U.S. Environmental Protection Agency
Region III Superfund Program

Record of Decision
Operable Units 2 & 4

Greenwood Chemical Superfund Site
Newtown, Albemarle County, Virginia

September 2005

ORIGINAL

RECORD OF DECISION
GREENWOOD CHEMICAL SITE
OPERABLE UNITS 2 and 4

DECLARATION

SITE NAME AND LOCATION

Greenwood Chemical Site
Newtown, Albemarle County, Virginia
VAD003125374
Operable Units 2 and 4

STATEMENT OF BASIS AND PURPOSE

This decision document presents the selected remedial action for Operable Units 2 and 4 at the Greenwood Chemical Site ("Site") located in Newtown, Albemarle County, Virginia, which was chosen in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended ("CERCLA"), 42 U.S.C. §§ 9601 et seq., and to the extent practicable, the National Oil and Hazardous Substances Pollution Contingency Plan ("NCP"), 40 C.F.R. Part 300 et seq., as amended

This decision is based on the Administrative Record, which has been developed in accordance with Section 113(k) of CERCLA, and which is available for review at the Jefferson-Madison Regional Library and at the United States Environmental Protection Agency (EPA Region III, Docket Room in Philadelphia, Pennsylvania). Additionally, the Administrative Record may be viewed at http://www.epa.gov.arweb or at the Administrative Record link on the sidebar of the EPA Region 3 Hazardous Waste Site Cleanup Division homepage at http://www.epa.gov/reg3hwmd. The Administrative Record Index identifies each of the items comprising the Administrative Record upon which the selection of the remedial action is based.

The Commonwealth of Virginia concurs with the selected remedy. (See attached letter dated September 22, 2005)

ASSESSMENT OF THE SITE

The response action selected in this Record of Decision is necessary to protect public health or welfare or the environment from actual or threatened releases of hazardous substances, pollutants or contaminants from this Site that may present an imminent and substantial endangerment to public health or welfare.

DESCRIPTION OF THE REMEDY

This final ROD reaffirms the enhanced ground water pump and treat remedy selected as the second operable unit interim action and establishes performance standards for the ground water. The pump and treat system will also establish hydraulic containment of the contaminants in the deep soil source area (operable unit 4, located beneath areas excavated as part of the operable unit one remedial action completed in 1996). The risk-based performance standards are specified in Table 5 and will be achieved throughout the area of attainment within 30 years.

The principle threats once presented by hazardous substances at the Greenwood Chemical site were treated by EPA through earlier response actions at the Site. This Selected Remedy addresses lower level threats presented by residual contaminants in ground water.

This selected remedy is intended to be the final response action for the Site. The selected remedy includes the following components:

- Soil cover over the former drum disposal and manufacturing areas
- Enhanced ground water pump and treat system to prevent migration of contaminated ground water to the area of attainment
- Treatment of recovered ground water to achieve VPDES discharge standards prior to discharge to on-Site stream
- Long-term ground water monitoring
- 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 ground water from the aquifer beneath the Site for use as a potable water source; any interference with the ground water extractions wells, treatment system, and related equipment; and any removal of the soil cover without written permission of VDEQ, and EPA as appropriate.

STATUTORY DETERMINATIONS

The selected remedy is protective of human health and the environment, complies with Federal and State requirements that are applicable or relevant and appropriate to the remedial action, is cost-effective and utilizes permanent solutions and alternative treatment (or resource recovery) technologies to the maximum extent practicable.

This selected remedy also satisfies the statutory preference for treatment as a principal element of the remedy (i.e., reduces the toxicity, mobility, or volume of hazardous substances, pollutants, or contaminants as a principal element through treatment) by providing for treatment of ground water.

Because this remedy will result in hazardous substances, pollutants, or contaminants remaining on-site above levels that allow for unlimited use and unrestricted exposure, a statutory review will be conducted no less often than every five years after initiation of remedial action, in accordance with Section 121(c) of CERCLA, 42 U.S.C. § 9621(c), to ensure that the remedy is, or will be, protective of human health and the environment. The last five-year review of this Site was completed on September 29, 2003.

DATA CERTIFICATION CHECKLIST

The following information is included in the Decision Summary section of this Record of Decision. Additional information can be found in the Administrative Record file for this Site.

- Chemicals of concern and their respective concentrations;
- Risk assessment;
- Cleanup levels established for chemicals of concern and the basis of the levels;
- Determination that no source material is present which constitutes a principal threat;

- Current and reasonably anticipated future land use assumptions and current and potential future beneficial uses of ground water used in the risk assessment and ROD;

- Potential land and ground water use that will be available at the Site as a result of the selected remedy;

- Estimated capital, annual operation and maintenance (O&M), and total present worth costs, discount rate, and the number of years over which the remedy cost estimates are projected; and

- Key factor(s) that led to selecting the remedy.

AUTHORIZING SIGNATURE

This ROD documents the selected remedy for ground water and deep soil at the Greenwood Chemical Superfund Site. The Commonwealth of Virginia Department of Environmental Quality concurs with the remedy.

[signature] 9/22/05

Abraham Ferdas, Director
Hazardous Site Cleanup Division
United States Environmental Protection Agency, Region III

Date

ORIGINAL

I. DECISION SUMMARY

This Record of Decision ("ROD") is issued by the United States Environmental Protection Agency ("EPA"), the lead agency for the Greenwood Chemical Superfund Site under the National Oil and Hazardous Substances Pollution Contingency Plan ("NCP"), 40 C. F. R. Part 300, pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended, ("CERCLA"), in consultation with the Virginia Department of Environmental Quality ("VDEQ"), the support agency. This ROD is based on documents contained in the Administrative Record file for the Site.

A. SITE NAME, LOCATION, AND BRIEF DESCRIPTION

The Greenwood Chemical Site (National Superfund Database ID No. VAD003125374) is located in the village of Newtown, Albemarle County, Virginia between the cities of Waynesboro and Charlottesville ("Site"). See Figure 1. The Site encompasses an area of approximately 34 acres, of which 18 acres were used for chemical manufacturing and waste disposal activities. The two main areas of the Site are known as the "manufacturing area" and the "drum disposal area." A more detailed Site location map is presented in Figure 2.

The Site is currently an undeveloped property as EPA has removed the former chemical production buildings, waste disposal areas, and contaminated surface soils as part of previous EPA response actions. These response actions were financed using monies from the Superfund.

This ROD addresses Operable Units 2 and 4 ("OU-2" and "OU-4") of the Site. OU-2 consists of ground water and was the subject of an interim ROD in September 1990. This final OU-2 ROD establishes ground water cleanup goals. OU-4 consists of deep contaminated soil located beneath the former manufacturing area and drum disposal area (see Figure 2). As discussed in detail below, these contaminated subsurface soils do not present a direct risk to human health or the environment since they are generally more than 15 feet below the ground surface, but they do constitute a potential source of contamination to the ground water.

B. SITE HISTORY AND ENFORCEMENT ACTIVITIES

The Greenwood Chemical Company manufactured a variety of chemicals used in industrial, agricultural, photographic and pharmaceutical processes. Chemical manufacturing operations began in approximately 1947, and terminated in 1985 when a chemical vapor fire destroyed the main processing building and resulted in the death of four workers. Former operations at the Site have led to the release of hazardous substances into the environment.

Former Site features within the manufacturing area included chemical processing buildings, offices and laboratory space, storage trailers and sheds, a pump house, a concrete bunker, seven treatment lagoons and several abandoned structures. The former drum disposal area is located approximately 500 feet southwest of the manufacturing area, comprising a drum disposal trench along the western Site boundary. Approximately 400 crushed and intact drums were removed from the trench by EPA during a 1987 response action. Historic Site features are shown in Figure 3.

The manufacture of specialty chemicals at the Site began in approximately 1947 under the name of Cockerille Chemical Company. The facility was sold to the Greenwood Chemical Company ("GCC") in 1968 and continued to operate under that name until its closure. The primary compounds produced at the Site included naphthalene acetic acid, 1- naphthaldehyde, and naphthoic acid. In addition, arsenic salts were used as catalysts in producing chloromethylnaphthalene, an intermediary in the production of naphthalene acetic acid. Production processes used toluene, naphthalene derivatives, sodium cyanide and inorganic arsenic salts. The GCC reported using between one and ten tons of cyanide per year to the Virginia Department of Toxic Substances, from 1972 to 1974.

Manufacturing activities at the Site involved the handling of large numbers of drums containing various chemicals, comprising waste, feedstock, intermediate, and final products. A series of interconnected wastewater "treatment/disposal" lagoons were associated with chemical processing activities. Wastewater was discharged from the process buildings through a series of floor drains, interconnected piping and open ditches to one or more of the lagoons.

In July 1987, the Greenwood Chemical Site was placed on the National Priorities List ("NPL") of Superfund Sites.

EPA response activities were initiated in 1987 with an emergency removal action to address the immediate threats posed by the Site. The scope of this action included removal of buried and surface drums and smaller containers of chemicals, and removal of sludge associated with former lagoons 1, 2 and 3 and construction of a temporary cap over those areas. This action was completed in 1988. In November 1989, EPA determined that further removal action was necessary to repair the temporary cap over the former drum disposal area and to construct several drainage swales around the waste lagoons to prevent further erosion.

Since the beginning of EPA involvement with this 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 several former owners and operators of the facility and various entities which did business with Greenwood Chemical. EPA issued a unilateral administrative order in 1993 to several of the PRPs to conduct the OU-1 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.

From the late 1980's through the 1990's, the GCC remained an active corporation and maintained an inventory of laboratory chemicals. In recent years the GCC has not conducted any business operations on-Site, and abandoned scores of small containers of hazardous substances within trailers overgrown with vegetation and degraded laboratory and office facilities. In 2004 EPA completed an additional removal action to address these remaining abandoned chemicals.

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 ground water contamination. The 1990 RI/FS process, including several preliminary reports, provided the basis for Records of Decision for OU-1, OU-2, the 1991 Explanation of Significant Differences ("ESD") which defined OU-3, and the 1994 ESD. See Section D (Scope and Role of Operable Units or Response Actions) for a summary of these decision documents.

EPA's understanding of the nature and extent of remaining contamination at the Site has been supplemented by additional investigative studies performed as part of the OU-1 and OU-2 Remedial Designs, additional soil characterization in areas of concern, and on-going ground water monitoring. This information has been used to better define the extent of contamination in the deep soil and to determine the likelihood that these contaminants would migrate. EPA completed a Focused Feasibility Study ("FFS") for OU-4 describing the remedial action objectives and comparing cleanup alternatives for deep soil contamination. In June 2005, EPA completed the Ground Water Investigation and Focused Feasibility Study ("GWI/FFS") to develop ground water cleanup levels necessary to meet the remedial action objectives established in the 1990 Interim ROD. The findings of these reports are summarized in Section E (Site Characteristics).

C. COMMUNITY PARTICIPATION

The OU-4 Final Feasibility Study Report, the Ground Water Remedial Investigation and Focused Feasibility Study Report (OU-2), and the Proposed Plan for the Greenwood Chemical Site in Newtown, Virginia were made available to the public on June 23, 2005. They can be found in the Administrative Record file and the information repository maintained at the EPA Docket Room in Region III and at the Jefferson-Madison Regional Library in Crozet. The notice of the availability of the Proposed Plan for OU-2 and OU-4 was published in the *Daily Progress* in Charlottesville and the *News Virginian* in Waynesboro on June 22, 2005. A public comment period was held from June 23, 2005 to July 22, 2005. In addition, a public meeting was held on July 6, 2005 to present the Proposed Plan to the local community and to seek comment. At this meeting, representatives from EPA and the VDEQ discussed the proposed response actions for OU-2 and OU-4 and answered questions about Site conditions. EPA's response to the comments received during this period is included in the Responsiveness Summary, which is Part III of this Record of Decision.

D. SCOPE AND ROLES OF OPERABLE UNITS 2 & 4

The problems at the Greenwood Chemical Site are complex. As a result, early on in the cleanup EPA divided the work into four components called Operable Units ("OU's"), in addition to the Removal Actions it has undertaken. An operable unit is a portion of a Superfund Site that is addressed separately from the rest of the Site, to allow for easier project management. The OU's at the Greenwood Chemical Site and the actions EPA has taken to address them are as follows:

- OU-1 (shallow soil): EPA issued a ROD on December 29, 1989 which selected a remedy comprised of excavation, off-site incineration, stabilization and/or disposal of contaminated soil and sludge associated with Lagoons 1, 2 and 3, and off-site disposal of abandoned containers of chemicals left in the process buildings. The OU-1 remedial action was completed in fall 1996.
- OU-2 (ground water): EPA issued an interim ROD on December 31, 1990 in which it determined that preliminary action was necessary to initiate the reduction in the toxicity, mobility and volume of ground water contaminants and to eliminate elevated risks presented by surface water in lagoons 4 and 5. The interim remedy selected in this ROD was extraction and treatment of ground water and lagoon water in an on-Site water treatment plant. The interim ROD deferred the final decision for ground water cleanup until final ground water cleanup goals could be developed. The water treatment system began operation in March 2001. The system currently consists of five extraction wells which convey contaminated ground water to a treatment plant located in the southern portion of the Site, downgradient of the manufacturing and drum disposal source areas. The physical layout of the system is shown in Figure 4.

This ROD includes EPA's final ground water cleanup goals and identifies the Agency's selected remedy for ground water at the Site.

- OU-3 (manufacturing buildings): The ESD EPA issued on July 17, 1991 required removal of former manufacturing buildings A, B and C and their contents. One purpose of this activity was to access and further characterize underlying contaminated soil. EPA completed the removal and proper disposal of the buildings and contents in 1993. This soil was excavated during the OU-1 remedial action. (The location of the former manufacturing buildings is shown in Figure 3.)

- OU-4 (deep soil source areas): Addresses the deeper contaminated soil occurring beneath the vertical limits of the OU-1 soil excavation activities. This operable unit is described in the March 24, 1994 ESD for OU-1, which provided that "EPA will establish a separate operable unit to address the deeper contaminated soils that are below the excavation depths specified in the OU-1 Remedial Design ("RD")." Deep contamination is located beneath the former manufacturing and drum disposal areas, and has migrated into the shallow zone of underlying fractured bedrock.

  This ROD selects a final remedy for the OU-4 deep soils.

- Removal Actions: In addition to the removal action conducted between 1987 and 1989 (described in Section B), on June 22, 2004 EPA issued an Action Memorandum ("Action Memo") which required removal and proper off-site disposal of the remaining chemicals abandoned by Greenwood Chemical, properly closing out lagoons 4 and 5, and excavation and off-site disposal of remaining arsenic-contaminated surface soil. The arsenic cleanup level selected by EPA was 27 milligrams per kilogram ("mg/kg"). This cleanup level makes it safe to reuse the Site for industrial or recreational purposes. The Action Memo also required excavating and transporting contaminated lagoon sludge to an appropriately permitted disposal facility and backfilling with clean soil. A soil cover (minimum of 2-feet-thick) was installed over the entire excavation area. This removal action was completed in May 2005.

In summary, this ROD presents EPA's Selected Remedy for addressing OU-2 (ground water) and OU-4 (deep soil source areas). The selected remedy described in this Record of Decision includes final cleanup levels for ground water and is intended to be the final response action for the Site.

E. CURRENT AND POTENTIAL FUTURE LAND AND WATER USES

The Site is currently inactive except for response activities. The setting is rural and land use surrounding the Site is generally undeveloped/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 approximately 100 yards north of the Site. 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. Previous response actions completed by EPA anticipate safe and beneficial use of the Site for industrial or recreational purposes.

As discussed in Section F (Site Characteristics) below, the topography of the Site slopes to the southeast and levels off at the southern end. Ground water beneath the Site is not currently being used, however, surrounding properties do utilize ground water 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 ground water 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.

F. SITE CHARACTERISTICS

See Figure 5 for the conceptual site model.

Geologic/Hydrogeologic Setting

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 soil ranging in thickness from 0 - 15 feet. Beneath the soil is a relatively thick layer of saprolite formed from the chemical weathering of the bedrock. The composition of the saprolite is predominantly silty clay. The soil has a relatively high clay content of approximately 30% by weight. Consolidated rock is generally encountered below the water table. Shallow bedrock, however, was encountered in several locations at depths above the water table.

Ground water at the Site is present in both the soil and underlying fractured bedrock. Two distinct water bearing units (aquifers) have been identified in the soil (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 in the soil at depths ranging from 5 feet to 35 feet below ground surface ("bgs").

The water table generally follows surface topography. Ground water in the soil layer flows in a southeasterly direction toward West Stream, a tributary of Stockton Creek into which it discharges. The bedrock ground water flow system is controlled by the nature and extent of bedrock fracturing. The direction of ground water flow in the bedrock is also in a southeasterly direction. Ground water 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 ground water is upward. The water table is generally located at or above the top of the bedrock.

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

Since completion of the remedial investigation in 1990, the surface features of the Site have changed significantly due to response actions taken by EPA. There has also been significant alteration and regrading associated with removal of soils in the manufacturing area. Buildings have been removed, the former lagoons and the drum disposal area were excavated and backfilled with clean soil and the Site was graded.

Subsurface Soil Contamination

Deep soil sampling identified elevated levels of 12 Site-related contaminants of potential concern ("COPCs") remaining in subsurface soil. The list of COPCs includes the following organic compounds and metals: 4-chloroanaline (up to 48 mg/kg), arsenic (up to 7,120 mg/kg), benzene (up to 4.3 mg/kg), bis(2-ethylhexyl)phthalate (up to 0.91 mg/kg), chlorobenzene (up to 23 mg/kg), cyanide (up to 1,000 mg/kg), methylene chloride (up to 61 mg/kg), naphthalene (up to 1,780 mg/kg), tetrachloroethylene (up to 8.2 mg/kg), tetrahydrofuran (up to 9,000 mg/kg), toluene (up to 5,900 mg/kg) and trichloroethylene (up to 50 mg/kg). Contaminants in the deep soil zone are concentrated beneath the former manufacturing and drum disposal areas. These contaminated subsurface soils do not present a direct contact risk since they are generally more than 15 feet below the ground surface but they do constitute a potential source of contamination to the ground water.

The areal extent of organic and inorganic contamination in subsurface soil was estimated by entering sample results into a mathematical computer model which predicted the volume of contaminated soil present. Figure 6 shows the estimated limits of contaminated soil based on the model rather than actual samples collected at the boundaries. The vertical extent of contamination is based on the conservative assumption that the entire vertical thickness of the subsurface soil is uniformly contaminated with COPCs.

Site-specific Preliminary Remediation Goals ("PRGs") were initially developed during the FFS for subsurface contaminated soil. EPA's objective was to determine the extent to which subsurface soil would need to be addressed, by excavation or in-situ treatment, such that the ground water could be safe to drink at the property boundary in the absence of any ground water containment (i.e., ground water recovery well system). The subsurface soil PRGs are only directly relevant to the cleanup alternatives which include excavating these materials as part of the remedy. For each of the twelve contaminants identified above, EPA used a theoretical model to calculate the highest concentration that could remain on Site and still meet a safe drinking water level (including MCLs where available) for each of those contaminants. More details on the development of subsurface soil PRGs are provided in Exhibit 1 (How Did EPA Develop Deep Soil Preliminary Remediation Goals and Estimate the Volume of Soils To Be Excavated?).

Ground Water Contamination

A total of 56 ground water monitoring wells (shallow and deep) have been installed at the Site to characterize ground water contamination (see Figure 7). Seven (7) of the wells are located upgradient of the two deep soil source areas. Ground water in these seven upgradient wells is not contaminated with Site-related contaminants. Thirty three (33) wells have been placed within the current waste management area, the area comprised of deep soil source areas extending to the former Lagoon 5.[1] The remaining 16 wells are located downgradient from the waste management area.

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[1] The "Waste Management Area" is that part of the Site which includes the former drum disposal and manufacturing areas and any residual soil contamination underlying the excavated limits of former Lagoons 4 and 5. This area of deep soil contamination is the only potential continuing source of contamination to ground water. See Figure 11.

Elevated concentrations of hazardous substances are present in the ground water beneath and downgradient of the primary source areas (manufacturing area and drum disposal area) extending to the former Lagoon 5, referred to as the waste management area. Ground water within the waste management area has the highest concentrations of contaminants, including some contaminants which are not migrating from that area due to low mobility.

- The primary contaminants detected in the ground water within the waste management area include benzene (up to 260 ug/l), bis(2-chloroethyl)ether (up to 76 ug/l), bromodichloromethane (up to 4.1 ug/l), carbon tetrachloride (up to 1,200 ug/l), 4-chloroaniline (up to 39 ug/l), chlorobenzene (up to 790 ug/l), chloroform (up to 390 ug/l), 2-chlorophenol (up to 4.3 ug/l), dibromochloromethane (up to 3.6 ug/l), 1,2-dibromoethane (up to 3.7 ug/l), 1,2-dichlorobenzene (up to 280 ug/l), 1,4-dichlorobenzene (up to 7.8 ug/l), cis-1,2-dichloroethane (up to 330 ug/l), 1,2-dichloroethane (up to 580 ug/l), 1,2-dichloropropane (up to 4.1 ug/l), cis-1,3-dichloropropene (up to 330 ug/l), 4,6-dinitro-2-methylphenol (up to 0.75 ug/l), 4-methylphenol (up to 18 ug/l), naphthalene (up to 400 ug/l), 4-nitroaniline (up to 4.6 ug/l), N-nitroso-di-n-propylamine (up to 1.0 ug/l), trichloroethene (up to 1,500 ug/l), tetrachloroethene (up to 87 ug/l), toluene (up to 120 ug/l), trans-1,3-dichloropropene (up to 4.0 ug/l), 1,1,2-trichloroethane (up to 4.1 ug/l) and vinyl chloride (up to 83 ug/l).

Ground water in the "Area of Attainment"[2] only has elevated concentrations of six of the contaminants found in the waste management area (albeit at much lower concentrations than are found there). EPA has determined that these six compounds are migrating from the deep soil source area via ground water.

- The contaminants of concern ("COC") detected in the ground water at one or more of the wells outside the waste management area are bis(2-chloroethyl)ether (up to 1.4 ug/l), carbon tetrachloride (up to 19 ug/l), 1,2-dichloroethane (up to 20 ug/l), tetrachloroethene (up to 25 ug/l), trichloroethene (up to 120 ug/l) and vinyl chloride (up to 4.8 ug/l). In addition, arsenic was detected in one perimeter well at 6.0 ug/l.

The remedy selected in the OU-2 Interim ROD called for the installation of a system of ground water recovery wells and the construction and operation of a water treatment plant. The ground water pump and treat system began operation in March 2001. The current ground water recovery system consists of five bedrock extraction wells at or just downgradient of the deep soil source area. The treatment plant utilizes a combination of chemical precipitation and ultraviolet/oxidation and carbon filtration technologies to treat the contaminated ground water.

Surface Water and Seep Assessment

In 2004, EPA collected surface water samples from the small intermittent streams which are tributaries to West Stream, the West Stream, the South Pond, and the East Pond (see Figure 8). Low concentrations of VOCs, including TCE and carbon tetrachoride, were detected in a short stretch (SW-13 and SW-08) of an intermittent stream located at the southernmost portion of the Site. This is the topographic low elevation of the Site, where the ground water table is very close to the surface, indicating likely discharge of contaminated ground water into the shallow stream

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[2] The "Area of Attainment" is the area of the Site in which the ground water performance standards will be met. This area encompasses the entire contaminated ground water plume beginning at the boundary of the waste management area.

bed. Nonetheless, the contaminants were detected at concentrations so low that the surface water meets the Virginia surface water quality standards, and EPA has determined that it does not present an unacceptable risk to human health or the environment. The water quality was even higher at sampling points downstream, indicating clean ground water is also discharging to the stream. Analysis of samples from the West Stream, the South Pond and the East Pond themselves do not indicate the presence of Site-related contamination.

Off-Site (Residential) Ground Water Quality Assessment

Residential wells have been sampled and analyzed for Site-related contamination periodically since the late 1980's with the most recent round of sampling conducted in June 2004. Nine residential wells were tested within a one-half mile radius of the Site. Water samples were collected from wells that were either hydraulically downgradient or side gradient of the Site. No Site-related contaminants were detected above EPA Maximum Contaminant Levels ("MCLs") or above any other risk-based action levels.

Site-Wide Ground Water Assessment

Most of the contamination identified at the Site appears to be limited to the overburden and the shallow bedrock aquifer in the immediate vicinity of the deep soil source areas extending to Lagoon 5. Minimal contamination was detected in the deep bedrock. Two possible explanations for this observation are: 1) there is a lack of interconnection between the shallow and deep bedrock fracture zones; and 2) there is a general upward vertical gradient of ground water from the deep to the shallow fracture zones, which reduces downward contaminant migration.

The most concentrated portion of the "plume" extending from the former manufacturing area is located at the center of the Site along the following array of wells: MW-23 (recovery well), OB-5, MW-18D1/D2, BR-8 (recovery well), OB-7, BR-6 (recovery well). The branch of the plume extending toward PMW-5 follows a localized dip in the topography. A second "plume" appears to exist close to the former drum disposal area along the following array of wells: MW-2D, OB-1, BR-2 (recovery well). The highest concentrations of contaminants are located mostly north and east of the ground water treatment plant, though high concentrations are also located south of the drum disposal area. The most contaminated well on the Site consistently has been MW-23. (see Figure 9)

EPA performed a capture zone analysis to 1) determine if the existing recovery wells are containing the contaminated ground water on Site and, 2) identify additional ground water recovery well locations which may be necessary to achieve containment.

The capture zone analysis identified a significant gap in the area between recovery wells BR-2 and BR-6, which may be resulting in contaminant migration to unaffected portions of the aquifer (see Figure 10). This is substantiated by the monitoring well data. The capture zone analysis concluded that a minimum of three new recovery wells are required in this vicinity to contain the plume, each pumping at a rate of 3 gpm .

The other area that EPA determined requires installation of additional recovery wells to contain the contaminated ground water is the area near PMW-5 at the eastern boundary of the Site. Sample results indicate VOC concentrations over 146 ug/l at PMW-5. This perimeter well monitors ground water following a local eastward dip in the topography and appears not to be affected by the existing recovery well network. The capture zone analysis concluded that a minimum of two new recovery wells are required in the vicinity of BR-5 and PMW-5 to contain the plume, each pumping at a rate of 2 gpm.

The capture zone analysis and associated ground water sampling confirmed that recovery wells BR-2 and BR-7 are successfully containing contaminated ground water from the former Drum Disposal Area.

G. SUMMARY OF SITE RISKS

Selection of Chemical of Concern

The 1990 Remedial Investigation included a baseline risk assessment to estimate the human health hazards that could result if contamination at the Site was not addressed. This assessment was conducted to identify existing and future risks that the Site would present if conditions at the Site were not addressed. The Baseline Human Health Risk Assessment ("BLRA") evaluated human health risks considering the residential[3] and trespasser land use scenarios and was subsequently updated to consider industrial and recreational land use scenarios. The BLRA documented that hazardous substances in soil, ground water, and surface water and sludge in the lagoons presented unacceptably high risks to human health and the environment and warranted response actions to mitigate those risks.

As summarized in Section B (Site History and Enforcement Activities) and Section D (Scope and Role of Operable Units 2 & 4), EPA has conducted significant response actions which remediated the unacceptable risks presented by hazardous substances previously located at the former chemical manufacturing plant, including the former lagoons and the surface soil.

The updated BLRA does establish that there are contaminants of concern remaining in the ground water which warrant action to mitigate the risks. Ground water is the only contaminated media at the Greenwood Chemical Site which continues to present an unacceptable risk to human health and the environment (assuming a future use scenario). Off-Site residential well sampling indicates that no unacceptable risk is currently presented to offsite private well users.

EPA determined that the only contaminants which potentially present an unacceptable risk to human health at the Site are five VOCs – (carbon tetrachloride, 1,2-dichloroethane, tetrachloroethene, trichloroethene and vinyl chloride) – and one SVOC: [bis(2-chloroethyl)ether]. Each of these contaminants has been found at one or more wells outside the waste management area at a level of concern.[4] See Table 1 for a summary of chemicals of concern in ground water and respective exposure point concentrations.

Exposure Assessment

There is no current on-Site use of ground water at the Greenwood Chemical Site. The updated risk assessment considered potential risks posed to future residents using ground water beneath or downgradient of the Site as a source of drinking or showering/bathing water. The exposure

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[3] EPA has determined that recreational or industrial land use is the reasonably anticipated future land use for this former chemical plant property. Possible residential use of ground water outside the "waste management area" of the Site is the basis for ground water cleanup standards.

[4] While multiple contaminants are found within the waste management area, EPA has determined that only the six identified compounds are found within the Area of Attainment at levels which present an unacceptable risk.

routes evaluated include drinking, inhalation of contaminants while showering, and direct skin contact with ground water.

The objective of the exposure assessment is to estimate the amount of each chemical of concern at a site that may actually be taken into the body (i.e., the intake level or dose). Conservative modeling assumptions are used to estimate the amount of exposure. For example, in the hypothetical future use scenario (which assumed residential drinking water wells installed in the Area of Attainment), an adult resident is assumed to ingest 2 liters of water per day, 350 days per year, over a 30-year exposure duration.[5] Child residents are assumed to ingest 1.2 liters of water per day, 350 days per year for six (6) years. Body weights are specified as 70 kg for adults and 15 kg for children. Refer to the GWI/FFS dated June 2005 for the complete list of exposure parameters utilized in the human health risk assessment.

Inhalation exposures during showering are estimated using modeling techniques. The modeling technique for adults accounts for inhalation of contaminants during showering, as well as after showering while the person remains in the room. Dermal exposure for children while bathing is estimated assuming total body contact for 0.33 hours per day, 350 days per year for six years.

Carcinogenic risks are calculated as an incremental lifetime risk and, therefore, incorporate terms to represent the exposure duration (years) over the course of a lifetime (70 years, or 25,550 days). Noncarcinogenic risks are calculated using the concept of chronic and subchronic exposures.

Toxicity Assessment

The toxicity assessment characterizes the inherent toxicity of a compound and helps to identify the potential health hazard associated with exposure to each of the chemicals of concern. Toxicological values derived by EPA were used in the Risk Assessment. These values include reference doses ("RfDs") for adverse but non-carcinogenic effects and cancer slope factors ("CSFs") for the effects of known or possible human carcinogens.

RfDs, which are expressed in units of mg/kg-day, are estimates of lifetime daily exposure levels of chemicals for humans, including sensitive individuals, that are not likely to cause deleterious effects. Estimated intakes of chemicals from environmental media (e.g., the amount of a chemical ingested from contaminated drinking water) can be compared to the RfD. RfDs are derived from human epidemiological studies or animal studies to which uncertainty factors are incorporated which help to ensure that the RfDs will not underestimate the potential for adverse noncarcinogenic effects.

CSFs have been developed by EPA's Carcinogenic Assessment Group for estimating increased lifetime cancer risks associated with exposure to potentially carcinogenic chemicals. CSFs, which are expressed in units of $(mg/kg\text{-}day)^{-1}$, are multiplied by the estimated intake of a potential carcinogen, in mg/kg-day, to provide an upper-bound estimate of the increased lifetime cancer risk. The term "upper-bound" reflects the conservative estimate of the risks calculated from the CSF. Use of this approach makes underestimation of the actual cancer risk highly unlikely. CSFs are derived from the results of human epidemiological studies or animal bioassays to which animal to human extrapolation and uncertainty factors have been applied. See Table 2A and 2B for toxicity data for known or suspected carcinogens and non-carcinogens, respectively.

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[5] 30-year exposure duration assumes that exposure occurs for 6 years as a child and 24 years as an adult.

Risk Characterization

The revised Baseline Risk Assessment characterized the potential health risks associated with hypothetical future exposures to ground water at the Greenwood Chemical Site. The current onsite risk and hazard presented by contaminated ground water is zero, because no one is drinking the ground water.

For carcinogens, risks are generally expressed as the incremental probability of an individual's developing cancer over a lifetime as a result of exposure to the carcinogen. Excess lifetime cancer risk is calculated from the following equation.

Risk = CDI x SF

where: risk = a unitless probability (e.g., 2×10^{-5}) of an individual's developing cancer
CDI = chronic daily intake averaged over 70 years (mg/kg-day)
SF = slope factor, expressed as $(mg/kg\text{-}day)^{-1}$.

These risks are probabilities that are generally expressed in scientific notation (e.g., 1×10^{-4} or 1E-4). An excess lifetime cancer risk of 1×10^{-6} indicates that an individual experiencing the reasonable maximum exposure estimate has a 1 in 1,000,000 chance of developing cancer as a result of site-related exposure. This is referred to as "excess lifetime cancer risk" because it would be in addition to the risks of cancer individuals face from other causes such as smoking or exposure to too much sun. The chance of an individual's developing cancer from all other causes has been estimated to be as high as one in three. EPA's generally acceptable risk range for site-related exposures is between 1×10^{-4} (or 1 in 10,000) and 1×10^{-6} (or 1 in 1,000,000). Remedial Action is warranted at a site when the calculated cancer risk level exceeds 1×10^{-4}.

The potential for noncarcinogenic effects is evaluated by comparing an exposure level over a specified time period (e.g., life-time) with a RfD derived for a similar exposure period. An RfD represents a level that an individual may be exposed to that is not expected to cause any deleterious effect. The ratio of exposure to toxicity is called a hazard quotient ("HQ"). An HQ <1 indicates that a receptor's dose of a single contaminant is less that the RfD, and that toxic noncarcinogenic effects from that chemical are unlikely. The hazard index ("HI") is generated by adding the HQs for all COCs that affect the same target organ (e.g., liver) or that act through the same mechanism of action within a medium or across all media to which a given individual may reasonably be exposed. An HI <1 indicates that, based on the sum of all HQ's from different contaminants and exposure routes, toxic noncarcinogenic effects from all contaminants are unlikely. An HI>1 indicates that site-related exposures may present a risk to human health.

The HQ is calculated as follows:

Non-cancer HQ = CDI/RfD

where: CDI = chronic daily intake
RfD = reference dose.

CDI and RfD are expressed in the same units and represent the same exposure period (i.e., chronic, subchronic, or short-term).

Tables 3A and 3B summarize the respective cancer risk levels calculated for children and adults exposed to ground water. Tables 4A and 4B summarize the respective noncarcinogenic hazard levels calculated for children and adults exposed to ground water. Each of these risk levels exceed EPA's expectations for acceptable risk.

For the calculated future use scenario, carcinogenic risk exceeded 1×10^{-4} for ground water for both adults and children. Trichloroethene and vinyl chloride were the primary contributors to the total excess cancer risk under this scenario. The carcinogenic risk to a associated with drinking ground water at the Site boundary has been estimated at 3.45×10^{-4} for a child and 3.1×10^{-4} for an adult. When the child and adult risks are combined the estimated lifetime carcinogenic risk is 6.6×10^{-4} (This risk corresponds to one additional case of cancer for every 1,515 persons exposed). The lifetime risk is for future ingestion, inhalation and dermal exposure to ground water. EPA considers ground water with a carcinogenic risk over 1×10^{-4}, or one in 10,000 persons exposed, to be unacceptable. The non-carcinogenic HI exceeded 1 for the ground water ingestion and bathing (residential) exposure scenarios. The HI is driven by trichloroethene and carbon tetrachloride. Ground water with a HI of over 1.0 is considered to be unacceptable for human consumption over the long term due to potential adverse effects.

Adults and children drinking contaminated ground water could be exposed to unacceptable health risks if Site ground water contamination is not addressed and no restrictions are placed on future use of the Site. The response action selected in this ROD is necessary to protect the public health or welfare or the environment from the actual or threatened releases of hazardous substances into the environment.

H. REMEDIAL ACTION OBJECTIVES

The Remedial Action Objectives ("RAOs") for the unacceptable risks associated with the ground water at this Site include:

- Preventing human exposure to contaminated ground water in the future (both on-Site and off-Site) until ground water cleanup levels are achieved;
- Preventing discharge of contaminated ground water to surface water at concentrations that exceed water quality or human health criteria;
- Containing the contaminant plume to prevent migration off-Site to ensure that downgradient private water supplies continue not to be impacted;
- Restoring ground water quality in the area of attainment (entire ground water plume beginning at the boundary of the waste management area) within approximately 30 years to levels that do not pose an unacceptable risk to human health or the environment.

Development of Cleanup Goals for Ground Water

This subsection summarizes how Ground Water Cleanup Goals for ground water at the Site were developed.

Maximum Contaminant Levels ("MCLs") and non-zero Maximum Contaminant Level Goals ("MCLGs") have been established under the Safe Drinking Water Act (applicable to certain public water supplies) and are considered relevant and appropriate standards for CERCLA cleanups of ground water. However, merely meeting the chemical-specific MCLs and non-zero MCLGs at the property boundary would still result in a cumulative risk in excess of 1×10^{-4} due to the fact that there are multiple contaminants associated with the Site. In accordance with the

NCP, EPA has calculated lower, risk-based target concentrations to set a sufficiently protective remediation level. Risk-based target concentrations are concentration levels that result in a cumulative carcinogenic risk within EPA's target risk range of 1 x 10^{-4} to 1 x 10^{-6} and a HI equal to or less than 1.

In accordance with 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" shown in Figure 11.

Table 5
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 x 10^{-5}. The final RBRG for each of the other five contaminants was set at a level equivalent to a 1 x 10^{-5} risk.

The ground water risk-based remediation goals ("RBRGs") set forth in Table 5 fall within the acceptable risk range of a cancer risk of 1 x 10^{-4} to 1 x 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.

I. DESCRIPTION OF REMEDIAL ALTERNATIVES

The OU-4 FFS, dated January 2002, and the GWI/FFS, dated June 2005, discuss the range of alternatives EPA evaluated to address risks presented by the Site, and together with the Administrative Record provide information supporting the alternative ultimately selected by EPA. The alternatives EPA considered are based on those presented in the FFS and GWI/FFS.

As noted above, based on the potential impacts to human health and the environment, currently only ground water at the Site warrants additional action to minimize potential exposure to hazardous substances. Since the deep soil contamination in the former manufacturing and drum disposal areas is a continuing source to ground water, additional action to address the deep soils was considered in some of the alternatives.

Alternative 1: **No Action (Existing Permeable Soil Cover and Pump and Treat System)**

Capital Cost:	$ 0
Annual **O&M** Cost:	$ 454,000[6]
Present Worth Cost:	$5,634,000
Time to Implement:	Immediate

The NCP requires that EPA consider a "No Action" alternative for every Superfund site to establish a baseline or reference point, against which each of the Remedial Action alternatives are compared. In the event that the other identified alternatives do not offer substantial benefits in the protection of human health and the environment, the No Action alternative may be considered a feasible approach. This alternative leaves the Site in its current state and all current and potential future risks would remain. Since the pump and treat system is currently being operated on the Site, and significant response actions have already been implemented above and downgradient of the subject subsurface soil, the "no action" alternative for subsurface soil and ground water at the Greenwood Chemical Site is better described as "no further action."

The "No Action" alternative involves leaving the clean, permeable soil cover that was backfilled over the former drum disposal and manufacturing areas in place as the final cover. The existing clean soil cover is a minimum of 2-feet-thick. Previous response actions addressed contaminated surface soil such that the property can be safely reused for recreational or industrial purposes. The clean soil cover was constructed as part of the OU-1 remedial action and the subsequent surface soil removal activities. The existing soil cover has been graded and vegetated to minimize erosion. This alternative is based on Alternative 2 for the Manufacturing and Drum Disposal Areas (Permeable Cap & Institutional Controls) in the FFS, as modified by EPA, with the permeable soil cover recognized as already being in place.

Alternative 1 would allow the continued infiltration of rain water through the contaminated subsurface soils which are at an elevation higher than the ground water table, because the existing soil cover is permeable. The infiltration of rain water leaches contaminants into the aquifer and incrementally contributes to the migration of contaminants to the ground water.

The No Action alternative for ground water would maintain the existing pump and treat system selected and implemented in accordance with the Interim ROD for OU-2. The existing five-extraction-well configuration would not be modified and the volume of ground water extracted would not be increased. Most of the contaminated ground water would continue to be captured and contaminants would be removed prior to the treated water being discharged to the unnamed tributary to West Stream. This alternative would continue to allow some contaminated ground water to flow around or between the existing recovery wells. The ground water quality would not meet applicable or relevant and appropriate regulatory standards for drinking water and

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[6] This is the annual operation and maintenance cost for the existing pump and treatment system being implemented in accordance with Interim Record of Decision for Operable Unit 2.

would continue to be unsafe to drink beyond the waste management area. The long-term human health and environmental risks remaining at the Site would not change.

Alternative 2: Existing Permeable Soil Cover with Enhanced Pump and Treat System

Capital Cost:	$ 365,000
Annual O&M Cost:	$ 463,000
Present Worth Cost:	$6,110,000
Time to Implement:	5 months

This alternative is based on Alternative 2 for the Manufacturing and Drum Disposal Areas (Permeable Cap & Institutional Controls) in the FFS, combined with Alternative #2 in the GWI/FFS, as modified by EPA. This alternative augments the existing permeable soil cover included in Alternative 1 with an enhanced ground water pump and treat system described below.

Alternative 2 would augment the existing five-well ground water pumping network with additional wells necessary to prevent the continued migration of Site-related contaminants to West Stream and off-Site locations (see Figure 11). The GWI/FFS estimates that an additional five wells screened to withdraw ground water in the upper 50 feet of bedrock would be required. All recovered ground water would be managed through the continued operation of the water treatment plant installed pursuant to the 1990 Interim ROD for OU-2. The enhanced pump and treat system would capture contaminated ground water, thereby preventing contaminant migration from the Site. The series of ground water extraction wells would be operated in concert to achieve the final Site-specific risk-based ground water cleanup goals (Table 5) beyond the waste management area. Periodic evaluation of the performance and effectiveness of the ground water extraction system would be performed. The ground water extraction system would be modified as necessary to achieve the performance standards beyond the waste management area.

The existing water treatment plant has a design flow rate of 45 gpm. The present contribution from the five recovery wells varies between 20-25 gpm. Analysis of ground water data and the design influent concentrations at the existing treatment plant indicate that the additional volume of ground water can likely be processed without modification to the treatment system. The ground water treatment plant would meet regulatory discharge standards.

Operation and maintenance activities for this alternative would include: maintaining the extraction wells, operating the treatment plant, and performing periodic ground water level and chemical measurements to confirm that Site ground water is being captured. Routine chemical analyses of plant effluent would be conducted with quarterly bioassay tests to confirm that the discharge meets State requirements. The net present worth estimate was based on a 30-year operation period.

Institutional controls would be implemented to ensure that prospective users of the Site are aware that deep soil contamination is present, to prevent: the extraction of ground water from the aquifer beneath the Site for use as a potable water source; any interference with the ground water extractions wells, treatment system, and related equipment; and any removal of the soil cover without written permission of VDEQ, and EPA as appropriate. No institutional controls would be required for off-Site properties. Specific institutional controls would consist of both of the following:

1. a deed notice identifying the Site as a Superfund Site and prohibiting (1) residential use of the property, (2) on-Site potable use of ground water, (3) any activity that would adversely impact the operation of the pump and treat system, (4) any removal of the soil cover without written permission of the EPA and/or VDEQ and (5) deep excavation without a site-specific health and safety plan. Any soil excavated from the former Manufacturing or Drum Disposal Areas would need to be sampled and managed in an appropriate manner; and,

2. the granting of easements for Site access to the Commonwealth of Virginia (and their designees if requested) to monitor the constructed remedy, operate and maintain the ground water treatment system, and ensure that restrictions on land use are being maintained.

Alternative 2A: Existing Permeable Soil Cover, In-Situ Chemical Oxidation with Enhanced Pump and Treat System

Capital Cost:	$ 5,664,000
Annual O&M Cost	$ 463,000
Total Present Worth Cost:	$11,409,000
Time to Implement:	18 months

This alternative is based on Alternative 2 for the Manufacturing and Drum Disposal Areas (Permeable Cap & Institutional Controls) in the FFS, combined with Alternative #4 in the GWI/FFS, as modified by EPA. This alternative includes all of Alternative 2 activities described above, and adds the in-situ chemical oxidation of contaminants in ground water described below.

In addition to the actions described under Alternative 2, Alternative 2A involves in-situ treatment of organic contaminants in the saturated subsurface with a chemical oxidant such as potassium permanganate (KMnO4). Chemical oxidation works when the oxidant comes into direct contact with the contaminant and destroys it by converting the contaminant to innocuous compounds, such as carbon dioxide and water. The chemical reagent is typically injected directly into the subsurface and allowed to flow with the ground water into contaminated areas.

Most of the organic contaminants found at the Site have been successfully cleaned from the environment at other sites using in-situ chemical oxidation, including 1,2-dichloroethene, trichloroethene, and tetrachloroethene. Unfortunately, chemical oxidation would not likely be effective for other Site-related contaminants, such as carbon tetrachloride and bis(2-chloroethyl)ether. Little or no decrease in carbon tetrachloride or bis(2-chloroethyl)ether would be expected with the use of relatively stable oxidants such as KMnO4. Stronger oxidants which may be capable of destroying the carbon tetrachloride or bis(2-chlorothyl)ether are less stable, meaning that the oxidant does not maintain its ability to oxidize contaminants for very long once injected into the subsurface.

Alternative 2A would address some organic contaminants in the fractured bedrock beneath the deep soils source areas as well as the contaminants dissolved in the ground water constituting the "plumes." For cost estimation purposes, the conceptual design includes fabrication and installation of approximately 40 injectors, each with a radius of influence of 50-feet that collectively covers an area approximately 850 feet x 400 feet. The aquifer was estimated to be 50 feet thick and predominantly a combination of overburden and bedrock aquifer. In addition, the natural oxidant demand, due to Site unknowns such as aquifer heterogeneity and geochemistry, is estimated to be 1g/kg.

During the construction of the ground water treatment plant and associated recovery wells as part of the OU-2 interim remedy, it was observed that the overburden (saprolite) yielded minimal quantities of ground water. Attempts were made to install recovery wells in the overburden, but these wells frequently clogged with sediments and ran dry within a few days after installation. Therefore, this alternative would address the bedrock aquifer and associated contamination only. It should be noted that although this alternative has the potential to clean up most of the contaminants in the bedrock aquifer, several significant contaminants would not likely be destroyed by in-situ chemical oxidation. In addition, since the oxidant would only be applied to the fractured bedrock, there would still be a potential for the bedrock aquifer to be "re-contaminated" by contaminants remaining in the soil above the bedrock. This would require treating the bedrock aquifer with additional doses of the chemical oxidant.

For estimation purposes, it is assumed that three applications of the chemical oxidant, 3 to 6 months apart, would be required to affect a major reduction in the total contaminant mass in the ground water.

There are no additional institutional controls or long-term operation and maintenance costs associated with the chemical oxidation component of this alternative.

Since some contaminants would not likely be destroyed via chemical oxidation, the ground water would not meet drinking water standards and would remain unsafe to drink. The enhanced pump and treat system would be implemented as described in Alternative 2 to capture contaminated ground water and achieve remedial action objectives. Institutional controls identical to those described in Alternative 2 would have to be implemented to prevent the extraction of ground water from the aquifer within the waste management area for use as a potable water supply.

Alternative 3: Impermeable Cap with Enhanced Pump and Treat System

Capital Cost:	$ 4,290,000
Annual O&M Cost:	$ 510,000
Total Present Worth Cost:	$10,614,000
Time to Implement:	24 months

This alternative is based on Alternative 3 for the Manufacturing and Drum Disposal Areas (Impermeable Cap & Institutional Controls) in the FFS, combined with Alternative #2 in the GWI/FFS, as modified by EPA.

This alternative includes all the actions described under Alternative 2 described above, except that an impermeable cap would be constructed on top of the existing permeable soil cover.

This alternative involves the construction of a multi-layer impermeable cap over both the Manufacturing and Drum Disposal Areas. For performance and cost estimation purposes, design criteria for Resource Conservation and Recovery Act ("RCRA") Subtitle C caps were assumed. The actual cap profile (materials and thickness of respective layers) would be developed in the Remedial Design. A 7-acre impermeable cap would cover the areas with contaminated subsurface soil (Figure 6). The cap would reduce the amount of precipitation that infiltrates through contaminated soil above the water table and presently leaches contaminants into the ground water. However, most of the mass of hazardous substances located in the subsurface are in the saturated zone. The impermeable cap would not have any impact on ground water moving through the contaminated subsurface soil below the ground water table and down the slope of the hill.

The actual size and location of the capped area would be determined during the Remedial Design phase of the project. The cap would be a multi-layer composite barrier system that minimizes the long-term migration of liquids into the capped area. The various components of a generic multi-layered cap are described from the ground surface down to the top of contaminated soil as follows:

- Vegetative Topsoil Layer: A 6-inch topsoil layer and low-maintenance vegetative cover would be provided to stabilize the cap system and reduce the potential for erosion.
- Select Fill Layer: A compacted layer of fill material, 18 inches in thickness.
- Drainage Layer: A drainage layer would minimize the hydraulic gradient above the impermeable layer (permeability equal to 12 inches of sand at 1E–02 cm/sec or a geonet with transmissivity equal to or greater than 3E-05 m^2/sec).
- Low Permeability Barrier: A barrier which, when constructed, would have a sufficiently low permeability such that it prevents infiltration. (This layer would provide a hydraulic barrier to minimize infiltration of precipitation into the contaminated soil thus reducing leaching of COCs in the soil to ground water). The low permeability barrier would be comprised of two major components. The synthetic (upper) layer is designed to prevent infiltration of liquids into the soil. The underlying low permeability (1E-07 cm/sec) layer provides added assurance that liquids entering the soil will be minimized should a breach of the synthetic layer occur.
- Bedding Layer: The first layer over the area would utilize the existing 24-inch thick clean soil cover constructed over the former drum disposal area and manufacturing area. The area would be compacted to provide a workable graded surface on which the remaining layers of the cover system would be constructed.

An engineered surface water runoff and erosion control system would be designed in accordance with Virginia Storm Water Management and Erosion and Sedimentation Control Regulations and installed to control surface runoff. The system would include surface grading and storm water retention basins and outfall structures as necessary.

Operation and Maintenance would be performed to ensure the integrity of the cap. The landfill cap maintenance plan would require removal of deep-rooted plants to protect the liner. Maintenance activities would also include the repair of sedimentation controls and erosion damage.

The enhanced ground water pump and treat system would be installed and maintained as described in Alternative 2.

Institutional controls would be implemented to ensure that the integrity of the impermeable cap would be maintained and the Site would not be used in a manner inconsistent with the remedy. Any construction on the capped portion of the property would need to be designed to avoid damage to the cap. No institutional controls would be required for off-Site properties. Specific institutional controls would consist of both of the following:

1. a deed notice identifying the Site as a Superfund site and prohibiting (1) residential use of

the property, (2) on-Site potable use of ground water, (3) any activity that would adversely impact the integrity of the impermeable cap or operation of the pump and treat system; and,

2. the granting of easements for Site access to the Commonwealth of Virginia (and their designees if requested) to monitor the constructed remedy, operate and maintain the ground water treatment system, and ensure that restrictions on land use are being maintained.

Alternative 4: Soil Excavation, Off-Site Treatment and Disposal with Enhanced Pump and Treat System

Capital Cost:	$106,018,000
Annual O&M Cost:	$ 463,000
Total Present Worth Cost:	$111,763,000
Time to Implement:	42 months

This alternative is based on Alternative 1 for the Manufacturing and Drum Disposal Areas (Excavation & Institutional Controls) in the FFS, combined with Alternative #2 in the GWI/FFS Report, as modified by EPA.

Under Alternative 4, all clean soil over the deep contaminated soil would be excavated and stockpiled for subsequent use as clean backfill. The underlying soil determined to exceed PRGs (see Exhibit 1) would be excavated and segregated from clean soil. The soil excavation would continue until all soils exceeding the deep soil PRGs were removed or bedrock was encountered. The estimated volume of soil exceeding PRGs in the manufacturing and drum disposal areas is 116,555 yds^3.

For cost estimation purposes, it was assumed that all contaminated soil would need to be transported to a RCRA Subtitle C hazardous waste treatment, storage and disposal facility ("TSDF"). The soil excavated during the OU-1 remedial action conducted in 1996 required thermal destruction (incineration) to comply with applicable regulations. Based on project history and past contaminated soil excavation activities conducted at the Site, it was assumed that all soil removed would be RCRA-listed waste which would require treatment prior to land disposal.

Dust and vapors occurring during excavation, temporary storage and transportation to the TSDF would be managed with standard engineering controls such as wetting with water, tarping and/or use of specialty foam. The excavated areas would be backfilled with clean soil to replace the contaminated soil that was disposed of off-site. A layer of topsoil would be placed over the backfill material and the surface would be re-vegetated.

A significant mass of hazardous substances have migrated into the fractured bedrock beneath the contaminated subsurface soil and beyond practical excavations limits. The enhanced ground water pump and treat system would be installed and maintained as described in Alternative 2, above, to achieve remedial action objectives.

Institutional controls would be implemented to prevent residential use or the extraction of ground water from the aquifer beneath the Site for use as a potable water source. Specific institutional controls would consist of both of the following:

1. a deed notice identifying the Site as a Superfund site and prohibiting (1) residential use of the property, (2) on-Site potable use of ground water, and (3) any activity that would adversely impact the operation of the pump and treat system; and,

2. the granting of easements for Site access to the Commonwealth of Virginia (and their designees if requested) to operate and maintain the ground water treatment system, and to ensure that restrictions on residential land use are being maintained.

Alternative 4A: Soil Excavation, Off-Site Treatment and Disposal of Contaminated Soil, In-Situ Chemical Oxidation with Enhanced Pump and Treat System

Capital Cost:	$111,317,000
Annual O&M Cost:	$ 463,000
Total Present Worth Cost:	$117,062,000
Time to Implement:	60 months

Alternative 4A includes the remedial actions described in Alternative 4 augmented by the in-situ chemical oxidation remedial action described under Alternative 2A.

After the excavation and off-site disposal of the contaminated soil above the bedrock, a chemical oxidant would be injected into fractured bedrock to destroy the contaminants which are amenable to oxidation. As discussed in Alternative 2A above, contaminants such as carbon tetrachloride and bis(2-chloroethyl)ether will not likely be removed by oxidation. The enhanced pump and treat system would be implemented as described in Alternative 2 to capture contaminated ground water and achieve remedial action objectives beyond the waste management area.

Institutional controls identical to those described in Alternative 4 would be implemented. There are no additional institutional controls or long-term operation and maintenance costs associated with the chemical oxidation component of this alternative.

J. EVALUATION OF ALTERNATIVES

Evaluation Criteria

Below is a description of the nine criteria set forth in the NCP, 40 CFR §300.30(e)(9), which EPA used to evaluate each of the remedial alternatives summarized above. The purpose of the comparative analysis is to identify the advantages and disadvantages of each alternative relative to the others. These nine criteria can be categorized into three groups: threshold criteria, primary balancing criteria, and modifying criteria.

Threshold criteria must be satisfied in order for a remedial alternative to be eligible for selection. Primary balancing criteria are used to weigh trade-offs between alternatives. State acceptance and community acceptance are modifying criteria formally taken into account after public comment is received on the Proposed Plan. Provided below is a summary of the relative performance of the alternative with respect to each of the criteria. This summary provides the basis for EPA's determination of which alternative provides the best balance of all the criteria.

Threshold Criteria

• Overall Protection of Human Health and the Environment addresses whether a remedy provides adequate protection and describes how risks are eliminated, reduced, or controlled through treatment, engineering controls, or institutional controls.

• Compliance with Applicable or Relevant and Appropriate Requirements ("ARARs") addresses whether or not a remedy will meet all Federal and State environmental requirements, standards, criteria, and limitations that are applicable or relevant and appropriate.

Primary Balancing Criteria

• Long-term Effectiveness and Permanence refers to expected residual risk and the ability of the remedy to maintain reliable protection of human health and the environment over time, once cleanup levels have been met. This criterion includes the consideration of residual risk theat will remain onsite following remediation and the adequacy and reliability of the management controls (e.g., institutional controls).

• Reduction of Toxicity, Mobility or Volume Through Treatment addresses the degree to which treatment will be used to reduce the mobility, toxicity, or volume of contaminants causing Site risks.

• Short-Term Effectiveness addresses the period of time needed to achieve protection and any adverse impacts on human health and the environment that may be posed during the construction and operation of the remedy until cleanup goals are achieved.

• Implementability addresses the technical and administrative feasibility of the remedy, including the availability of materials and services needed a particular option.

• Cost includes estimated capital (construction), operation and maintenance ("O&M"), and net present worth costs. (The present worth analysis is used to evaluate expenditures that occur over different time periods by discounting all future costs to a common base year, usually the current year. This analysis allows the cost of the remedial action alternatives to be compared on the basis of a single figure representing the amount of money that, if invested in the basis year and disbursed as needed, would be sufficient to cover all costs associated with the remedial action over its planned life.)

Modifying Criteria

• State Acceptance indicates whether the Commonwealth concurs with, opposes, or has no comment on the selected remedy.

• Community Acceptance considers whether the community agrees with the proposed remedy.

This is assessed in detail in the ROD responsiveness summary (attached) which addresses public comments received on the Administrative Record and the Proposed Plan.

The following discussion summarizes how each alternative considered in this Record of Decision compares against each other with respect to these evaluation criteria.

1. Overall Protection of Human Health and Environment

A primary requirement of CERCLA is that the selected remedial alternative be protective of human health and the environment. EPA determines that a remedy is protective when it reduces current and potential risks to acceptable levels within the established risk range posed by each exposure pathway at the Site.

Alternative 1 (No Action - Existing Permeable Soil Cover and Pump and Treat System) would not effectively reduce risk to human health and the environment. The only unacceptable risk remaining at the Site is presented by contaminated ground water, assuming a future use scenario. Some contaminants in ground water appear to be by-passing the existing ground water recovery well network and moving off the Site. If Alternative 1 were selected ground water at the Site would continue to be unsafe to drink. Since Alternative 1 does not meet the threshold criteria of protection of human health and the environment it will not be considered further in this analysis.

All of the remaining remedial alternatives (Alternatives 2, 2A, 3, 4, and 4A) received an overall positive rating for protection of human health and the environment, primarily due to the enhanced pump and treat component. Each of the remaining alternatives would upgrade the existing recovery well network to capture contaminated ground water before it migrates off-Site. Each remaining alternative considered also includes institutional controls to prevent the installation of drinking water wells on the Site and long-term monitoring of ground water.

Alternative 2 (Permeable Soil Cover with Enhanced Pump and Treat) would not implement any additional engineering controls or treatment technology to reduce the mass of contaminants in the deep soil or fractured bedrock. Alternative 2 achieves protectiveness primarily by collecting contaminated ground water before it migrates off-Site.

Alternative 2A (Permeable Soil Cover, Enhanced Pump and Treat with In-Situ Chemical Oxidation) would include in-situ chemical oxidation to destroy some of the contaminant mass in the fractured bedrock but would not be effective for all of the contaminants found on the Site. Alternative 3 (Impermeable Soil Cap and Enhanced Pump and Treat) would use an impermeable cap constructed over the former manufacturing and drum disposal areas to reduce infiltration of precipitation through contaminants in subsurface soil. The reduced infiltration would marginally reduce migration of contaminants from unsaturated soil to the underlying ground water. However, neither the treatment included in Alternatives 2A nor the engineering controls included in Alternative 3 would result in a remedy that would be protective of human health and the environment without the pump and treat component of the respective remedies.

Alternative 4 (Excavation with Enhanced Pump and Treat) would excavate contaminated soil above the bedrock for off-site treatment and disposal. Alternative 4A (Excavation, Enhanced Pump and Treat with In-situ Chemical Oxidation) would use in-situ chemical oxidation to further destroy some contaminant mass in the fractured bedrock after the contaminated soil was excavated. However, even Alternatives 4 and 4A require its respective ground water treatment components to achieve protectiveness because significant contamination is located in the fractured bedrock and beyond the practical limits of excavation, and the oxidation would not be effective for all of the contaminants

2. Compliance with Applicable or Relevant and Appropriate Requirements ("ARARs")

Any cleanup alternative selected by EPA must comply with all applicable or relevant and appropriate federal and state environmental requirements. Applicable requirements are those substantive environmental standards, requirements, criteria, or limitations promulgated under federal or state law that are legally applicable to the Remedial Action to be implemented at the Site. Relevant and appropriate requirements, while not directly applicable, address problems or situations sufficiently similar to those encountered at the Site such that their use is well-suited to the particular Site, and which EPA has decided must be met. Additionally, To Be Considered ("TBC") requirements are those which, while not required at this Site because they are not ARARs, EPA considers, and may follow.

Each of the remaining Alternatives (2, 2A, 3, 4, and 4A) would include the continued operation of the on-Site water treatment plant which would continue to meet the effluent discharge standards and monitoring requirements established under the Virginia Pollutant Discharge Eliminations System ("VPDES").

EPA understands that GCC's manufacturing operations may have generated F002 and F005 listed hazardous wastes that could have been discharged into the on-Site lagoon system as late as April, 1985, when production ceased. For purposes of this remedial action, EPA has assumed that the RCRA Regulatory Requirements, including Land Disposal Regulations (40 CFR Part 268, as adopted in 9VAC20-60-268, "LDRs"), and Minimum Technology Requirements (40 CFR 265, as adopted in 9 VAC20-60-265, "MTRs"), are applicable to the excavation and off-site disposal Alternatives 4 and 4A, which involve off-site transportation of contaminated soil. Virginia has an EPA-approved RCRA program; thus Virginia's Waste Management Regulations will generally govern instead of federal RCRA regulations. (Note that Virginia's Waste Management Regulations are similar to the federal RCRA regulations.).

Finally, as noted above, MCLs under the Safe Drinking Water Act are relevant and appropriate with respect to each of the alternatives which involve continuation of the ground water pump and treatment system, and all MCLs and non-zero MCLGs are expected to be achieved in the area of attainment outside of the waste management area.

All of the substantive federal and state ARARs which EPA has identified for the remedial alternatives in this Proposed Plan, as well as the TBCs, are summarized in Table 6. Alternatives 2, 2A, 3, 4, and 4A would comply with ARARs.

3. Long-Term Effectiveness and Permanence

Alternatives 2, 2A, 3, 4 and 4A would each be effective in maintaining reliable protection of human health and the environment over time once cleanup goals are achieved. The ground water pump-and-treat component of each of the remaining remedial alternatives has a high degree of long-term effectiveness and permanence. The treatment technologies utilized in the water treatment plant are well understood and easy to implement. However, there is considerable uncertainty as to whether the ground water beneath the Site can be successfully restored to levels acceptable for drinking water within 30 years, if ever. The ground water extraction system is expected, however, to contain the contaminated ground water within the waste management area, and the ground water pump-and-treat component would gradually remove contaminant mass from the ground water. Moreover, as noted above, all MCLs and non-zero MCLGs are expected to be achieved outside the waste management area. Thus, the long-term effectiveness of the ground water alternative depends on an effective recovery well network to prevent any potential for exposure off-Site and the institutional controls to prevent exposure on-site.

Alternatives 2 and 3 would rank well on long-term effectiveness and permanence. The permeable soil cover (Alternative 2) would support natural vegetation and would not require any special maintenance activities. The engineered impermeable cap (Alternative 3) would have some marginal reduction to the leaching of contaminants from the unsaturated zone to the ground water, thereby reducing the mass loading to the water treatment plant. The impermeable cap would have a design-life of 50-100 years and support a vegetated cover limited to grasses and shallow-rooted shrubs. Alternatives 2A, 4 and 4A rate better with respect to permanence because some of the contaminants, which are the source of ground water contamination, would be excavated and removed from the Site and/or be treated to destroy some contaminant mass. Alternative 4A ranks the best on permanence because the excavated soil would be treated in conformance with RCRA LDRs and disposed of at an off-site TSDF, and contaminants amenable to oxidation would be destroyed in the fractured bedrock. Nevertheless, the ground water pump and treat component would still be required to maintain the effectiveness of this Alternative.

Alternative 3 would require institutional controls to prevent future use activities from affecting the integrity of the engineered low-permeability cap. Each of the remaining alternatives would require institutional controls to prevent the installation of potable water wells on the Site until the quality of underlying ground water is restored to safe levels[7]. Since all institutional controls would require permanent monitoring, the different types of institutional controls had little effect on the alternatives analysis with respect to long term effectiveness.

4. Reduction of Toxicity, Mobility, and Volume through Treatment

Section 121(b) of CERCLA, 42 U.S.C. § 9621(b), established a preference for Remedial Actions that include treatment that permanently and significantly reduces the toxicity, mobility, or volume of contaminants.

Alternatives 2, 2A, 3, 4, and 4A each involve the collection and treatment of contaminants in ground water. In each of these scenarios, the contaminant mass from the ground water would continue to be removed from the environment and conveyed to the water treatment plant. The water treatment plant employs chemical precipitation, ultraviolet light oxidation (UV oxidation), and carbon filtration. The UV oxidation step destroys organic contaminants and is a non-

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[7] It is anticipated that even if the contaminated soil that presents a continuing source of contaminants to the ground water is removed, the quality of ground water beneath the Site would not return to acceptable levels for a great number of years.

reversible process.

The permeable soil cover included in Alternative 2 would provide limited reduction in vertical infiltration of rain water through the unsaturated contaminated subsurface soils. Through proper grading and support of a healthy stand of vegetation, the reduced infiltration would marginally reduce the migration of contaminants to the ground water for subsequent collection and treatment in the water treatment plant. Alternative 3 would incorporate an engineered multi-layered cap that would nearly eliminate vertical infiltration of rain water and reduce the mass of contaminants migrating from the unsaturated soil to the ground water.

Alternatives 4 and 4A would involve excavation of subsurface soil where concentrations of hazardous substances exceed cleanup standards. The excavated soil would be transported to an off-site RCRA TSDF. All material received by the TSDF would likely be subject to RCRA LDRs, and would be treated as appropriate prior to disposal. Alternatives 2A and 4A would reduce toxicity of many of the contaminants in the saturated soils and ground water. Under these alternatives, a chemical oxidant, such as potassium permanganate (KMnO4), would be injected into the fractured bedrock aquifer. The oxidant could come into direct contact with degradable contaminants and react to break those hazardous substances into harmless compounds. Not all of the contaminants in subsurface soil and ground water at the Site are degradable with a stable oxidant, however. Of the alternatives considered, Alternative 4A would provide the best reduction of toxicity, mobility, and volume through treatment as subsurface soil exceeding cleanup criteria would be excavated and sent to a TSDF for treatment and some of the contaminants remaining in ground water would be treated in situ.

5. Short-term Effectiveness

All the alternatives achieve good short-term effectiveness. The permeable soil cover (Alternative 2) and impermeable cap (Alternative 3) alternatives, however, are expected to have the greatest short-term effectiveness. These alternatives are superior to Alternatives 4 and 4A because they minimize the exposure risk to the community, workers and the environment during implementation. Alternatives 4 and 4A would offer the least short-term effectiveness given the large scale of the excavation and the increased time required to complete this work. Alternative 3, 4 and 4A would introduce a statistically small incremental risk due to potential traffic accidents caused by the number of trucks needed to haul materials for the impermeable cap (Alternative 3) or the excavation and backfill alternatives (Alternatives 4 and 4A).

Alternatives 4 and 4A would require controls to minimize risks presented to site workers and the community by airborne dust, exposure to contaminated soil, and vaporization of contaminants of concern during construction. These risks can be readily controlled using established construction methods. Alternatives 2A and 4A present some additional occupational hazards to site workers handling chemical oxidants. Alternatives 3, 4 and 4A would require controls in order to minimize impacts associated with storm water runoff during construction. Standard erosion and sedimentation control methods would be employed to control storm water runoff.

The ground water component of the remaining Alternatives achieves good short-term effectiveness. There would be little potential for exposure to Site contaminants during installation of additional recovery wells. Construction of the enhanced ground water pump-and-treat system would take approximately 5 months. The potential for significant exposure to Site-related contaminants during the operation of the pump-and-treat system is minimal.

6. Implementability

This evaluation criterion addresses the difficulties and unknowns associated with implementing the cleanup technologies associated with each alternative, including the ability and time necessary to obtain required permits and approvals, the availability of services and materials, and the reliability and effectiveness of monitoring.

Alternatives 2, 3 and 4 can reasonably be implemented using commonly employed engineering and construction methods, equipment, materials, and personnel. Relative to other alternatives, the impermeable capping and permeable soil cover alternatives are administratively easier to implement because no excavation and removal of impacted soil from the Site is required.

The chemical oxidation included in Alternatives 2A and 4A is difficult to effectively implement in the field. The chemical reaction between the oxidant and the target contaminant only occurs when the respective molecules physically come into contact. While injection of the water-born oxidant into the ground is not difficult, the further delivery of the oxidant into the fractured bedrock system, within the specific fissures containing contaminants, is difficult to accomplish successfully. A strong oxidant that is capable of degrading a wider variety of contaminants, including carbon tetrachloride, would lose its potency too quickly to be effective in the field. A more stable chemical oxidant such as $KMnO4$ would not likely be effective degrading some of the contaminants such as carbon tetrachloride or bis(2-chloroethyl)ether.

Alternatives 4 and 4A involving the excavation of contaminated soil would require coordination with other state and local agencies in order to transport contaminated material off-site for treatment and disposal. Alternatives 2A and 4A would require coordination with the federal and state water protection programs to establish and meet requirements for injection of the chemical oxidant into the ground water. The construction of each of these alternatives would employ methods, equipment and specialists that are readily available from more than one vendor and are sufficiently demonstrated.

Expansion of the existing ground water pump-and-treat system can be readily implemented. Ground water modeling has already been performed to select the most appropriate locations for additional recovery wells. Materials and services are readily available for installation of extraction wells and modification of the treatment system, as appropriate.

7. Cost

Evaluation of costs for each alternative generally includes calculation of direct and indirect capital costs, and annual O&M costs, both calculated on a present worth basis. An estimated capital, annual O&M, and total present worth cost for each of the alternatives has been calculated for comparative purposes, and is presented in Table 7.

Direct capital costs include costs of construction, equipment, building and services, and waste disposal. Indirect capital costs include engineering expenses, start-up and shutdown, and contingency allowances. Annual O&M costs include labor and material, chemicals, energy, and fuel; administrative costs and purchased services; monitoring costs; and insurance, taxes, and license costs. For cost estimation purposes, a period of 30 years has been used for O&M. In reality, maintenance of a site with waste left in place would be expected to continue beyond this period. Similarly, the actual duration of operation for the ground water extraction and treatment system would depend on its ability to successfully limit migration of Site-related contaminants, and to achieve acceptable water quality on Site. The actual cost for each alternative is expected to be in a range from 50 percent higher than the costs estimated to 30 percent lower than the costs estimated. The evaluation was based on the Focused Feasibility Study cost estimates, as modified by EPA. The present worth is based on both the capital and O&M costs, and provides the means of comparing the cost of different alternatives. The present worth cost includes costs for the long-term operation of the ground water pump-and-treat system.

Table 7
Summary of Estimated Costs

	Capital Cost	Annual O&M Cost	Present Worth
Alternative 1	$0	$454,000	$5,634,000
Alternative 2	$365,000	$463,000	$6,110,000
Alternative 2A	$5,664,000	$463,000	$11,409,000
Alternative 3	$4,290,000	$510,000	$10,614,000
Alternative 4	$106,018,000	$463,000	$111,763,000
Alternative 4A	$111,317,000	$463,000	$117,062,000

8. State Acceptance

The Commonwealth of Virginia concurs with the selected remedy (Alternative 2).

9. Community Acceptance

A public comment period was held to solicit comments from the community from June 23, 2005 to July 22, 2005. In addition, a public meeting was held on July 6, 2005 to present the Proposed Plan to the local community and further solicit input from the citizens. All public comments received from the community were supportive of EPA's identified Alternative 2, which had been identified as EPA's "preferred alternative" in the Proposed Plan. A summary of the comments received during the public comment period and EPA's responses are included in the Responsiveness Summary, which is Part III of this Record of Decision.

K. PRINCIPAL THREAT WASTES

The NCP, at 40 CFR § 300.430(a)(l)(iii)(A), establishes an expectation that EPA will use treatment to address any principal threats posed by a site, whenever practicable. "Principal threat" wastes are generally defined as source materials (contaminated materials that acts as a reservoir for migration of contamination to ground water, surface water, or air, or acts as a source for direct exposure) considered to be highly toxic or highly mobile such that risks from such materials cannot be effectively reduced through containment, or which would present a significant risk to human health or the environment should exposure occur. EPA does not consider the residual contamination in the deep soil or ground water to be "principal threat" wastes.

L. THE SELECTED REMEDY AND PERFORMANCE STANDARDS

EPA carefully considered state and community acceptance of the remedy prior to reaching the final decision regarding the selected remedy.

The Agency's selected remedy is Alternative 2: *Existing Permeable Soil Cover with Enhanced Pump and Treat System, Institutional Controls, and Long-Term Monitoring.* Based on current information, this alternative provided the best balance among the alternatives with respect to the nine criteria EPA uses to evaluate each alternative.

Summary of Rationale for the Selected Remedy

When EPA assembled remedial alternatives capable of achieving protectiveness and ARARs, the enhanced ground water pump and treat component which is the primary component of the Selected Remedy was included in each of the alternatives (other than No-Action). The enhanced pump and treat component was included in each of these alternatives because they were not judged to be capable of achieving the remedial action objectives without the hydraulic containment provided by the ground water recovery wells. The more robust response actions included in the other alternatives considered were unable to meet the remedial action objectives without the hydraulic containment because the contaminants have migrated to the fractured bedrock, beyond the limits of excavation, and some of those contaminants are resistent to in-situ treatment. The Selected Remedy was judged to be capable of meeting the remedial action objectives without the inclusion of additional components. The Selected Remedy provides the best balance of tradeoffs with respect to the balancing and modifying criteria. Moreover, the Selected Remedy rated superior to the other alternatives when considering the Short-Term Effectiveness, Implementability and Cost-Effectiveness criteria. The excavation and treatment alternatives rated marginally better when considering Long Term Effectiveness and Permanence and Reduction of Toxicity, Mobility and Volume through Treatment. The Commonwealth of Virginia concurred with EPA's Selected Remedy and all public comments received during the 30-day public comment period were supportive of the Selected Remedy.

Description of the Selected Remedy

The existing five-well ground water pumping network will be augmented with additional wells necessary to prevent the migration of Site-related contaminants from the waste management area to West Stream and off-Site locations (see Figure 11). It is estimated that an additional five wells screened to withdraw ground water in the upper 50 feet of bedrock will be required. Hydro-fracturing techniques will be employed during recovery well installation to increase water recovery rates.

The series of ground water extraction wells will be operated in concert to achieve the final Site-specific risk-based ground water cleanup goals (Table 5). Periodic evaluation of the performance and effectiveness of the ground water extraction system will be performed. The ground water extraction system will be modified as necessary to achieve the performance standards beyond the waste management area.

Recovered ground water will be conveyed to the existing water treatment plant, installed pursuant to the 1990 Interim ROD for OU-2. Contaminated ground water will be piped to the equalization tank constructed beneath the existing plant and through the treatment train for contaminant abatement prior to discharge of clean water to a small tributary to West Stream. The treatment processes include a combination of chemical precipitation, ultraviolet/oxidation and carbon filtration technologies to treat the contaminated ground water. The ground treatment plant will continue to meet the VDPES discharge standards.

The existing water treatment plant has a design flow rate of 45 gpm. The present contribution from the five recovery wells varies between 20-25 gpm. Analysis of ground water data and the design influent concentrations at the existing treatment plant indicate that the additional volume of ground water called for under the selected alternative can likely be processed without modification to the treatment system. If additional capacity is required, the water treatment plant will be modified to accommodate the increased flow.

Operation and maintenance activities for this alternative will include: maintaining the extraction wells, operating the treatment plant, performing periodic ground water level and chemical measurements to confirm that Site ground water is being captured, and performing periodic inspections to confirm that the institutional controls are being maintained. Routine chemical analyses of plant effluent will be conducted with quarterly bioassay tests to confirm that the discharge meets State requirements. O&M for the soil cover already constructed over the waste management area will include seeding as necessary to prevent erosion of the clean soil cover. The net present worth estimate is based on a 30-year operation period.

Institutional controls would be implemented to ensure that prospective users of the Site are aware that deep soil contamination is present, to prevent: the extraction of ground water from the aquifer beneath the Site for use as a potable water source; any interference with the ground water extractions wells, treatment system, and related equipment; and any removal of the soil cover without written permission of the EPA and/or VDEQ. Specific institutional controls would consist of both of the following:

1. a deed notice identifying the Site as a Superfund Site and prohibiting (1) residential use of the property, (2) on-Site potable use of ground water, (3) any activity that would adversely impact the operation of the pump and treat system, (4) any removal of the soil cover without written permission of the EPA and/or VDEQ and (5) deep excavation without a site-specific health and safety plan. Any soil excavated from the former Manufacturing or Drum Disposal Areas would need to be sampled and managed in an appropriate manner; and,

2. the granting of easements for Site access to the Commonwealth of Virginia (and their designees if requested) to monitor the constructed remedy, operate and maintain the ground water treatment system, and ensure that restrictions on land use are being maintained.

Summary of the Estimated Remedy Costs

Table 8 presents a detailed summary of the estimated costs to implement the Selected Remedy. The information in this cost estimate summary table is based on the best available information regarding the anticipated scope of the remedial alternative. Changes in the cost elements are likely to occur as a result of new information and data collected during the engineering and design of the remedial alternative. Major changes may be documented in the form of a memorandum in the Administrative Record file, an ESD, or ROD amendment. This is an order-of-magnitude engineering cost estimate that is expected to be within +50 to –30 percent of the actual project cost.

The estimated costs to implement this remedy are listed below and include installation of additional ground water recovery wells, construction of associated water conveyance system (i.e., pipes and pumps), operation and maintenance of the water treatment plant ground water monitoring for a period of 30 years.

Capital Cost:	$ 365,000
Annual O&M Cost:	$ 463,000
Present Worth Cost:	$6,110,000
Time to Implement:	5 months

Expected Outcome of the Selected Remedy

Exposure to contaminated ground water outside the waste management area will be controlled through hydraulic containment using ground water recovery wells, treatment of the captured ground water, and institutional controls until the ground water cleanup levels are achieved. Exposure to ground water within the waste management area will be controlled through institutional controls only.

Ground water in the area presently occupied by the contaminated ground water plume beyond the waste management area will achieve the ground water cleanup levels presented in Table 9. The purpose of this response action is to control potential risks posed by drinking and showering with ground water when considering a future use scenario. The results of the baseline risk assessment indicate that existing conditions at the Site pose an excess lifetime cancer risk of 6.6×10^{-4} from drinking of, and bathing/showering with, contaminated ground water. This risk relates to carbon tetrachloride, 1,2-dichloroethane, tetrachloroethene, trichloroethene, vinyl chloride and bis(2-chloroethyl)ether concentrations present at one or more wells outside the waste management area at a level of concern. The Selected Remedy will prevent the migration of contaminants from the waste management area so that concentrations of each of the contaminants will diminish to below the contaminant-specific cleanup level listed in Table 9. Each of the target cleanup levels identified in Table 9 would correspond to an excess lifetime cancer risk of 10^{-5}, except the target cleanup level for vinyl chloride. The 0.5 ug/l vinyl chloride target cleanup level was established based on its practical quantitation limit. The practical quantitation limit is the lowest concentration of a specific chemical that can be routinely quantified and reported by a laboratory. The selected remedy will still result in the achievement of a level of vinyl chloride which lies within EPA's acceptable risk range. Each of the target cleanup levels established also comply with Federal and State ARARs. The ground water will be monitored to ensure that the cleanup levels are achieved.

Table 9
Ground Water Cleanup Levels Beyond the Waste Management Area

Chemical of Potential Concern	Cleanup Level (ug/l)	Basis for Cleanup Level	Risk at Cleanup Level
1,2-Dichloroethane	5.0	Maximum Contaminant LevelL	Cancer risk = 1×10^{-5}
Bis(2-Chloroethyl)Ether	0.5	Risk Assessment	Cancer risk = 1×10^{-5}
Carbon Tetrachloride	4.0	Risk Assessment	Cancer risk = 1×10^{-5}
Tetrachloroethene	0.8	Risk Assessment	Cancer risk = 1×10^{-5}
Trichloroethene	1.0	Risk Assessment	Cancer risk = 1×10^{-5}
Vinyl Chloride	0.5*	Risk Assessment	Cancer risk = 4×10^{-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 4E-05. The cleanup level for each of the other five contaminants was set at a level equivalent to a 1E-05 risk.

Ground water in the impacted fractured bedrock moves at a rate of approximately 25 feet per year. It is estimated that the ground water cleanup levels will be achieved within 30 years. Once ground water cleanup levels are achieved, ground water within the Area of Attainment will be available for potable use and the need for Institutional Controls can be reevaluated as part of the CERCLA Five Year Review Process.

Response actions completed for previous operable units have addressed all media other than ground water at the Site. The Greenwood Chemical Site is available for recreational or industrial use as a result of response actions already completed.

M. STATUTORY DETERMINATIONS

Under CERCLA §121 and the NCP, the lead agency must select remedies that are protective of human health and the environment, comply with applicable or relevant and appropriate requirements (unless a statutory waiver is justified), are cost-effective and utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable. In addition, CERCLA includes a preference for remedies that employ treatment that permanently and significantly reduces the volume, toxicity or mobility of hazardous wastes as a principal element and a bias against off-site disposal of untreated wastes. The following sections discuss how the selected remedy meets these statutory requirements.

Protection of Human Health and the Environment

The selected remedy, Alternative 2, will protect human health and the environment by capturing contaminated ground water moving from the waste management area and treating the recovered ground water in an onsite treatment plant. Institutional controls will prevent exposure to the contaminated ground water within the waste management area. Temporary institutional controls will prevent exposure to the existing ground water plume until the quality of the aquifer is restored to safe levels. The existing permeable soil cover over the deep soil source area will continue to prevent exposure to contaminants beneath the former drum disposal and waste manufacturing areas.

By continuing the pumping and treating of the contaminated ground water, the Selected Remedy will prevent the existing plume from migrating to current ground water users, and restore ground water quality the beyond the waste management area to Federal drinking water standards and health-based levels. The remaining potential human health risk levels will be within EPA's acceptable risk range for carcinogens (less than 1×10^{-4}) and the non-carcinogen hazard will be below the level of concern (a hazard quotient less than or equal to 1). There are no short-term threats associated with the selected remedy that cannot be readily controlled. The water treatment plant will be meet all water quality discharge standards. No adverse cross-media impacts are expected from the selected remedy.

Compliance with Applicable or Relevant and Appropriate Requirements

The Selected Remedy of pumping and treating of ground water will attain all remedy-specific applicable or relevant and appropriate requirements, which are included in Table 6 of this ROD.

Cost-Effectiveness

In EPA's judgement, the Selected Remedy is cost-effective and represents a reasonable value for the money spent. In making this determination, the following definition was used: "A remedy shall be cost-effective if its costs are proportional to its overall effectiveness." [NCP §300.430(f)(1)(ii)(D)]. This was accomplished by evaluating the "overall effectiveness" of those alternatives that satisfied the threshold criteria (i.e., were both protective of human health and the environment and ARAR-compliant). Overall effectiveness was evaluated by assessing three of the five balancing criteria in combination (long-term effectiveness and permanence; reduction in toxicity, mobility, and volume through treatment; and short-term effectiveness). Overall effectiveness was then compared to costs to determine cost-effectiveness. The relationship of the overall effectiveness of this remedial alternative was determined to be proportional to its costs and hence this alternative represents the best value for the money to be spent.

The estimated present worth cost of the Selected Remedy is $6,110,000. Although Alternative 1 is $500,000 less expensive, under that alternative contaminated ground water would continue to migrate past the existing ground water recovery wells, and therefore the Selected Remedy is more cost effective. EPA believes that the enhanced pump and treat system included in the Selected Remedy will provide an overall level of protectiveness comparable to Alternatives 2A, 3, 4, and 4A at a significantly lower cost.

Utilization of Permanent Solutions and Alternative Treatment Technologies (or Resource Recovery Technologies) to the Maximum Extent Practicable

EPA has determined that the Selected Remedy represents the maximum extent to which permanent solutions and treatment technologies can be utilized in a practical manner at the Site. Of those alternatives that are protective of human health and the environment and comply with ARARs, EPA has determined that the Selected Remedy provides the best trade-offs in terms of the five balancing criteria, while also considering the statutory preference for treatment as a principal element and bias against off-site treatment and disposal and considering State and community acceptance.

The principal threats once presented by hazardous substances at the Greenwood Chemical site were treated by EPA through earlier response actions at the Site. This Selected Remedy addresses lower level threats presented by residual contaminants with hydraulic containment, on-site ground water treatment, institutional controls and long-term monitoring and maintenance to provide the necessary level of protection of human health and the environment.

The enhanced ground water pump and treatment component included in the Selected Remedy was included in each of the alternatives determined to achieve protectiveness and achieve ARARs. It was the enhanced ground water pump and treat component which enabled the remaining alternatives to achieve the threshold criteria. Although Alternatives 2A, 4 and 4A rate marginally better than the Selected Remedy when considering Long-Term Effectiveness and Permanence and Reduction of Toxicity, Mobility and Volume through Treatment due to the additional treatment of source material through in-situ oxidation and/or incineration, the Selected Remedy rates superior to each of these alternatives when considering its Short-Term Effectiveness, Implementability and Cost-Effectiveness. The Commonwealth of Virginia concurred with EPA's Selected Remedy and all public comments received during the 30-day public comment period were supportive of the Selected Remedy.

Preference for Treatment as a Principal Element

There are no "principal threats" remaining at the Site, however the Selected Remedy does address the contaminated ground water by processing it through an on-site ground water treatment plant. By utilizing treatment as a significant portion of the remedy, the statutory preference for remedies that employ treatment as a principal element is satisfied.

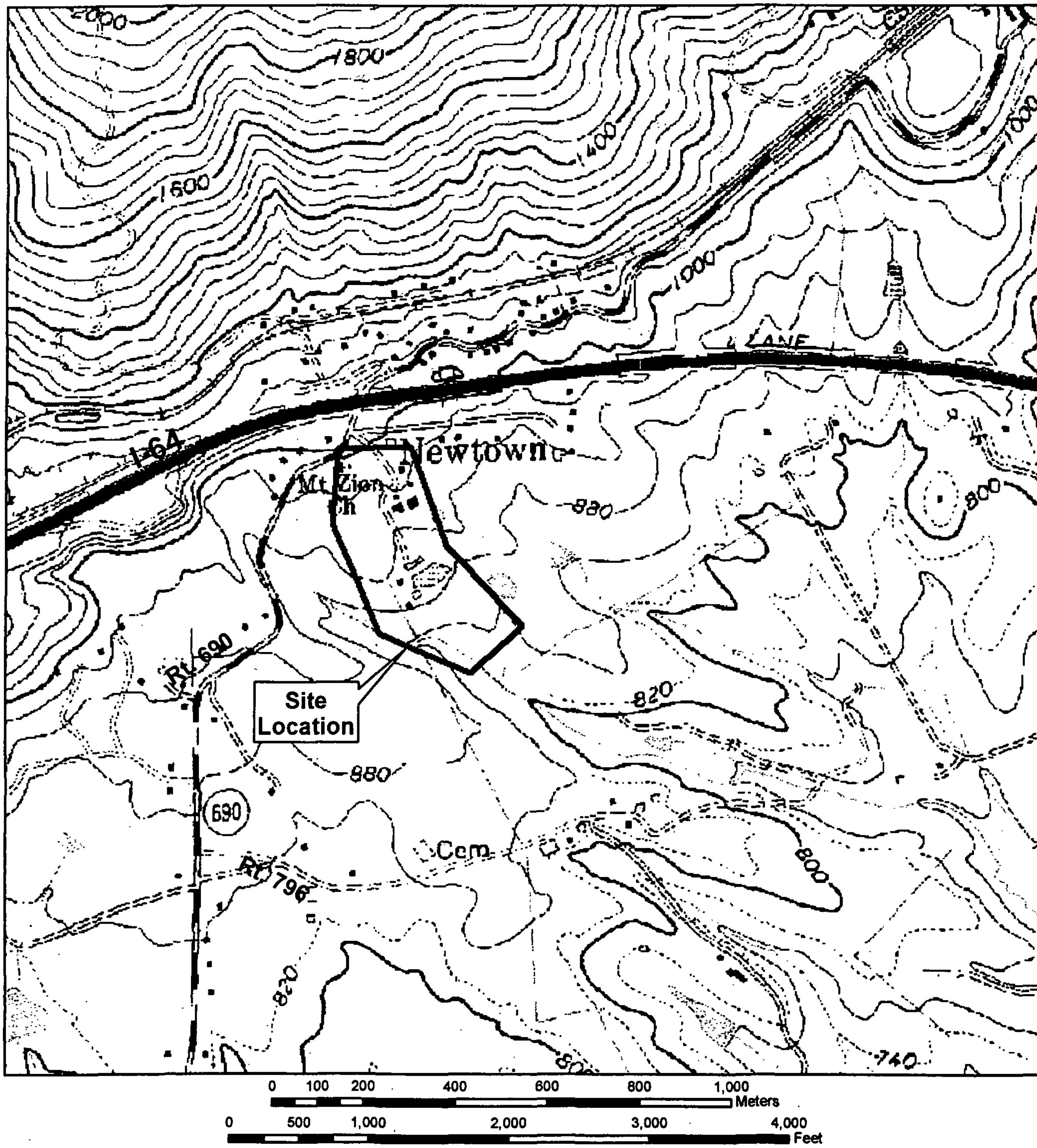
Five-Year Review Requirements

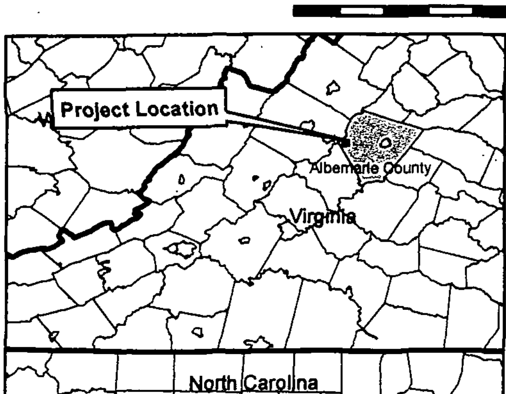
Because this remedy will result in hazardous substances, pollutants, or contaminants remaining on-site above levels that allow for unlimited use and unrestricted exposure, a statutory review will be conducted no less often than every five years after initiation of remedial action to ensure that the remedy is, or will be protective of human health and the environment.

N. DOCUMENTATION OF SIGNIFICANT CHANGES/CLARIFICATIONS FROM PREFERRED ALTERNATIVE OF PROPOSED PLAN

There are no significant changes from the preferred alternative of the Proposed Plan.

FIGURES





U.S. Environmental Protection Agency

GREENWOOD CHEMICAL SUPERFUND SITE

Albermarle County
Greenwood, Virginia

Figure 1
Site Location Map

ORIGINAL

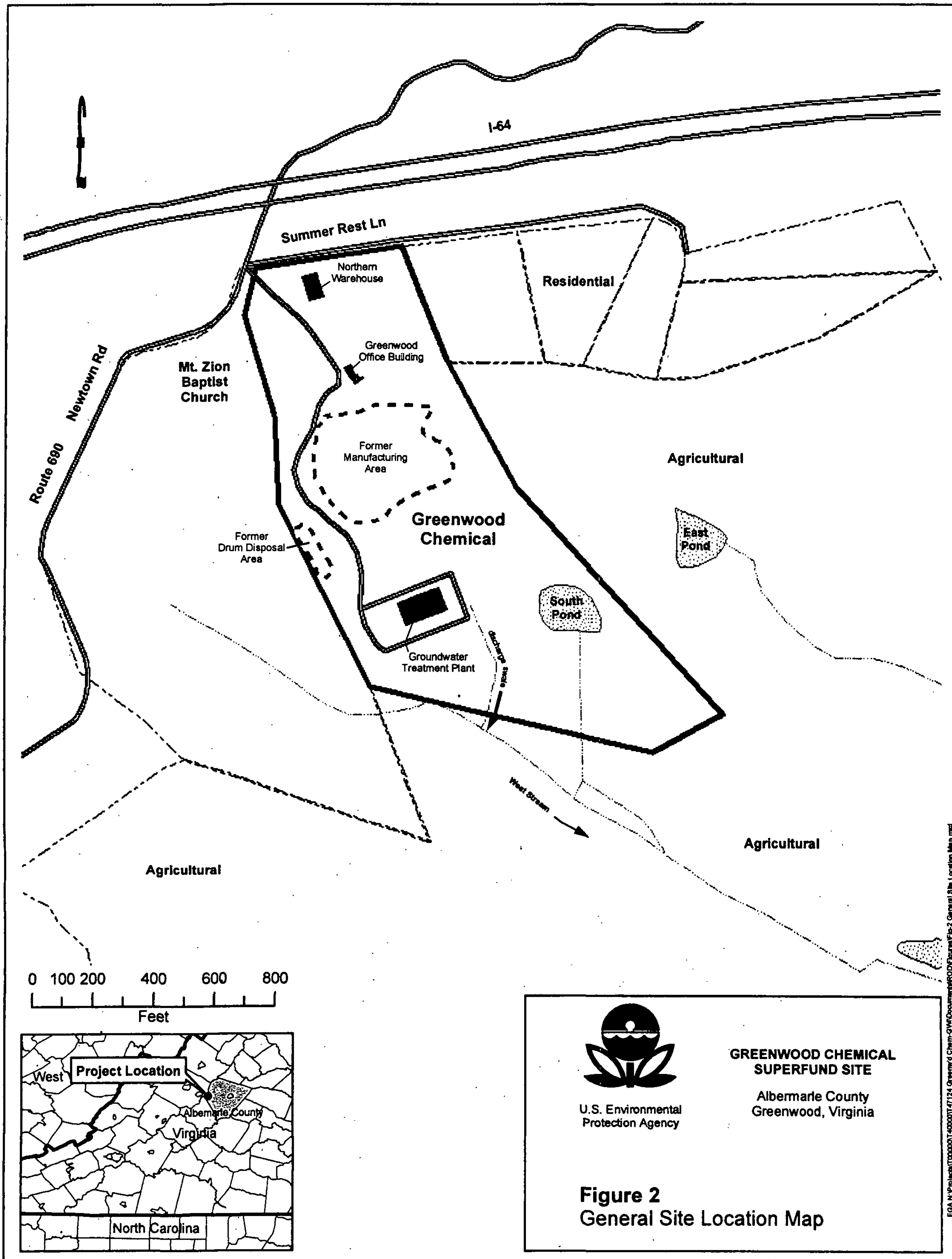
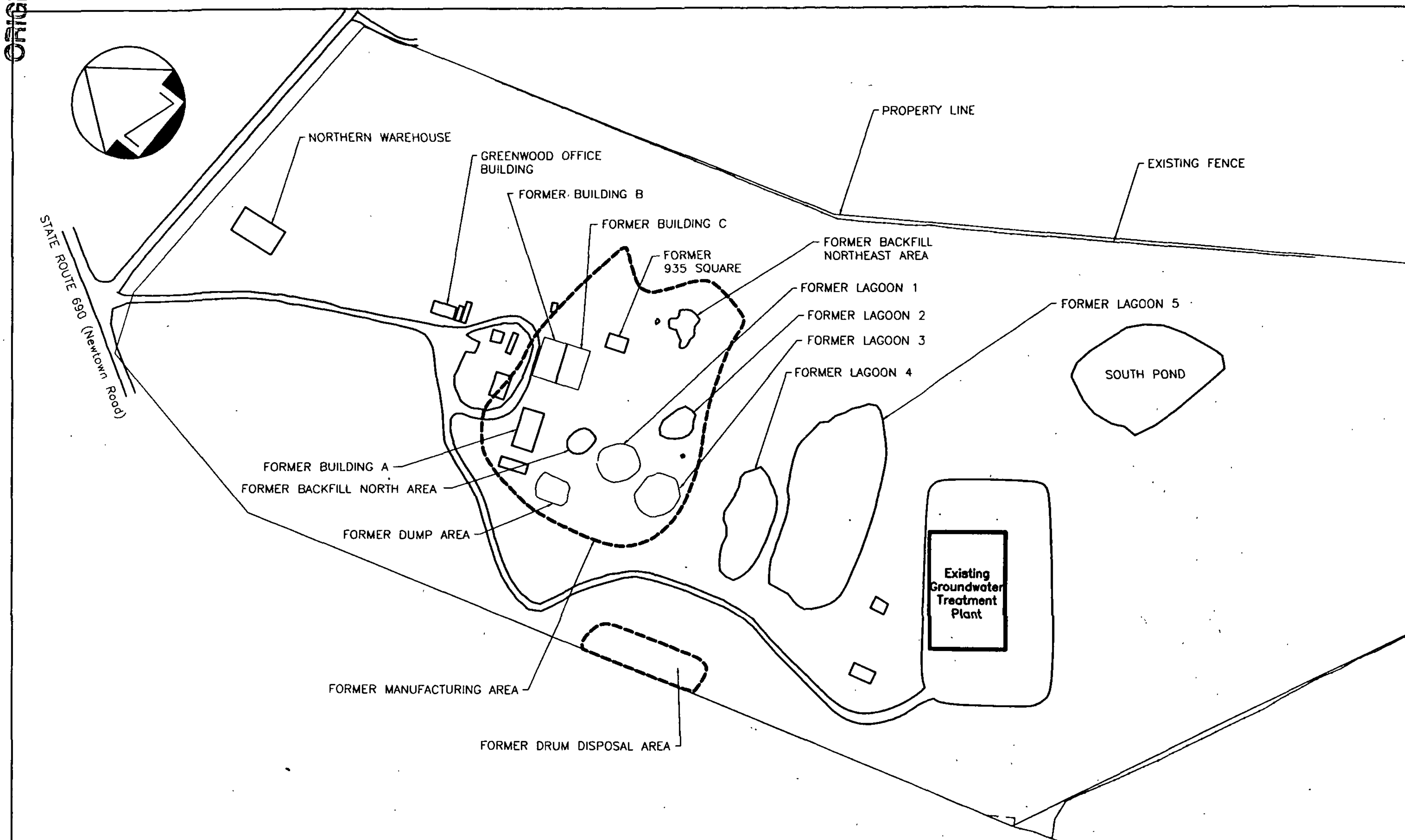


Figure 2
General Site Location Map



U.S. Environmental Protection Agency

GREENWOOD CHEMICAL SUPERFUND SITE

Albemarle County
Greenwood, Virginia

Figure 3
Historic Site Features

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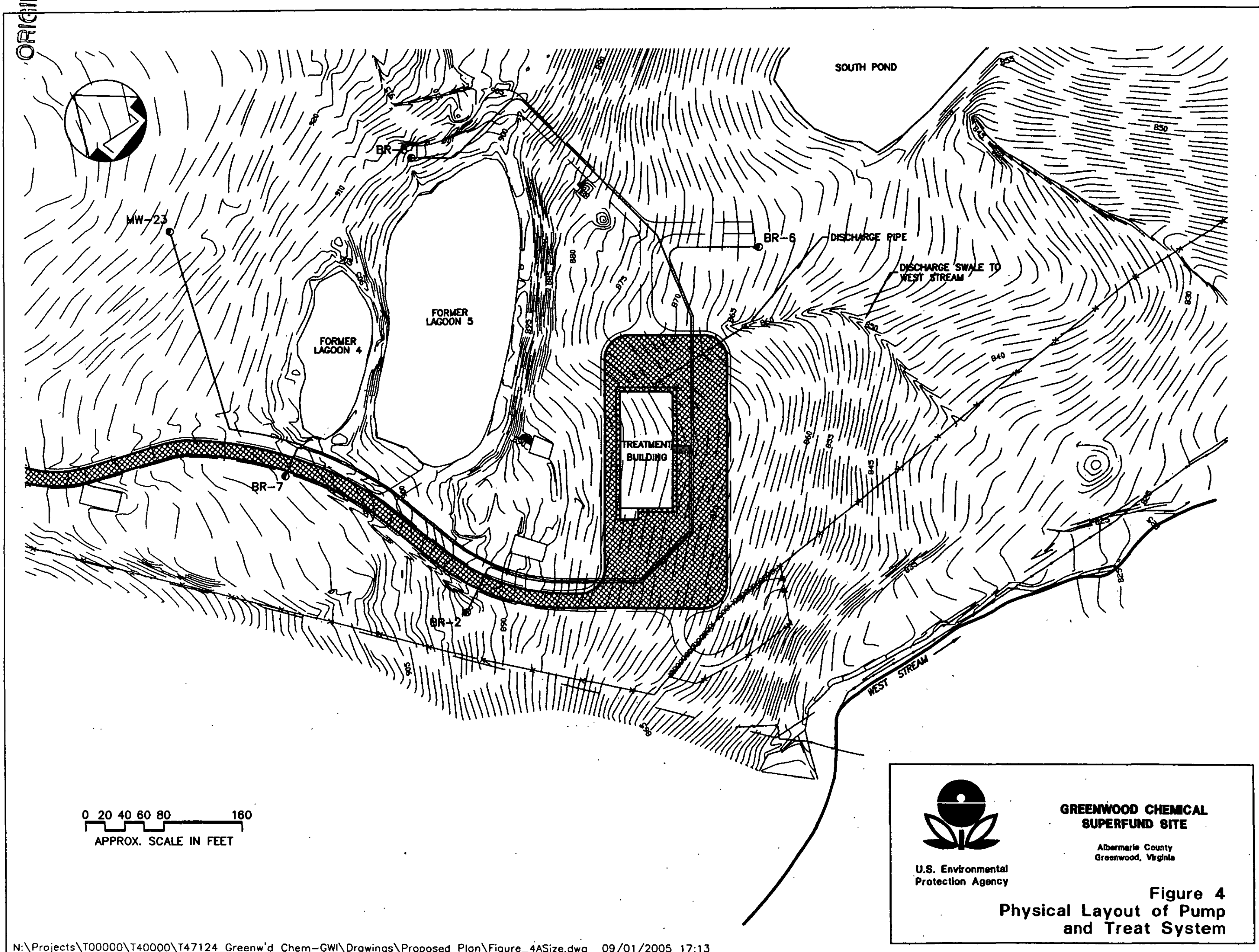

Figure 4
Physical Layout of Pump and Treat System

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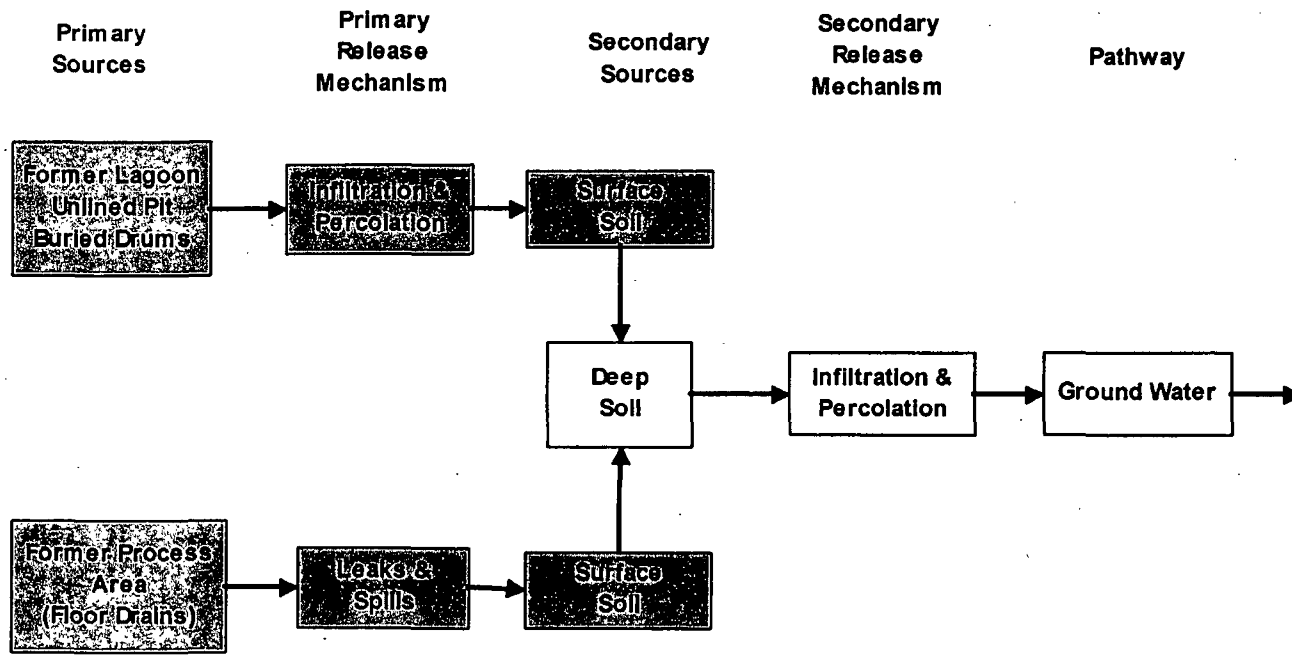
CONCEPTUAL SITE MODEL FOR CONTAMINATED GROUNDWATER
GREENWOOD CHEMICAL SITE, ALBEMARLE COUNTY, VIRGINIA



Receptor

Exposure Route	Adult Resident	Child Resident
Ingestion	X	X
Dermal (Bathing)		X
Vapor Inhalation (Showering)	X	

Key:

X This exposure route was evaluated in the human health risk assessment. The resident adult was assumed to be exposed to groundwater (as tap water) via the ingestion and inhalation (while showering) exposure routes. The resident child was assumed to be exposed to groundwater via the ingestion and inhalation (while bathing) exposure routes.

[shaded box] Note that all primary sources of contamination including the former lagoons, unlined pits, buried drums, surface soils, and former process have been remediated; only deep soil contamination remains on site.

U.S. Environmental Protection Agency

GREENWOOD CHEMICAL SUPERFUND SITE

Albermarle County
Greenwood, Virginia

Figure 5
Conceptual Site Model
For Contaminated Groundwater

ORIGINAL

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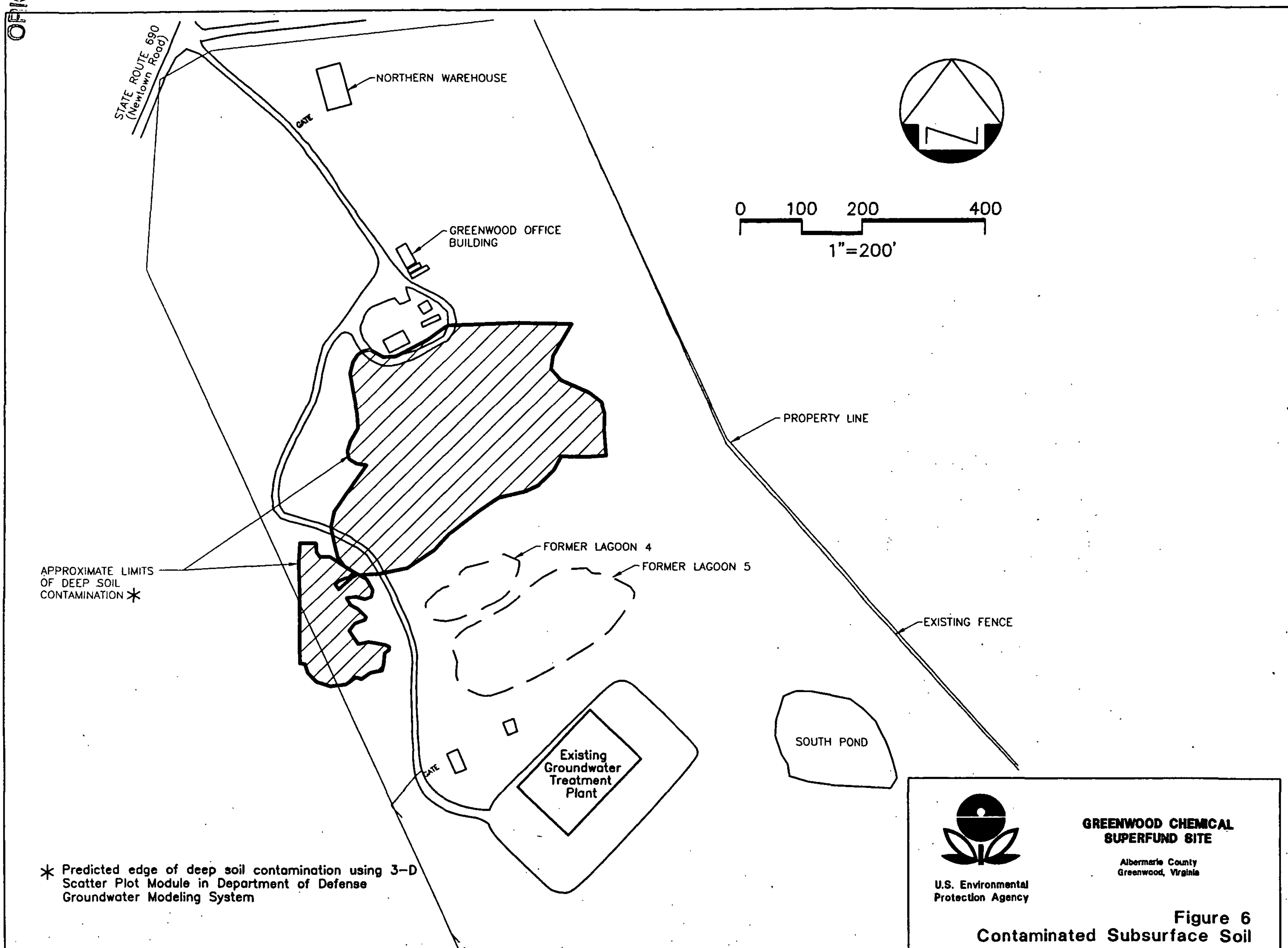

Figure 6
Contaminated Subsurface Soil

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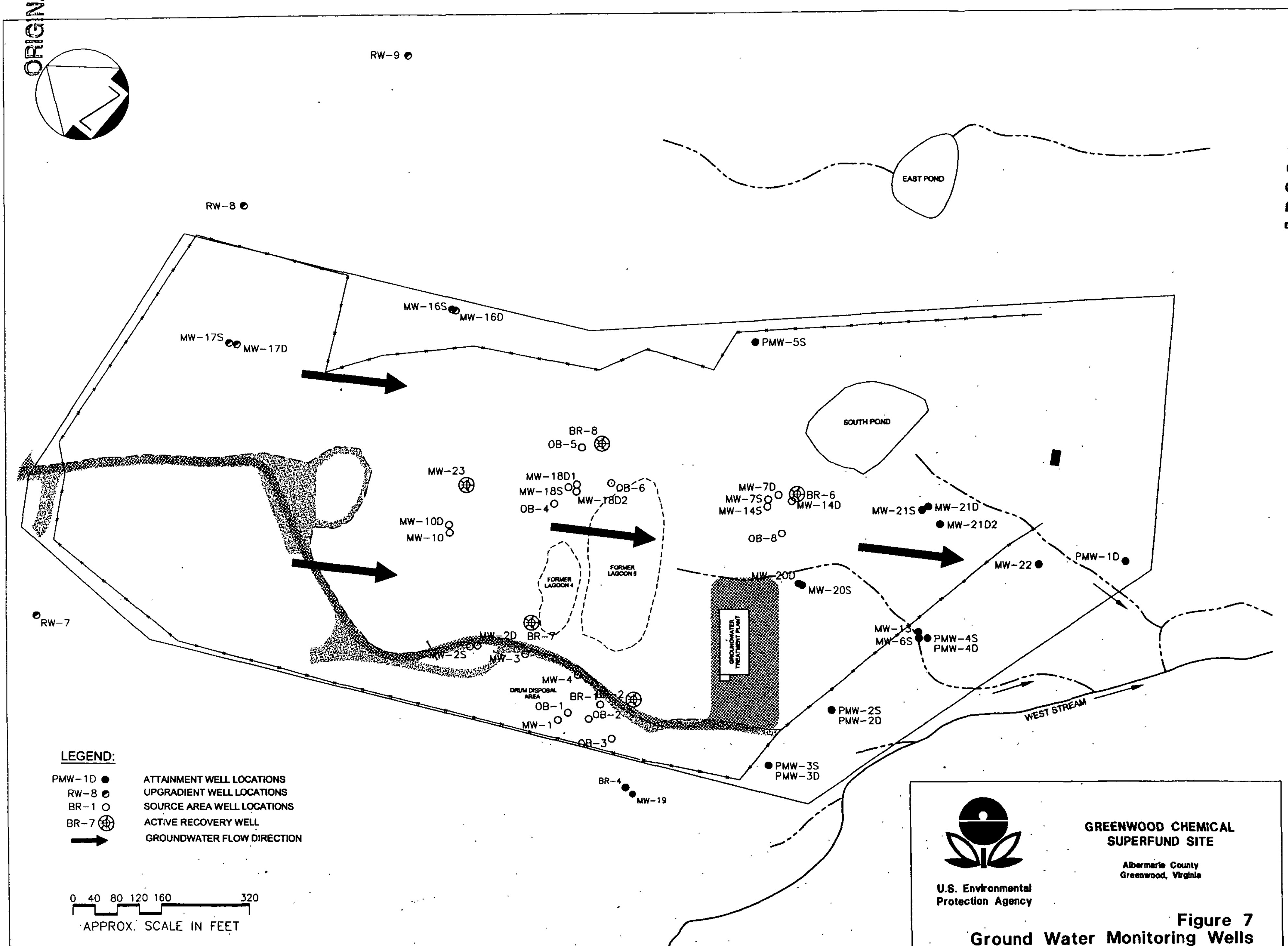

Figure 7
Ground Water Monitoring Wells

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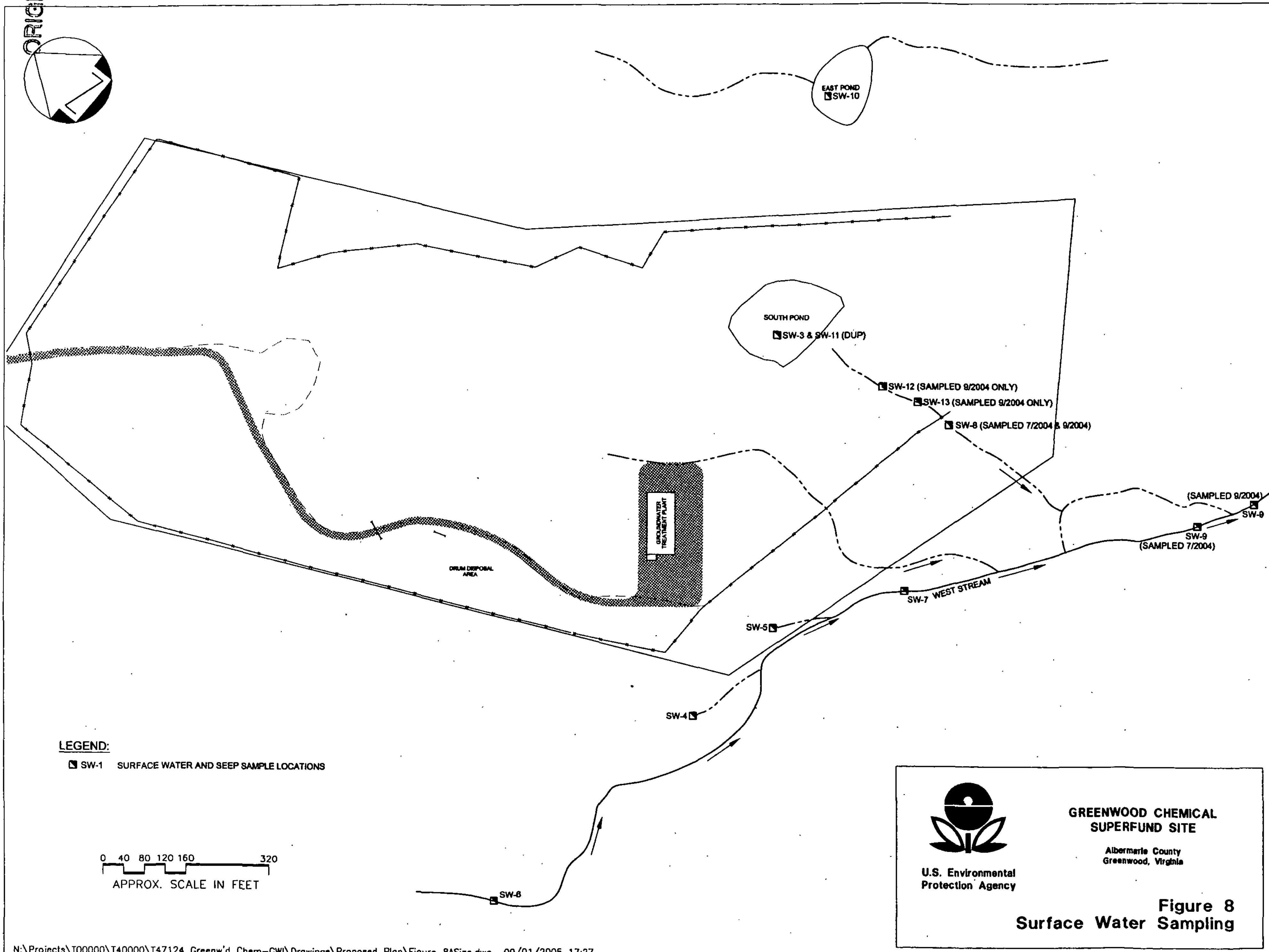

Figure 8
Surface Water Sampling

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ORIGINAL

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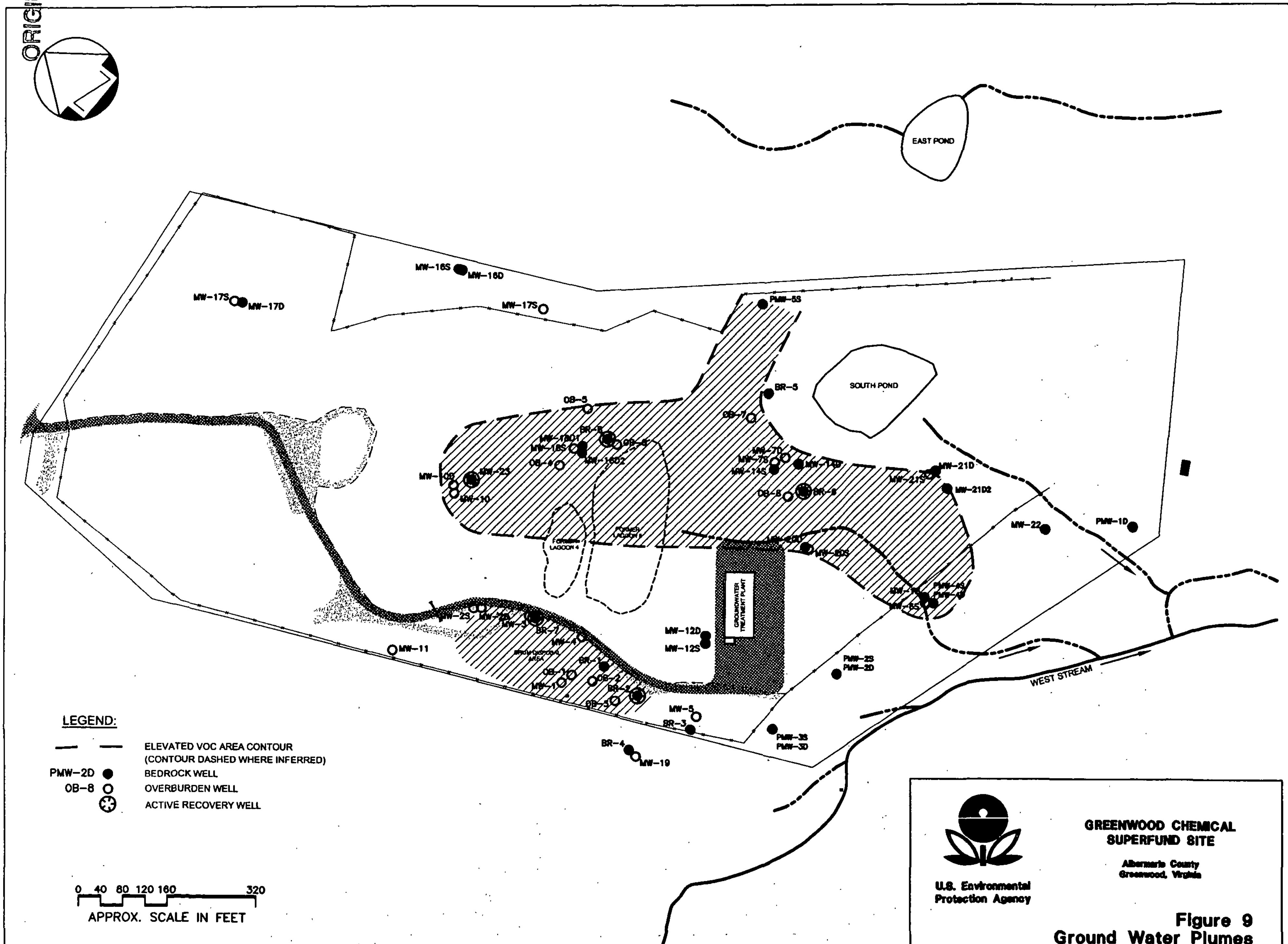

Figure 9
Ground Water Plumes

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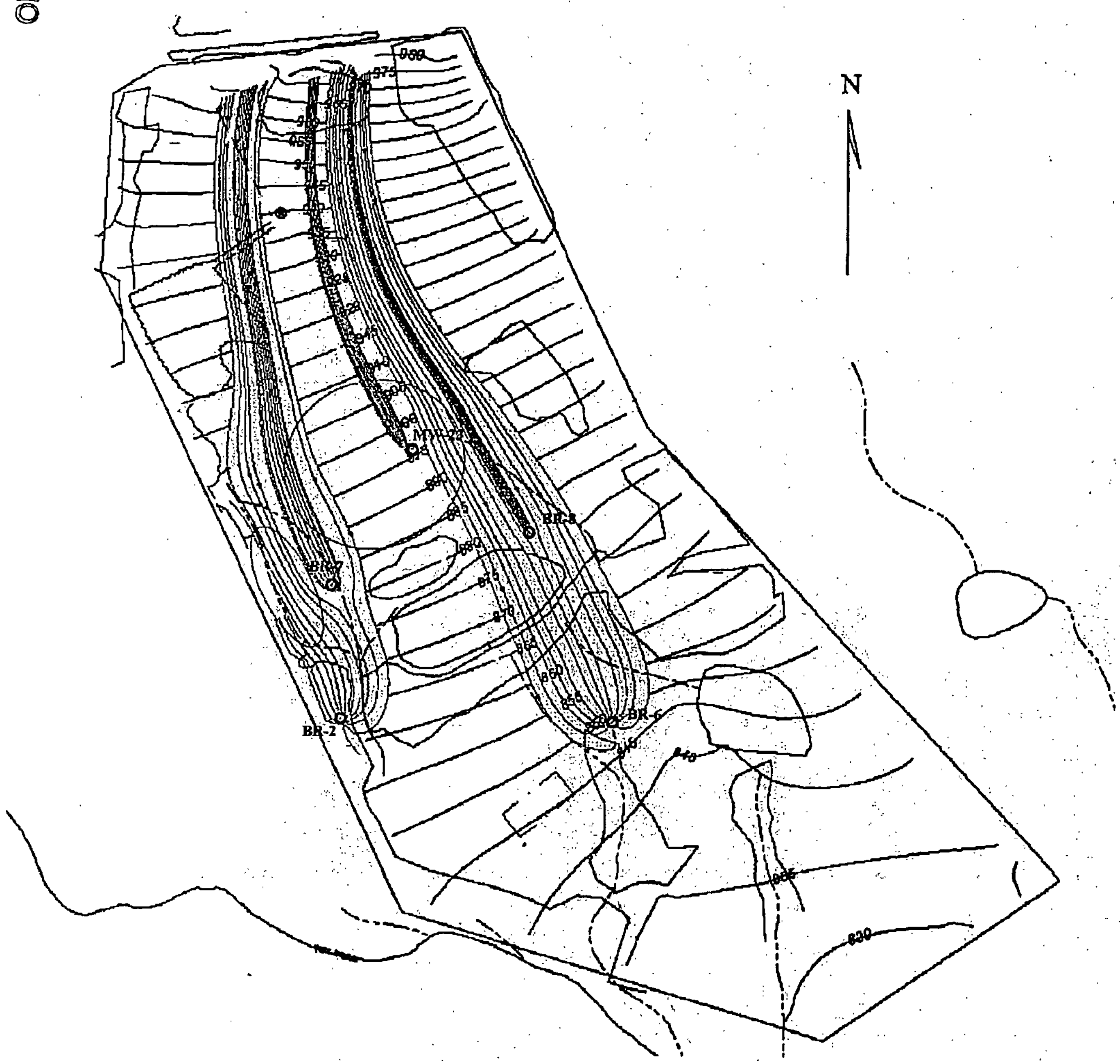

Known Source Areas of Contamination

Particle Path (1 year between arrows)

Recovery Well Location

Capture Zone

Pumping Rates

MW-23	1.5 gpm
BR-2	5.1 gpm
BR-6	3.8 gpm
BR-7	2.0 gpm
BR-8	0.5 gpm

U.S. Environmental Protection Agency

GREENWOOD CHEMICAL SUPERFUND SITE

Albermarle County
Greenwood, Virginia

Figure 10
Capture Zone Analyses
Existing Recovery Wells
Area Of Influence

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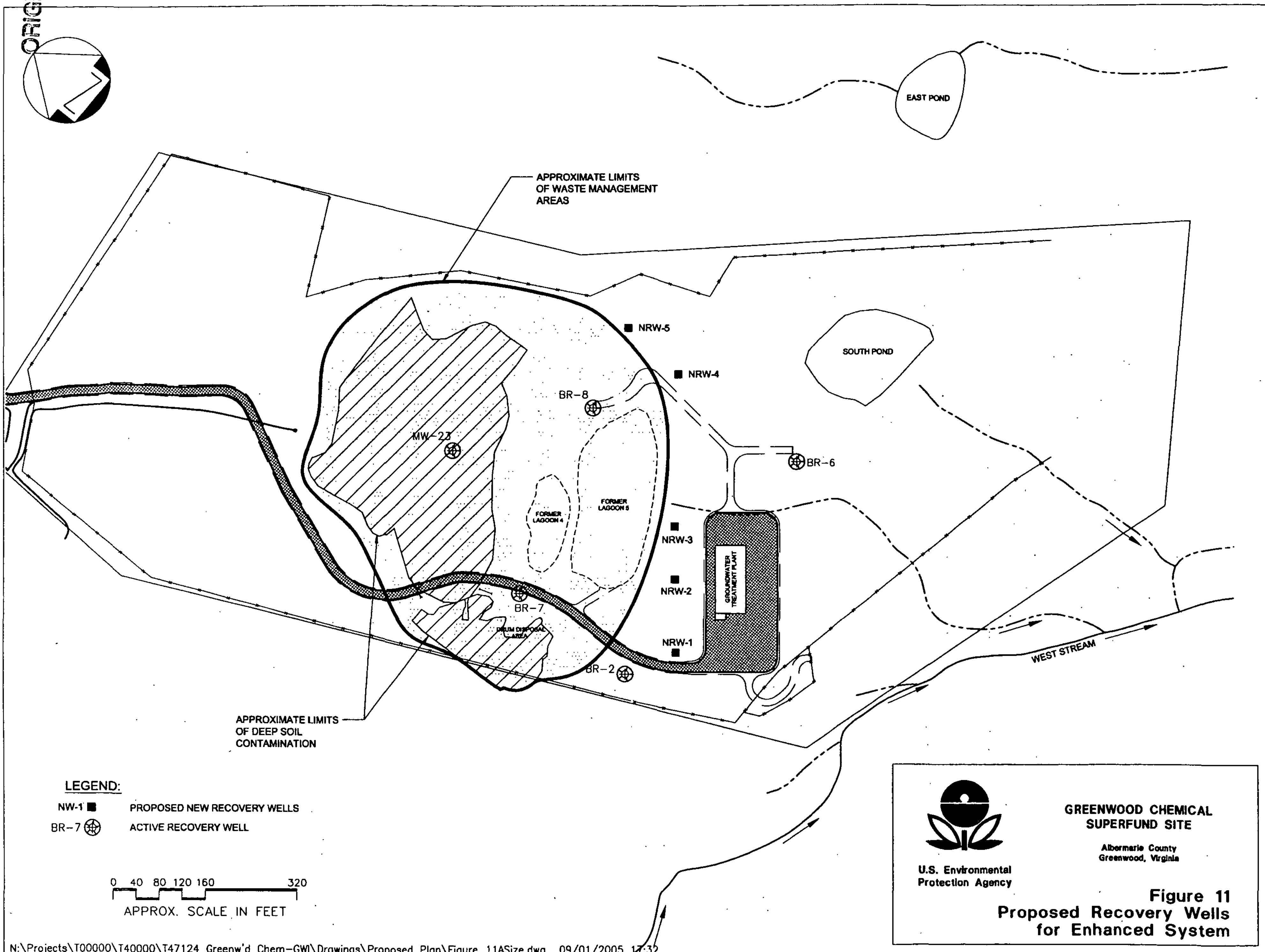

Figure 11
Proposed Recovery Wells
for Enhanced System

TABLES

Table 1
Summary of Ground Water Chemicals of Concern and Exposure Point Concentrations

Scenario Timeframe: Current/Future
Medium: Groundwater from Perimeter Wells
Exposure Medium: Groundwater

Exposure Point	Primary Chemical of Concern	Concentration Detected		Units	Frequency of Detection	Exposure Point Concentration	Exposure Point Concentration Units	Statistical Measure
		Min	Max					
All Perimeter Wells	1,2-Dichloroethane	5.3E-04	2.00E-02	mg/L	5 / 16	1.82E-02	mg/L	95% UCL
	bis(2-chloroethyl)Ether	5.40E-05	1.40E-03	mg/L	10 / 16	7.12E-04	mg/L	95% UCL
	Carbon Tetrachloride	3.10E-04	1.90E-02	mg/L	6 / 16	1.32E-02	mg/L	95% UCL
	Tetrachloroethene	8.80E-04	2.50E-02	mg/L	10 / 16	7.40E-03	mg/L	95% UCL
	Trichloroethene	8.10E-05	1.20E-01	mg/L	15 / 16	5.45E-02	mg/L	95% UCL
	Vinyl chloride	3.30E-04	4.8E-03	mg/L	4 / 16	1.92E-03	mg/L	95% UCL

Key

Min: Minimum detected concentration
Max: Maximum detected concentration
mg/L: Milligram per liter
95%UCL: 95-percent upper confidence limit

This table presents the chemicals of concern (COC) and exposure point concentrations (EPC) for the COCs that were determined to be "risk drivers" in groundwater when evaluated in the GI/FFS human health risk assessment dated June 2005. The exposure point concentration is the concentration used to estimate the exposure and risk for the COCs in the groundwater. Chemicals categorized as risk drivers have a noncancer hazard quotient greater than 1 or a cancer risk greater than 1E-06. Chemicals were also categorized as risk drivers if they contributed to a total cancer risk greater than 1E-4 or an HI=1 (based on target organs). The table includes the range of concentrations detected for the risk drivers, as well as the frequency of detection (i.e., the number of times the chemical was detected in the samples collected at the site), the EPC, and how the EPC was derived. The table indicates that trichloroethene was the most frequently detected risk driver in groundwater. The 95% UCL on the arithmetic mean was used as the EPC for all of the risk drivers.

ORIGINAL

Table 2A
Cancer Toxicity Data Summary

Pathway: Ingestion, Dermal

Primary Chemical of Concern	Oral Cancer Slope Factor	Dermal Cancer Slope Factor	Slope Factor Units	Weight of Evidence/ Cancer Guideline Description	Source	Date (MM/DD/YYYY)
1,2 Dichloroethane	9.1E-02	9.1E-02	$(mg/kg\text{-}day)^{-1}$	B2	IRIS	08/11/2004
bis(2-chloroethyl)Ether	1.1E+00	1.1E+00	$(mg/kg\text{-}day)^{-1}$	B2	IRIS	08/11/2004
Carbon tetrachloride	1.3E-01	1.3E-01	$(mg/kg\text{-}day)^{-1}$	B2	IRIS	08/11/2004
Tetrachloroethene	5.4E-01	5:4E-01	$(mg/kg\text{-}day)^{-1}$	–	R3-O	04/14/2004
Trichloroethene	4.0E-01	4.0E-01	$(mg/kg\text{-}day)^{-1}$	B1	NCEA	08/2001
Vinyl chloride	7.2E-01	7.2E-01	$(mg/kg\text{-}day)^{-1}$	–	R3	05/06/2001

Pathway: Inhalation

Primary Chemical of Concern	Unit Risk	Units	Inhalation Cancer Slope Factor	Units	Weight of Evidence/ Cancer Guideline Description	Source	Date (MM/DD/YYYY)
1,2 Dichloroethane	2.6E-05	$(\mu g/m^3)^{-1}$	9.1E-02	$(mg/kg\text{-}day)^{-1}$	B2	IRIS	08/11/2004
bis(2-chloroethyl)Ether	3.3E-04	$(\mu g/m^3)^{-1}$	1.1E+00	$(mg/kg\text{-}day)^{-1}$	B2	IRIS	08/11/2004
Carbon tetrachloride	1.5E-05	$(\mu g/m^3)^{-1}$	5.3E-02	$(mg/kg\text{-}day)^{-1}$	B2	IRIS	08/11/2004
Tetrachloroethene	–	$(\mu g/m^3)^{-1}$	2.0E-02	$(mg/kg\text{-}day)^{-1}$	–	R3-O	04/14/2004
Trichloroethene	–	$(\mu g/m^3)^{-1}$	4.0E-01	$(mg/kg\text{-}day)^{-1}$	B1	NCEA	08/2001
Vinyl chloride	4.4E-06	$(\mu g/m^3)^{-1}$	1.5E-02	$(mg/kg\text{-}day)^{-1}$	–	R3	05/06/2001

Key

–: No information available
IRIS: Integrated Risk Information System, U.S. EPA
NCEA: National Center for Environmental Assessment
R3: Region 3, U.S. EPA
R3-O: Source of toxicity value listed as "other" in the U.S. EPA Region 3 Risk-based Screening Concentration Table
$(mg/kg\text{-}day)^{-1}$: 1/Milligram per kilogram per day
$(\mu g/m^3)^{-1}$: 1/Microgram per cubic meter

EPA Group:

A Human carcinogen
B1 Probable human carcinogen - Indicates that limited human data are available
B2 Probable human carcinogen - Indicates sufficient evidence in animals and inadequate or no evidence in humans
C Possible human carcinogen
D Not classifiable as a human carcinogen
E Evidence of noncarcinogenicity

This table provides carcinogenic risk information, which is relevant to the chemicals of concern (COC) in groundwater. At this time, slope factors are not available for the dermal route of exposure. Thus, the dermal slope factors used in the risk assessment have been extrapolated from oral values. An adjustment factor is sometimes applied, and is dependent upon how well the chemical is absorbed via the oral route. Adjustments are particularly important for chemicals with less than 50% absorption via the ingestion route; however, adjustment is not necessary for the chemicals (that is, the risk drivers) evaluated for groundwater at this site. The oral cancer slope factors were used as the dermal carcinogenic slope factors.

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Table 2B
Non-Cancer Toxicity Data Summary

Pathway: Ingestion, Dermal

Primary Chemical of Concern	Chronic/ Subchronic	Oral RfD Value	Oral RfD Units	Dermal RfD	Dermal RfD Units	Primary Target Organ	Combined Uncertainty/ Modifying Factors	Sources of RfD:Target Organ	Dates of RfD:Target Organ (MM/DD/YYYY)
1,2-Dichloroethane	Chronic	2.0E-02	mg/kg-day	2.0E-02	mg/kg-day	Kidney	3,000	NCEA	10/31/2002
bis (2-chloroethyl) Ether	Chronic	–	–	–	–	–	–	–	–
Carbon tetrachloride	Chronic	7.0E-04	mg/kg-day	7.0E-04	mg/kg-day	Liver	1,000	IRIS	08/11/2004
Tetrachloroethene	Chronic	1.0E-02	mg/kg-day	1.0E-02	mg/kg-day	Liver/ Body Weight	1,000	IRIS	08/11/2004
Trichloroethene	Chronic	3.0E-04	mg/kg-day	3.0E-04	mg/kg-day	Liver/ Kidney/ Fetus	3,000	NCEA	08/31/2001
Vinyl chloride	Chronic	3.0E-03	mg/kg-day	3.0E-03	mg/kg-day	Liver	30	IRIS	08/11/2004

Pathway: Inhalation

Primary Chemical of Concern	Chronic/ Subchronic	Inhalation RfC	Inhalation RfC Units	Inhalation RfD	Inhalation RfD Units	Primary Target Organ	Combined Uncertainty/ Modifying Factors	Sources of RfC:RfD: Target Organ	Dates of RfD:RfC:Target Organ (MM/DD/YYYY)
1,2-Dichloroethane	Chronic	4.9E-03	mg/m³	1.4E-03	mg/kg-day	Liver	–	R3-N	04/14/2004
bis (2-chloroethyl) Ether	Chronic	–	–	–	–	–	–	–	–
Carbon tetrachloride	Chronic	2.0E-03	mg/m³	5.7E-04	mg/kg-day	Liver	3,000	NCEA	04/11/1994
Tetrachloroethene	Chronic	4.9E-01	mg/m³	1.4E-01	mg/kg-day	CNS	100	NCEA	06/27/1997
Trichloroethene	Chronic	4.0E-02	mg/m³	1.1E-02	mg/kg-day	CNS/ Liver/ Endocrine System	1,000	NCEA	08/31/2001
Vinyl chloride	Chronic	1.0E-01	mg/m³	2.9E-02	mg/kg-day	Liver	30	IRIS	08/11/2004

Key

–: No information available
CNS: Central nervous system
IRIS: Integrated Risk Information System, U.S. EPA
mg/kg-day: Milligram per kilogram per day
NCEA: National Center for Environmental Assessment
R3-N: Source of toxicity value listed as "NCEA" in the U.S. EPA Region 3 Risk-based Screening Concentration Table

This table provides non-carcinogenic risk information, which is relevant to the chemicals of concern (COC) in groundwater. The chronic toxicity data for these chemicals of concern have been used to develop oral reference doses (RfD) and inhalation reference concentrations (RfC). The available toxicity data indicate that target organs (or systems) affected by exposure to these chemicals of concern include the liver, kidney, body weight, developing fetus, (reproductive effect), central nervous system, and endocrine system. No oral RfD, inhalation RfC, or extrapolated inhalation RfD was available for bis(2-chloroethyl)ether. As was the case for the carcinogenic data, dermal RfDs can be extrapolated from the oral RfDs by applying an adjustment factor, as appropriate; however, adjustment is not necessary for the chemicals (that is, the risk drivers) evaluated for groundwater at this site.

Table 3A
Risk Characterization Summary – Carcinogens

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child

Medium	Exposure Medium	Exposure Point	Primary Chemical of Concern	Carcinogenic Risk			
				Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater	Groundwater	All Perimeter Wells	1,2-Dichloroethane	1.1E-05	N/A	2.5E-07	1.1E-05
			bis (2-chloroethyl) Ether	5.1E-06	N/A	6.7E-08	5.1E-06
			Carbon tetrachloride	1.1E-05	N/A	1.4E-06	1.2E-05
			Tetrachloroethene	2.6E-05	N/A	7.2E-06	3.3E-05
			Trichloroethene	1.4E-04	N/A	1.1E-05	1.5E-04
			Vinyl chloride	1.2E-04	N/A	3.8E-06	1.2E-04
						Groundwater Risk Total =	**3.45E-04†**
						Total Risk =	**3.45E-04†**

Key

N/A: Not applicable; this route of exposure is not applicable to this receptor. The future resident child was assumed to be exposed to groundwater via the ingestion pathway and the dermal pathway (that is, when bathing).

This table provides risk estimates for the significant routes of exposure to groundwater (as tap water). The significant routes of exposure for the child resident include ingestion of groundwater and dermal contact with groundwater during bathing. These risk estimates are based on a reasonable maximum exposure and were developed by taking into account various conservative assumptions about the frequency and duration of a child's exposure to groundwater, as well as the toxicity of the chemicals of concern (COC). The total risk from direct exposure to contaminated groundwater at this site to a future child resident is estimated to be 3.45E-04 (3.3E-04 for the risk drivers) . This risk levels indicates that if no clean-up action is taken, an individual would have an increased probability of about 1 in 2,900 of developing cancer as a result of site-related exposure to the COCs (that is, those chemicals of concern that contribute the majority of the cancer risk).

† This table only presents the six primary contaminants of concern; however, the Groundwater Risk Total and the Total Risk values are based on all the contaminants that were detected in the groundwater at the site. For more details on the risk calculations of the other (secondary) contaminants, the reader is referred to the Ground-Water Investigation and Focused Feasibility Study Report, Appendix C (Risk Assessment) dated June 2005.

ORIGINAL

Table 3B
Risk Characterization Summary – Carcinogens

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Primary Chemical of Concern	Carcinogenic Risk			
				Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater	Groundwater	All Perimeter Wells	1,2-Dichloroethane	1.6E-05	1.1E-06	N/A	1.7E-05
			bis (2-chloroethyl) Ether	7.4E-06	5.1E-07	N/A	7.9E-06
			Carbon tetrachloride	1.6E-05	4.5E-07	N/A	1.6E-05
			Tetrachloroethene	3.8E-05	9.6E-08	N/A	3.8E-05
			Trichloroethene	2.0E-04	1.4E-05	N/A	2.1E-04
			Vinyl chloride	1.3E-05	1.9E-08	N/A	1.3E-05
						Groundwater Risk Total =	**3.1E-04†**
						Total Risk =	**3.1E-04†**

Key

N/A: Not applicable; this route of exposure is not applicable to this receptor. The future resident adult was assumed to be exposed to groundwater via the ingestion pathway and the inhalation pathway (that is, when showering).

This table provides risk estimates for the significant routes of exposure to groundwater (as tap water). The significant routes of exposure for the adult resident include ingestion of groundwater and inhalation of volatiles in groundwater during showering. These risk estimates are based on a reasonable maximum exposure and were developed by taking into account various conservative assumptions about the frequency and duration of an adult's exposure to groundwater, as well as the toxicity of the chemicals of concern (COC). The total risk from direct exposure to contaminated groundwater at this site to a future adult resident is estimated to be 3.1E-04 (3E-04 for the risk drivers). This risk levels indicates that if no clean-up action is taken, an individual would have an increased probability of about 1 in 3226 of developing cancer as a result of site-related exposure to the COCs (that is, the risk drivers in groundwater).

† This table only presents the six primary contaminants of concern; however, the Groundwater Risk Total and the Total Risk values are based on all the contaminants that were detected in the groundwater at the site. For more details on the risk calculations of the other (secondary) contaminants, the reader is referred to the Ground-Water Investigation and Focused Feasibility Study Report, Appendix C Human Health Risk Assessment dated June 2005.

Table 4A
Risk Characterization Summary – Non-Carcinogens

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child

Medium	Exposure Medium	Exposure Point	Primary Chemical of Concern	Primary Target Organ	Non-Carcinogenic Hazard Quotient			
					Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater	Groundwater	All Perimeter Wells	1,2-Dichloroethane	Kidney	7.0E-02	N/A	1.6E-03	7.2E-02
			bis (2-chloroethyl) Ether	–	–	–	–	–
			Carbon tetrachloride	Liver	1.4E+00	N/A	1.8E-01	1.6E+00
			Tetrachloroethene	Liver/ Body Weight	5.7E-02	N/A	1.6E-02	7.3E-02
			Trichloroethene	Liver/ Kidney/ Fetus	1.4E+01	N/A	1.1E+00	1.5E+01
			Vinyl chloride	Liver	4.9E-02	N/A	1.6E-03	5.1E-02
							Groundwater Hazard Total =	**1.7E+01†**
							Receptor Hazard Index =	**1.7E+01†**
							Liver Hazard Index =	**1.7E+01**
							Kidney Hazard Index =	**1.5E+01**

Key

–: Toxicity criteria are not available to quantitatively address this route of exposure.
N/A: Not applicable; this route of exposure is not applicable to this receptor. The future resident child was assumed to be exposed to groundwater via the ingestion pathway and the dermal pathway (that is, when bathing).

This table provides hazard quotients (HQ) for each route of exposure and the hazard index (HI; sum of the HQs) for all routes of exposure for a future child resident. The Risk Assessment Guidance for Superfund (RAGS) states that, generally, a HI greater than 1 indicates the potential for adverse noncancer effects. The estimated HI of 17 indicates that the potential for adverse noncancer effects could occur from exposure to contaminated groundwater containing the chemicals of concern.

† This table only presents the six primary contaminants of concern; however, the Groundwater Hazard Total and the Receptor Hazard Index values are based on all the contaminants that were detected in the groundwater at the site. For more details on the risk calculations of the other (secondary) contaminants, the reader is referred to the Ground-Water Investigation and Focused Feasibility Study Report, Appendix C Human Health Risk Assessment dated June 2005.

ORIGINAL

Table 4B
Risk Characterization Summary – Non-Carcinogens

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Primary Chemical of Concern	Primary Target Organ	Non-Carcinogenic Hazard Quotient			
					Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater	Groundwater	All Perimeter Wells	1,2-Dichloroethane	Kidney Liver	2.5E-02	2.5E-02	N/A	5.0E-02
			bis (2-chloroethyl) Ether	–	–	–	–	–
			Carbon tetrachloride	Liver	5.2E-01	4.3E-02	N/A	5.6E-01
			Tetrachloroethene	Liver/ Body Weight/ CNS	2.0E-02	9.9E-05	N/A	2.0E-02
			Trichloroethene	CNS/Liver Kidney/ Fetus/ Endocrine System	5.0E00	9.0E-03	N/A	5.0E+00
			Vinyl chloride	Liver	1.8E-02	1.3E-04	N/A	1.8E-02
							Groundwater Hazard Total =	**5.8E+00†**
							Receptor Hazard Index =	**5.8E+00†**
							Liver Hazard Index =	**5.6E+00**
							Kidney Hazard Index =	**5.1E+00**

Key

–: Toxicity criteria are not available to quantitatively address this route of exposure.
N/A: Not applicable; this route of exposure is not applicable to this receptor. The future resident adult was assumed to be exposed to groundwater via the ingestion pathway and the inhalation pathway (that is, when showering).

This table provides hazard quotients (HQ) for each route of exposure and the hazard index (HI; sum of the HQs) for all routes of exposure for a future adult resident. The Risk Assessment Guidance for Superfund (RAGS) states that, generally, a HI greater than 1 indicates the potential for adverse noncancer effects. The estimated HI of 5.8 indicates that the potential for adverse noncancer effects could occur from exposure to contaminated groundwater containing the chemicals of concern.

† This table only presents the six primary contaminants of concern; however, the Groundwater Hazard Total and the Receptor Hazard Index values are based on all the contaminants that were detected in the groundwater at the site. For more details on the risk calculations of the other (secondary) contaminants, the reader is referred to the Ground-Water Investigation and Focused Feasibility Study Report, Appendix C Human Health Risk Assessment dated June 2005.

ORIGINAL

Note: Tables 5, 7 and 9 embedded in text

TABLE 6

KEY ARARs FOR GREENWOOD CHEMICAL REMEDIATION ALTERNATIVES

Except where noted, the following are ARARs for all alternatives except No-Action.

ARAR OR TBC	LEGAL CITATION	CLASSIFICATION	SUMMARY OF REQUIREMENT	FURTHER SPECIFICATION AND/OR DETAILS REGARDING ARARs IN THE CONTEXT OF REMEDIATION
Safe Drinking Water Act: Maximum Contaminant Levels and Maximum Contaminant Level Goals	42 U.S.C. § 300(f); 40 C.F.R. §§ 141.11-16; 40 C.F. R. §§ 141.50-52	Relevant and Appropriate	MCLs are enforceable standards for public drinking water supply systems which have at least 15 service connections or are used by at least 25 persons. MCLGs are non-enforceable health-based goals for similar systems. These requirements are not directly applicable since ground water in the vicinity of the Site is used as a private drinking water supply. However, under the circumstances of this Site, MCLs and MCLGs are relevant and appropriate requirements which were considered in establishing ground water cleanup levels.	EPA regulation establishes that, where relevant and appropriate, MCLGs set at levels above zero will be attained at CERCLA sites and that, where the MCLG is set at zero, the MCL will be attained. The MCLs/non-zero MCLGs will be met in ground water within the "area of attainment." The more stringent of the Federal or State MCLGs/MCLs will be attained.
Virginia Waterworks Regulation	12 VAC 5-590-440, Tables 2.2 and 2.3	Relevant and Appropriate		
Clean Water Act: Federal Ambient Water Quality Criteria	33 U.S.C. § 1314	Relevant and Appropriate	These are non-enforceable guidelines published pursuant to Section 304 of the Clean Water Act that set the concentrations of pollutants which are considered adequate to protect human health and aquatic life.	All Commonwealth waters are designated for recreational uses, propagation and growth of aquatic life, wildlife, and the production of edible and marketable natural resources. The standards for freshwater aquatic life and non-public water supplies set forth in the Commonwealth's water quality standards will be attained. Those Federal Water Quality Criteria which deal with these designated uses will be attained where a state standard does not exist.
Virginia Water Quality Standards	9 VAC 25-260-5 to 550	Relevant and Appropriate	These are criteria to maintain surface water quality.	

ARAR or TBC	Legal Citation	Classification	Summary of Requirement	Further Specification and/or Details Regarding ARARs in the Context of Remediation
Virginia Surface Water Antidegradation Policy	9 VAC 25-260-30	TBC	Provides that, at a minimum, the level of water quality necessary to protect existing uses shall be maintained and protected. Where water quality exceeds water quality standards, that quality must be maintained and protected, with certain exceptions.	These standards will be attained. The surface waters at issue have not been designated as providing "exceptional environmental settings and exceptional aquatic communities or exceptional recreational opportunities" within the meaning of 9 VAC 25-260-30(A)(3).
Virginia Anti-Degradation Policy for Groundwater	9 VAC 25-280-30	TBC	Provides that if the concentration of any constituent in groundwater is less than the limit set forth in Virginia's groundwater standards, the "natural quality" for the constituent shall be maintained. Further requires that "natural quality" shall be maintained for constituents for which Virginia has not set standards. Variances are permissible under certain circumstances.	With respect to each contaminant of concern for which no Virginia groundwater standard exists (e.g. vinyl chloride), the remedial action will attain "natural quality," provided that this level is above detection level and attaining such level is not technologically impracticable.
Clean Water Act: National Discharge Elimination System Requirements	40 C.F.R. Part 122	Applicable	These are enforceable standards for direct discharge of pollutants to surface waters of the United States.	The more stringent of the Federal and State substantive requirements will be attained. No permits shall be required for on-site discharges.
Virginia Pollutant Discharge Elimination System	9 VAC 25-31-10 to 940	Applicable	These are standards for discharging pollutants into surface waters of the State	
Virginia Hazardous Waste Regulations Identification Generation Transportation	9 VAC20-60-12 to 1505 9 VAC 20-60-261 9 VAC 20-60-262 9 VAC 20-60-263	 Applicable Applicable Applicable	These regulations establish standards for the identification, generation, transportation and disposal of hazardous waste.	The substantive requirements of these regulations will be attained in the event RCRA hazardous waste is identified.

ARAR OR TBC	LEGAL CITATION	CLASSIFICATION	SUMMARY OF REQUIREMENT	FURTHER SPECIFICATION AND/OR DETAILS REGARDING ARARS IN THE CONTEXT OF REMEDIATION
Virginia Regulations Governing the Transportation of Hazardous Materials	9 VAC 20-110-10 to 130	Applicable	These regulations establish standards for the transportation of hazardous materials	The substantive requirements of these regulations will be attained.
Virginia Solid Waste Management Regulations:	9 VAC 20-80-10 to 790	Applicable	These regulations govern the handling, storage, treatment, and disposal of solid waste	The substantive requirements of these regulations will be attained.
Virginia Erosion and Sediment Control Regulations	4 VAC 50-30-10 to 110	Applicable	Requires preparation of an erosion and sediment control plan for activities involving land clearing, grading and other earth disturbances and establishes erosion and sediment control criteria	Alternatives 3, 4 and 4A would require significant earth disturbances. The substantive requirements of these regulations will be attained. No permits are required.
Virginia Stormwater Management Regulations	4 VAC 3-20-10; 60(A)-(G), (J)-(L); 71; 81(A); and 85(A), (B), and (D).	Applicable	These regulations establish criteria for management of storm water within the Commonwealth.	The substantive requirements of these regulations will be attained. No permits are required.
Virginia Ambient Air Quality Standards: Particulate Matter	9 VAC 5-30-60	Applicable	These regulations establish standards for particulate matter in ambient air.	The substantive requirements of these regulations will be attained during construction activities. No permits are required.
Virginia Air Regulations: New and Modified Stationary Sources: Compliance and Standards of Performance for Visible Emissions and Fugitive Dust/Emissions	9 VAC 5-50-20; 60 to 120	Applicable	These regulations establish standards for visible and fugitive dust emissions from new/modified stationary sources.	The substantive requirements of these regulations will be attained during construction activities. No permits are required.

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Table 8 - Cost Estimate Summary For Selected Remedy

Capital Costs For Chosen Remedy

	Description	Quantity	Unit	Unit Cost	Cost
1.	Existing pump and treat groundwater treatment plant is adequate and assume existing process configuration is sufficient	_	LS	$0.00	$0
2.	Clearing and road construction for drill rig access	_	LS	$13,000.00	$13,000
3.	Construction of six new recovery wells	6	EA	$31,000.00	$186,000
4.	Construct five additional monitoring wells	5	EA	$5,000.00	$25,000
5.	Two week pump test of all recovery wells	1	LS	$20,000.00	$20,000
6.	Installation of pumps in the five new recovery wells	5	EA	$5,000.00	$25,000
7.	Piping to connect the new recovery wells to the GWTP (1"-dia Sch. 40 PVC pipe)	2,000	LF	$2.50	$5,000
8.	Trenching to connect pipes to GWTP (3-ft wide and 4-ft deep)	1,500	LF	$12.00	$18,000
9.	Remedial design	_	LS		$35,500
Subtotal					**$292,000**
Contingency Allowances (15%)					$43,800
Project Management and Support (10%)					$29,200
Total Capital Cost					**$365,000**

Annual Operation And Maintenance Costs For Chosen Remedy

	Description	Quantity	Unit	Unit Cost
1.	Base fee for plant operation (including labor)	1	Annual	$200,000.00
2.	Electricity for 30 kW UV/OX and other equipment	1	Annual	$40,000.00
3.	Chemicals including caustic, acid, hydrogen peroxide, and ferric chloride	1	Annual	$20,000.00
4.	Routine maintenance, including spare parts, cleaning, etc.	1	Annual	$30,000.00
5.	Replacement of liquid phase GAC	1	Annual	$18,000.00
6.	O&M sampling and VPDES sampling analytical costs	1	Annual	$30,000.00
7.	Waste sludge disposal costs	1	Annual	$5,000.00
8.	Groundwater monitoring analytical costs	1	Annual	$70,000.00
9.	Project management, technical support, etc.	1	Annual	$50,000.00
		Total Annual O&M Cost		**$463,000.00**

Table 8 (con't) - Summary Of Present Worth Analysis

Year	Capital Cost	Annual O&M Cost	Total Cost	Discount Factor (7%)	Present Worth
0	$ 365,000.00		$ 365,000.0	1.000	$ 365,000
1		$463,000	$ 463,000.0	0.935	$ 432,710
2		$463,000	$ 463,000.0	0.873	$ 404,402
3		$463,000	$ 463,000.0	0.816	$ 377,946
4		$463,000	$ 463,000.0	0.763	$ 353,220
5		$463,000	$ 463,000.0	0.713	$ 330,113
6		$463,000	$ 463,000.0	0.666	$ 308,516
7		$463,000	$ 463,000.0	0.623	$ 288,333
8		$463,000	$ 463,000.0	0.582	$ 269,470
9		$463,000	$ 463,000.0	0.544	$ 251,841
10		$463,000	$ 463,000.0	0.508	$ 235,366
11		$463,000	$ 463,000.0	0.475	$ 219,968
12		$463,000	$ 463,000.0	0.444	$ 205,578
13		$463,000	$ 463,000.0	0.415	$ 192,129
14		$463,000	$ 463,000.0	0.388	$ 179,559
15		$463,000	$ 463,000.0	0.362	$ 167,813
16		$463,000	$ 463,000.0	0.339	$ 156,834
17		$463,000	$ 463,000.0	0.317	$ 146,574
18		$463,000	$ 463,000.0	0.296	$ 136,985
19		$463,000	$ 463,000.0	0.277	$ 128,023
20		$463,000	$ 463,000.0	0.258	$ 119,648
21		$463,000	$ 463,000.0	0.242	$ 111,821
22		$463,000	$ 463,000.0	0.226	$ 104,505
23		$463,000	$ 463,000.0	0.211	$ 97,668
24		$463,000	$ 463,000.0	0.197	$ 91,279
25		$463,000	$ 463,000.0	0.184	$ 85,307
26		$463,000	$ 463,000.0	0.172	$ 79,727
27		$463,000	$ 463,000.0	0.161	$ 74,511
28		$463,000	$ 463,000.0	0.150	$ 69,636
29		$463,000	$ 463,000.0	0.141	$ 65,081
30		$463,000	$ 463,000.0	0.131	$ 60,823
TOTALS	$ 365,000.00	$ 13,890,000	$ 14,255,000		**$ 6,110,400**

Total Present Worth Cost **$ 6,110,400**

Notes

1. Groundwater P&T costs based on actual annual operational costs of the from 3/02 to 3/03.
2. Capital Cost estimates are not discounted because the construction work will be performed in the first year.
3. O&M costs are reported as present worth estimates given 7% discount rate for a 30 year duration.
4. Five new recover wells pumping a total of 13 gpm (three @ 3gpm and two @ 2gpm each) is assumed to be sufficient for capture.
5. Capture zones for the new wells will be defined based on two week pump tests conducted in a staggered manner.
6. Five additional monitoring wells will be required to define the capture zones of the newly installed recovery wells.
7. Capital and O&M costs based on existing well drilling and O&M data, professional judgment, and based on telephonic quotes from vendors.
8. Cost estimate based on EPA Manual EPA 540-R-00-002 guidance document.
9. LS = Lump Sum; LF = Linear Foot; SY = Square Yard; CY = Cubic Yard

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EXHIBIT

EXHIBIT 1

How Did EPA Develop Deep Soil Preliminary Remediation Goals ("PRGs") and Estimate the Volume of Soils To Be Excavated?

Recognizing that hazardous substances in deep subsurface soil represents a continuing source of contamination to ground water, the 2002 FFS considered the possibility of a cleanup option which would remove enough contaminated deep soil such that ground water could be restored to safe drinking water standards without the need to operate the ground water pump and treatment system (Alternatives 4 and 4A in this Record of Decision). The following discussion summarizes the process EPA used to estimate the amount of contaminated soil which would need to be removed to eliminate the continued leaching of unacceptably high concentrations of hazardous substances to the ground water.

Development of Deep Soil Preliminary Remediation Goals

Site-specific cleanup goals for subsurface soil were initially developed so that ground water would not be adversely impacted by hazardous substances leaching from those soils. For the purposes of establishing these goals, it was assumed that a drinking water well could be installed and safely operated at the Site boundary, and that no other ground water containment system (i.e., the existing pump and treat system, or a subsurface cut off wall) would be operated. Beginning with chemical-specific cleanup levels[1] that would need to be met in the ground water at the Site boundary, EPA used a model to calculate a chemical-specific soil cleanup level for each contaminant in deep soil. These chemical-specific soil cleanup levels were calculated using a combination of leach testing and a dilution/attenuation factor ("DAF"). The leach testing method utilized – the Synthetic Precipitation Leaching Procedure ("SPLP") – was designed to determine the mobility of both organic compounds and metals present in solids, such as soils. In this case, the primary concern was movement of hazardous substances from the contaminated subsurface soil to the ground water. A DAF of 20 was used to account for the reduction in contaminant concentrations in the ground water that would occur naturally as the ground water flows from the contaminated soils to the property boundary.

The PRGs shown in Table 1 represent the cleanup levels for deep soil which would theoretically lead to ground water safe to drink at the property boundary of the Site without the need for a ground water containment system.

Development of Deep Soil Volumetric Estimates

The deep soil PRGs were used to generate the soil volume estimate presented in Table 2. The 2002 FFS utilized a mathematical computer model[2] along with site-specific information – such as deep soil sampling results – and the deep soil PRGs discussed above to estimate the area of deep soils which have elevated levels of contamination and constitute an unacceptable source to the ground water (See Figure 6 in the Record of Decision). Volume estimates for deep contaminated soils were calculated based on the following factors:

1. Manufacturing Area: The areal extent was calculated by combining the perimeter of the overlapping areas of organic and inorganic soil contamination (approximately 3.0 acres). An average combined depth of 20 feet was selected for estimating the soil volume.

2. Drum Disposal Area: The areal extent was calculated by combining the perimeter of the overlapping areas of organic and inorganic soil contamination (approximately 0.5 acres). An average depth of 30 feet was selected for estimating the soil volume.

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[1] The chemical-specific cleanup levels utilized at the property boundary were MCLs, where available, or health-based limits listed in EPA's Soil Screening Level User's Guide (1996).

[2] The 3-D Scatter Point module in "The Department of Defense Ground Water Modeling System" (2001)

The volumes of deep soil exceeding PRGs estimated in this fashion are conservative given the assumption that the entire vertical thickness of the deep soil is uniformly contaminated.

Table 1
Subsurface Soil Preliminary Remediation Goals (mg/kg)

Contaminant of Concern	Deep Soils PRG to Protect Ground Water (mg/kg)	Maximum Concentration Detected (mg/kg)	
		Drum Disposal Area	Manufacturing Area
4-Choroanaline	2	32	48
Arsenic	400	1050	7120
Benzene	2.2	4.3	3.5
Bis(2-ethylhexyl) phthalate	0.3	0.9	0.9
Chlorobenzene	16.6	17	23
Free Cyanide[a]	14.6	80.3	1,000
Naphthalene	400	1780	130
Tetrachloroethylene	2.4	8.2	4.5
Tetrahydrofuran	0.4	Not Detected	9,000
Toluene	600	5,900	620
Trichloroethylene	10	Not Detected	50

[a] Free Cyanide was measured as total cyanide

Table 2
Volume Estimates for Areas of COC Contamination Above Ground Water PRG[1]

Area (Name)	Area (Acres)	Volume (yds^3)
Manufacturing Area	3.0	92,907
Drum Disposal Area	0.5	23,648
Total (entire Site)	3.50	116,555

Note: The estimated soil volumes do not include the approximately 11,000 yds^3 clean fill which was used to replace contaminated soils previously excavated during the OU-1 remedial action and otherwise grade the former manufacturing area.

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RESPONSIVENESS SUMMARY
FOR THE PROPOSED REMEDIAL ACTION PLAN
FOR THE GREENWOOD CHEMICAL SUPERFUND SITE
OPERABLE UNITS TWO & FOUR

NEWTOWN, ALBEMARLE COUNTY, VIRGINIA

Public Comment Period
June 23, 2005 to July 22, 2005

Overview

On June 22, 2005 EPAreleased the Proposed Remedial Action Plan ("Proposed Plan") for Operable Units Two & Four of the Greenwood Chemical Superfund Site ("Site"), and announced the opening of the 30-day public comment period. On July 6, 2005 EPA and VDEQ held a public meeting in Greenwood to present the Proposed Plan to the local community and to seek comment. At this meeting, representatives from EPA and the VDEQ discussed the site history, environmental investigations, feasibility studies, proposed response actions for OU-2 and OU-4 and answered general questions about Site conditions.

The Proposed Plan detailed EPA's preferred alternatives to clean up the residual contamination at the Site, giving consideration to the following nine evaluation criteria:

Threshold Criteria

- Overall protection of human health and the environment
- Compliance with Federal, state, and local environmental and health laws

Balancing Criteria

- Long-term effectiveness and permanence
- Reduction of mobility, toxicity, or volume of contaminants through treatment
- Short-term effectiveness
- Implementability
- Cost

Modifying Criteria

- State acceptance
- Community acceptance

EPA carefully considered state and community comments on the clean-up alternatives before reaching the final decision regarding the remediation plan. EPA's Record of Decision ("ROD") details EPA's final clean-up decision.

EPA's Selected Remedy is summarized below. Based on current information, the remedy selected provides the best balance among the alternatives considered with respect to the nine evaluation criteria EPA used to evaluate each alternative. EPA's Selected Remedy addresses deep soil contamination and the potential for future exposure to contaminated groundwater.

The Selected Remedy includes the following components:

- Soil cover over the former drum disposal and manufacturing areas
- Enhanced ground water pump and treat system to prevent migration of contaminated ground water to the area of attainment

- Treatment of recovered ground water to achieve VPDES discharge standards prior to discharge to on-Site stream
- Long-term ground water monitoring
- 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 ground water from the aquifer beneath the Site for use as a potable water source; any interference with the ground water extractions wells, treatment system, and related equipment; and any removal of the soil cover without written permission of VDEQ, and EPA as appropriate.

This Responsiveness Summary provides a summary of issues raised during the public comment period, including comments made during the July 6, 2005 public meeting. All verbal and written comments received from the community were supportive of the cleanup alternative EPA had identified as its preferred option. Commenters included area residents, representatives of a citizens groups and local government.

1. A citizen asked EPA to discuss any potential downsides to the Selected Remedy.

EPA Response: When balanced against the nine criteria and compared to each of the other cleanup options evaluated, EPA believes that the Selected Remedy represents the best response for the site. However, the Agency does recognize that the Selected Remedy does include containment of hazardous substances in the deep source area, and thus will result in contamination remaining onsite. Thus long-term involvement of EPA and the Commonwealth of Virginia will be required to operate the pump and treat system and confirm that the property is not being used in a manner inconsistent with the remedy. It should be noted that each of the alternatives considered recognized that some contamination would remain because EPA was not able to develop a cleanup option capable of removing or destroying the contaminants of concern.

Alternative 4A, which included excavation and incineration of contaminated soil above the bedrock and in-situ chemical oxidation of contaminants in the fractured bedrock, had the potential for removing the greatest mass of contamination. However, the feasibility study indicated that even after spending approximately $100 million implementing excavation and treatment components of Alternative 4A, the pump and treat remedy would still be required to address the contaminants in the fractured bedrock that could not be excavated or treated. For further information see EPA's response to Issue No. 2.

2. A citizen asked if EPA could actually remove the contamination in the bedrock if Alternative 4 were to be selected.

EPA Response: Alternative 4 (Excavation with Enhanced Pump and Treat) would excavate contaminated soil above the bedrock for off-site treatment and disposal. However, a significant mass of hazardous substances has migrated into the fractured bedrock beneath the contaminated subsurface soil, which is beyond practical excavations limits. Thus the enhanced ground water pump and treat system would still need to be installed and maintained as described in Alternative

2 (Selected Remedy) to achieve remedial action objectives.

EPA developed and considered Alternative 4A (Excavation, Enhanced Pump and Treat with In-situ Chemical Oxidation) to address the contaminants that Alternative 4 alone would leave in the bedrock. Alternative 4A would use in-situ chemical oxidation to further destroy some contaminant mass in the fractured bedrock after the contaminated soil was excavated. However, even Alternative 4A would require the ground water treatment components to achieve protectiveness because significant contamination is located in the fractured bedrock and beyond the practical limits of excavation.

3. Several citizens asked if the withdrawal of ground water by the pump and treat system would affect the water levels in the residential wells in the vicinity and the surface water flow in West Stream.

EPA Response: There are two primary reasons that the pump and treat system will not have a significant drawdown on area residential wells or West Stream. Firstly, the mountainous topography limits potential impacts upgradient and side-gradient to the extraction wells. Secondly, the design of the pump and treat system is extremely localized and works with the natural system. The Site is on a hillside which slopes from the north to the south and flattens out at the southern end. The natural flow of ground water generally follows the topography, flowing down the hill. At the base of the hill, the ground water flows upward and discharges to the intermittent stream. The water treatment plant releases clean water directly to the same stream. Thus the pump and treat system "catches" ground water as it flows down the hill and discharges it to the stream at the base of the hill at the southern end of the property to which the ground water would otherwise naturally discharge. This water balance is very similar to the natural system.

4. Citizens noted that information EPA presented several years ago did not indicate that the ground water contaminant plume was leaving the Site. A citizen referred to the current map (see Figure 9 in the ROD) showing an "arm" of the ground water plume branching to the east and migrating beyond the property boundary. The citizen asked why EPA did not know the plume was migrating off the site before and whether EPA knows the extent of the plume now.

EPA Response: While it is possible that some part of the contaminant plume is migrating offsite, EPA believes that the selected remedy will capture it, and in any event will prevent it from spreading any further. The Ground Water Investigation and Focused Feasibility Study which EPA completed in June 2005 was designed to fill in any existing data gaps with respect to EPA's understanding of ground water at the Site, and to develop a final ground water cleanup decision. The primary objective of the investigation was to comprehensively determine if the existing recovery wells were containing the contaminated ground water on Site and, as appropriate, to identify additional ground water recovery well locations which may be necessary to achieve containment.

EPA determined that additional monitoring wells were necessary along the perimeter of the Site to fill in existing data gaps. Of relevance to this comment, EPA focused on a small gully located on the eastern side of the property. Recognizing that ground water generally flows downhill, in the same direction as surficial topography, in 2004 EPA placed ground water monitoring well PMW-5 at that precise location to determine if this gully might create localized ground water flow to the east.

EPA has now placed 56 ground water monitoring wells on or around the Site, and with the exception of the eastern gully EPA has been able to define the boundaries of the plume in every direction. With respect to the gully, EPA does know that a branch of the plume "follows the gully" to the eastern boundary, but does not know exactly how far beyond the plume may extend. However, based on the levels of contaminants observed in the adjoining wells, its capture zone analysis, and modeling, EPA has concluded that the installation of additional recovery wells in the vicinity of BR-5 and PMW-5 will contain the plume. EPA will continue to monitor the ground water in the vicinity to confirm that contaminated ground water is captured and make any necessary adjustments.

5. Citizens noted that EPA is cleaning the Site to the point that it could be safely reused for recreational and industrial purposes. Citizens asked if there is potential that a manufacturing facility will be re-established on the Site and what type of recreational activities the property is safe for.

EPA Response: Implementation of response actions at the Site cleanup will ensure that it is appropriate to reuse the property for manufacturing, recreational or industrial purposes should the property owner and local land use officials so choose. Acceptable recreational uses could include any activity involving several days of use per week, all year around, such as hiking, sledding, etc.

6. A citizen asked what assurance do we have as a community that EPA will maintain its long-term commitment to continue to manage the Site?

EPA Response: EPA and VADEQ will continue to be actively involved at the Site. For the next several years EPA will be operating the treatment plant, after which VADEQ will operate it. Additionally, as required by CERCLA for sites such as Greenwood Chemical, and as set forth in the ROD, EPA will review the Site's remedy every five years to assure that it remains protective of human health and the environment.

7. A citizen asked whether the land still belongs to the Greenwood Chemical Company, whether it has paid anything for the cleanup, and what is the status of Greenwood Chemical Company itself?

EPA Response: The land still belongs to Greenwood Chemical Company. Greenwood Chemical, and its President each reached settlements with the United States under which they reimbursed EPA for some of its response costs, based on their ability to pay. Greenwood Chemical Company remains an intact corporation, although as far as EPA knows it no longer engages in any chemical-related business.

8. A citizen asked if any of the residential wells in the vicinity of the Site have been impacted by Site contaminants.

EPA Response: Residential wells have been sampled and analyzed for Site-related contamination periodically since the late 1980's, and most recently in June 2004. Nine residential wells were tested within a one-half mile radius of the Site in 2004. Water samples were collected from wells that were either hydraulically downgradient or side gradient of the Site. No Site-related contaminants have been found in any residential wells at levels above EPA Maximum Contaminant Levels ("MCLs"), or indeed above any other risk-based action levels.

9. A citizen asked whether wells that were tested by EPA were artesian wells or dug wells? The citizen noted that several artesian springs are located on their farm and that they have had problems with the health of wildlife, including frogs and small fish.

EPA Response: A few of the wells in the ground water monitoring program are "artesian." A well is referred to as "artesian" when the ground water is under sufficient pressure that it naturally flows out the top of the well. A natural spring is an example of an "artesian" well. Several of the EPA wells at the bottom of the slope are "artesian."

All available scientific data indicate that site-related contamination is not presenting an unacceptable risk to environment receptors. As a result of this comment EPA agreed to sample the water from the springs in question. EPA completed the sampling event in July 2005 and preliminary results indicate that the springs have not been impacted by the Site.

10. A citizen asked how often official personnel are on Site to monitor the pump and treat process.

EPA Response: EPA has a full time treatment plant operator on Site five days per week (40 hours per week) and a part time operator on Site during critical activities such as process water or ground water sampling or changing out the carbon media used in the filtration system.

11. A citizen asked whether there is a fence to prevent children from inadvertently getting into harms way.

EPA Response: The property is currently fenced to prevent dumping on the Site and vandalism to the ground water pump and treat and monitoring well system. However, response actions already implemented at the Site have made it safe to for children to play on the property with respect to the chemical hazards once presented by the Site. The property is privately owned and access has not been granted for public recreational use. EPA cleaned up and closed out the lagoons that were once utilized by Greenwood Chemical's manufacturing operations. There is one pond remaining on the property, referred to as South Pond by EPA. EPA has sampled South Pond and found it to be clean.

12. A citizen asked how often the ground water is monitored and whether the chemistry is stable.

EPA Response: EPA has been monitoring the ground water quarterly. Residential wells are being monitored annually. The chemistry has been relatively stable from quarter to quarter.

13. A citizen asked what EPA's role would be if an adjacent parcel underwent extensive development and new wells were installed in the vicinity of the Site.

EPA Response: Land use is a local and State decision. EPA and VDEQ would work together to learn the how the existing land use would be changed and to evaluate whether the constructed remedy would continue to be protective of human health and the environment. EPA and VDEQ would educate the prospective developer of site conditions and, as appropriate, work cooperatively to ensure the property could be safely used by the property owner.

14. A citizen asked if there is a risk of the contaminant plume actually reaching the stream and whether it is an imminent threat.

EPA Response: Contaminated ground water discharging to the stream does not represent an imminent threat. Recent environmental sampling indicates that under the current pump and treat scenario (five recovery wells), low concentrations of VOCs, including TCE and carbon tetrachoride, have been detected in a short stretch of an intermittent stream located at the southernmost portion of the Site. This is the topographic low elevation of the Site, where the ground water table is very close to the surface, indicating likely discharge of contaminated ground water into the shallow stream bed. Nonetheless, the contaminants were detected at concentrations so low that the surface water meets the Virginia surface water quality standards, and EPA has determined that it does not present an unacceptable risk to human health or the environment. The water quality was even higher at sampling points downstream, indicating clean ground water is also discharging to the stream. Analysis of samples from the West Stream, the South Pond and the East Pond themselves do not indicate the presence of Site-related contamination. The additional ground water recovery wells to be installed as part of the Selected Remedy will likely further reduce the potential for contaminated ground water discharge to the stream.

Part II: Responses to Written Comments

15. In a one-page e-mail to EPA dated July 12, 2005, a citizen submitted a written comment stating that she understands the rationale for the cleanup alternative identified as the

preferred option. She stated that she would like to know the potential effect of interrupting the treatment operation for an extended period, several months or longer.

EPA Response: EPA does not see any reason that the treatment operation would be interrupted for an extended period of time. Nevertheless, ground water at the Site moves very slowly. EPA has calculated the ground water flow rate as follows: the groundwater flows through the fractured bedrock at a rate of approximately 25 ft/year, and through the aquifer above the bedrock at approximately 13 feet/year. For this reason any change to this system will also occur slowly to.

As explained in the ROD, EPA is using a "line" of ground water recovery wells to establish a hydraulic barrier that will capture most of the contaminated water as it moves down slope. Once contaminants have moved past our "line" of wells we have to rely on natural processes (such as dilution, adsorption onto soils, and natural chemical degradation) to dissipate the impact to the environment.

The Selected Remedy calls for installation of additional wells to more effectively "cut off" the continued migration of contaminants to the leading edge of the ground water plume. This will help those natural processes to attenuate the contaminant concentrations. Hypothetically, if we were to shut the wells off for a prolonged period of time the contaminated ground water will resume its slow travel down the hill, some of it will discharge to the stream. If it lasts for too long we will see the concentrations of those contaminants increase and the plume could eventually expand. If we were to shut the wells off all together, forever, we would see the plume expand to the point that the natural processes are in equilibrium with the migration from the source area. It is unknown how far it would expand. It we stopped the wells too long, or altogether, contaminated ground water naturally discharging to the stream may also potentially lead to unacceptable risks. As it stands today the water quality in the stream remains high.

16. EPA received a one-page e-mail dated July 7, 2005 and another e-mail dated July 9, 2005 from local citizens offering full support for the EPA's preferred alternative.

EPA Response: EPA appreciates the support these citizens have expressed for its Selected Remedy.