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Third
Five-Year Review Report

for

Greenwood Chemical Superfund Site

Newtown

Albemarle County, Virginia

September 2008

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Five-Year Review Report
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List of Acronyms

ARAR	Applicable or Relevant and Appropriate Requirement
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
EPA	United States Environmental Protection Agency
ESD	Explanation of Significant Difference
GCC	Greenwood Chemical Company
GWI/FFS	Groundwater Investigation/Focused Feasibility Study
GMNC	Contaminated Groundwater Migration Not Under Control
HEUC	Current Human Exposure Controlled
HI	Hazard Index
LTRA	Long Term Remedial Action
MCL	Maximum Contaminant Level
MG	Million Gallons
NCP	National Contingency Plan (the "National Oil and Hazardous Substances Pollution Contingency Plan")
NPL	National Priorities List
O&M	Operation and Maintenance
OU	Operable Unit
PAH	Polycyclic Aromatic Hydrocarbon
PRP	Potentially Responsible Party
RA	Remedial Action
RAO	Remedial Action Objective
RD	Remedial Design
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RPM	Remedial Project Manager
RCRA	Resource Conservation and Recovery Act
SWRAU	Site-Wide Ready for Anticipated Reuse
SSC	State Superfund Contract
TAL	Target Analyte List
TCL	Target Compound List
TIC	Tentatively Identified Compound
USACE	United States Army Corps of Engineers
VDEQ	Virginia Department of Environmental Quality
VPDES	Virginia Pollution Discharge Elimination System
VOC	Volatile Organic Compound

Executive Summary

The remedy for the Greenwood Chemical Site in Newtown, Virginia (Site) included dismantling a former chemical production facility, packaging and transporting drums and miscellaneous abandoned chemicals off-site for proper disposal, draining chemical lagoons, excavating sludge, contaminated soil and buried drums for off-site treatment and/or disposal, pumping contaminated groundwater for treatment in an on-Site water treatment plant, institutional controls and monitoring. The Site has been addressed in four operable units (OUs):

- OU1 – Lagoons and disposal areas were excavated and transported to a permitted thermal destruction facility for treatment;
- OU2 – Ground water recovery wells were installed for "hot-spot" removal to prevent groundwater from migrating toward drinking water sources and treat recovered water in the on-Site treatment plant;
- OU3 – Former manufacturing buildings removed; and,
- OU4 – Ground water recovery wells used to contain contaminated groundwater within a waste management area (deep below OU1 excavations) to restore ground water quality within the area of attainment, and treat recovered water in the on-Site treatment plant.

The four OUs have been completed and are operational and functional. The Site achieved construction completion with the signing of the Preliminary Close-Out Report on September 30, 2005. The trigger for this Third Five-Year Review was the signature of the last five year review on September 29, 2003.

The remedial actions at OUs 1 and 3 are protective and remedial actions at OUs 2 and 4 are protective in the short term. Because complete hydraulic containment has not been achieved and institutional controls are not in place remedial actions are not protective in the long term. There is no current exposure to contaminated groundwater; however, in order for the remedy to be protective in the long-term the following actions must be taken: 1) adjust the recovery well alignment to establish hydraulic containment of the waste management area and restore groundwater quality in the area of attainment; 2) evaluate the vapor intrusion pathway; and, 3) implement institutional controls.

As part of this Five Year Review the GPRA Measures have also been reviewed. The GPRA Measures and their status are provided as follows:

Environmental Indicators
Human Health: Current Human Exposure Controlled (HEUC)
Groundwater Migration: Contaminated Groundwater Migration Not Under Control (GMNC)

Site-wide RAU
The Site is not Site-Wide Ready for Anticipated Use (SWRAU) but is expected to achieve SWRAU on 9/30/10.

Five-Year Review Summary Form

SITE IDENTIFICATION		
Site name: Greenwood Chemical Superfund Site		
EPA ID: VAD003125374		
Region: 3	**State: VA**	**City/County: Newtown/Albemarle**
SITE STATUS		
NPL status: ■ Final ☐ Deleted ☐ Other (specify)		
Remediation status (choose all that apply): ☐ Under Construction ■ Operating ☐ Complete		
Multiple OUs?* ■YES ☐ NO	**Construction completion date:** 9/30/2005	
Has Site been put into reuse? ☐ YES ■ NO		
REVIEW STATUS		
Lead agency: ■ EPA ☐ State ☐ Tribe ☐ Other Federal Agency _____		
Author name: Eric Newman		
Author title: Remedial Project Manager	**Author affiliation:** U.S. EPA Reg. 3, HSCD	
Review period: 1/4/2008 – signature date		
Date(s) of Site inspection: 7/17/2008		
Type of review: ■ Post-SARA ☐ Pre-SARA ☐ NPL-Removal only ☐ Non-NPL Remedial Action Site ☐ NPL State/Tribe-lead ☐ Regional Discretion		
Review number: ☐ 1 (first) ☐ 2 (second) ■ 3 (third) ☐ Other (specify) _____		
Triggering action: ☐ Actual RA Onsite Construction at OU #____ ☐ Actual RA Start at OU#____ ☐ Construction Completion ■ Previous Five-Year Review Report ☐ Other (specify)		
Triggering action date ***(from WasteLAN)***: 9/29/2003		
Due date ***(five years after triggering action date)***: 9/29/2008		

Five-Year Review Summary Form, cont'd.

Issues:
1. Recovery well network has not yet demonstrated hydraulic containment of the waste management area.
2. Evaluate potential of vapor intrusion for future industrial or recreational land use scenario.
3. Implement institutional controls in accordance with the 2005 OU2/4 final ROD.

Recommendations and Follow-up Actions:
1. Continue efforts to adjust the alignment of recovery wells to establish hydraulic containment of the waste management area.
2. Evaluate potential of vapor intrusion for future industrial or recreational land use scenario.
3. Implement institutional controls.

Protectiveness Statement:
The remedy at OU1 is protective of human health and the environment. Contaminated soil and waste material was excavated and transported off-Site for treatment and/or disposal to minimize migration to groundwater and direct exposure. The excavated areas were backfilled with clean soil. The remedial action objectives have been met.

The remedy at OU2/4 is expected to be protective of human health and the environment, and in the interim, exposure pathways that could result in unacceptable risks are being controlled. Complete hydraulic containment has not yet been achieved but there is no current exposure to contaminated groundwater. In order for the remedy to be protective in the long term the following actions must be taken: 1) adjust the recovery well alignment until complete hydraulic containment of the waste management area is achieved; 2) evaluate the vapor intrusion pathway; and, 3) implement institutional controls on the Site.

The remedy at OU3 is protective of human health and the environment. The former manufacturing buildings and chemical wastes stored within those buildings were dismantled and properly disposed off-Site. The remedial action objectives have been met.

The remedial actions at OUs 1 and 3 are protective and remedial actions at OUs 2 and 4 are protective in the short term. Because complete hydraulic containment has not been achieved and institutional controls are not in place remedial actions are not protective in the long term. There is no current exposure to contaminated groundwater; however, in order for the remedy to be protective in the long-term the following actions must be taken: 1) adjust the recovery well alignment to establish hydraulic containment of the waste management area to restore groundwater quality in the area of attainment; 2) evaluate the vapor intrusion pathway; and, 3) implement institutional controls.

Five-Year Review Report

I. Introduction

The purpose of the five-year review is to determine whether the remedy at a Site is protective of human health and the environment. The methods, findings, and conclusions of reviews are documented in five-year review reports. In addition, five year review reports identify issues found during the review, if any, and recommendations to address them.

The United States Environmental Protection Agency (EPA) is preparing this five year review report pursuant to the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) § 121 and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). CERCLA §121states:

> *If the President selects a remedial action that results in any hazardous substances, pollutants, or contaminants remaining at the site, the President shall review such remedial action no less often than each five years after the initiation of such remedial action to assure that human health and the environment are being protected by the remedial action being implemented. In addition, if upon such review it is the judgment of the President that action is appropriate at such site in accordance with section [104] or [106], the President shall take or require such action. The President shall report to the Congress a list of facilities for which such review is required, the results of all such reviews, and any actions taken as a result of such reviews.*

The Agency interpreted this requirement further in the NCP; 40 Code of Federal Regulations §300.430(f)(4)(ii) states:

> *If a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure, the lead agency shall review such action no less often than every five years after the initiation of the selected remedial action.*

The EPA Region 3 has conducted a five-year review of the remedial actions implemented at the Greenwood Chemical Superfund Site, Newtown, Albermarle County, Virginia. See Figure 1. This review was conducted from January 2008 through September 2008. The purpose of the five-year review is to determine whether the remedy at the Site is protective of human health and the environment. The methods, findings, and conclusions of the review are documented in this report.

This is the third five-year review for the Greenwood Chemical Site. The triggering action for this review is the date of the second five-year review: September 29, 2003. The five-year review is required due to the fact that hazardous substances, pollutants, or contaminants remain at the Site above levels that allow for unrestricted use.

II. Site Chronology

The table below summarizes important events and relevant dates in the chronology of the Greenwood Chemical Site.

Table 1: Chronology of Site Events

Event	Date
Chemical Manufacturing Operations	1947-1985
Finalized on National Priorities List (NPL)	July 22, 1987
EPA begins Emergency Removal Actions	October 15, 1987
NPL Listing	July 22, 1987
Operable Unit 1 (OU1) Record of Decision (ROD) issued requiring excavation, treatment and disposal of surface soil and sludge and off-Site disposal of abandoned chemicals.	December 29, 1989
Operable Unit 2 (OU2) Interim ROD issued requiring groundwater pump and treat to be implemented as a preliminary action.	December 31, 1990
Explanation of Significant Differences (ESD) No. 1 clarified that former manufacturing buildings needed to be demolished to access contaminated soil. Referred to as OU3.	July 17, 1991
OU1 State Superfund Contract (SSC) signed	October 17, 1991
EPA accepted the OU3 Remedial Action Report documenting demolition and disposal of buildings	October 15, 1993
ESD-2 clarified that excavation required by OU1 ROD would extend to practical limits of excavation; deeper contamination would be addressed by an OU4 Record of Decision.	March 24, 1994
EPA completed Remedial Design for OU1; excavation, treatment and off-Site disposal of contaminated soil and sludge	June 30, 1994
EPA accepted the OU1 Remedial Action Report documenting completion	September 3,1996
EPA completed Remedial Design for Interim Remedy OU2, including water treatment plant	September 29, 1997
First Five-Year Review issued	January 23, 1998
Final inspection and acceptance of constructed water treatment plant (Interim OU2)	May 9, 2000
Interim OU2 remedy determined to Operational and Functional	May 15, 2002
EPA accepted the Interim OU2 Remedial Action Report documenting completion	September 19, 2003
Second Five-Year Review issued	September 29, 2003
Issue Action Memo, Remove Lagoons 4&5 and arsenic-contaminated surface soil	June 22, 2004 – May 2005
OU2 (final) and OU4 ROD issued requiring containment of deep soils and achieving groundwater performance standards with upgraded pump and treat system	September 22, 2005
Preliminary Closeout Report issued	September 30, 2005
EPA accepts Interim OU2 Remedial Action Report	July 10, 2006

III. Background

Physical Characteristics

The Greenwood Chemical Site is located at 634 Newtown Road in the village of Newtown, Albemarle County, Virginia between the cities of Waynesboro and Charlottesville (Site). See Figure 1. The Site is owned by the Greenwood Chemical Company (GCC) and encompasses 33.59 acres, of which approximately18 acres were used for chemical manufacturing and waste disposal activities.

EPA dismantled and removed the former chemical production buildings and other facility features. The Site is currently inactive except for an on-Site water treatment plant for recovered groundwater operated as a long-term response action. See Figure 2. The entire Site is enclosed by a chain-link fence. The gate is opened during weekday business hours to accept deliveries at the treatment plant. The gate is locked in the evenings and on weekends.

The setting is rural and land use surrounding the Site is generally undeveloped woodlands or agricultural. There is a residential area along Summers Rest Road east of the northern property boundary. The Mt. Zion Baptist Church is located adjacent the northwest corner of the Site. The Mt. Zion Baptist Church owns the undeveloped woodland along the western property boundary. The properties east and south of the Site are agricultural, currently used for cattle pastures. The farms in the area are generally 100+ acres and include a residence. Interstate 64 passes 100 yards north of the Site.

The topography slopes to the south-southeast and levels off at the southern end of the Site. Groundwater beneath the Site is not currently being used, however, surrounding properties do utilize groundwater for potable and agricultural purposes. Surface water features on the Site are limited to a small pond, referred to as "South Pond," and several intermittent streams which serve as tributaries to a perennial stream designated as "West Stream" located south of the Site. The groundwater treatment plant discharges clean water to one of the intermittent streams flowing to West Stream. West Stream meanders through cattle pastures and ultimately enters Stockton Creek several miles south of the Site.

Land and Resource Use

The historic land use of the Site was agricultural until 1946. Starting in 1947 a chemical manufacturing plant specializing in pharmaceutical intermediates began operations. From 1947 until 1985, chemicals including pharmaceutical, dye and paint intermediates, plant growth regulators and photographic chemicals were manufactured on-Site. The two main areas of the property utilized by GCC for business operations are known as the "manufacturing area" and the "drum disposal area." A more detailed Site location map with features associated with historic land use is presented in Figure 3. Historic features within the manufacturing area included

chemical processing buildings, offices and laboratory space, storage trailers and sheds, a pump house, a concrete bunker, five treatment lagoons and several abandoned structures.

Major manufacturing operations at the Site ceased in 1985; EPA and the Virginia Department of Environmental Quality (VDEQ) response teams began to clean the Site up shortly thereafter. From the late 1980's through the 1990's the GCC remained an active corporation and maintained an inventory of laboratory chemicals in storage units on Site. In 2004 EPA found that GCC abandoned scores of small containers of hazardous substances within trailers and degraded laboratory facilities. The business component of facility has been inactive since that time.

The projected land use for the former Greenwood Chemical Site is light industrial, recreational or conservancy/open space. The other land uses surrounding the Site are expected to remain the same. Response actions completed by EPA anticipate safe and beneficial use of the Site for industrial or recreational purposes.

Hydrogeology

The groundwater aquifer underlying the Site is currently not used as a drinking water source. However, in surrounding residential areas the bedrock aquifer is the primary source of drinking water. The area surrounding the Site is not presently serviced with public water. The closest residential well is located approximately 400 feet from the Site, while the closest downgradient well is approximately 2,500 feet from the Site. The dominant groundwater flow direction is to the east-southeast in the direction of Stockton Creek and its tributaries.

The topography of the Site slopes predominantly to the southeast and levels off at the southern end. Total relief across the Site is approximately 196 feet with an average grade of 10 percent. The majority of the Site is covered with overburden ranging in thickness from 0 - 15 feet. Groundwater at the Site is present in both the overburden and underlying fractured bedrock. Two distinct water bearing units (aquifers) have been identified in the overburden and bedrock. Aquifer testing indicates that the two water bearing units exhibit a high degree of hydraulic interconnection sufficient to consider the two units to be part of a single aquifer system. Significant movement within the bedrock is limited to its uppermost 50 feet. The water table at the Site is encountered at depths ranging from 5 feet to 35 feet below ground surface.

The water table generally follows surface topography. Groundwater in the overburden layer flows in a southeasterly direction toward West Stream, a tributary of Stockton Creek into which it discharges. The bedrock groundwater flow system is controlled by the nature and extent of bedrock fracturing. The direction of groundwater flow in the bedrock is also in a southeasterly direction. Groundwater located in the sloped areas of the Site generally has a downward vertical gradient (water moves downward from the overburden to the shallow bedrock). Topography at the southern end of the Site levels off and the vertical gradient of the groundwater is upward. The water table is generally located at or above the top of the bedrock.

In the southern portion of the Site, the groundwater elevations are at, or slightly above, ground surface elevations. Since the groundwater is found close to the surface in the southern portion of the Site, this indicates that the area serves as a groundwater discharge area. The West Stream and associated features at the southern periphery of the Site are probably groundwater discharge features.

History of Contamination

The Greenwood Chemical Company operated a small volume batch chemical manufacturing facility. Chemical manufacturing operations began in approximately 1947 under the name of Cockerille Chemical Company. The facility was sold to GCC in 1968 and continued to operate under that name until its closure. In April 1985, a toluene vapor fire destroyed the main processing building and resulted in the death of four workers. The plant ceased operations shortly thereafter. The facility produced chemicals for application in industrial, agricultural, pharmaceutical and photographic processes. The primary compounds manufactured at the Site during the 1980s included naphthalene acetic acid, 1-naphthaldehyde, and naphthoic acid. In addition, arsenic salts were used as catalysts in the production of chloromethylnaphthalene, an intermediary in the production of naphthalene acetic acid. Production processes used toluene, naphthalene derivatives, sodium cyanide and inorganic arsenic salts. In addition, naphthalene derivatives, sodium cyanide, sulfuric acid, hydrogen peroxide and paraformaldehyde were also used. Manufacturing activities involved the handling of large numbers of drums containing waste, feedstock, intermediate and final products.

In the course of these operations liquid wastes were discharged through floor drains in the process buildings to a series of unlined lagoons adjacent to the plant. The unlined lagoons were interconnected by unlined drainage ditches or above-ground piping. Liquid hazardous waste was routinely spilled onto process building floors and drained into the ground beneath and adjacent to the process buildings. In addition, drums were systematically buried on plant property. Trenches were used for the disposal of large quantities of 55-gallon drums containing hazardous substances. This activity resulted in the contamination of soil, groundwater, surface water and lagoon sludge. Contamination in groundwater consists primarily of volatile organic compounds (VOCs) including 1,2-dichloroethane, carbon tetrachloride and vinyl chloride, semi-volatile organic compounds including naphthalene and other organic compounds such as bis (2-chloroethyl) ether.

Initial Response

In June 1985 the Virginia Department of Health completed a Preliminary Assessment that documented the presence of numerous unidentified drums of chemicals and chemicals in the waste lagoons. The report concluded by recommending that EPA conduct a detailed site investigation to further assess the potential for harm to the public health and environment at the Site.

In 1986, EPA evaluated the Site for a possible removal action. Between May 1986 and December 1987, the EPA Emergency Response Team and Technical Assistance Team planned

and implemented a detailed sampling of the lagoons, lagoon sludge, and surface and subsurface soils. In addition, monitoring wells were installed to conduct a hydrogeological investigation and a magnetometer and soil gas survey was conducted. Analysis of the samples from the various media showed the presence of numerous hazardous substances at the Site.

EPA proposed the Greenwood Chemical Site for inclusion on the CERCLA National Priorities List (NPL) in March 1987 and placed the Site on the NPL on July 22, 1987 (see 55 Fed Reg. 27263).

Between 1987 and 1990, EPA conducted two removal actions which included the removal of drums and smaller containers of chemicals (both buried and surface), the removal and treatment of lagoon water and sludges. In 1987, approximately 400 buried drums and 32 pressurized gas cylinders were excavated and removed from the Site. Waste water from lagoons 1, 2 and 3 was pumped into lagoon 4, treated with activated carbon, and released to lagoon 5. In addition contaminated lagoon sludges were excavated and removed from the Site for disposal. Also, certain sludges were stabilized onsite with kiln dust and placed in a temporary lined vault constructed within the lagoon 3 excavation area. In November 1989, EPA determined that further removal action was necessary after heavy rains in the region damaged the temporary soil/synthetic membrane cap covering the former drum disposal area. EPA repaired the temporary cover and several drainage swales were constructed around the waste lagoons to prevent further erosion.

Basis for Taking Action

In October 1988 EPA initiated a site-wide Remedial Investigation. EPA conducted a baseline risk assessment using all available data collected during previous removal work and identified data gaps. Several data gaps were identified in the baseline risk assessment; however, it became clear that some initial steps could be taken to address obvious environmental problems at the Site. In order to simplify the management of the Site, EPA has divided the Site into components or Operable Units (OUs). The Operable Units for the Site are listed as follows:

- OU1: Source control remedy (soil)
- OU2: Interim groundwater and lagoon water remedy
- OU3: Removal of Process Buildings and waste chemicals
- 2004/2005 Removal (not assigned an OU #): Surface Soil, Lagoons 4 and 5, laboratory chemicals
- OU2/4: Final groundwater and deep soil source areas

EPA has issued three Records of Decision (RODs) and issued one Action Memorandum for the Site after placing it on the NPL. The first ROD addressed the OU1 source control

remedy. The second ROD addressed the OU2 interim groundwater and lagoon water remedy. The third ROD reaffirmed the groundwater pump and treat remedy selected as an interim action and established performance standards for groundwater (OU2). The third ROD also addressed remaining deep soil contamination (OU4) located beneath areas excavated as part of OU1. See Section IV (Remedial Actions) for a detailed discussion of respective remedy decisions.

A Remedial Investigation and Feasibility Study (RI/FS) for the entire Greenwood Chemical Site was completed in August 1990. The report characterized the nature and extent of soil, surface water, sediment and groundwater contamination. The 1990 RI/FS process, including several preliminary reports, provided the basis for Records of Decision for OU1, OU2, the 1991 Explanation of Significant Differences (ESD) which defined OU3, and the 1994 ESD.

The baseline risk assessment determined that risk pathways driving the risk at the Site under current and future use scenarios were dermal contact and ingestion of contaminated soil and ingestion of contaminated groundwater. The baseline risk assessment completed for the OU1 (1989) and OU2 (1990) RODs assumed a future residential land use scenario. The baseline risk assessment completed for the final OU2/4 ROD (2005) assumed industrial and recreational future land use based on recommendations from state and local officials.

Soil

The carcinogenic risks were highest for exposures to surface soil due to elevated concentrations of arsenic. Arsenic was the primary contributor to both the total excess cancer risk and the non-carcinogenic risk for exposure to soil[a]. The soil cleanup levels selected for organic compounds were based on the potential for migration to groundwater because the soil to groundwater performance standards were more conservative (i.e., lower) than cleanup concentrations developed for direct contact with soil assuming residential use. See Table 2 for soil cleanup standards for organics used during OU1 soil excavation[b]. The arsenic cleanup level in soil (27 mg/kg) was based on the direct exposure route because it was lower than the soil to groundwater target.

Groundwater

The 1990 interim OU2 ROD established that groundwater beneath the Site was grossly contaminated, primarily in the center of the Site (beneath the manufacturing area and the drum disposal area). The eleven contaminants identified as driving the risk assuming ground water consumption were:

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[a] The primary ecological risk driver was also arsenic in surface soil.

[b] In areas where arsenic was the only contaminant of concern present, excavation was deferred to the removal response taken in 2004/2005.

Groundwater	
Arsenic	Non-carcinogenic polycyclic aromatic hydrocarbons (PAHs)
Benzene	Semi-volatile Tentatively Identified Compounds (TICs)
Methylene Chloride	Toluene
Trichloroethene	Volatile TICs
Chlorobenzene	Cyanide
Tetrachlorethene	

The interim ROD deferred establishment of groundwater cleanup levels to a subsequent ROD. See Operable Unit 2 (Final) and Operable Unit 4 Remedy Selection on Page 14 for final groundwater cleanup level discussion.

Lagoons 4 and 5

The response action for lagoon water was based on cyanide concentrations which exceeded the Virginia Water Quality Criteria for cyanide (5.2 ug/l). The cyanide levels presented an unacceptable risk to aquatic life. Once the lagoon was drained, the sludge/sediment was determined to exceed the soil cleanup level for arsenic.

IV. Remedial Actions

Operable Unit 1 Remedy Selection

On December 29, 1989, EPA issued the OU1 ROD selecting a remedy to address contaminated soils remaining in the lagoons and other disposal areas after emergency removal actions had been completed to address the sludges from those areas. The remedial action objectives are to prevent direct exposure to contaminated soils and to eliminate the continued migration of contaminants to the underlying groundwater. As stated above, the OU1 ROD was based on a baseline risk assessment and focused feasibility study conducted by EPA utilizing data collected during previous removal actions.

The ROD developed cleanup standards for each compound considering: 1) the direct contact exposure route; and, 2) its potential to migrate from soil to groundwater. The cleanup standards developed for the protection of groundwater were more stringent than the standards developed for direct contact in each case except arsenic. The selected remedy included

excavation and offsite treatment and/or disposal of soils exceeding site-specific cleanup standards. See Table 2. The major components of the selected remedy include:

- Excavation of soil exceeding risk-based cleanup levels (soil associated with Lagoons 1, 2, 3 and Backfill North were estimated at 4,500 cubic yards[c]);
- Off-Site treatment of contaminated soil in a Resource Conservation and Recovery Act (RCRA)-permitted thermal destruction facility (i.e., incinerator);
- Treated soil was to be analyzed and stabilized/solidified in compliance with RCRA land ban restrictions, if necessary, prior to its disposal in a RCRA-permitted Subtitle C landfill;
- Excavated areas were to be backfilled with clean fill and re-vegetated; and,
- Abandoned chemicals located in on-Site buildings were to be treated via thermal destruction and disposed of off-Site.

Operable Unit 3[d] Remedy Selection (Explanation of Significant Differences-1)

An Explanation of Significant Differences (ESD-1) augmenting the remedy selected in the OU1 ROD was issued on July 17, 1991. The OU1 ROD had been issued based on preliminary nature and extent of contamination data available at the time. The final RI Report completed in September 1990 identified additional contaminated soils exceeding risk-based soil cleanup levels (identified in the OU1 ROD) extending beneath on-Site Process Buildings A, B and C. ESD-1 required the removal of the process buildings to allow delineation of soils exceeding cleanup levels. The primary changes described in ESD-1 were:

- The Process Buildings A, B, and C were to be dismantled, decontaminated to the extent possible and appropriately disposed of in an off-Site landfill. Contaminated demolition debris was to be disposed of in a RCRA Subtitle C landfill; nonhazardous debris was to be disposed of in a RCRA Subtitle D landfill;

ESD-2 (modification to Operable Unit 1 Remedy Selection)

An Explanation of Significant Differences (ESD-2) modifying the remedy selected in the OU1 ROD was issued on March 24, 1994. ESD-2 presented the findings of soil sampling completed during pre-design activities in the footprint of the demolished process buildings and other disposal areas refining the extent of contamination estimates. ESD-2 asserted that contaminated soils in the source areas to be addressed by OU1 extended beyond the depth of feasible excavation. The ESD-2 determined 15-feet to be the practical limit of cost-effective excavation and established that EPA would evaluate appropriate response actions for the deeper contaminated soils as Operable Unit 4. Further, ESD-2 modified the cleanup levels presented in the OU1 ROD based on an extensive fate and transport modeling program completed as part of

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[c] These soils were considered to be a principal threat to human health and the environment and are shown in Table 2
[d] Removal of process buildings and waste chemicals are referred to as Operable Unit 3 for administrative tracking purposes.

pre-design activities[e]. See Table 2. The fate and transport model used more site specific information and a revised model.

ESD-2 determined that the remedy for OU1 would address contaminated soil in the following additional areas of the Site:

- The Backfill North area extending to and beneath former Process Building A;
- An area including the location of former process Buildings B and C; and
- The former Drum Disposal Area, the Waste Dump area, the Northeast Drum Area, and other areas if subsequent sampling revealed contaminant concentrations above risk-based levels.

The area of contaminated soil requiring remediation increased from the 1.5 acres estimated in the original OU1 ROD to approximately 7 acres. The estimated volume of soil to be transported off-Site for treatment and/or disposal increased from 4,500 cubic yards to approximately 11,000 cubic yards. ESD-2 also noted the following clarification to the original remedy:

- Certain areas on the Site were only contaminated with elevated levels of arsenic. These arsenic-contaminated soils do not pose an unacceptable risk through the groundwater pathway but only through direct contact. Noting that the incineration technology selected for OU1 is inappropriate for arsenic, EPA deferred the remediation of these arsenic-contaminated soils to a subsequent decision document.

OU1 and OU3 Remedy Implementation

Since the initiation of EPA involvement with the Site, the Superfund has been used to finance all investigation and remediation activity. A total of 30 Potentially Responsible Parties (PRPs) were ultimately identified, including former owners and operators of the facility and various entities which did business with Greenwood Chemical. The major PRPs for the Site were issued a Unilateral Administrative Order in 1994 to conduct the OU1 remedial action (RA) but the PRPs declined to perform the RA. Thereafter, EPA made the decision to proceed with cleanup utilizing the Superfund. All subsequent removal and remedial activities have been accomplished with Superfund financing. EPA has recovered a portion of its response costs from 15 PRPs pursuant to several judicial settlements.

The work associated with OU3 was the first remedial action to be performed at the Site. The former process buildings A, B and C and the abandoned chemicals stored in these buildings presented an obstacle to efficient excavation of contaminated soils required for OU1. In

[e] The soil performance standard established in ESD-2 were the only soil performance standards implemented. Accordingly, the list of soil performance standards included in the 1989 ROD are not included in this Five-Year Review Report

accordance with an interagency agreement, on November 27, 1991, the U.S. Army Corps of Engineers (USACE) awarded the contract to OHM Remediation Services Corp to remove the abandoned chemicals within the process buildings and subsequently demolish the process buildings under the direction of the Rapid Response Team, thereby initiating RA. OHM mobilized to the Site in December 1991 to begin construction in the field. Major milestones included:

- Installation of a security fence;
- Removal of abandoned chemical containers in and around the buildings;
- Demolition, decontamination and off-Site disposal of 4 concrete block buildings (process buildings A, B and C and a laboratory/office building);
- Removal of metal shed (storage shed/garage); and,
- Decontamination and proper disposal of six aboveground chemical storage tanks, one underground chemical storage tank and associated piping.

The OU3 work was completed in a manner consistent with the requirements of the July 1991 ESD and all project work plans. USACE maintained a continuous presence on Site and performed routine inspections throughout field implementation. In March 1993 EPA, USACE and VDEQ conducted the final inspection and concluded that construction had been completed in accordance with the project work plans. The final inspection did not result in the development of a punch list. On October 15, 1993, the EPA Remedial Branch Chief accepted the Remedial Action Report documenting successful completion of the RA for OU3.

On June 30, 1990, EPA entered into an interagency agreement with the U.S. Army Corps of Engineers (USACE) to develop a remedial design (RD) for the remedy selected in the OU1 ROD. The USACE completed the RD consistent with the remedy selected in the OU1 ROD and modified by the ESD-2 on June 30, 1994. In accordance with an interagency agreement, on August 31, 1995 the USACE awarded a contract to Ogden Remediation Services to construct the remedy in accordance with the approved RD, thereby initiating the RA. Ogden mobilized to the Site in February 1996 to begin construction in the field. Major milestones included the following:

- Excavation of approximately 11,000 yd^3 of contaminated soil from the areas discussed above;
- Shipment by rail of contaminated soils to a thermal destruction facility (incinerator) in Utah for treatment;
- Disposal of residue (ash) in an adjacent RCRA Subtitle C landfill;
- Implementation of stormwater drainage controls around excavation areas; and,
- Backfilling, regrading and revegetation of excavation areas.

The work was completed and a prefinal inspection resulted in the development of a punch list of items which needed to be addressed. On August 8, 1997 EPA, USACE and VDEQ conducted the final inspection and concluded that construction had been completed in accordance with the remedial design plans and specifications. On September 3, 1997, the EPA

Remedial Branch Chief accepted the Remedial Action Report documenting successful completion of the RA for OU1.

Operable Unit 2 (Interim) Remedy Selection

On December 31, 1990, EPA issued an Interim ROD for operable unit 2 initiating a pump and treat remedy to minimize migration of contaminated groundwater toward residential wells. The ROD was considered "interim" because the selection of groundwater cleanup goals was deferred to a subsequent ROD after further study. The remedial action objectives are to minimize migration of contaminants toward residential wells, eliminate unacceptable environmental risks in Lagoons 4 and 5, and to obtain additional information regarding aquifer characteristics to assist in designing a final groundwater remedy. As stated above, the interim OU2 ROD was based on a baseline risk assessment and a groundwater focused feasibility study conducted by EPA utilizing data collected during Remedial Investigation. The major components of the interim OU2 selected remedy include:

- Installation and operation of groundwater recovery wells to prevent migration of contaminated groundwater from the Site;
- Monitoring the effectiveness of the groundwater extraction network and systematic optimization to meet objectives over time; and
- Construction and operation of a water treatment plant to treat the recovered groundwater and surface water collected in Lagoons 4 and 5. The treatment plant discharge to surface water (tributary to West Stream) must meet VPDES criteria.

Operable Unit 2 (Interim) Remedy Implementation

On February 20, 1992, EPA awarded a work assignment to CH2M Hill to develop a remedial design for the remedy selected in the interim OU2 ROD. CH2M Hill completed the RD on September 19, 1997. In accordance with an interagency agreement, on July 2, 1998 the U.S. Army Corps of Engineers awarded a contract to Norair Engineering to construct the remedy selected in interim OU2 ROD in accordance with the approved RD, thereby initiating the RA. Norair mobilized to the Site on September 18, 1998 to begin construction in the field.

Major milestones included the following:

- Installing and operating of five bedrock groundwater recovery wells (BR-2, BR-7, MW-23, BR-8 and BR-6);
- Installing of a floating pump assembly and pumping surface water from Lagoon 5 to the on-Site water treatment plant;
- Constructing a water treatment plant utilizing the following treatment train: precipitation, ultraviolet/chemical oxidation and carbon adsorption;
- Install plumbing necessary to convey recovered groundwater and lagoon surface water to the treatment plant;

- Beginning to operate the water treatment plant so that discharge consistently achieves VPDES criteria; and
- Installing an expanded monitoring well network.

The work was constructed in accordance with the remedial design plans and specifications. The final inspection and EPA/USACE, and VDEQ acceptance was completed May 9, 2000. The water treatment system began continuous operations on May 15, 2000, including initiation of routine groundwater monitoring. During the initial year the treatment plant operators were on-Site making equipment adjustments (as necessary) to ensure consistent and effective operation of the treatment system. Field testing and laboratory analyses confirmed that the plant was operating satisfactorily. On May 15, 2001, EPA and VDEQ determined the water treatment system to be operational and functional. On September 19, 2003, the EPA Remedial Branch Chief accepted the Remedial Action Report documenting successful completion of the interim RA for OU2.

2004/2005 Removal Remedy Selection – Surface Soil, Lagoons 4 and 5 (No Operable Unit #)

On June 22, 2004 EPA issued an Action Memorandum to address additional laboratory chemicals abandoned by GCC, properly close out Lagoons 4 and 5, and to address the remaining arsenic-contaminated surface soil. The primary components of the removal response action include:

- Excavation and off-Site disposal contaminated lagoon sludge (Lagoons 4 and 5) and surface soil with arsenic concentration greater than 27 mg/kg.
- Backfill with 2 feet clean soil.
- Removal and proper off-Site disposal of laboratory chemicals abandoned on-Site.

2004/2005 Removal Remedy Implementation

On June 28, 2004, EPA mobilized to the Site with Kemron Environmental, Inc. to begin removal activities. All chemicals were removed from buildings and trailers, containers were laboratory packed for off-Site Disposal. On October 4, 2004, the drums were picked up for disposal by Chemical Analytics, Inc.

Between August 2004 and November 2004, EPA drained the lagoons by pumping the water to the on-site treatment plant and closed out the lagoons. Dewatered sludge/sediment was excavated until confirmation samples demonstrated arsenic concentrations below 27 mg/kg. The former lagoons were then backfilled with clean soil and seeded.

Between June 2004 and June 2005, EPA delineated all areas containing greater than 27 mg/kg arsenic in soil. The soil sampling program determined that no excavated soils were RCRA-characteristic waste. Approximately 19,500 tons of arsenic-contaminated soil and sludge was excavated, sampled and appropriately disposed in a solid waste landfill. EPA implemented

an extensive confirmation sampling program to document that all soils with elevated arsenic concentrations were removed. The excavations were backfilled with a minimum 2-feet clean soil and seeded for erosion control.

Operable Unit 2 (Final) and Operable Unit 4 Remedy Selection

On September 22, 2005, EPA issued a final ROD for groundwater (OU2) and deep soil contamination[f] (OU4). The ROD (OU2/4 ROD) established groundwater performance standards for the second operable unit interim action pump and treat system. In addition, the OU2/4 ROD defined the area including the deep soil contamination as a "waste management area." The OU2/4 ROD selected hydraulic containment of the waste management area utilizing an enhanced version of the pump and treat system selected for interim OU2. The remedial action objective was to contain the contaminant plume within the waste management area and to restore groundwater quality in the area of attainment. The response action was based on the Groundwater Investigation and Focused Feasibility Study (GWI/FFS) completed in June 2005. The GWI/FFS included a groundwater capture zone analyses that recommended additional wells be added to the existing five-well groundwater extraction network.

In summary, the enhanced groundwater pump and treat system and associated groundwater cleanup standards was the selected remedy for OU2 and OU4. The risk-based performance standards are specified in Table 3 and will be achieved throughout the area of attainment within 30 years. The major components of the selected remedy include the following:

- Continued operation of an enhanced groundwater pump and treat system to prevent migration of contaminated groundwater to the area of attainment[g];
- Continued treatment of recovered groundwater to achieve VPDES discharge standards prior to discharge to on-Site stream;
- Soil cover over the former drum disposal and manufacturing areas[h];
- Long-term groundwater monitoring; and,
- Institutional controls to be implemented and maintained by the property owner to ensure that prospective users of the Site are aware that deep soil contamination is present, and to prevent: the extraction of groundwater from the aquifer beneath the Site for use as a potable water source; any interference with the groundwater extractions wells, treatment system, and related equipment; and any removal of the soil cover without the written permission of VDEQ, and EPA as appropriate.

[f] Deep soil contamination located beneath areas excavated during OU1remedial action is referred to as OU4.
[g] The groundwater pump and treat system was initiated per interim OU2 ROD. The final OU2/4 ROD established groundwater cleanup goals and an "area of attainment" setting forth the point of compliance.
[h] Installation of the clean soil cover was completed during the 2004/2005 removal response activities.

Final OU2 and OU4 Remedy Implementation

EPA determined that the groundwater related components of the remedy selected in the Final OU2/4 ROD were most efficiently implemented as optimization upgrades to the in-progress interim OU2 remedy. Accordingly, on June 30, 2005, EPA issued a revision to the OU2 Operation and Maintenance (O&M) work assignment directing TetraTech, EPA's contractor, to install additional groundwater recovery wells to the existing five-well network. The additional wells were required to establish hydraulic containment of the waste management area so that groundwater performance standards would be achieved at the "area of attainment." Remedial design documents for system upgrades were prepared by TetraTech. Final specifications and drawings were approved by EPA on September 12, 2005. TetraTech mobilized to the Site to initiate well installation based on preliminary designs on August 15, 2005. The major components of the enhanced pump and treat remedy implemented at the Site include:

- Six additional recovery wells installed using the 1) drilling, 2) geophysical survey, 3) hydro-fracturing, 4) targeted zone screening sequence;
- Locking vaults were installed over each recovery well;
- Piping and wiring necessary to connect the new wells to the treatment plant were installed;
- Pumps were installed and the Programmable Logic Controller was modified;
- Long term groundwater monitoring was refined to measure effectiveness of recovery well network; and,
- **Institutional controls have not yet been established.**

The work progressed in a manner consistent with the EPA-approved design and work plans. The work was monitored, inspected and audited by construction quality assurance and construction quality control personnel. In addition, EPA and VDEQ personnel performed periodic review exercises and inspections during the implementation of the response action.

EPA and the State conducted a pre-final inspection on September 29, 2005 and developed a punch list of items yet to be completed. The new wells went on-line in December 2005. A final inspection conducted on May 16, 2006 confirmed that all significant items on the punch list had been satisfactorily addressed. On July 10, 2006, the Associate Director, Office of Superfund Remediation accepted the Interim Remedial Action Report documenting successful completion of the RA for OU2. The report is considered "interim" because groundwater performance standards are projected to take 30 years to be achieved.

The groundwater treatment plant effluent has consistently met its respective VPDES discharge limits. An extensive groundwater monitoring program is in effect to evaluate the effectiveness of establishing the hydraulic containment necessary to achieve groundwater performance standards at the area of attainment. See Long Term Monitoring/Operation and Maintenance below.

The soil cover that was selected as a final remedy over the former drum disposal and manufacturing areas was acknowledged in the OU2/4 ROD to have been already completed during Removal Response actions conducted by EPA in 2004 and 2005 (see discussion above).

EPA expects to work with GCC, the property owner, to place the requisite Easement and Protective Covenant in the near future. EPA representatives are on the Site operating the water treatment plant on a daily basis. No activities have been observed that would violate the institutional controls. The subject property is fenced and the gate is locked each night and weekend.

The Preliminary Closeout Report was issued for the Site on September 30, 2005. The Report documents that the EPA completed construction activities at the Greenwood Chemical Superfund Site in accordance with *Closeout Procedures For National Priorities Sites* (OSWER Directive 9320.2-09A-P).

Long-Term Monitoring/System Operation and Maintenance (O&M)

Response actions associated with OU1, OU3 and the 2004/2005 Removal do not include any operation and maintenance activities. These response actions required demolition/excavation and off-Site treatment and/or disposal of materials at appropriately permitted facilities. All areas were subsequently backfilled with clean fill and vegetated.

The long-term operations, maintenance and monitoring requirements for the Greenwood Chemical Site are set forth in the final OU2/4 ROD. Administratively, EPA implemented the more comprehensive O&M requirements by incorporating the updated performance goals into a revised work plan for the OU2 remedy.

EPA is managing the long term response action (LTRA) at the Greenwood Chemical Site utilizing federal funds and a 10% cost share from the Commonwealth of Virginia. EPA transitioned the contract for the O&M at Greenwood from TetraTech to EA Engineering and Science on January 1, 2008. EPA contracted EA Engineering Science to conduct O&M at the Site in accordance with the work plan dated December 7, 2007. Operation of the water treatment system is being conducted in accordance with the O&M Manual prepared by CH2M Hill dated June 2001, as amended. Operational changes have been made to the manual to incorporate treatment system upgrades. The primary activities associated with O&M include the following:

- Operation of the groundwater recovery well network and water treatment facility.
- Inspection and maintenance of each component of the treatment system.
- Monitoring treatment plant effluent quality and submission of monthly discharge monitoring reports to demonstrate compliance with the Virginia State Water Control Law, Code of Virginia §§ 62.1-44.2 et. seq., and the site-specific discharge limits established in accordance with VPDES Regulations (VR 680-14-01).

- Environmental monitoring appropriate to evaluate the effectiveness of the groundwater recovery well network in establishing hydraulic containment of the waste management area. Monitoring includes generation of potentiometric maps and water quality sampling to measure progress toward meeting performance standards in the area of attainment.

- Inspection and maintenance of access to water treatment facility and all environmental monitoring points.

- Adjusting and upgrading the recovery well network as appropriate to achieve and maintain hydraulic containment and optimize water treatment system.

- Annual sampling of residential wells.

- Preparation of Quarterly Monitoring Reports and Annual O&M Reports. Annual O&M Reports assess LTRA activities and include an engineering evaluation of system effectiveness and optimization analyses.

The water treatment plant is consistently operating as designed. Since the Second Five-Year Review was issued in 2003 the most significant changes to the treatment system were:

- Eliminating flows from Lagoons 4 and 5 (closed out during 2004/2005 Removal);
- Shutting down the UV/chemical oxidation unit[i]; and,
- Adding six new extraction wells.

The treatment system has increased treatment flow rates from 6.3 million gallons/year to 19.4 million gallons/year. Routine effluent monitoring has documented that the water quality discharged from the treatment facility meets numeric limits established by VDEQ without exception and by a wide margin.

In 2006, inspection of the carbon treatment vessel revealed that the interior tank walls had been degraded due to corrosion. EPA replaced the two 2,000-gallon carbon treatment vessels with two 5,000-gallon vessels to provide longer treatment periods before the carbon media requires change-out. The new vessels walls were coated with Teflon for corrosion resistance.

The water treatment plant has one full-time operator and one part time operator on staff. In addition, the treatment system can be monitored 24 hours/day via PC-Anywhere Software. Operational uptime at the treatment plant was more than 98% and 95% in 2006 and 2007, respectively. The short downtimes that did occur were due to power outages and system maintenance (e.g., carbon replacement).

As discussed above, the OU2/4 selected remedy was based on a June 2005 groundwater

[i] In June 2005 EPA shut down the UV/chemical oxidation unit on a pilot basis. The pilot program demonstrated that the water treatment plant met its effluent performance standards at reduced cost.

capture zone analyses that concluded that the original five-well extraction network was not effectively containing contaminated groundwater in the waste management area. The original wells were capturing a majority of water moving through the area but two gaps were identified. In 2005 additional recovery wells were installed to: 1) close a gap between two recovery wells (BR-2 and BR-6); and, 2) capture groundwater following a local eastward dip in the topography near monitoring well PMW-5 along the eastern property boundary. Successfully capturing groundwater in these two areas of concern is necessary to establish hydraulic containment of contaminated groundwater and to achieve groundwater performance standards in the area of attainment within 30 years.

The expanded 11-recovery well network has been in operation since December 2005. Groundwater moves very slowly through small, sometimes discontinuous fractures in the bedrock. EPA carefully reviewed the 2006 and 2007 Annual O&M Reports to determine if the additional wells were achieving the desired containment. Early indications are that the three new wells place between BR-2 and BR-6 have closed the gap and are preventing bypass. However, the three wells placed upgradient of PMW-5 have not successfully captured the water following the dip along the eastern property boundary. Groundwater monitoring completed at PMW-5 has not documented a positive change in water quality at that point.

In July 2008 EPA installed three additional monitoring wells on the adjacent parcel east, and side or downgradient, of PMW-5. The additional wells have been integrated into the groundwater monitoring program and will provide important information about fractures, groundwater flow and water quality in that area.

Downgradient and side-gradient residential wells and local cattle ponds have been sampled annually. No site-related contaminants have ever been detected above EPA Maximum Contaminant Levels (MCLs) or above any other risk-based action levels.

O&M costs associated with the groundwater pump and treat system include the following categories:

- Labor
- Utilities (electricity)
- Consumables (treatment chemicals)
- Engineering Support/Technical Oversight
- Sampling and Monitoring (process, groundwater, discharge)
- Non-Routine Operations (sludge generation and disposal)
- Installation/abandonment of extraction and monitoring wells to optimize system

Operation costs for the last two years, extending through July 2008, are listed in Table 4. The August 2006 through July 2007 costs represent routine operation of the expanded 11-recovery well network. The operation costs incurred from August 2007 through July 2008 also include administrative expenses associated with transitioning O&M responsibilities from TetraTech to EA Engineering and Science and expenses for installation of 3 new monitoring wells downgradient of PMW-5. Over the next few years EPA expects that additional expenses

will be incurred making adjustments to the recovery well alignment necessary to achieve complete hydraulic containment. Annual costs of routine operation and maintenance activities associated with the treatment plant are expected to be relatively stable. The O&M costs for the first two years of operation of the expanded recovery well system area generally consistent with the final OU2/4 ROD estimated costs of approximately $463,000 per year.

Table 4- Annual System Operations/O&M Costs

Dates		Total Cost rounded to nearest $1,000
From	To	
8/1/2006	7/31/2007	$453,000
8/1/2007	7/31/2008	$509,000

Closing out the lagoons had a beneficial impact on treatment plant efficiency. The high dissolved solids concentrations (relative to ground water) in the lagoon surface water required more frequent backwashing of the sand filters and generated more sludge. There has been approximately 50% less sludge generation since the lagoons were eliminated. Due to the low rate of solids generation, the sludge (solids) handling system including the filter press is only operated approximately once per year. The treatment system generates approximately 8-10 tons of filter cake annually. RCRA TCLP testing of the sludge has consistently demonstrated that the sludge is non-hazardous. The filter cake is disposed in a solid waste landfill within Virginia. The sludge is defined as a "special waste" under the Virginia Waste Management Regulations.

Groundwater and treatment plant effluent monitoring results are summarized in the Quarterly Operations and Groundwater Monitoring Reports and Annual O&M Reports and are discussed in the data review section of this document.

V. Progress Since the Last Review

The second five-year review for the Site was completed in September 2003. EPA has achieved significant progress since the last review, including conduct of a major removal action and issuance and implementation of the final OU2/4 ROD.

Protectiveness Statements from the Second Five-Year Review (Italics)

*The remedy for **OU1** completed in 1996 is protective of human health and the environment. Exposure pathways that could result in unacceptable risks have been eliminated by the removal of the contaminated soil. Immediate threats from contaminated soil in the source areas (manufacturing area and drum disposal area) have been addressed by excavation and off-site treatment and disposal. The response action for OU1 left waste (deep soil contamination) on-site above unrestricted use and unlimited exposure guidelines. Therefore, a five-year review is required as long as the waste remains in place. The response actions for OU1 are protective in that the remedial action objectives were achieved and the final OU2/4 ROD for the site will address remaining contaminated soil and institutional controls.*

Progress Since Second Five-Year Review – EPA issued the final OU2/4 ROD on September 22, 2005. The selected remedy established a "waste management area" which includes the deep soil contamination source areas referred to above. The OU2/4 remedial action objective is to contain the hazardous substances located at depths below those excavated during OU1 remediation using a groundwater recovery well network. The OU2/4 selected remedy established groundwater performance standards which must be met in the "area of attainment" (i.e., outside the limits of the waste management area). The original five-well extraction network is being expanded to establish hydraulic containment. In 2005 an additional 6 groundwater recovery wells were added to the network. Effective hydraulic containment of groundwater has not yet been demonstrated but EPA is continuing to assess and adjust the system as appropriate. The OU2/4 selected remedy includes institutional controls. EPA expects to work with the property owner to place an Easement and Protective Covenant on the property in the near future.

In addition (though not mentioned in the respective protectiveness statement), ESD-2 modified the OU1 selected remedy by deferring remediation of surface soils which were only contaminated with arsenic to a subsequent decision document. ESD-2 noted that the elevated arsenic did not pose a soil to groundwater migration threat. Further, arsenic would not be destroyed by the incineration technology implemented on OU1 excavated soils.

On June 22, 2004, EPA issued an Action Memorandum calling for, among other things, excavation and offsite disposal of arsenic contaminated soil and arsenic contaminated sludge located in Lagoons 4 and 5. EPA determined that the presence of elevated arsenic in lagoon sludge/sediments and elevated cyanide in lagoon surface water presented and unacceptable threat to human health and the environment. The lagoons were drained and water was treated at the on-Site treatment plant. Approximately 19,500 tons of arsenic-contaminated soil and sludge was excavated, sampled and appropriately disposed in a solid waste landfill. The former lagoons and excavated areas were backfilled with 2-feet of clean soil. The removal work began in June 2004

and was completed on June 30, 2005.

*The **OU2 ROD (December 1990)** contained the final response action for lagoon water and **an interim action for the groundwater**. The existing OU2 (groundwater pump and treat system) was selected as an interim remedy in the ROD since final groundwater cleanup goals could not be determined at the time. The goals of this remedial action were (1) to initiate reduction of groundwater contaminant toxicity, mobility and volume (2) minimize the migration of groundwater contaminants (3) collect data on aquifer and contaminant response to remediation measures and (4) eliminate unacceptable risks posed by water in Lagoons 4 and 5. The interim action for groundwater and final action for lagoon water is protective in that the goals of the response action listed above are being achieved. The final ROD for the site will address site specific risk-based groundwater cleanup levels.*

The lagoon component of the OU2 remedy has been in full-scale operation since the treatment system was brought on line in early 2001. This component is protective of human health and the environment in that contaminated lagoon water is pumped from lagoon 4 and 5 to the treatment plant for final processing prior to discharge. Exposure pathways that could result in unacceptable risks have been eliminated though the collection and treatment of lagoon water. Immediate threats associated with the lagoon water are being addressed through the treatment process.

Progress Since Second Five-Year Review - See discussion above for confirmation that the final OU2/4 ROD was issued on September 22, 2005. The selected remedy included the groundwater performance standards called for in the interim OU2 protectiveness statement. Subsequent to the issuance of the Second Five-Year Review, EPA determined that the contaminated sludge and surface water in the lagoons presented an unacceptable risk to human health and the environment. Even after several years of routing the lagoon surface water through the water treatment plant the lagoon water continued to exhibit concentrations of cyanide greater than ambient surface quality standards for protection of aquatic life. Although the onsite water treatment plant was providing adequate treatment to meet VPDES discharge standards, EPA determined that the lagoons were unlikely to become a valuable resource to wildlife. EPA determined that the best response action was elimination of the lagoons. The lagoons were originally built by Greenwood Chemical to treat aqueous chemical wastes. The removal action was completed on June 30, 2005.

*The remedy for **OU-3** completed in 1993 is protective of human health and the environment. Exposure pathways that could result in unacceptable risks have been eliminated by removal of the former process buildings and their contents. Immediate threats associated with the buildings have been addressed by dismantlement and off-site disposal of contaminated debris. Additional response action associated with OU-3 is not required. No further review of OU-3 is required.*

Progress Since Second Five-Year Review - No follow-up action is necessary.

*A **protectiveness statement for OU-4 cannot be made at this time** since the OU-4 remedy has not commenced. The plan is to issue the OU-4 ROD in early 2004. The remedial design for*

the selected remedy will be initiated following issuance of the ROD. EPA expects the remedy for OU-4 to be completed prior to the next five-year review for the Site.

Progress Since Second Five-Year Review - EPA issued the final OU2/4 ROD on September 22, 2005. Remedial action has been completed. The LTRA is on-going and adjustments to the recovery well system are being made in an iterative manner until hydraulic containment is achieved. EPA expects to work with the property owner to place an Easement and Protective Covenant on the property in the near future.

See Table 5 for recap of the Recommendations for Follow-up that were identified during the second Five-Year Review and a summary of the progress made in relation to the issues.

VI. Five-Year Review Process

Administrative Components

EPA notified EA Engineering and Science, and state and local officials of the initiation of the five-year review in January 2008. The Greenwood Chemical Five-Year Review Team was led by Eric Newman, EPA's Remedial Project Manager (RPM), with EPA technical support staff Kathy Davies (Hydrogeologist), Nancy Jafolla (Toxicologist), and Trish Taylor (Community Involvement Coordinator). Tom Modena, VDEQ Project Manager, assisted in the review as the representative of the support agency. The five-year review schedule extended from January through September 2008. The five-year review included the following administrative components:

- Community Involvement;
- Document Review;
- Data Compilation and Review;
- Site Inspection;
- Interviews and Public Notification; and
- Five-Year Review Report Development and Review.

Community Involvement

The plan and schedule established for public outreach during the conduct of the five-year review process included public announcements and communications with local officials and residents. EPA used the annual residential well sampling event as an opportunity to conduct interviews with local citizens. EPA also contacted and interviewed area citizens who had attended the OU2/4 Proposed Plan public meeting held in Greenwood in July 2005 and the citizens who submitted public comments on that proposed plan. EPA contacted and provided a comprehensive update of Site progress to local public health officials including:

- Carl Christiansen, Virginia Department of Health – Office of Drinking Water

- Josh Rubinstein, Albemarle County Water Resources
- Jeff McDaniel, Albemarle County Health Department

A notice announcing that EPA was conducting a five-year review for the Site was published in the *Daily Progress* and the *News Virginian* on September 8, 2008.

Document Review

Documents reviewed in the process of conducting this five-year review included the last five-year review, the 1989 ROD, the 1990 Interim ROD, the 1991 and 1994 ESDs, the June 2004 Action Memorandum, the 2005 On-Scene Coordinator Report, the 2005 final OU2/4 ROD, the 2006 and 2007 Annual O&M Reports including treatment plant operational data, and monitoring data (treatment plant discharge and groundwater monitoring). A complete list of documents reviewed can be found in Attachment A.

An assessment of the Applicable or Relevant and Appropriate Requirements (ARARs) was conducted during the document review. The assessment determined that the ARARs are being met and/or are still appropriate for the remedies in place at the Site. The major ARARs include:

- MCLs and non-zero MCLGs are still promulgated under the Safe Drinking Water Act, 40 CFR § 141.11-16; 40 CFR §§ 141.50-51 and are still relevant and appropriate to the groundwater cleanup remedy in the area of attainment.

- MCLs and non-zero MCLGs are still promulgated under the Virginia Waterworks Regulation, 12 VAC 5-590-440, Tables 2.2 and 2.3 and are still relevant and appropriate to the groundwater cleanup remedy in the area of attainment.

- Discharge limitations into surface waters of the Commonwealth are still promulgated under the Virginia Pollutant Discharge Elimination System, 9 VAC 25-31-10 to 940 and are still applicable to the effluent discharge from the on-Site water treatment facility. A permit is not required for on-Site discharge; however, the substantive standards must be attained.

Data Review

Groundwater Monitoring

Groundwater monitoring has been conducted at the Greenwood Chemical Site since the late 1980s.

The final OU2/4 selected remedy requires hydraulic containment of the waste management area so that the groundwater performance standards (see Table 3) can be met in the area of attainment within 30 years. EPA has tailored the groundwater monitoring program to collect the data necessary to assess the effectiveness of the recovery well network and to measure

water quality in the area of attainment.

There are currently 59 groundwater wells located across of the Site and hydraulically down gradient of the Site. The current groundwater monitoring plan includes approximately 20 wells for quarterly monitoring (including extraction wells) and 40 wells for annual water quality monitoring. Water level measurements can be collected from all 59 wells to generate potentiometric maps.

In addition, residential well sampling is conducted on an annual basis, generally in April or May. The last sampling event was conducted in May 2008. Over the last five years 9 residential wells within an approximate one-half mile radius of the Site have participated in the sampling program. No site–related contaminants have ever been detected above MCLs or above any other risk-based action level in a residential well.

The groundwater samples are analyzed for Target Compound List (TCL) volatile and semi-volatile organic compounds and Target Analyte List (TAL) metals. A data validation package is submitted for each set of quarterly results. This five-year review focused on the quarterly reports presented in the 2007 Annual O&M Plan (April, June, and October 2007 and January 2008).

Flow rates and water quality data from extraction wells were reviewed along with potentiometric maps to evaluate the effectiveness of the recovery well network in establishing hydraulic containment of the waste management area. The most concentrated portion of the "plume" within the waste management area appears to be located at the center of the Site between recovery wells MW-23, CW-4 and CW-3 (See Figure 4), north and east of the treatment plant. This is consistent with previous years, as MW-23 was originally placed in the center of the former manufacturing area as a hot-spot recovery well. The water level measurements indicate that the recovery wells arrayed across the Site are likely containing groundwater moving down-slope toward the southern boundary. EPA determined it did not have enough monitoring wells placed near monitoring well PMW-5 to confirm that the new recovery wells CW-4, CW-5 and CW-6 have cut off the groundwater moving to the east in the vicinity of monitoring well PMW-5. The adjacent property owner granted EPA access to install 3 additional monitoring wells downgradient of CW-5 and monitoring well PMW-5 to better understand groundwater flow in this area. The new monitoring wells were installed in July 2008 and will be added to the quarterly sampling program. It is expected that further adjustments to the recovery well system will be required (i.e., adding wells or changing extraction well alignment). Careful review of water quality trends in monitoring wells within the area of attainment over the next several years will be required before EPA can definitively demonstrate that the hydraulic containment of the waste management area has been achieved.

The data review confirmed that the groundwater in the area of attainment remains above groundwater performance standards. Data trends will need to be graphed over the next several years to confirm that the project is on track to meet performance standards within 30 years.

The review team looked at the water quality along the property boundary to determine if

contaminants are migrating off the Site property. The four perimeter monitoring well locations (PMW-1, PMW-2, PMW-3 and PMW-4) that were placed along the southern property boundary all meet MCLs but do not yet meet the site-specific groundwater performance standards[j]. The two off-Site wells west of the property boundary near the former drum disposal area (MW-19 and BR-04) meet both MCLs and site specific performance standards. The well placed along the eastern boundary of the property (PMW-5) remains contaminated with trichloroethene at concentrations more than a magnitude greater than the MCL. Three new extraction wells (CW-4, CW-5 and CW-6) were placed upgradient of PMW-5 in 2005. CW-4 and CW-5 are recovering relatively high concentrations of trichloroethene but a reduction in trichloroethene concentration at PMW-5 is not yet evident.

Groundwater Pump and Treat System

Table 6 shows the average influent concentrations to the treatment plant from 2002 through 2007. The average influent concentrations have been fairly constant (within an order of magnitude) since the treatment system began operation.

A treatment system value engineering and efficiency analyses completed in Spring of 2005 determined that the UV/chemical oxidation system was not required to meet VPDES discharge limits and shutting it down would decrease O&M costs at the plant. EPA shut down the UV/chemical oxidation system on June 16, 2005 on a pilot basis. There have been no noticeable differences in the effluent quality since the UV/chemical oxidation unit was shut down.

The total volume of groundwater treated in 2007 was 19.41 million gallons (MG) and the cumulative quantity of groundwater treated is approximately 70 MG. Table 7 presents the annual groundwater and lagoon water recovery and treatment rates from 2001 to 2007. Lagoons 4 and 5 were closed in November 2004; the six new recovery wells came on-line in December 2005.

Table 7: Treatment Plant Flow Rates 2001-2007

Year	Lagoon Water (gal/yr)	Groundwater (gal/yr)	Total (gal/yr)
2001	0 (Zero)	5,928,652	5,928,652
2002	258,539	4,775,987	5,034,526
2003	430,847	5,961,277	6,392,124
2004	2,212,850	6,549,862	8,762,712
2005	0 (Zero)	6,878,236	6,878,236
2006	0 (Zero)	17,638,447	17,638,447
2007	0 (Zero)	19,409,215	19,409,215

[j] The site specific performance standards are lower than MCLs to account for the potential cumulative risk of multiple contaminants.

Based on the plant flow rate and influent contaminant concentrations, the mass of organic contaminants removed from the groundwater has increased from 25.2 pounds in 2003 (the first full year of operational data) to 56.0 pounds in 2007. See Table 6.

Monitoring of the groundwater treatment system effluent for VPDES discharge requirements is conducted on a monthly basis and Discharge Monitoring Reports are submitted to VDEQ. VPDES discharge parameters include flow, pH, total cyanide, total lead, total aluminum, dissolved metals (trivalent chromium, hexavalent chromium, copper, mercury, nickel, zinc, cadmium), trichloroethene, bis-2-ethylhexyl phthalate, methylene chloride, benzene, tetrachloroethene, toluene, chloroform, carbon tetrachloride, 1,2-chlorobenzene, 1,2-dichloroethane, bis-2-chloroethyl ether, chlorobenzene, and naphthalene. In addition, plant effluent is tested for whole effluent toxicity and chronic whole effluent toxicity on a quarterly basis. Review of the monthly discharge monitoring reports submitted in 2007 confirmed effluent discharge was within the VPDES required limits.

Site Inspection

EPA and Virginia DEQ representatives maintain a continuous presence on the Site to operate the government-financed water treatment plant. On July 17, 2008 Eric Newman, EPA's Remedial Project Manager for the Site and EA Engineering and Science representatives (water treatment plant operators Gary Funkhouser and Natalie Schroeder) conducted a systematic Site inspection specifically focused on evaluating the condition of engineered features and the protectiveness of the constructed remedy as part of the five-year review process. Weather at the time of inspection was hot and sunny.

The objective of the inspection was to assess the protectiveness of the remedy, including the integrity of the soil cover and the operation of the wastewater treatment plant. The water treatment plant was physically inspected with a walk through. Each monitoring and recovery well was inspected and determined to be in operable condition; proper access to wells has been maintained. The soil cover constructed over the former drum disposal and former manufacturing areas were inspected and found to be well vegetated. Conveyance details such as ditches and culverts, and treatment plant discharge points were observed to be free of debris. All components of the remedial action were confirmed operational and functional. No significant issues have been identified regarding the physical condition of the Site, the monitoring points or the operation of the water treatment plant.

Institutional controls are not yet in place to prohibit disturbance of the implemented remedy or use of groundwater for potable purposes. During the Site inspection no activities were observed or reported that would violate the land use restrictions called for in the OU 2/4 ROD. The subject property was fenced, the soil cover and surrounding areas were undisturbed, and no new uses of groundwater were observed. The gate to the facility is only opened during standard business hours.

Interviews

EPA RPM Newman conducted many interviews with treatment plant employees, local residents and local officials to inform them that EPA was completing the Five-Year Review process to confirm that the constructed remedy remains protective. Although this is the third Five-Year Review completed for the Greenwood Site, it is the first review conducted since the final remedy has been selected and in place. During each interview Mr. Newman outlined the review process, including a detailed review of environmental monitoring and maintenance reports, a field inspection of the constructed remedy, and a literature review to confirm that the performance standards remain protective when considering the most up-to-date regulatory standards and toxicity data of site-related compounds. Mr. Newman conveyed the importance of communicating with local citizens and public officials to learn of any concerns related to the Site.

In April 2008, Mr. Newman called the several area residents who participate in EPA's annual residential well sampling program to schedule dates for the 2008 sampling event. During those calls Mr. Newman provided an overview of the on-going five year review process and the role of the community interviews. The local citizens interviewed include:

- Janet Sims, resident on Summer Rest Lane and the point-of-contact for the Mt. Zion Baptist Church – May 13, 2008
- Ben Washington, resident on Newtown Road – April 23, 2008
- Elizabeth Burgess, resident on Newtown Road – April 23, 2008
- Barbara Chakmakian, Piedmont Farm – April 28, 2008
- Dice Hammer, Ridgely Farm – April 22, 2008
- Harry Lankenau, Ramsay Farm – May 27, 2008

None of the citizens interviewed expressed any specific concerns related to the Site and noted that concerns about the Site have diminished over the years. The local citizens were aware of the work that EPA has completed. Several citizens mentioned having read the Fact Sheets EPA sent to the community in 2004 and 2005 describing the status of on-going cleanup activity. Based on the interviews, the local citizens are comfortable with the work completed. The citizens expressed general satisfaction that EPA does maintain an interest in the Sites and reviews them for continued protectiveness after cleanups have occurred.

On April 22, 2008, Mr. Newman called Mr. Dice Hammer by telephone. Mr. Hammer is the owner of Ridgely Farm, the large farm located adjacent the Site to the east and south. In addition to the overview of the on-going five year review process and the role of the community interviews, Mr. Newman discussed the detailed status of EPA's efforts to prevent groundwater from migrating eastward. Mr. Hammer was aware of the cleanup work that EPA performed over the years and that EPA expanded the recovery well network to contain the contaminants on-Site. Mr. Newman told Mr. Hammer of the most recent sampling results in the vicinity of PMW-5,

along the shared property boundary (the eastern side of the Greenwood Chemical property). Specifically, that EPA could not yet confirm that the new wells had cut off groundwater moving along the topographic dip to the east. Upon Mr. Newman's request, Mr. Hammer granted EPA access to install a few new monitoring wells on his side of the property boundary. Mr. Hammer expressed an interest in cooperating with the groundwater investigation so that EPA can successfully prevent contaminants from extending beneath his property. Mr. Hammer asserted that Ridgely Farm is a working farm and that monitoring wells need to be installed in a manner that would not interfere with his on-going work. EPA agreed to install the wells flush-mounted to the ground. The new wells were installed in July 2008. Mr. Hammer stated that he understands that EPA will use the data collected from the wells on his property to refine the on-going cleanup action.

On July 17, 2008, Mr. Eric Newman was on-Site to conduct the Site inspection and interview the water treatment plant operators Gary Funkhouser and Natalie Schroeder about community concerns that they may have heard of. Mr. Funkhouser lives in the community and has operated the Greenwood water treatment plant since 2001. Ms. Schroeder also lives in the community and has been working at the Greenwood Site since 2006. Mr. Funkhouser and Ms. Schroeder informed Mr. Newman that no negative concerns related to the protectiveness of the selected remedy have been raised to their attention.

On October 22, 2007 Mr. Newman called Mr. Al Cereghino, the owner of the now-inactive Greenwood Chemical Company. In addition to providing an overview of the progress of Site cleanup and the upcoming five year review process, Mr. Newman discussed the institutional controls that were part of the selected remedy for the Site. Mr. Cereghino stated that he understood that the property could be safely redeveloped for recreational or industrial purposes but that groundwater could not be used for potable purposes. In summary, Mr. Cereghino expressed that he generally supported the cleanup actions taken by EPA and that he has not had any inquiries from prospective purchasers. Mr. Cereghino told Mr. Newman that EPA has a lien on the property for 90% of its value and that Albermarle County has a lien for the remaining 10% to cover back taxes. Nevertheless, Mr. Cereghino indicated a willingness to cooperate with EPA by granting an Environmental Protection Easement and Declaration of Restrictive Covenant to be filed with Albemarle County. EPA will be following up on this matter in the near future.

VII. Technical Assessment

Question A: Is the Remedy functioning as intended by the decision documents?

Yes. The remedy is functioning as intended by the decision documents but not all remedial action objectives have been met yet. The recovery well network is capturing groundwater and treating the groundwater successfully before discharge. However, complete hydraulic containment has not been demonstrated along the eastern edge of the waste management area.

The LTRA is on-going and adjustments to the recovery well system are being made in an iterative manner until hydraulic containment is achieved. New monitoring wells were installed in July 2008 and have been added to the quarterly sampling program. It is expected that further adjustments to the recovery well system will be required (i.e., adding wells or changing extraction well alignment). Careful review of water quality trends in monitoring wells within the area of attainment over the next several years will be required before EPA can definitively demonstrate the hydraulic containment of the waste management area has been achieved.

The groundwater in the area of attainment remains above groundwater performance standards. Data trends will need to be graphed over the next several years to confirm that the project is on track to meet performance standards within 30 years.

The treatment system met VPDES discharge standards for all organic and inorganic parameters and effluent passed toxicity tests.

No impact has been detected in any residential drinking water wells or agricultural wells around the Site. EPA expects to work with the property owner to place an Environmental Easement and Protective Covenant on the property in the near future.

Question B: Are the exposure assumptions, toxicity data, cleanup levels, and remedial action objectives (RAOs) used at the time of remedy selection still valid?

Changes in Standards and TBCs

Have standards identified in the ROD been revised, and does this call into question the protectiveness of the remedy? Do newly promulgated standards call into question the protectiveness of the remedy? Have TBCs used in selecting cleanup levels at the site changed, and could this affect the protectiveness of the remedy?

The groundwater performance standards currently in effect were set in the 2005 ROD: 1,2-dichloroethane 5.0 ug/L; bis (2-chloroethyl) ether 0.5 ug/L; carbon tetrachloride 4.0 ug/L; tetrachloroethene 0.8 ug/L; trichloroethene 1.0 ug/L; and vinyl chloride 0.5 ug/L. These standards are at or below current federal and State Maximum Contaminant Levels (MCLs) of 1,2-dichloroethane 5.0 ug/L; carbon tetrachloride 5.0 ug/L; tetrachloroethene 5.0 ug/L; trichloroethene 5.0 ug/L; and vinyl chloride 2.0 ug/L. Bis (2-chloroethyl) ether does not have a promulgated federal or State MCL. In summary, the cleanup standards currently in effect are at or below current MCLs.

Changes in Exposure Pathways

Has land use or expected land use on or near the site changed?

No; local land use remains mixed residential, woodlands and agricultural.

Have human health or ecological routes of exposure or receptors been newly identified or changed in a way that could affect the protectiveness of the remedy? Are there newly identified contaminants or contaminant sources? Are there unanticipated toxic byproducts of the remedy not previously addressed by the decision documents? Have physical site conditions or the understanding of these conditions changed in a way that could affect the protectiveness of the remedy?

The selected remedy will result in high concentrations of volatile compounds remaining at depth. The anticipated future use of the Greenwood Chemical Site is recreational or industrial purposes. In the event that buildings were to be constructed in the vicinity of the waste management area a potential exposure route of concern would be vapor intrusion.

The only occupied building presently on the property or in the vicinity of the groundwater contamination is the large water treatment facility built on a slab. In addition to being constructed on a slab, the water treatment facility was designed with good ventilation suitable for processing ground water contaminated with elevated levels of VOCs. There are currently no other buildings in the vicinity of the Site. A study of the potential for vapor intrusion to buildings which may be constructed during future redevelopment of the property is recommended.

Changes in Toxicity and Other Contaminant Characteristics

Have toxicity factors for contaminants of concern at the site changed in a way that could affect the protectiveness of the remedy? Have other contaminant characteristics changed in a way that could affect the protectiveness of the remedy?

The toxicity data for contaminants remaining at the Greenwood Chemical Site were reassessed for the final OU2/4 ROD issued in 2005. The toxicity factors listed in Tables 2A and 2B of the 2005 ROD have not changed since then. The groundwater performance standards have not been met yet but the extent of the plume is reasonably well-defined.

The 27 mg/kg soil cleanup standard for arsenic contaminated surface soil was established in the 2004/2005 Removal Action. The exposure assumptions and toxicity factors for arsenic have not changed and this cleanup concentration remains protective.

Soil cleanup standards for organic compounds were developed in the OU1 ROD and modified by ESD-2. See Table 2. The baseline risk assessment and back-calculated cleanup standards completed for OU1 assumed the future land use to be residential. The soil cleanup levels selected for organic compounds were based on the potential for migration to groundwater because the soil to groundwater performance standards were more conservative (i.e., lower) than cleanup concentrations developed for direct contact and residential use. The soil cleanup standards set forth in ESD-2 were compared to the July 2008 Region III RBC Table for industrial

land use[k]. See Table 8. The analysis determined that the OU1 cleanup levels for carcinogens represent a cancer risk within or less than EPA's acceptable risk range of 10^{-4} to10^{-6} for all but one compound. The OU1 cleanup level for tetrahydrofuran would represent a 2.6 x 10^{-4} cancer risk if tetrahydrofuran remained in surface soil at 97,269 mg/kg (i.e., 9.72% tetrahydrofuran). This would be above EPA's goal of 1 x 10^{-4} cancer risk. It is very unlikely that tetrahydrofuran remains in surface soil at these extremely high levels for at least three reasons.

- Table 6 of the OU1 ROD reports that the maximum concentration of tetrahydrofuran measured at the site was 2.5 mg/kg. It is certainly possible that tetrahydrofuran was present at higher concentrations in areas of actual waste material (e.g., in a drum), but it is unlikely that it was present in soil after the disposal areas were excavated.
- The lagoons and disposal areas remediated during OU1 remedial action were contaminated with multiple contaminants. Excavation proceeded until the lateral extent of the excavation was confirmed clean or the depth reached approximately 15 feet. Tetrahydrofuran would be collocated with other contaminants and therefore would have been excavated to concentrations on average much lower than 97,269 mg/kg due to the proximity of other contaminants with much lower cleanup targets. For example, cleanup levels for benzene and trichloroethene are more than 5 orders of magnitude lower that the tetrahydrofuran cleanup level.
- The excavation areas were filled with clean fill and the former manufacturing was covered with a minimum of 2 feet of clean soil and vegetated.

Similarly, the OU1 soil cleanup levels for site-related non-carcinogenic compounds represent a Hazard Index of approximately 1.0 if they all affected the same target organ, with the exception of chlorobenzene. The OU1 cleanup level for chlorobenzene would represent an HI of 5.1 if chlorobenzene remained in surface soil at 7,708 mg/kg. This would be above EPA's target of less than 1.0 HI. It is very unlikely that chlorobenzene remains in surface soil at these high levels for the same three reasons stated above.

- Table 6 of the OU1 ROD reports that the maximum concentration of chlorobenzene measured at the site was 150 mg/kg. The presence of chlorobenzene was a potential contaminant of concern, but chlorobenzene was not driving the cleanup at the Site. The 150 mg/kg chlorobenzene measured before the cleanup began would only present 0.1 HI to an industrial worker. Again, it is possible that chlorobenzene was present at higher concentrations in areas of actual waste material, but it is unlikely that it was present at elevated concentrations in soil after the disposal areas were excavated.
- The lagoons and disposal areas remediated during OU1 remedial action were contaminated with multiple contaminants. Excavation proceeded until the lateral extent of the excavation was confirmed clean or the depth reached approximately 15 feet. Chlorobenzene would be collocated with other contaminants and therefore would have been excavated to concentrations on average much lower than 7,708 mg/kg due to the proximity of other contaminants with much lower cleanup targets. For example, cleanup

[k] EPA's 2005 Record of Decision established that the reasonably anticipated future land use at the Site is recreational or industrial.

levels for benzene, chloroform and 1,2-dichloroethane are more than 4 orders of magnitude lower that the chlorobenzene cleanup level.

- The excavation areas and former manufacturing was covered with a minimum of 2 feet of clean soil and vegetated.

Based on these considerations, EPA has a high degree of confidence that the OU1 cleanup levels remain protective of human health for the future industrial land use scenario.

In summary, direct contact with soil and groundwater is not expected to pose unacceptable risks under current conditions (i.e., exposure is currently being prevented). Groundwater has still not met performance standards in the area of attainment and would not be suitable for potable use at this time.

Changes in Risk Assessment Methods

Have standardized risk assessment methodologies changed in a way that could affect the protectiveness of the remedy?

There have not been significant changes since the final 2005 ROD. However, the vapor intrusion exposure route was not evaluated for VOCs in deep soils within the waste management area. This may become relevant if future redevelopment includes occupied buildings in the vicinity.

There have been significant changes in EPA's risk assessment guidance since the original risk assessment was performed. These include changes in dermal guidance, inhalation methodologies and exposure factors. The original risk assessment assumed a residential future land use and the ROD chose even lower performance standards because the soil to groundwater migration model generated lower concentrations. Accordingly, these changes are not expected to affect the protectiveness of the remedy.

Expected Progress Towards Meeting RAOs

Is the remedy progressing as expected?

Yes. The remedy has met all remedial action objectives established by the EPA decision documents with the exception of establishing hydraulic containment of the waste management area and subsequently meeting groundwater performance standards in the area of attainment. It is not unexpected that some degree of "trial and error" would be required to successfully align the groundwater recovery wells to achieve hydraulic containment. It is inherently difficult to predict appropriate extraction well locations due to the unpredictable nature/direction of fractures in bedrock. EPA will continue to adjust the recovery well alignment until the contaminated groundwater is contained within the waste management area.

Question C: Has any other information come to light that could call into question the protectiveness of the remedy?

No other information that has not been discussed already has come to light that would call into question the protectiveness of the remedy.

Technical Assessment Summary

In summary, groundwater cleanup within the area of attainment is progressing with the operation of the groundwater treatment systems, but hydraulic containment has not been demonstrated along the eastern edge of the waste management area. Adjustments to the recovery well alignment will be required until hydraulic containment is achieved. Data trends will need to be graphed over the next several years to confirm that the project is on track to meet performance standards within 30 years. An assessment of the potential for vapor intrusion to buildings which may be constructed during future redevelopment of the property is recommended.

EPA needs to establish the Environmental Easement and Protective Covenant on the property to implement the institutional controls in accordance with the 2005 ROD.

VIII. Issues

The table below summarizes the issues identified during this Five-Year Review for the Greenwood Chemical Superfund Site.

Table 9: Issues

Issues	Affects Current Protectiveness (Y/N)	Affects Future Protectiveness (Y/N)
1. Adjust alignment of recovery well network to establish hydraulic containment of the waste management area.	N	Y
2. Evaluate potential for vapor intrusion	N	Y
3. Implement institutional controls included in 2005 ROD	N	Y

IX. Recommendations and Follow-up Actions

Table 10: Recommendations and Follow-up Actions

Issue	Recommendations and Follow-up Actions	Party Responsible	Oversight Agency	Milestone Date	Affects Protectiveness (Y/N)	
					Current	Future
1.	Adjust alignment of recovery well network to establish hydraulic containment of the waste management area.	EPA	EPA	9/30/2011	N	Y
2.	Develop and implement plan for assessing vapor intrusion into potential future structures	EPA	EPA	9/30/2010	N	Y
3.	Modify remedy, to establish prohibitions on installing drinking water wells in the plume of contamination, then implement institutional controls.	EPA PRP VDEQ	EPA	9/30/2010	N	Y

X. Protectiveness Statement

The remedy at OU1 is protective of human health and the environment. Contaminated soil and waste material was excavated and transported off-Site for treatment and/or disposal to minimize migration to groundwater and direct exposure. The excavated areas were backfilled with clean soil. The remedial action objectives have been met.

The remedy at OU2/4 is expected to be protective of human health and the environment, and in the interim, exposure pathways that could result in unacceptable risks are being controlled. Complete hydraulic containment has not yet been achieved but there is no current exposure to contaminated groundwater. In order for the remedy to be protective in the long term the following actions must be taken: 1) adjust the recovery well alignment until complete hydraulic containment of the waste management area is achieved; 2) evaluate the vapor intrusion pathway; and, 3) implement institutional controls on the Site.

The remedy at OU3 is protective of human health and the environment. The former manufacturing buildings and chemical wastes stored within those buildings were dismantled and properly disposed off-Site. The remedial action objectives have been met.

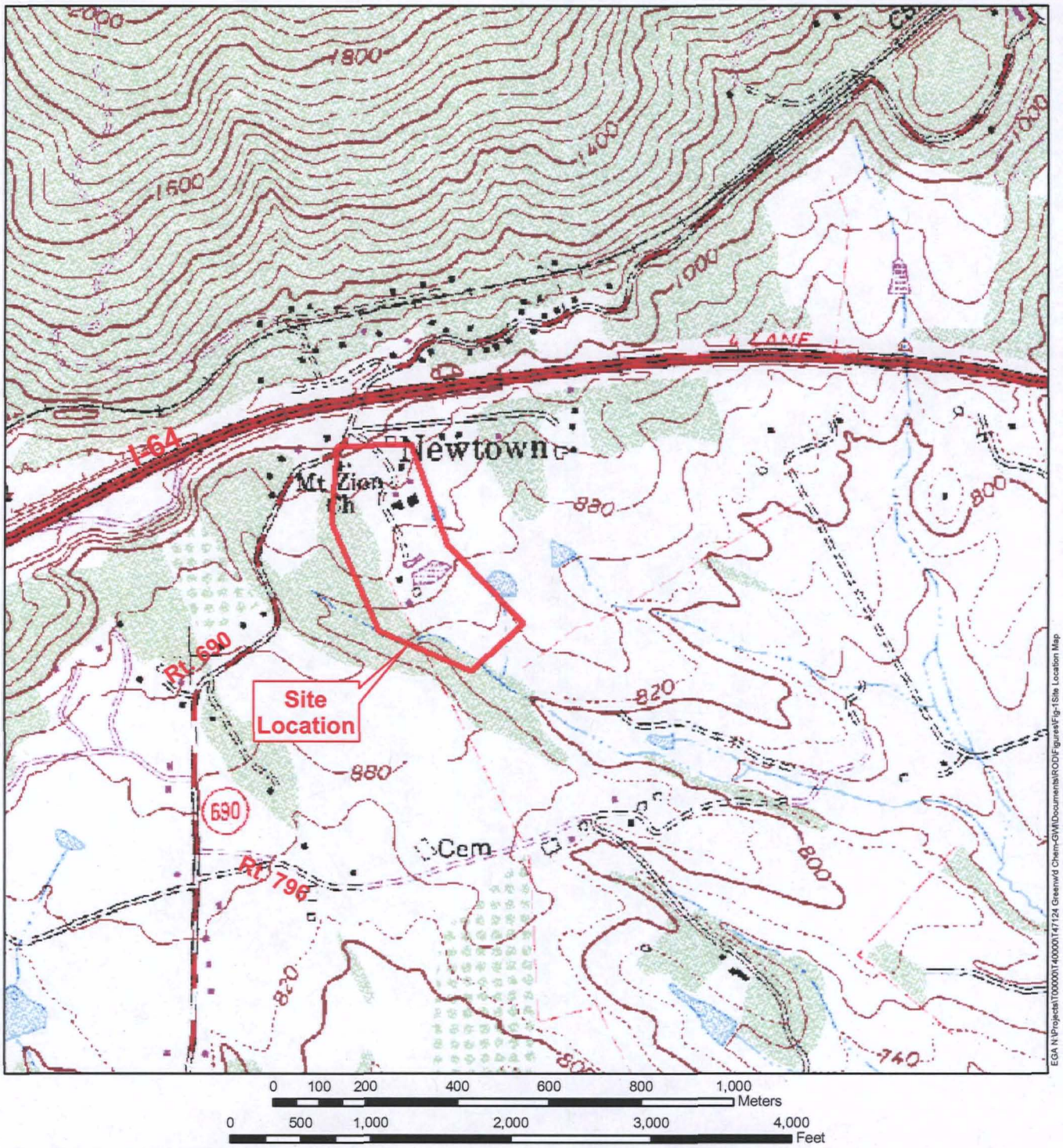
The remedial actions at OUs 1 and 3 are protective and remedial actions at OUs 2 and 4 are protective in the short term. Because complete hydraulic containment has not been achieved and institutional controls are not in place remedial actions are not protective in the long term. There is no current exposure to contaminated groundwater; however, in order for the remedy to

be protective in the long-term the following actions must be taken: 1) adjust the recovery well alignment to establish hydraulic containment of the waste management area and restore groundwater quality in the area of attainment; 2) evaluate the vapor intrusion pathway; and, 3) implement institutional controls.

XI. Next Review

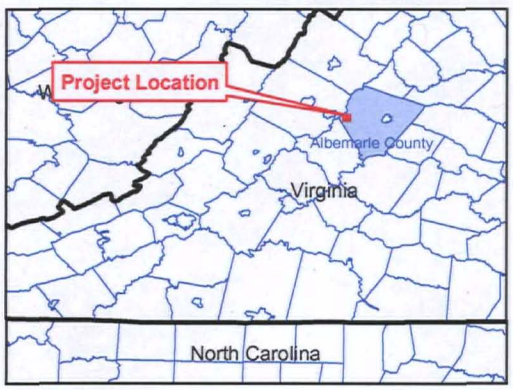
Since Site conditions do not allow for unlimited use and unrestricted exposure, EPA will need to conduct another five-year review of the Greenwood Chemical Site by September 2013, five years from the date of this review.

FIGURES



0 100 200 400 600 800 1,000 Meters

0 500 1,000 2,000 3,000 4,000 Feet



U.S. Environmental Protection Agency

GREENWOOD CHEMICAL SUPERFUND SITE

Albermarle County
Greenwood, Virginia

Figure 1
Site Location Map

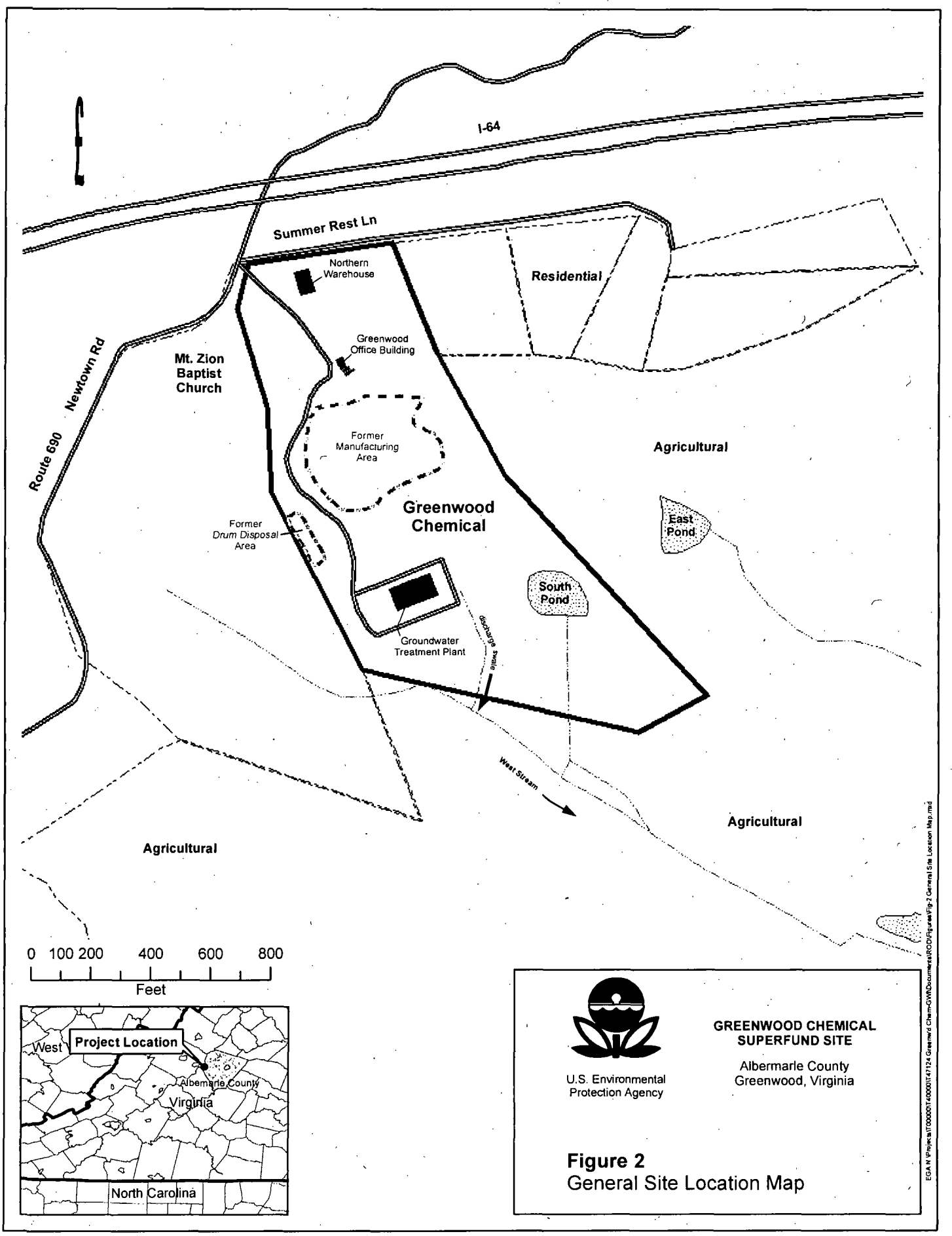
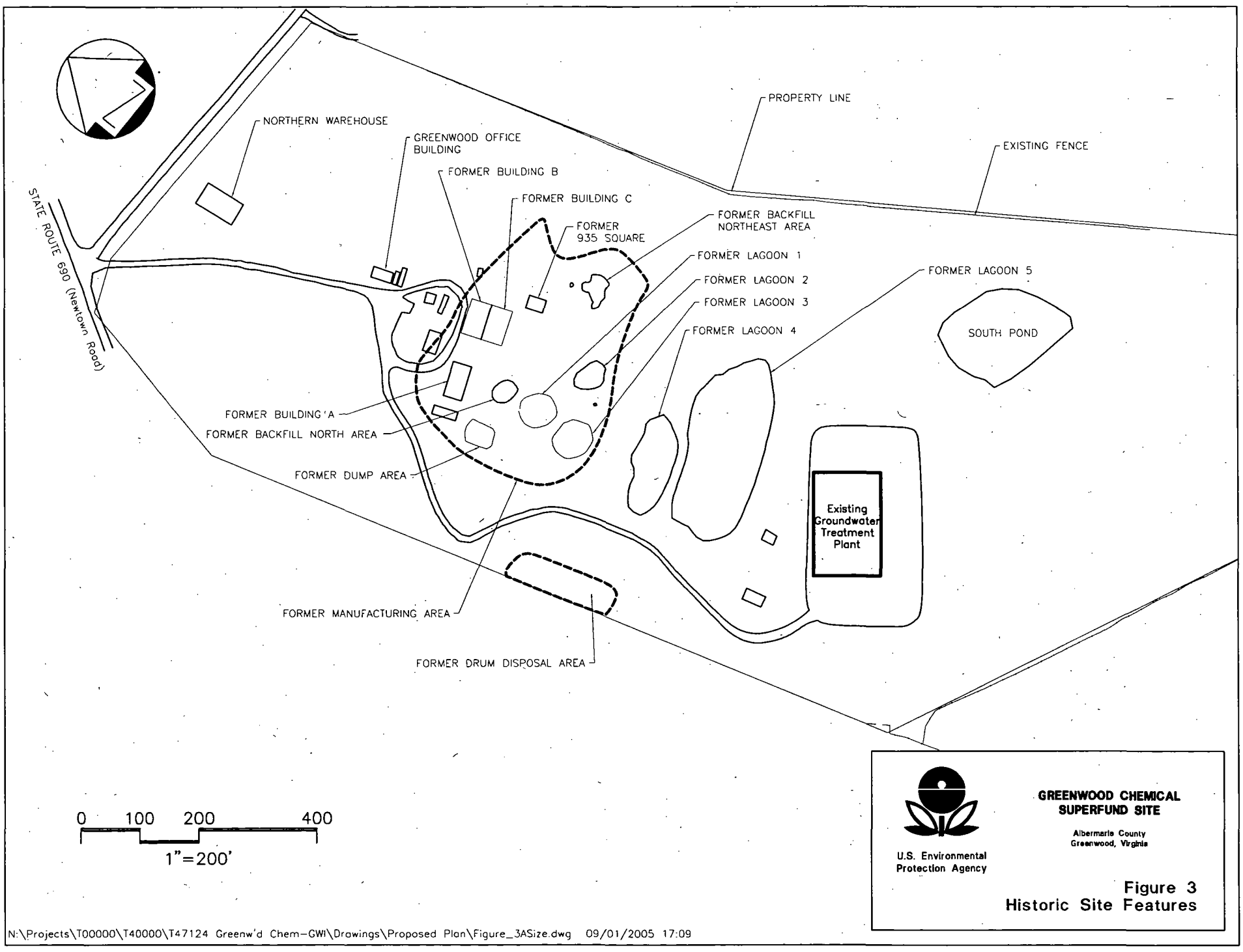
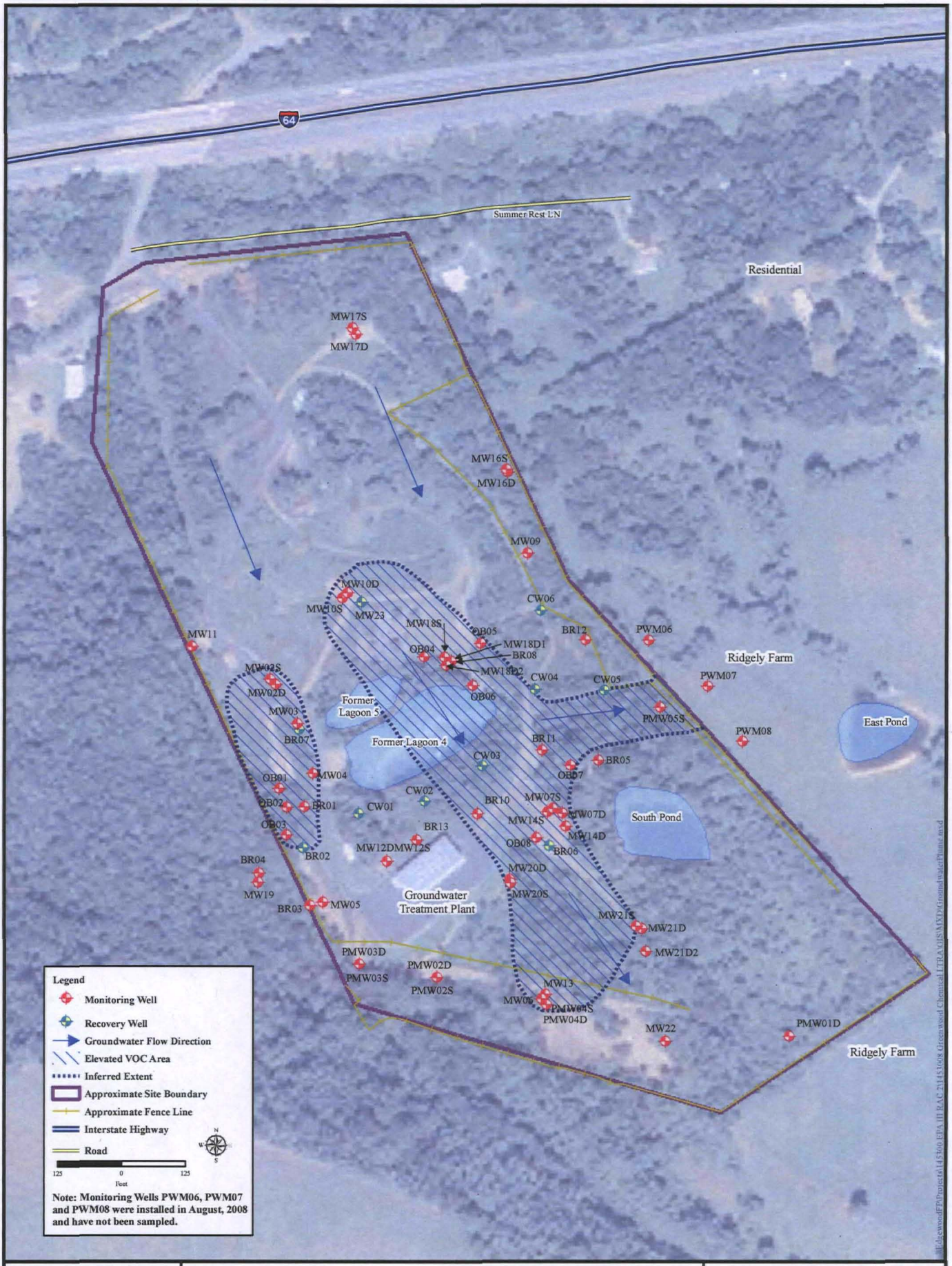


Figure 2
General Site Location Map


PROPERTY LINE
EXISTING FENCE
NORTHERN WAREHOUSE
GREENWOOD OFFICE BUILDING
FORMER BUILDING B
FORMER BUILDING C
FORMER 935 SQUARE
FORMER BACKFILL NORTHEAST AREA
FORMER LAGOON 1
FORMER LAGOON 2
FORMER LAGOON 3
FORMER LAGOON 4
FORMER LAGOON 5
SOUTH POND
STATE ROUTE 690 (Newtown Road)
FORMER BUILDING 'A
FORMER BACKFILL NORTH AREA
FORMER DUMP AREA
FORMER MANUFACTURING AREA
FORMER DRUM DISPOSAL AREA
Existing Groundwater Treatment Plant
0 100 200 400
1"=200'
U.S. Environmental Protection Agency
GREENWOOD CHEMICAL SUPERFUND SITE
Albermarle County
Greenwood, Virginia
Figure 3
Historic Site Features
N:\Projects\T00000\T40000\T47124 Greenw'd Chem-GWI\Drawings\Proposed Plan\Figure_3ASize.dwg 09/01/2005 17:09



EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

U.S. Environmental Protection Agency, Greenwood Chemical Site
Albemarle County
Greenwood, VA

FIGURE 4

PLUME AND WELL LOCATIONS

TABLES

Note: Tables 1, 4, 7, 9 and 10 are embedded in text

Table 2

SOIL CLEANUP LEVELS FOR CONTAMINANTS AT GREENWOOD CHEMICAL SUPERFUND SITE

	SOURCE AREA ACTION LIMITS (GROUNDWATER PROTECTION)	DRUM DISPOSAL ACTION LIMITS (GROUNDWATER PROTECTION)
CLEANUP LEVELS		
Volatile Organics	mg/kg	mg/kg
Benzene	0.225	0.0224
Chlorobenzene	7,708.7	*
Methylene Chloride	2,665.1	10.83
Tetrachloroethylene	*	0.2364
Trichloroethylene	*	0.0974
Toluene	40,917.6	101.4
1,2-Dichloroethane	0.124	*
Acetone	1,462.1	*
Tetrahydrofuran	97,269	*
Chloroform	0.219	0.3262
Semi-Volatile Organics		
Semi-Volatile TICs	*	158.6
4-Chloroanaline	565.7	*

Notes:

* Soil excavation for the referenced hazardous substances is not required because their cleanup levels have not been exeeded in the referenced area. See "Final Fate & Transport Modeling For Determination of Soil Cleanup Goals Protective of Ground water (February, 1993), Table ES-1, p. ES-3.

1. EPA has determined that acetone present in the Northern Warehouse Area may also require remediation, and through the risk-based modeling has determined that the cleanup level for acetone in this area is 10.1 mg/kg. However, the acetone cleanup level is not presented in this table because, to date, EPA has documented only one exceedance of this cleanup level in this area. Whether remediation of this area is necessary will depend upon additional soil sampling.

Table 3
Groundwater Performance Standards
(Excerpt from 2005 OU2/4 ROD)

In accordance with the NCP, cleanup options that include leaving the deep soils contamination in place require establishment of an area of attainment beyond the waste management area. Accordingly, EPA has developed chemical-specific cleanup goals for ground water which would not only meet the relevant and appropriate standards for drinking water but would also be sufficient to address the cumulative risk presented by multiple contaminants within the "area of attainment."

Table 3
Risk-Based Remedial Goals ("RBRG") for Ground Water - Area of Attainment

Chemical of Potential Concern	PQL (ug/l)*	MCL (ug/l)	Final RBRG (ug/l)
1,2-Dichloroethane	0.5	5.0	5.0
Bis(2-Chloroethyl)Ether	0.01	no MCL	0.5
Carbon Tetrachloride	0.5	5.0	4.0
Tetrachloroethene	0.5	5.0	0.8
Trichloroethene	0.5	5.0	1.0
Vinyl Chloride	0.5	2.0	0.5

* The RBRG of 0.5 ug/L selected for vinyl chloride is the **practical quantitation limit ("PQL")** and represents an approximate risk level of 4×10^{-5}. The final RBRG for each of the other five contaminants was set at a level equivalent to a 1×10^{-5} risk.

The ground water risk-based remediation goals ("RBRGs") set forth in Table 3 fall within the acceptable risk range of a cancer risk of 1×10^{-4} to 1×10^{-6} and a HI of 1, and assume that all six contaminants are present in a single well. In fact, the contamination at the Site varies by location, and no more than two contaminants above RBRGs were found in any one monitoring well. In summary, the contaminant-specific ground water cleanup goals were established at levels which: 1) comply with ARARs; 2) are detectable in a laboratory; and, 3) would achieve a cumulative risk within EPA's target risk range.

Table 5
Recommendations for Follow-up Actions from the Second Five-Year Review
-- 2008 Update --

1) Modify groundwater monitoring system
EPA installed additional monitoring wells at the perimeter of the Site and downgradient of 6 newly installed groundwater recovery wells. Monitoring these wells is necessary to confirm that RAOs and performance standards are being met. EPA has phased out routine sampling of the monitoring wells located within the waste management area. It is well documented that these wells are, and will continue to be, contaminated. The monitoring wells remain in place and are utilized for potentiometric mapping.
2) Determine the effectiveness of bedrock recovery well system in preventing off-Site migration
EPA conducted a capture zone analyses and determined that additional recovery wells were necessary to prevent off-Site migration. EPA installed 6 additional groundwater recovery wells within the bedrock aquifer to prevent off-Site migration. EPA will continue to monitor the effectiveness of the enhanced recovery well network configuration as part of its routine O&M activities and adjust the system as appropriate.
3) Modify monthly O&M Report to include contaminant mass reduction calculations and groundwater monitoring data for each well
EPA has upgraded the Quarterly O&M program and reporting methods in several ways, including utilizing "EQuIS" to create and maintain a groundwater monitoring database. Quarterly reports include a table detailing mass reduction data for each well. Quarterly and annual reports document the mass reduction achieved by the pump and treat program. The pump and treat system removed 75.8 lbs and 56 lbs of organic contaminants in 2006 and 2007, respectively. Concentrations at individual wells can be queried and trends and plumes can be plotted with the cumulative database.
4) Determine need for long-term operation of UV/Oxidation system and possible conversion
EPA completed an engineering analysis to evaluate the necessity of the UV/Oxidation system in the treatment train in Spring of 2005. The engineering evaluation concluded that the existing carbon filtration system would successfully achieve the quantitative discharge standards without the UV/Oxidation unit in the treatment train. EPA took the UV/Oxidation unit out of the treatment train in June 2005 on a pilot basis. The treatment plant continues to meet its performance standards without the UV/Oxidation.
5) Improve existing recovery well production or add additional recovery wells
EPA installed 6 additional groundwater recovery wells and is continuing to monitor the effectiveness of the enhanced groundwater recovery well network. EPA utilized a hydro-fracturing technique during well installation to increase extraction efficiency from wells placed in fractured bedrock.

Table 6
Treatment Plant Influent Concentrations and Organic Mass Removal

Month	CCl4	BCEE	Others	Total Org	Influent Flow	Lb Removed	Annual Total
Mar-02	207	23.5	106.1	336.6	327,184	0.9	
Apr-02	197	29	116	342	322,741	0.9	
May-02	210	27	176	413	327,458	1.1	
Jun-02	270	27	240	537	397,374	1.8	
Jul-02	400	46	222	668	541,603	3.0	18.5
Aug-02	190	35	221	446	563,167	2.1	
Sep-02	250	47	276	573	453,346	2.2	
Oct-02	410	48	423	881	434,044	3.2	
Nov-02	250	46	246	542	490,304	2.2	
Dec-02	130	22	85.4	237.4	530,810	1.1	
Jan-03	72	45	126.7	243.7	519,089	1.1	
Feb-03	470	21	303.7	794.7	459,077	3.0	
Mar-03	0	20	138	158	504,799	0.7	
Apr-03	83	12	53.5	148.5	412,636	0.5	
May-03	190	13	90.4	293.4	509,022	1.2	
Jun-03	210	22	240	472	541,938	2.1	25.2
Jul-03	320	24	197.2	541.2	538,729	2.4	
Aug-03	330	24	173.8	527.8	614,305	2.7	
Sep-03	400	25	287	712	501,655	3.0	
Oct-03	220	13	114.2	347.2	635,084	1.8	
Nov-03	510	24	314.6	848.6	688,806	4.9	
Dec-03	250	22	164.4	436.4	466,984	1.7	
Jan-04	360	24	219.1	603.1	911,079	4.6	
Feb-04	100	27	101.91	228.91	775,940	1.5	
Mar-04	250	15	572.8	837.8	734,302	5.1	
Apr-04	440	17	218.1	675.1	672,508	3.8	
May-04	140	17	154.7	311.7	661,850	1.7	
Jun-04	460	22	266.4	748.4	624,352	3.9	39.7
Jul-04	220	21	189.9	430.9	534,085	1.9	
Aug-04	350	16	239	605	538,252	2.7	
Sep-04	180	11	115.3	306.3	606,336	1.5	
Oct-04	210	7.4	159.7	377.1	807,601	2.5	
Nov-04	490	23	225.9	738.9	1,406,220	8.7	
Dec-04	260	15	154.56	429.56	490,187	1.8	
Jan-05	140	18	93.20	254.40	463,888	1.0	27.9
Feb-05	310	18	219.00	554.20	480,857	2.2	
Mar-05	460	20	213.90	703.00	627,217	3.7	
Apr-05	460	15	269.15	744.15	417,367	2.6	
May-05	410	6.8 J	257.50	667.50	556,098	3.1	
Jun-05	260	23	186.20	469.20	475,376	1.9	
Jul-05	280	15.5	126.70	422.20	503,597	1.8	
Aug-05	245	21.25	107.84	374.09	506,351	1.6	
Sep-05	190.2	9.24	113.86	313.30	452,948	1.2	

Month	CCl4	BCEE	Others	Total Org	Influent Flow	Lb Removed	Annual Total
Oct-05	98	17	127.90	242.90	489,829	1.0	
Nov-05	740	19	489.60	1,248.60	192,608	2.0	
Dec-05	130	11	309.20	450.20	1,583,054	5.9	
Jan-06	140	11	216.00	367.00	1,407,803	4.3	
Feb-06	130	8.3	259.60	397.90	1,350,960	4.5	
Mar-06	140	15	271.80	426.80	1,433,760	5.1	
Apr-06	280	12	380.10	672.10	1,225,250	6.9	
May-06	240	12	284.20	536.20	1,187,577	5.3	
Jun-06	210	14	264.00	488.00	1,352,785	5.5	75.8
Jul-06	300	13	325.60	638.60	1,639,485	8.7	
Aug-06	280	11	373.10	664.10	1,612,527	8.9	
Sep-06	290	13	382.90	685.90	1,384,525	7.9	
Oct-06	200	7.7	267.50	475.20	1,411,204	5.6	
Nov-06	210	13	281.90	504.90	1,491,593	6.3	
Dec-06	200	3.2	261.90	465.10	1,747,054	6.8	
Jan-07	120	7.4	168.20	295.60	1,734,053	4.3	
Feb-07	110	12	177.10	299.10	1,497,348	3.7	
Mar-07	130	5.8	187.80	323.60	1,357,745	3.7	
Apr-07	220	5	191.40	416.40	1,558,601	5.4	
May-07	230	9.6	201.90	441.50	1,601,221	5.9	
Jun-07	320	11	248.00	579.00	1,265,251	6.1	56.0
Jul-07	160	10	150.80	320.80	1,636,007	4.4	
Aug-07	190	5.4	117.70	313.10	1,597,163	4.2	
Sep-07	380	7.5	217.40	604.90	1,791,013	9.0	
Oct-07	120	8.5	217.50	346.00	1,485,646	4.3	
Nov-07	20	1.8	38.90	60.70	1,660,671	0.8	
Dec-07	130	9.2	188.40	327.60	1,545,735	4.2	

All concentrations in ug/l
Influent flow rate in gallons during the month

Table 8
Comparison of Soil Cleanup Levels used for OU1 ROD to Region III RBCs

Contaminant	Former Manufacturing Area (mg/kg)	Former Drum Disposal Area	Industrial RBC[a]	Approximate Risk of Highest Cleanup Concentration[b]
Benzene	0.225	0.0224	56.0 (C)	4.0 E-8
Chlorobenzene	7,708.7	*	1,500 (N)	5.1 (Hazard Index)
Methylene chloride	2,665.1	10.83	540 (C)	4.9 E-5
Tetrachloroethene	*	0.2364	27.0 (C)	8.7 E-8
Trichloroethene	*	0.0974	140.0 (C)	6.0 E-9
Toluene	40,917.6	101.4	46,000 (N)	0.89 (Hazard Index)
1,2-dichloroethane	0.124	*	22.0 (C)	5.6 E-8
Acetone	1,462.1	*	610,000 (N)	0.0024 (Hazard Index)
Tetrahydrofuran[c]	97,269	*	3800	2.6 E-4
Chloroform	0.219	0.3262	15 (C)	2.2 E-7
Semi-Volatile TICs[d]	*	158.6	92,000 (N)	0.017 (Hazard Index)
4-Chloroaniline	565.7	*	2,500 (N)	0.23 (Hazard Index)

Notes:
(C) – Carcinogen
(N) – Non-carcinogen
(*) – Not detected at a concentration greater than the cleanup level for this area

[a] Concentration in column represents a 1E-5 cancer risk for carcinogens or 1.0 Hazard Index for non-carcinogens
[b] This represents the theoretical incremental cancer risk that would be presented to the industrial worker if the respective compound were to be present in surface soil at the highest of the two OU1 cleanup concentrations. Hazard Index where noted.
[c] The EPA-NCEA withdrawn provisional RBC (available through October 2007) was utilized to generate the RBC for tetrahydrofuran because that is the best toxicity data available at this time.
[d] OU1 ROD states that naphthalene acetic acid (NAA) was used as a surrogate for semi-volatile TICs. EPA Toxicologist Nancy Jafolla used available toxicity information to generate a provisional industrial RBC for NAA.

ATTACHMENTS

ATTACHMENT A: List of Documents Reviewed

Record of Decision [OU1], Greenwood Chemical, Albemarle County, Newtown, VA, dated December 29, 1989

Record of Decision [Interim OU2], Greenwood Chemical, Albemarle County, Newtown, VA, dated December 31, 1990

Explanation of Significant Differences, Greenwood Chemical, Albemarle County, Newtown, VA, dated July 17, 1991

Explanation of Significant Differences, Greenwood Chemical, Albemarle County, Newtown, VA, dated March 24, 1994

Second Five-Year Review Report, Greenwood Chemical, Newtown, VA, September 2003

Record of Decision [final OU2 and OU4], Greenwood Chemical, Albemarle County, Newtown, VA, dated September 22, 2005

Request for Ceiling Increase, Change in Scope, and $2 Million Dollar Exemption for a Removal Action, Greenwood Chemical, Albemarle County, Newtown, VA, dated June 22, 2004

Final Draft Federal On-Scene Coordinator's After Action Report, Greenwood Chemical Co. Site, Greenwood, Albemarle County, VA, dated September 29, 2005

Preliminary Close-Out Report, Greenwood Chemical, Albemarle County, Newtown, VA, dated September 30, 2005

Interim Remedial Action Report, Well Upgrades and New Piping at the Greenwood Chemical Site, Greenwood (sic), Virginia, July 2006

Quarterly Operations and Ground Water Monitoring Report, 3rd Quarter, 2006, November 2006

Quarterly Operations and Ground Water Monitoring Report, 4th Quarter, 2006, January 2007

Quarterly Operations and Ground Water Monitoring Report, 1st Quarter, 2007, April 2007

Quarterly Operations and Ground Water Monitoring Report, 2nd Quarter, 2007, July 2007

Quarterly Operations and Ground Water Monitoring Report, 3rd Quarter, 2007, October 2007

Annual Operations and Maintenance Report for 2005, February 2006

Revised Annual Operations and Maintenance Report for 2006, July 2007

Greenwood Site 2007 Annual Report, March 7, 2008

Regional Screening Guidance for Chemical Contaminants at Superfund Sites, July 7, 2008