ft from MW-4)**
Benzene	3.46 ft/year	36.1 years
Chloroethane	6.29 ft/year	19.9years
Vinyl Chloride	12.6 ft/yrs	9.9 years
p-Dichlorobenzene	0.68 ft/year	183.8 year
Toluene	1.58 ft/year	79.1 years
Cis-1,2-dichloroethene	9.58 ft/year	13.0 years

The above table suggests that contamination has the potential to travel at or near the seepage velocities identified in the *ACM*. Summaries of the corrective action screening results as presented in the *ACM* are included as **Tables 8A-8E** (attached).

1.5.5 Chemical/Biochemical Processes

Chemical degradation processes, primarily that of half-life decay, are typically presented in relation to surface water measurements [10]. A man-made diversion ditch beginning at the northwest corner of the C&D landfill extends easterly along the northern property boundary and the identified contamination consisted of constituents dissolved in groundwater. Benzene, chloroethane, and vinyl chloride experience rapid volatilization in soil when released near the surface and to surface waters. *p*-Dichlorobenzene and toluene volatilize rapidly when released into surface waters and experiences low to moderate adsorption when released into soils.[1] Half-life reactions in groundwater vary greatly. A summary of published half-life reactions in groundwater is included below.

Half-Life in Groundwater[6]		
Constituent	**Half-Life (high)**	**Half-Life (low)**
Benzene	24 months	10 days
Chloroethane	31 months	5.5 weeks
Vinyl chloride	70 months	14 weeks
p-Dichlorobenzene	12 months	8 weeks
Toluene	12 months	8 weeks
Cis-1,2-dichlorethene	4 months	13 weeks
Lead	Stable	
Iron	Stable	

The identified COCs consisted of aromatic hydrocarbons, chlorinated aliphatic hydrocarbons and heavy metals dissolved in groundwater. Natural biodegradation of most chlorinated hydrocarbons, including halogenated aliphatics, occurs through reductive dechlorination. Reductive dechlorination occurs as the result of microbial activity that progressively removes chlorine atoms from chlorinated hydrocarbons through various oxidation-reduction reactions. Under anaerobic conditions, reductive dechlorination occurs through electron acceptor reactions, with the chlorinated hydrocarbons acting as electron donors rather than as a carbon source for microbial activity. Under aerobic and some anaerobic conditions, reductive dechlorination can occur as a result of electron donor reactions, during which chlorinated hydrocarbons act as both carbon and energy sources for microbial activity [2].

1.6 Regulatory Status

The Greene County Landfill operates as a C&D landfill constructed over a MSWLF landfill under permit #40-02. Assessment monitoring is currently performed on a semi-annual basis at the site.

2 CONTAMINANT CHARACTERIZATION

2.1 Contaminants of Concern

The following chemical compounds were identified in the *ACM* as being COCs:

- benzene – *aromatic hydrocarbon*
- chloroethane – *chlorinated aliphatic hydrocarbon*
- *cis*-1,2-dichlorothene - *chlorinated aliphatic hydrocarbon*
- vinyl chloride – *chlorinated aliphatic hydrocarbon*
- *p*-dichlorobenzene – *chlorinated aromatic hydrocarbon*
- toluene – *aromatic hydrocarbon*

- iron – *heavy metal*
- lead – *heavy metal*

2.2 Contaminant Source Confirmation

The source of the release has been identified as the MSW landfill. The mechanism suspected for the presence of this contamination is precipitation that has percolated through the landfill waste, allowing VOCs to partition from solid/liquid phases into a dissolved phase, and that has subsequently migrated downwards to mix with groundwater. To limit water percolation, the MSW unit was closed with an 18-inch thick cohesive soil cap (permeability of 1×10^{-5} cm/sec) and 18 inches of erosive layer. Ultimately groundwater will discharge into unnamed creeks located east of the landfill. These creeks are tributaries of Sandy Run. There are no known groundwater users located within 2,000 feet of the facility.

2.3 Source Control Measures

The landfill stopped receiving MSW by October 1998 and was closed with an 18-inch thick cap of cohesive soil with a permeability of 1×10^{-5} cm/sec, and an 18-inch erosive layer. As indicated in Appendix III (*Explosive Gas Control Plan for Greene County*) of the *Transition Plan*, the County installed a passive horizontal gas venting system around the perimeter of the landfill in 1994. Permanent probes (sampling points) installed around the perimeter of the landfill were constructed of 1-inch slotted Schedule 40 PVC pipe inserted into a 6-inch diameter augered hole to an approximate depth of six feet bgs. Probes were constructed with sufficient PVC riser to extend approximately three feet above the ground surface. The tops of the probes were capped with a PVC cap equipped with a ¼-inch NPT hose barb and 1-inch sample tubing. The bottom two feet of the borings were backfilled with pea gravel with an approximate one-foot thick cap of bentonite seal hydrated on top. The remaining annular space was backfilled with soil cuttings. Methane gas levels are monitored quarterly in the sampling points and landfill structures by County personnel using a combustible gas meter. Copies of the *Permanent Methane Monitoring Plan* (including the plan, a map of monitoring points, and the last three Methane Gas Monitoring Reports) and the *Permanent Methane Monitoring Plan* Approval Letter, dated September 13, 1994, provided by Greene County are presented in **Appendix C**.

2.4 Risk Assessment

Risk assessment was performed as part of the *ACM* and assumed direct contact with the identified contamination. Exposure pathways are limited to on-site contact with groundwater. Monitor wells are cased and secured with locking well caps. Access to the site is limited during operational hours. Adult hazard index values for the referenced COCs were "less than 1" from inhalation, dermal, and oral ingestion exposure. Additionally, child hazard index values for referenced COCs were less than 1 from inhalation, dermal, and oral ingestion exposure.

2.5 Contaminant Concentrations

2.5.1 Background Concentrations

Background water quality data is collected from upgradient monitor well MW-1R. Water quality samples have been collected since 1994. Historical background results are shown in **Table 5**. Current groundwater results are shown in **Table 6**.

2.5.2 Exceedances of Groundwater Quality Standards

Groundwater contaminants that have exceeded 2L Standards include: benzene, chloroethane, chromium, *cis*-1,2-DCE, *p*-dichlorobenzene, toluene, vinyl chloride, cadmium, lead, iron, and vanadium. Cadmium, chromium, and vanadium were found to be statistically insignificant and are, therefore, not considered COCs.

2.5.3 Exceedances of Surfacewater Quality Standards

Laboratory analysis of surfacewater samples have not detected contaminant concentrations in excess of established NCAC 2B surfacewater quality standards (2B Standards). Surface water samples are collected off-site at the tributary of Sandy Run. One (1) upstream sample and one (1) downstream sample are collected. Current surfacewater results are shown in **Table 7**. The upstream sampling point was dry during the March 2008 sampling event.

2.6 Media of Concern

Groundwater is the primary medium of concern at the site since it acts as the primary mechanism of transport for environmental contaminants emanating from the landfill. Dissolved-phase contaminants can potentially be transported via groundwater and discharged to surfacewater.

Landfill gas is a secondary medium of concern since it can transport VOCs that have partitioned into the vapor phase, allowing them to re-partition into the dissolved phase into groundwater.

3 SELECTED AND APPROVED REMEDY / TECHNICAL APPROACH

A number of factors influenced selection of remediation alternatives.

- The extent of detected contamination lies within the relevant point of compliance.
- There are no potable wells observed or reported within 2,000 feet of the facility.
- A man-made diversion ditch beginning at the northwest corner of the C&D landfill extends easterly along the northern property boundary.
- Contamination is below risk exposure levels.
- Contamination appears to be limited to the unconfined, surficial aquifer.
- Natural attenuation mechanisms appear to be actively controlling groundwater contaminant movement in this area.
- Modeling suggests that *cis*-1,2-DCE and vinyl chloride might reach the relevant point of compliance in approximately 10 years. This does not account for the effects of dilution, volatilization, dispersion, or contaminant degradation.

Remediation of relatively low level contamination in the 10 µg/L range can be difficult, expensive and may not be achievable. The most cost effective and efficient system for remediation is monitored natural attenuation (MNA) supplemented by phytoremediation.

3.1 Technical Approach (Monitored Natural Attenuation)

Bioscreen and *Biochlor* were initially run using data from MW-4 to assess the potential effectiveness of MNA. *Bioscreen* was focused on benzene due to the high half-life of two years. *Bioscreen* results presented a 47% decrease in contamination in five years through 1st-order decay and a 100% decrease in contamination through instantaneous reaction model. Results of *Bioscreen* are provided in **Appendix A**.

Biochlor was run using site specific data for *cis*-1,2-dichloroethene and vinyl chloride. Dual modeling was utilized based on high half-lives and low half-lives. High half-life results indicated an 8.1% decrease for *cis*-1,2-DCE and a 5.5% decrease for vinyl chloride in five years through biotransformation modeling. Low half-life results indicated a 51.4% decrease for *cis*-1,2-DCE and a 48.5% decrease for vinyl chloride in five years through biotransformation modeling. Biochlor results are provided in **Appendix A**.

To more clearly delineate the extent of dissolved-phase VOCs in groundwater, it is recommended that additional groundwater samples be collected in the vicinity of monitoring well MW-4. To reduce costs, groundwater sampling may be conducted using direct-push methods (e.g. GeoProbe®). Baseline sampling of monitoring wells MW-1R and MW-4 will be performed semi-annually for a two-year period (four events), and will incorporate the MNA performance parameters listed in **Section 4** and **Appendix B**. Stream water quality monitoring will consist of sampling existing upstream and downstream surfacewater sampling points, located along the unnamed tributary of Sandy Run (see **Plate 2**).

4 GROUNDWATER AND SURFACEWATER MONITORING PLAN

4.1 Groundwater Sampling and Monitoring

Data with which to monitor and evaluate the performance of remediation shall be obtained through a groundwater sampling and monitoring program. All groundwater samples collected from the monitoring wells will be analyzed for Appendix I or Appendix II constituents in accordance with 15A NCAC 13B.1630. Additionally, groundwater samples collected from monitoring wells MW-1R and MW-4 will be analyzed for the following MNA performance parameters:

MNA Performance Parameters

Parameter	Analysis Type	Analytical Method
Dissolved Oxygen (DO)	Field Reading	Multi-parameter Field Instrument w/ flow-through cell
PH	Field Reading	
Oxidation-Reduction Potential (ORP)	Field Reading	
Turbidity	Field Reading	
Conductivity	Field Reading	
Temperature	Field Reading	
Dissolved CO_2	Field Reading	Field Instrument / Hach Kit
Alkalinity (Total as $CaCO_3$)*	Laboratory/Field*	EPA 310.2
Chloride*	Laboratory/Field*	SM 4500-CLB
Iron	Laboratory	SM3111B
Nitrate*	Laboratory/Field*	EPA 353.2 / SM 2320B
Sulfate*	Laboratory/Field*	EPA 375.4 / SM 4500-SO4E
Sulfide*	Laboratory/Field*	EPA 376.1 or SM 4500SE
TOC/BOD/COD	Laboratory	EPA 415.1 / EPA 405.1 / EPA 410.1
Methane	Laboratory	RSK 175
Ethane, Ethene	Laboratory	RSK 175
Hydrogen	Laboratory	AM19GA
Volatile Fatty Acids	Laboratory	AM23G

*For budgetary considerations these analyses may be performed in the field using Hach® brand color wheel test kits.

4.2 Surfacewater Sampling and Monitoring

Surfacewater sampling will be conducted to monitor COC concentrations in the adjacent stream areas. To date, COC concentrations have been detected below respective 2B Standards. Two (2) surfacewater sampling points designated "Upstream" and "Downstream" have been established along an unnamed tributary of Sandy Run. The locations of both surfacewater sampling points are depicted in **Appendix B, Plate A**. All surfacewater samples are analyzed for Appendix I and Appendix II constituents. The *Groundwater and Surfacewater Sampling and Analysis Plan* is presented as **Appendix B**.

5 EVAULATION OF EFFECTIVENESS AND REPORT SUBMITTALS

5.1 Evaluation of Effectiveness

As remediation progresses at the site certain changes in the physical and chemical characteristics of the contaminant plumes should occur. In all areas contaminant concentrations are expected to decrease over the period of remediation, thus resulting in a decrease in the physical extent of the plume. The various methods for evaluating the effectiveness of remediation are discussed in the sections below.

5.1.1 Qualitative and Quantitative Evaluation

Qualitative Evaluation

Qualitative methods include graphical analysis of groundwater analytical data over time in order to visualize changing trends in groundwater chemistry that are expected to occur over time as a result of the various remedial mechanisms/processes that are occurring at the site (e.g. biodegradation, reductive dechlorination, etc.). Examples of graphical analyses that will be used include, but are not be limited to, time-series graphs of contaminant concentrations and groundwater levels, distance-concentration graphs of analytical data, and mapping of the contaminant plumes over time.

Quantitative Evaluation

Quantitative evaluation will be conducted through annual revision of *Bioplume* and *Bioscreen* models, and through analysis of groundwater analytical data using statistical tests for significance. Statistical significance tests can be grouped into two types, *inter-well* and *intra-well. Inter-well* methods determine statistical significance by examining trends in contaminant concentrations from performance wells with respect to those from background wells, which are used as a control group. As remediation progresses, the performance well data is expected to exhibit decreases in contaminant concentrations, while contaminant concentrations in the background wells are expected to remain relatively stable. Background wells are selected on the basis of location (typically upgradient) and analytical history (non-impacted wells are best). *Intra-well* methods determine statistical significance within individual performance wells by examining historical analytical results (time series) for a given well, thus indicating if changing contaminant concentrations at a given well location result from either remedial activity or natural fluctuation. Comparisons of background well data with sentinel and compliance well data will also be performed to monitor groundwater contaminant movement over time.

Various types of significance tests have been developed to analyze differing types of data populations based upon characteristics such as distribution type (normal vs. non-normal), trend type (changing vs. non-changing), percentage of "non-detect" results for a given population, and the sample population size. This allows for the selection of particular methods that are appropriate for a given situation. For the remedial activity at the subject facility the following statistical tests are proposed for use, although others may be used as the course of remediation progresses:

- Wilcoxon Rank-Sum (Inter-well) - *normal or non-normal data, invariant trends, < 90% non-detects, >3 samples/per well.*
- Parametric Prediction Limit (Inter-well) – *normal data, varying trends, < 15% non-detects.*
- Parametric Prediction Limit (Intra-well) – *normal data, varying trends, ≥ 4 samples/well, < 15% non-detects.*
- Non-Parametric Prediction Limit (Inter-Well & Intra-Well) – *normal or non-normal data, can tolerate high percentage of non-detects, compares recent to historical data.*

As indicated by the list above, it is important to note that, prior to conducting any test of statistical significance, a baseline of analytical data must first be established. For the MNA parameters listed in **Section 4.0** this baseline will consist of the four (4) semi-annual sampling events mentioned previously.

5.1.2 Evaluation of Plume Area

Monitoring well MW-1R will be used as the background well for inter-well statistical analysis of MNA data. Monitoring well MW-4 will be used as a performance well, while downgradient wells MW-5, MW-6, MW-7 and MW-8 will be used as compliance wells for assessment monitoring.

COC levels throughout the contaminant plume should decrease as a result of natural attenuation. Direct-push groundwater sampling around MW-4 may be necessary to collect additional information with which to evaluate plume movement and MNA performance.

5.2 Refining the Site Conceptual Model

Over the course of corrective action the site conceptual model will be refined in order to determine the appropriate course of remediation. Additional information on groundwater chemistry, site lithology, plume characteristics, etc. will be used to further improve understanding of contaminant fate and transport at the site, and to determine any changes to the approved remedial measures if necessary.

5.3 Report Submittals

Corrective action sampling and monitoring reports will be submitted on a semi-annual basis, within 30 days of receiving all complete laboratory analytical reports. All reports submitted regarding evaluation of effectiveness will establish trends of the indicator parameters and contain tables, maps and figures relating to field and laboratory data. Laboratory reports, groundwater maps, contamination concentration maps and cross sections will be included. Specific parameters for individual plume areas will also be ascertained.

6 CONTINGENCY PLAN

6.1 Contingency Plan

Should the selected remedial approach not perform as expected and/or the constituent concentrations do not decrease within five years after implementation of remedial measures, contingency plans will be needed.

6.1.1 Phytoremediation

Should MNA fail to significantly reduce contaminant concentrations within two years of implementation, the process will be enhanced by the introduction of phytoremediation procedures. To accelerate the natural evapotranspiration process and to allow for hydraulic containment (plume control), the area surrounding MW-4, MW-5, MW-7, and MW-8 will be thinned of juvenile trees (those trees with a diameter of less than 3 inches) and pines, and planted with hybrid willows of the genus *Salix*. Hybrid willows have been recognized as being *"phreatophytic"* (water-loving) trees with root systems that can extend up to 40 feet bgs. Phytoremediation is expected to occur through several processes: the release of enzymes from the root system that break down hydrocarbons (phytodegradation), limitation of infiltration by increasing evapotranspiration, and eventual uptake of hydrocarbons (phytoextraction). Available literature (e.g., Schnoor [9]) suggests an initial planting density of 1,000-2,000 trees/acre (~43 ft^2/tree). As the trees become established over time (1-2 years) competition between plants will reduce this density to ~600-800 trees/acre. The proposed phytoremediation area comprises approximately 1 acre; therefore, at the aforementioned planting density, a minimum of 1,200 hybrid willow seedlings will need to be planted at the onset of corrective action. Planting of seedlings will likely be performed by mechanical methods to reduce installation costs, and is tentatively scheduled to occur between August and September 2009.

Protective fencing to prevent damage to the seedlings by wildlife (e.g. deer) is recommended around the area of planting. The proposed phytoremediation area is depicted in **Plate 5**.

Groundwater sampling will be performed semi-annually on monitoring wells MW-1R, MW-4, MW- 5, MW-6, MW-7, and MW-8. Baseline sampling for the suite of MNA performance parameters listed in **Section 4** and **Appendix B** shall be performed for two years following planting of hybrid willow trees. Soil sampling may also be conducted to monitor potential salt accumulation in the root zone. Phytoremediation sampling and monitoring results, in addition to information on tree growth and health, shall be included as a separate section within the semi-annual monitoring reports.

6.1.2 Enhanced Bioremediation

Should MNA and phytoremediation fail to significantly reduce contaminant concentrations within three years of implementation, enhanced bioremediation may need to be employed. Several substrates that have been shown to effectively reduce contaminant concentrations include oxygen-release compound (ORC) and hydrogen release compound (HRC). ORC, as manufactured by Regenesis, Ltd., consists of a dry mixture of calcium hydroxides with potassium phosphates that, when mixed with water, is injected into the subsurface as a slurry. Issues to consider prior to its use are its high pH (11-13), and its insolubility, that may lead to settlement during mixing and handling. HRC has been shown to effectively enhance reductive dechlorination of halogenated hydrocarbons, but to be less effective with remediating aromatic hydrocarbons. The design and implementation of alternate injection substrates is beyond the scope of this CAP report.

6.2 Safeguard Measures and Site Security

Exposure pathways are limited to on-site contact with groundwater. Monitoring wells are cased and secured with locking well caps. Access to the site is limited during operational hours. Public water is available to the surrounding area.

6.3 Revisions

Requests for modification of the approved corrective action and implementation schedule will be submitted in writing to the Solid Waste Section. No actions regarding modification will be implemented until written approval is received from the Division of Waste Management.

7 SCHEDULE AND MAINTENANCE

7.1 Operations and Maintenance

Greene County will oversee day-to-day operation and upkeep of the remediation technology. Any equipment required for remediation will be the responsibility of the County. If problems with the remediation system arise, the Solid Waste Section will be notified and a written report will be issued. The Greene County Department of Solid Waste can be contacted at (252) 747-5720 regarding daily activities.

7.2 Timeline

Implementation of corrective action will begin within 30 days of CAP approval. Initial activities will consist primarily of administrative tasks including scheduling of drilling and remediation sub-contractors, permit preparation/submittal, and materials purchasing. A timeline estimate for sampling events and performance evaluation is presented in **Table 9**.

8 FINANCIAL ASSURANCE REQUIREMENTS

In general accordance with 15A NCAC 13B .0546, demonstration of financial assurance was achieved through the local government financial test. Semi-annual sampling costs are/were estimated in the post closure financial assurance. However, even though estimated costs to perform corrective action and an initial contingency plan (phytoremediation) are relatively minor, to date, financial assurance for corrective action has not been submitted. MNA sampling is incorporated with the semi-annual sampling. The additional expense for MNA is seen in laboratory costs.

GeoProbe Groundwater Sampling Subcontractor Services..$2,500
MNA Samples (4 @ $750/sample)...$6,000
Estimated Total Cost..$8,500

The estimated additional expense to clear and grub the recommended area around MW-4, MW-5, MW-7, and MW-8, and purchase and plant approximately 1,000 willow trees is:

Phytoremediation.. $5,000

A revised financial assurance mechanism including the above-listed CAP cost estimate is being sent directly from the County's Chief Financial Officer to the Section and, once reviewed and approved, will be incorporated into this document.

9 COMPLETENESS OF CORRECTIVE ACTION

Results indicate that reduction of the low level contamination can be achieved through MNA supplemented with phytoremediation. There is no indication that the contamination will reach the relevant point of compliance within a reasonable time period. Institutional controls limit access to the site. Public water is available to the surrounding area. The source area has been capped to limit the infiltration. MNA will be implemented to correspond with semi-annual sampling.

Respectfully submitted
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