SEABOARD CHEMICAL CORPORATION FACILITY
AND
CITY OF HIGH POINT RIVERDALE DRIVE LANDFILL

REMEDIAL INFORMATION
AND
RECOMMENDATIONS

Prepared by:

SEABOARD GROUP II
AND
CITY OF HIGH POINT, NC

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EXECUTIVE SUMMARY

The representatives of the City of High Point, NC and Seaboard Group II ("Parties") have reviewed and evaluated the comprehensive information and data collected since 1994 when they began to cooperate in the performance of a remedial investigation and feasibility study of the former Seaboard Chemical Corporation facility ("Seaboard Facility") and the City of High Point Riverdale Drive Landfill ("Landfill") (The Seaboard Facility and Landfill are collectively referred to as the "Site"). The Site is located in Jamestown, Guilford County, North Carolina.

In addition, the Parties have cooperated in the preparation and submission to the North Carolina Department of Environment and Natural Resources ("DENR") of a Remedial Investigation Report, Baseline Risk Assessment Report, Feasibility Study Report, and the associated supplemental reports to those documents. The reports were submitted to DENR for review, comment and approval. In addition, they were made available to the public for review and comment in accordance with notices published in the Greensboro News and Record newspaper on July 15, 1999 and August 10, 2004, the High Point Enterprise newspaper on July 15, 1999 and August 15, 2004 and the North Carolina Register on July 1, 1999 and September 15, 2004.

This document presents the remedy that is recommended by the Parties to address the containment and remediation of impacted soils and ground water at the Site. The proposed remedy will provide the containment and treatment necessary to ensure an effective and viable remedy that is fully protective of public health, safety and the environment.

This remedy takes into consideration the findings of the Remedial Investigation ("RI"), Baseline Risk Assessment ("BRA") and Feasibility Study ("FS"), and the currently known technical limitations on remediation of dense non-aqueous phase liquids ("DNAPL") in fractured bedrock settings. As a result, engineering and institutional controls are proposed along with leachate and ground water extraction and treatment for plume containment and contaminant reduction. This remedy will control the potential for

off-site migration of impacted ground water and leachate into the Deep River and, in the future, into Randleman Reservoir[1].

This recommended remedy addresses these objectives through the following components:

- Isolation of landfill leachate and leachate-impacted ground water to prevent its migration to the waters of the Deep River and the Northern and Southern Intermittent Streams;
- Stabilization of landfill slopes and enhancements of the existing caps at the Site;
- Extraction of ground water to contain plume migration and capture impacted ground water recharge into the Deep River and the Northern and Southern Intermittent Streams;
- Treatment of extracted ground water to reduce contaminant mass;
- The use of natural treatment processes (i.e., constructed wetlands and uplands phytoremediation) to provide sustainable and cost effective treatment of extracted ground water;
- Physical and chemical treatment supplements (i.e. aeration and ozone-oxidation methods) to the natural treatment processes to provide effective treatment during periods when the natural systems are being started up or may be operating with limited effectiveness;
- Continued use and maintenance of the existing fence and warning signs to restrict unauthorized access to the Site;
- Permanent land use restrictions on the Seaboard Facility and the property immediately across the Deep River from the

[1] Construction of a Dam on the Deep River approximately 15 miles downstream of the Site is complete. When filled, the Randleman Reservoir will be created (also referred to as Randleman Lake) and will raise the elevation of the surface water in the area of the Site to 682 feet m.s.l. The reservoir will become a drinking water source for area communities.

Site to prevent future uses of impacted ground water or activities which could result in unacceptable exposure risks

- Long-term periodic Site inspections and Agency reviews; and
- Long-term, periodic ground water and surface water monitoring.

A thorough evaluation of all of the alternatives for remediation of the Site has been performed by the Parties. After carefully evaluating those alternatives, the Parties believe that this proposed remedy will provide the most effective technically feasible remediation incorporating both containment of contaminant migration and reduction of contaminant mass through treatment of extracted ground water, while achieving all of the remedial objectives.

SUPPORTING INFORMATION

INTRODUCTION

This Remedy Recommendation Document has been developed for the Seaboard Facility and the Landfill which are located in Jamestown, Guilford County, North Carolina. It has been prepared in accordance with the Remedial Investigation Administrative Order on Consent ("AOC") entered into with DENR on January 30, 1996 and the Feasibility Study AOC entered into on July 22, 1997.

PURPOSE

Remedial investigations conducted at the Site have documented the presence of chlorinated and non-chlorinated hydrocarbon compounds in soils, leachate and ground water. The remedial investigation results indicate the presence of dense non-aqueous-phase liquids in the fractured bedrock aquifer underlying the Site. The purpose of this remedy recommendation is to propose a protective remedial strategy for the impacted soils, leachate and ground water based on the results of the remedial investigation, baseline risk assessment and feasibility study. The remedial strategy proposes natural attenuation, contaminant mass reduction and containment of impacted soils, leachate and ground water.

BACKGROUND

SITE DESCRIPTION AND HISTORY

The general Site location is shown in Figure 1. The Site consists of two properties as shown on Figure 2. The Seaboard Facility property is located at 5899 Riverdale Drive, Jamestown, NC. The adjacent Landfill, a closed municipal solid waste landfill, bounds the Seaboard Facility on two sides. Land use is primarily rural, with very little residential use within a 4-mile radius of the Site. Private residences and agricultural land are located adjacent to the north and west boundaries of the landfill, and to the west and south across Riverdale Drive. Land use at the Site is industrial. The Site is bounded on the north and east by the Riverdale Drive Landfill, on the west by the City's Material Recycling Facility, on the south by Riverdale Drive, and on the east by the Deep River.

The City's Eastside Waste Water Treatment Plant ("EWWTP") is located to the south across Riverdale Drive. Interstate Highway 85 borders the southeast corner of the Site.

SEABOARD FACILITY DESCRIPTION AND HISTORY

The Seaboard Facility is comprised of approximately 13 acres of land, of which approximately 5-acre were developed for use as a plant and office area. The remaining area is undeveloped, wooded and bisected by a small unnamed stream (referred to as the Southern Intermittent Stream or "SIS"). The Seaboard Facility is bordered to the north and east by the Landfill as depicted on Figure 2.

Between 1974 and 1989 Seaboard Chemical Corporation operated solvent recovery and fuel blending processes at the Facility, and was granted Interim Status under the Resource Conservation and Recovery Act ("RCRA") as a treatment, storage and disposal facility in 1982. The facility was divided into 13 operating areas corresponding to the different activities conducted. These included, among other things, distillation, fractionation and condensation of organic solvent wastes. Seaboard also provided services such as thermo-setting monomer purification and recovery, chrome steel drum drying, solids pulverizing, batching and mixing. In addition, three surface impoundments were in service at the facility during the time that Seaboard was in operation. Other supporting operations included wastewater treatment, storage of incoming wastes in drums and above ground storage tanks, storage of certain recyclable materials in dedicated tanks and operation of two boilers located in a house. The property had also been used for chemical processing before Seaboard's ownership, during the period prior to 1974. Prior to that, time the property was reportedly used as a hog-slaughtering and processing facility.

The Seaboard Chemical Corporation ceased all activities in 1989, and the facility is no longer in operation. The Company ceased all activities when it was denied a special use permit by Guilford County. The corporation declared bankruptcy and was not able to fund the cost of performing the necessary site closure. The property is owned at this time by the bankruptcy estate of

Seaboard Chemical Corporation and administered by J. Brooks Reitzel, Jr. bankruptcy trustee.

Following abandonment of the facility by the owner, DENR requested parties that may have used the services of Seaboard Chemical Corporation in the past (also referred to as potentially responsible parties or "PRPs") attend a meeting held in Raleigh, NC in 1990. Following that meeting, Seaboard Group I was formed by the PRPs for the purpose of conducting a voluntary removal action for potentially hazardous materials remaining at the site and to develop some initial assessment information.

Removal activities were conducted during 1990 and 1992 to remove all remaining waste materials and certain tanks and equipment from the Seaboard Facility. In addition, an initial screening evaluation of the Site was performed, and a Remedial Investigation Work Plan was developed. Following that removal activity, Seaboard Group I was dissolved.

Seaboard Group II ("Group") was then formed to perform a remedial investigation and to prepare a baseline risk assessment, feasibility study and flow and solute transport model for the Site. Seaboard Group II was also to performed certain other functions necessary to develop a conceptual remedy for the Site. The Group entered into an agreement with the City of High Point to perform a remedial investigation since the close proximity of the landfill and Seaboard Chemical Corporation facility made joint investigation of the two sites advantageous for both the City and the Group The Parties then entered into AOCs with DENR to perform the remedial investigation on January 30, 1996 and the feasibility study on July 22, 1997.

RIVERDALE LANDFILL DESCRIPTION AND HISTORY

The Landfill portion of the Site is comprised of approximately 150 acres. The Landfill was operated using customary methods for approximately 40 years beginning in the 1950's and ending in October 1993. Prior to use as a solid waste landfill the property was undeveloped woodland and agricultural land. The Landfill was permitted by the North Carolina DENR Solid Waste Section in 1979.

During Landfill operations, sections of the SIS and the entire length of the Northern Intermittent Stream ("NIS"), an unnamed tributary that dissects the northern portion on the landfill, were piped, and solid waste was used to fill the drainage valleys. Waste was also placed over the top of the pipes, which are presently under approximately 100 feet of solid waste.

The Landfill was divided into four primary areas. These included the central section ("Area A"), the northwestern section ("Area B"), the southeastern section ("Area C"), and the former burn pits area and soil residue mound. These areas are depicted on Figure 2. During the construction of the landfill cells there was a very limited lateral leachate collection system installed near the discharge of the Southern Intermittent Stream. No liner system was installed beneath the landfill, and the waste material was placed directly upon the existing soil. During operation, some of the waste materials were shredded prior to placing them in the landfill. In other areas, the waste materials were bailed prior to placing them in the landfill.

In 1989, a leachate collection system was added to control surface seeps, or leachate leakage, along the slopes of the landfill. The leachate from these seeps is presently collected in storage tanks and subsequently pumped into tank trucks and treated off-site. The quantity of leachate managed in this system varies, but averages approximately 60,000 gallons per month.

From approximately 1966 to 1970, Landfill operations included the disposal and open burning of spent solvents. The area in which these activities took place is referred to as the "former burn pit area." These burn pits were filled with solvent materials and were set on fire when a sufficient quantity was accumulated. Periodically the burn pits were cleaned of residue and the resulting soil residue was pushed out of the burn pit and accumulated in a mound. Presently this mound consists of approximately 600 cubic yards of contaminated soils. This area is referred to as the "soil residue mound" (Figure 2) and is located in an area near the landfill scale house.

The Landfill is now capped with approximately two feet of native soil and vegetative cover. The cap was installed prior to any regulations concerning the soil compaction required. Therefore,

the permeability of the landfill cap is not known at this time. The depth of the Landfill material varies, but can be as deep as 130 feet.

SUMMARY OF REMEDIAL INVESTIGATION

The RI was conducted by Blasland, Bouck & Lee, Inc. ("BB&L") (BB&L, March 1999). The RI activities were conducted in two phases. Phase I took place from April 1996 through September 1997. Phase II took place from April 1998 through September 1998. The BB&L Remedial Investigation Report also summarized the findings of several prior investigations conducted at the Site between 1980 and 1993.

The major field tasks completed during the course of the two RI phases included ground-water sampling, aquifer testing, installation of monitoring wells, leachate wells, river and stream piezometers, and a variety of supplemental geotechnical, geophysical, soil gas, river and stream flow, and hydrogeologic mapping studies. A conceptual site hydrogeological model was also developed and refined as part of the RI, and the RI data supported the development of a numerical ground water flow and solute transport model. From these activities, the nature and extent of contaminant releases have been comprehensively characterized for the Seaboard facility soils, the former landfill burn pits and soil residue mound, the landfill and the leachate collection system, and the ground water and surface water at the Site. An overall summary of the major Site conditions, based on previous Site investigations and studies, is presented in this section of this document.

SITE CONCEPTUAL HYDROGEOLOGICAL MODEL

A site conceptual hydrogeological model was developed, tested and refined throughout the RI and FS processes. The conceptual model provides a thorough characterization of the site hydrogeology, contaminant migration pathways, plume geometry and ground water discharge to surface water. The site conditions and the conceptual model are summarized in this section

The Site hydrogeology is characteristic of the regional Piedmont aquifer system and consists of three aquifer units: the saprolite or

partially weathered rock aquifer, the shallow bedrock aquifer and the deep bedrock aquifer.

The saprolite or partially weathered rock aquifer is the uppermost aquifer across much of the Site, but is locally absent where the water table occurs below the top of bedrock. The thickness of this aquifer, where present, is generally less than 20 feet but extends to depths of 90 feet in certain areas of the Site. The shallow bedrock aquifer extends from the top of competent bedrock to a depth where ground water flow becomes limited due to the lack of open fractures. The base of the shallow bedrock zone at the Site is variable but generally occurs at depths of 200 to 400 feet. The deep bedrock aquifer extends downward from the base of the shallow bedrock aquifer and is characterized by low permeability and limited ground water flow.

The primary ground water movement at the Site occurs within the saprolite and shallow bedrock aquifer zones. The saprolite and shallow bedrock aquifers are hydraulically interconnected. Based on historical monitoring well gauging data, the depth to ground water at the Site ranges from approximately 7 feet at the Southern Intermittent Stream north of the Seaboard Chemical facility to approximately 69 feet at the south end of the landfill property along Riverdale Drive.

The potentiometric surface of shallow ground water in the saprolite aquifer generally follows the original topography of the Site. The saprolite aquifer is locally absent where the water table occurs below the top of bedrock, generally beneath the topographic high point locations. Ground water flow within the shallow bedrock aquifer is primarily through fractures in the bedrock and is strongly controlled by subsurface geologic structures such as faults, fracture zones, and mafic dikes. These discrete geologic features are moderately to steeply dipping tabular structures with associated fracture zones along the margins. The structures are oriented primarily in a north-south or east-west direction, and their intersection results in an irregular pattern of bedrock blocks bounded by the linear discrete geologic structures. The fracture zones along the discrete features are generally more permeable and better connected than the regional or background fracture sets within the bedrock blocks. The higher permeability and interconnectivity of the fracture zones along the

discrete features serve as the preferred ground water flow paths and contaminant migration pathways. The intersections of structural geologic features create zones of greater permeability within the shallow bedrock aquifer.

Several prominent geologic structures have been identified and mapped at the Site. The most significant geologic features are as follows:

- Southern Intermittent Stream Fault
- Seaboard Dike
- PW-5D Dike/Fault
- Regional Fault/Dike
- Deep River Fault

The Southern Intermittent Stream Fault zone represents a ground water flow and contaminant migration pathway to the east, toward the Deep River. Ground water flow is diverted northward from the fault by north-south trending geologic structures which extend to the east-west segment of the Deep River in the vicinity of the mouth of the SIS. At the east-west segment of the Deep River, the river course is controlled by the Deep River Fault. This southward-dipping fault intercepts the main contaminant plume at the Deep River. The Regional Fault or Mafic Dike serves as a natural cut-off feature to limit the eastward migration of contaminants within the shallow bedrock aquifer, and limit the discharge zone of contaminated ground water into the Deep River. Similarly, the Seaboard Dike that extends from the Seaboard facility northeastward to the vicinity of the west end of the east-west segment of the river appears to represent a northwest boundary of the main contaminant plume. The monitoring well network at the Site is designed to evaluate hydrogeologic conditions and monitor ground-water quality along the inferred primary ground water contaminant migration pathways.

Based on water level elevation data collected during several ground water monitoring events conducted during the performance of the RI and on an annual basis since 1997, the overall Site lateral hydraulic gradient is toward the Deep River and the vertical hydraulic gradient in the bedrock aquifer is upward in the vicinity of the Deep River immediately north and south of the

river. The water level and gradient data are consistent with fundamental hydrogeologic concepts of ground water flow to a river. As a result, although there may be some limited excursion of contaminants from the south side to the north side of the Deep River, the majority of the contaminant mass is mixing with surface water at the Deep River stream bed.

OPERABLE UNITS

For RI purposes, the Site was divided into four operable units ("OUs") which were defined as:

- OU1 – Former Seaboard Soils (including the metal debris areas);
- OU2 – Contaminated Ground Water Associated with the Site (OU1, OU3, and OU4);
- OU3 – City of High Point Riverdale Drive Landfill Soils (including the leachate collection system); and
- OU4 – City of High Point Riverdale Drive Landfill Former Burn Pits Area and Soil Residue Mound.

OU1 - SEABOARD SOIL

All soil samples collected from the Seaboard Facility during the Remedial Site Investigation (Geraghty &Miller ("G&M"), 1993) and the RI exhibited constituent concentrations that are below the DENR S-1 (residential exposure) screening criteria. This includes soil samples collected in the Metal Debris area located immediately north of the fenced facility where scrap metal equipment (i.e. pipes, tanks) was stored. Additionally, most of the Seaboard site has been capped with concrete.

Soil samples collected from the Seaboard Facility during the Remedial Site Investigation and the RI exhibited constituent concentrations that are above the DENR S-3:G-1 (movement of contaminants from soil to ground water used for drinking water) screening criteria for 1,2-DCA, 2-butanone, acetone, chlorobenzene, ethylbenzene, PCE and total xylenes. Proposed institutional controls, including permanent land use restrictions, will ensure that there are no foreseeable on-site uses of ground

water or activities that will result in unacceptable exposures to soil contaminants. Moreover, the soil concentrations are orders of magnitude lower than the existing ground water concentrations (which indicates that the soils are not a significant source of the existing ground water contamination), and their locations are all above the water table and capped with concrete. This restricts surface water infiltration or percolation and thus contaminant leaching.

OU2 – GROUND WATER ASSESSMENT INCLUDING SURFACE WATER CHARACTERIZATION

Ground water exists beneath the site primarily in a bedrock aquifer that is discontinuously overlain by saprolite or solid waste contained in the landfill. The Site Conceptual Hydrogeological Model describes the hydrogeology of the Site. This Model includes five prominent geologic structures which are near-vertical faults, fractures and mafic dikes that were identified and mapped during the RI (Figure Figures 3A & 3B). The higher permeability and interconnectivity of the fracture zones along the discrete features allows them to serve as the preferred ground water flow paths and contaminant migration pathways at the Site.

Ground water flow generally follows pre-development site topography, with flow originating from the Seaboard facility and the Landfill and moving towards the Deep River to the north and east (Figure 4A & 4B). As a result, most ground water that passes beneath the Site (including ground water discharges to the two on-site intermittent streams) eventually discharges to the Deep River. Although some contaminants were detected in monitor wells installed within the floodplain immediately north of the Landfill across the Deep River during some of the ground water monitoring events, the RI results confirm that this is a localized condition. Contaminants migrating beneath the Deep River eventually discharge back to the river.

Based on historical ground water sampling conducted since 1996, a number of volatile organic compounds ("VOC") and semi-volatile organic compounds ("SVOC"), as well as several inorganic constituents, were detected at concentrations above the North Carolina 2L ground water standards. The North Carolina 2L ground water quality standards are protective of ground water for use as

a potential source of drinking water. The monitoring data indicate that the contaminant mass in the saprolite aquifer is limited in extent due to the limited occurrence of ground water in the saprolite zone at the Site (Figure 5A). The VOC analytical data indicate that the contaminant mass primarily occurs in the bedrock aquifer and is concentrated along the discrete geologic features identified in the Site Conceptual Hydrogeologic Model (Figure 5B). Discrete interval sampling of the shallow bedrock aquifer at select well locations indicates that the practical vertical extent of the contaminated portions of the shallow bedrock aquifer has been identified (Figures 6, 7 and 8).

Evidence from the RI supports the occurrence of DNAPL within the shallow bedrock aquifer beneath the source areas at the Seaboard Facility. Several samples from monitoring wells and Deep River piezometers were found to exhibit concentrations of chlorinated hydrocarbons that exceeded 1 to 10 percent of the published aqueous solubilities for each of these hydrocarbons. Chlorinated hydrocarbon concentrations in excess of 1 to 10 percent of their aqueous solubilities are a widely recognized indicator of the potential presence of DNAPLs in the subsurface. The occurrence of DNAPL source material within the subsurface is a controlling factor in the development of remedial objectives for aquifer remediation at the Site.

Measurements of natural attenuation parameters, which included dissolved oxygen, redox, chloride, sulfate, nitrate, iron and VOC transformation products were made to assess the potential for natural degradation of VOCs in ground water at the Site. This data suggest the active process of reductive dechlorination is occurring at the Site. Given the magnitude of the contaminant concentrations in the VOC plume which originates on the Seaboard Facility and commingles with leachate as it migrates beneath the Landfill toward the Deep River (Figure 8), natural attenuation by itself is not expected to reduce the contaminant mass in the ground water beneath the Site to concentrations protective of human health in the near term. However, monitoring data indicate that limited remediation of the dissolved plume by natural attenuation is occurring at the Site.

Surface water quality monitoring results from the Deep River and Southern and Northern Intermittent Streams indicate the presence

of impacts from contaminants originating at the Site (Figure 9). The concentrations of select organic constituents in the Deep River stream bed piezometers (which were installed coincident with the primary ground water-to-surface water discharge zone) indicate that the impacted ground water has reached the east-west segment of the Deep River stream bed (Figure 10).

An off-Site well survey indicates that there are no existing water supply wells located down gradient of the Site or the area of impacted ground water. The well survey identified 81 water wells within a 1-mile radius of the Site, however, all the wells are hydraulically removed from the area where site-related contaminants in ground water exist or are expected to migrate. Further, sampling of the nearest potable supply wells, located west of the Landfill on Riverdale Drive and across the Deep River from the Site, did not reveal detectable concentrations of any Site-related constituents

OU3 – LANDFILL CHARACTERIZATION

In portions of the Landfill, leachate is being collected by the City of High Point through an existing leachate collection system and treated off site at the EWWTP. Leachate quality, as determined in samples collected from two leachate monitoring wells installed as part of the RI, as well as from three of the existing leachate collection tanks, contains a variety of organic and inorganic constituents, including chlorinated VOCs, 1,4-dioxane, benzene, toluene and xylenes. Ground water monitoring results indicate impacts to ground water quality by leachate-related constituents in the vicinity of the Landfill, including areas hydraulically removed from the VOC plume origination at the Seaboard Facility (Figure 8).

OU4 - FORMER BURN PITS EVALUATION

Analyses of soil samples collected from the soil residue mound indicated that all compound concentrations were below TCLP regulatory levels of concern, with the samples testing below RCRA hazardous waste levels. The former burn pits area was extensively investigated through soil samples collected from five test pits and 15 soil borings. Some constituents (six organic compounds and four inorganic metals) exceeded applicable screening criteria in

the test pits. However, no VOC concentrations exceeding the S-1 screening criteria were observed in samples taken from the soil borings. All of the impacted soil is currently underneath capped landfill cells at depths of 6 to 14 feet below ground surface. The soil analyses indicate that the area of impacted soil was delineated by the soil-sampling program. Based on historical monitoring data, ground-water samples from monitoring wells installed within and down gradient of the former burn pits area contain VOCs at concentrations above the respective North Carolina 2L ground water standards. However, the ground water samples exhibited no exceedance of 2L Standards for any of the constituents detected in the test pit soil samples.

SUMMARY OF BASELINE RISK ASSESSMENT

Results of the human health and ecological risk assessment for the Site are presented in the Baseline Risk Assessment Report for the Site dated 30 March 1999 (ERM, 1999). The BRA was conducted in accordance with the approved BRA Work Plan and applicable DENR and U.S. Environmental Protection Agency ("U.S. EPA") requirements. The main conclusions of the BRA are summarized below.

HUMAN HEALTH RISK ASSESSMENT

Based on a conservative estimation of risk for each identified receptor population, potential worst-case carcinogenic and non-carcinogenic risks were estimated. Only industrial or commercial uses of the Site are expected to occur in the future, so residential scenarios were not evaluated during the risk assessment. To address U. S. EPA requirements, four conservative human exposure scenarios for on-Site soils and surface water were considered:

- On-site adolescent trespasser;
- Landfill worker;
- Future on-site worker; and,
- Future construction worker.

Furthermore, human health risks from ground water beneath the Site were assessed by modeling potential future impacts of discharges into Deep River and future Randleman reservoir.

The conclusions of the BRA are discussed below.

SOIL

The BRA evaluated potential risks associated with soils at the Seaboard Facility as well as soils from the former burn pits. Overall, no unacceptable non-carcinogenic risks were identified for soil under any of the exposure scenarios evaluated. Despite the extremely conservative exposure assumptions (i.e., that the impacted soils at a depth of 6 to 13 feet below grade are available for direct contact at the ground surface and throughout the soil column), the cumulative carcinogenic risks for each of the exposure scenarios are at or below the acceptable cancer risk range of $1x10^{-6}$ to $1x10^{-4}$. Finally, based on LEADSPREAD modeling, lead concentrations in the former burn pits soil were not found to present any unacceptable risks.

SURFACE WATER

The BRA evaluated potential exposures to surface water from the Southern and Northern Intermittent Streams and the Deep River. Based on the results of the BRA, no unacceptable non-carcinogenic risks were identified for surface waters under any of the exposure scenarios evaluated. Cumulative carcinogenic risks in excess of $1x10^{-6}$ were identified for the adolescent trespasser breathing organic vapors from the Southern Intermittent Stream, although the risk was well within the acceptable risk range of $1x10^{-6}$ to $1x10^{-4}$, the exposure scenario was extremely conservative, and the risks for the other exposure scenarios were below $1x10^{-6}$. Furthermore, the maximum carcinogenic risk was below $1x10^{-5}$, which is considered acceptable by U. S. EPA for workplace exposure.

With respect to modeled surface water concentrations in Deep River under the future Randleman Reservoir land-use scenario, all estimated concentrations at the drinking water intake were well below acceptable drinking water standards, even for the worst-case low flow conditions. Therefore, no unacceptable levels of the detected constituents are anticipated to be present in drinking

water withdrawn from the proposed water intake[2] as a result of discharges from the Site, even if no remediation were conducted.

GROUND WATER

Based on exceedances of North Carolina's ground water quality standards, potential risks to hypothetical users of ground water down gradient of the Site were evaluated in the BRA. These potential risks were estimated from a worst-case hypothetical future scenario that assumed a residential drinking water well will be placed at the edge of the Randleman Reservoir, and that the well will contain the maximum levels of ground water contamination encountered on the north side of the Deep River. The closest actual residential well is located approximately 1,000 feet farther to the northeast of the Deep River, and no site related constituents were detected in this well.

Based on the worst-case hypothetical exposure scenario, potential non-carcinogenic risks were estimated to exceed acceptable levels. Potential carcinogenic risks were found to exceed the acceptable risk range of $1x10^{-6}$ to $1x10^{-4}$ using current risk assessment protocols. Estimated non-carcinogenic risks were found to exceed the target Hazard Index of 1.0; however, it is important to note that actual samples collected from the nearest residential well did not contain any site-related VOCs[3], and actual existing risks are therefore well within acceptable levels.

Because the potential risks from hypothetical future uses of groundwater exceed acceptable levels, the FS evaluated potential approaches for the remediation of groundwater and the prevention of potentially unacceptable future risks. Proposed institutional controls will be used to control this exposure pathway.

ECOLOGICAL RISK ASSESSMENT

An Ecological Risk Assessment ("ERA") was also performed as part of the BRA. The purpose of the ERA was to estimate potential risks

[2] As a result of the creation of the Randleman Reservoir a drinking water intake will be located approximately 10 miles south of the Site.
[3] See "Site Specific Compounds of Concern" on Pages 26 and 27 for a list of "site related VOCs"

to ecological receptors from the Site contaminants. The conclusions of the ERA are summarized below.

SOIL

Based on the results of the Tier I screening analysis and the subsequent risk assessment, it was concluded that the habitats and associated wildlife observed at the Site were typical of the area. Three constituents of potential concern ("COPCs") were identified in soil, but were detected at concentrations representative of naturally occurring levels, and are not believed to be Site-related. Thus, no further evaluation of soils with respect to potential ecological risks was considered to be warranted.

SURFACE WATER

Four COPCs were identified in the Northern Intermittent Stream, nine in the Southern Intermittent Stream, and two in the Deep River. Because both intermittent streams are piped when they intersect landfill material, the streams are limited in their ability to support aquatic life and there is little opportunity for terrestrial receptors to be exposed to surface water contaminants.

With respect to the organic COPCs, their presence in surface water at concentrations of potential concern is very localized and several of the compounds are volatile constituents which should readily volatilize once entering the surface water system. Therefore, no unacceptable exposures to organic COPCs in the Northern and Southern Intermittent Streams are anticipated.

The only remaining COPCs associated with surface water are the inorganic constituents. However, their presence is not considered to be Site-related and is instead believed to be associated with naturally occurring levels of inorganics in surface water. An evaluation of background inorganic constituents in the Deep River confirmed this conclusion. Therefore, no further evaluation of ecological risks with respect to surface water was considered to be warranted.

SUMMARY OF SOLUTE TRANSPORT MODELING

SITE GROUND WATER FLOW AND TRANSPORT MODEL

Following development of the Site Conceptual Hydrogeologic Model during the RI, a numerical ground water flow and solute transport model for the Site was developed by Synesis Environmental, Inc. (SEI, 1999). The modeling effort utilized a variation of the U. S. EPA accepted MODFLOW (McDonald and Harbaugh, 1988) model, enhanced to allow for better representation of Site conditions and contaminant transport. Conditions represented by the model include the numerous structural geologic features at the Site, current ground water flow and contaminant transport conditions, and potential future ground water flow and contaminant transport conditions following the creation of the Randleman Reservoir. Potentially applicable remediation scenarios were also evaluated with the model.

Significant results and conclusions from the modeling effort are as follows:

- The model has been calibrated with actual field data, and provides a reasonable representation of groundwater flow and contaminant transport at the Site;

- There may be a significant increase in the volume of water captured by the Southern Intermittent Stream as a result of raising the water level in the Deep River associated with the creation of Randleman Reservoir;

- Contaminant loadings from ground water to the Southern Intermittent Stream and the Deep River could potentially increase in the future, particularly after the flow conditions are altered by Randleman Reservoir; however, there is significant uncertainty associated with the predicted magnitude of an increase because of uncertainty with the DNAPL migration and the rate of natural attenuation;

- Elevated ground water contaminant concentrations are likely to persist at the Site over a long period of time as a result of the DNAPL sources in the shallow bedrock, even if currently known and practically available groundwater remediation approaches are undertaken.

It should be noted that predictions of surface water concentrations in Randleman Reservoir adjacent to the Site and at the drinking water intake under possible future ground water flow and contaminant transport conditions have not been evaluated. Such an evaluation may be included as part of the routine performance evaluation of the remediation system under the remedial monitoring program.

RANDLEMAN LAKE SURFACE WATER QUALITY MODELS

BLACK & VEATCH RANDLEMAN LAKE REPORT

The Piedmont Triad Regional Water Authority ("PTRWA") has constructed a dam on the Deep River approximately 15 miles downstream of the Site which will create Randleman Reservoir, a drinking water supply and recreational lake for the Triad area. According to the PTRWA, the proposed Randleman Reservoir will flood the Deep River valley to a normal pool elevation of approximately 682 feet above mean sea level and contain 56,220 acre-feet of water. The surface area of the reservoir will be 3,230 acres. Construction of the dam was scheduled to begin in 1999 but legal challenges to the 401 certification and 404 permits caused significant delays. Construction of the dam is substantially complete at this time; however, the infrastructure construction is still in progress. Intake for the water purification plant will be located near the dam, more than 10 miles downstream from the Site.

Black & Veatch ("B&V") prepared a support document (B&V, 1994) to the Environmental Impact Study required under the NEPA. Part of the scope of the report was to conduct a Toxic Substances Study to identify potentially significant sources of toxic substances that may enter the proposed reservoir. A model was used to predict the possible concentrations of organic constituents that may be present at the proposed water intake. Several VOCs were selected for modeling because they were detected in several ground water samples collected from monitoring wells on the Seaboard Facility. The potential impact of the Landfill was also estimated. Finally, effluent water quality data from the EWWTP, which discharges to Deep River, was also considered.

The B&V report (1991) contains the following conclusions:

- Water in Randleman Reservoir will be safe to drink;
- Ground water contamination from the Seaboard Facility and the Landfill will not have a significant adverse impact on the Randleman Reservoir water quality;
- Concentrations of organic and inorganic pollutants at the proposed water intake will be less than the concentrations predicted in previous reports; and,
- The Piedmont Triad Regional Water Authority analysis performed by Tetra Tech, Inc. for the Proposed Randleman Reservoir concludes that the Site will present no unacceptable risks to the reservoir.

The PTRWA engaged Tetra Tech, Inc. to analyze potential water quality in the proposed Randleman Reservoir with respect to toxic organic chemicals from four identified areas of concern, including the potential leaching of contaminants from the ground water and leachate at the Site. A model was developed to estimate expected concentrations of toxic organics from the EWWTP, the Deep River watershed and drainage area and the Site. Based upon the modeling analysis, Tetra Tech concluded that "none of these concerns appears to represent a threat to the WS-IV classification of the reservoir."

Tetra Tech's evaluation considered a small section of the reservoir adjacent to the Site, as well as the reservoir as a whole. Comparing the modeling maximum screening upper-bound concentrations associated with the Site to relevant water quality standards and criteria, Tetra Tech concluded that in each case the maximum predicted concentrations were well below the water quality criterion. Furthermore, actual concentrations should be much lower than those predicted because of the highly conservative assumptions that were used in the screening analysis. Therefore, "no excursion of water quality associated with ground water loading from the Seaboard Chemical or Riverdale Landfill Site is expected" (Tetra Tech, 1998). Tetra Tech's modeling analysis has been reviewed by the Division of Water Quality and is considered to be a conservative evaluation of potential impacts to Randleman Lake.

SUMMARY OF FEASIBILITY STUDY

A FS was conducted by ERM to identify and evaluate remedial alternatives for addressing potentially unacceptable risks to human health and the environment identified in the RI and BRA. The areas of potential concern are shown in Figure 2. The ultimate goal of the FS was to determine the most appropriate remedial approach for impacted media at the Site, based on the established evaluation criteria, consistent with current and future anticipated uses and applicable regulatory requirements.

The FS was conducted in full accordance with the applicable requirements of the AOC for the Site, the FS Work Plan which was approved by DENR, and the National Contingency Plan (40 CFR §300), and follows the general sequence and intent for conducting Feasibility Studies as presented in the U.S. EPA's "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (U. S. EPA, 1988). To the extent appropriate, the FS considers remedial alternatives that can mitigate exposures through institutional controls, containment, and reduction of contaminant concentrations and mass through treatment or removal. Potential remedies were analyzed taking into consideration the expected future land uses and the existence of Randleman Reservoir.

The remedial action objectives developed for the Site and considered in the FS include the following:

- achieve adequate protection of human health and the environment for potential future uses at the site and adjacent areas; and,
- ensure that there are no unacceptable potential risks to human health and the environment resulting from discharges to the Deep River following construction of the Randleman Reservoir; and,
- address all applicable remediation standards to the extent practicable.

The remedial alternatives considered in the FS address the remedial action objectives by reducing constituent concentrations

in soil and ground water or by controlling the exposure pathways of concern.

Based on the remedial action objectives and a screening of potential remedial technologies, six remedial alternatives were developed for the Site. Each remedial alternative was evaluated in detail against the required U. S. EPA evaluation criteria, and a comparative analysis of the remedial alternatives was conducted.

With the exception of a no action alternative, all alternatives generally meet the established remedial action objectives, provided that significant changes in Site conditions do not occur. Based on the comprehensive investigation of Site conditions and the results of the contaminant transport model and feasibility study, no practical remedial alternatives are available to reduce on-site groundwater concentrations to below the G-1 ground water quality standards within a reasonable near term time frame. Based on the indicated presence of DNAPL within the fractured shallow bedrock aquifer at the Site, the FS concluded that no current technology exists which can be employed to effect in the near term an aquifer restoration that is consistent with U. S. EPA guidance for similar sites (U. S. EPA, 1993).

All the alternatives other than the no action alternative include institutional controls and natural attenuation to prevent unacceptable exposure risks in the future. Most of the alternatives included additional measures to address differing Site conditions in the future, such as potentially increased contaminant loading to the Deep River or Randleman Reservoir through groundwater or through surface water from the Southern Intermittent Stream.

COMPLICATIONS PRESENTED BY THE PRESENCE OF DNAPL

Determination of the proposed remedial strategy was based in part on the issues presented by DNAPL contamination at the Site. The occurrence of dissolved VOC concentrations in ground water at the Site at levels of 1 to 10 percent of aqueous solubilities indicates the presence of DNAPLs in the subsurface. Experience over the past decade has shown that achieving established ground water clean up standards is not practicable in the short term at similar sites due to remedial technology limitations. The U.S. EPA developed OSWER Directive 9234.2-25: "Guidance for Evaluating

the Technical Impracticability of Ground Water Restoration" to address the issue of whether groundwater clean up goals are technically achievable at a particular site, and how to establish an alternative, protective clean up strategy where near term restoration is determined to be impracticable. The prevalence and intractability of DNAPL contamination are among the principal reasons this guidance was developed. Most of the sites where the U.S. EPA has determined ground water restoration to be technically impracticable have DNAPLs present.

The general source location of DNAPLs at the Site is known and has been characterized. The location of the source area of DNAPLs is the subsurface soils and fractured bedrock beneath and down gradient of the former processing areas of the Seaboard Facility. Closure activities were conducted at the processing areas in 1990 and 1992 to remove surface waste materials and certain equipment from the Seaboard Facility. Based on a detailed evaluation of remedial alternatives in the FS, locating and achieving complete removal and remediation of DNAPLs from the complex geologic subsurface environment is considered infeasible within a reasonable time frame. The technical impracticability of near term ground water restoration at the Site was confirmed through the results of the comprehensive technology screening and analysis in the FS. The remedial simulations of the solute transport modeling further demonstrated that groundwater restoration is impractical at the Site. The model simulations show that hydraulic containment and recovery will have only a limited effect in removing DNAPL, and will involve very long remediation time frames. Nevertheless, they represent the most practical and effective means of containment of contaminant migration.

PROPOSED REMEDIAL DESIGN

OVERVIEW

The proposed remedial design consists of groundwater extraction and treatment in combination with institutional controls including site access control, recorded land use restrictions and restriction of water supply well construction. The proposed remedy will prevent movement of contaminants into the Deep River and the Northern and Southern Intermittent Streams and prevent exposure to impacted soils and groundwater at the Site. Because this remedy will involve a long time frame, extraction of ground water at a rate necessary to contain contaminant migration is proposed. Groundwater and surface water sampling will monitor the effectiveness of the remedy to ensure that there is no unacceptable migration of contaminants to the Deep River or Randleman Reservoir.

It has been determined that the most effective long term method to accomplish the treatment of the extracted ground water is through natural treatment processes such as engineered constructed wetlands and phytoremediation. This method will involve the use of treatment wetlands in combination with an upland phytoremediation system comprised of rapidly growing poplar trees and more slowly growing conifer trees to provide year-around treatment effectiveness for the extracted ground water.

Selection of the proposed remedy is based in part on the presence of DNAPL contamination at the Site. Given the presence of DNAPLs in the subsurface and the highly fractured and heterogeneous bedrock conditions present at the Site, restoration of groundwater quality to regulatory standards within a reasonable time frame has been determined to be technically impracticable. The remedial objectives and major components of the recommended remedy are discussed below.

REMEDIAL OBJECTIVES

To the extent practical, the objectives of remedial action at the Site include the following:

1. Contain the contaminated soils at the source areas to prevent direct contact by potential human and environmental receptors, reduce percolation and intrusion of storm water and reduce migration of compounds of concern ("COCs") into the groundwater; and,
2. Control migration of landfill leachate to prevent discharge to surface waters at the Site; and,
3. Control migration of contaminated ground waters and leachate at the site to prevent offsite migration and unacceptable impacts to surface waters; and,
4. Achieve compliance with North Carolina surface water quality standards for the COCs in the surface waters of the onsite streams and the Deep River; and,
5. Achieve compliance with North Carolina ground water quality standards for the COCs in the ground water beneath the Site; and,
6. Restrict future Site uses that could present potentially unacceptable exposure risks (e.g., residential development, use of impacted ground water, etc.).

SPECIFIC COMPOUNDS OF CONCERN

Site-related compounds of concern include:

Perchloroethene
1,2-Dichloroethane
1,1,1-Trichloroethane
1,1-Dichloroethane
1,1-Dichloroethene
1,2-Dichloroehthene
Trichloroethene
Vinyl Chloride
Chlorobenzene
Methylene Chloride
Chloroform
Benzene
Toluene
Xylenes
Acetone,

2-Butanone

1,4-Dioxane

The North Carolina surface water quality standards are summarized below.

Table 1 ***Maximum surface water contaminant concentrations (Through August 2004)***

Compound	Maximum Concentration (µg/l)	NC 2B (WS-IV) Surface Water Standard (µg/l)
Benzene	6.0	1.19
Chlorobenzene	189.0	488.0
Chloroethane	51.5	860.0
1,1-Dichloroethane	85.4	42.0
1,1 Dichloroethene	33.0	0.057
1,2 Dichloroethane	6.0	0.38
cis-1,2 Dichloroethene	87.2	33.0
1,4-Dioxane	806.0	3.0
Methylene Chloride	110.0	4.7
Tetrachloroethene	4.0	0.8
Toluene	4.0	11.0
1,1,1-Trichloroethane	66.0	200.0
Trichloroethylene	5.8	3.08
Vinyl Chloride	31.2	2.0

Analytical results from surface water samples collected at site since April 1997
Concentrations in bold exceed NC 2B Surface Water Standard
NE –No standard or remediation goal established

CAPPING OF SOURCE AREAS AND IMPACTED SOILS

SEABOARD FACILITY

The VOC-impacted soils underlying the former operations area of the Seaboard Facility are currently covered by concrete pavement. As part of the remediation plan, the existing concrete pavement will be utilized and maintained as a cap to prevent direct exposure to impacted soils and reduce infiltration of rainfall and potential migration of soil contaminants. Based on a visual inspection, an engineering evaluation has determined the general integrity of the existing concrete pavement and verified its effectiveness for use as a remedial cap. Areas in need of cap enhancement or repair will be addressed.

SOIL RESIDUE MOUND

The Soil Residue Mound consists of approximately 600 cubic yards of residue from the former burn pits. This area is located on the

south side of the access road between the former maintenance building and the Materials Recovery Facility (Figure 2). The Soil Residue Mound is currently vegetated with grass and volunteer pine trees. Approximately two feet of soil provides cover for the waste residue and supports the vegetative growth. As discussed in the OU-4 Former Burn Pits Evaluation section, testing of the waste residue determined the material to be non-hazardous by RCRA standards.

It is proposed to leave the Soil Residue Mound in place and improve the effectiveness of the existing soil cap. This will consist of removing all vegetation from the mound and re-working the existing cap soils to improve surface water runoff and stabilize the side slopes of the mound. Currently, the side slope on the south side of the mound is greater than 1:1 in places. Additional borrow soils will be obtained to improve the side slopes to an approximate 3:1 slope. After stabilization of the side slopes, a recompacted clay cover will be placed over the entire footprint of the mound. The clay cover will be eighteen inches in depth and recompacted to a permeability of less than or equal to $1x10^{-5}$ cm/sec. After installation of the clay cover, six inches of topsoil will be added to support the vegetative cover. The vegetative cover will consist of native grasses which will require periodic mowing and maintenance.

LANDFILL CAP INCLUDING FORMER BURN PITS AREA

The Landfill and former burn pit areas are currently capped with two feet of soil and vegetated with native grasses. The closure of the Landfill occurred in 1993 and was conducted in accordance with rules established by the NC Solid Waste Section. The Landfill is now in post-closure, which requires periodic monitoring and maintenance to assure stability of the cap and vegetative cover as well as the removal of leachate from the limited leachate collection system. It is proposed to continue the monitoring and maintenance requirements established by the NC Solid Waste Section.

GROUND WATER EXTRACTION SYSTEM

Pumping from ground water extraction wells is considered the most viable alternative to address the VOC-impacted ground water

migrating to the NIS, the SIS and the Deep River. Based on the results of ground water extraction testing conducted at the Site, a conceptual design has been developed for the number, locations and extraction (pumping) rates of recovery wells included in the ground water extraction system. The proposed extraction well locations are shown in Figure 11.

For the main plume of VOC-impacted groundwater migrating from the bedrock aquifer to the Deep River, the conceptual design includes placing a ground water extraction well in the bedrock aquifer at a location along the east-west segment of the Deep River near the SIS confluence. The purpose of the Deep River recovery well is to capture impacted ground water in the bedrock aquifer associated with releases from the Site in order to protect surface water quality in the Deep River. It is anticipated that pumping from the bedrock aquifer may also induce some drawdown in the overlying saprolite aquifer zone and provide some capture of shallow impacted ground water in the eastern SIS area. Based on extraction rate test results and allowing a contingency for the potential hydraulic effects of the future normal pool of Randleman Reservoir at the Site, the estimated pumping rate for the Deep River recovery well system is 20 to 30 gallons per minute ("gpm").

In the SIS area, the conceptual design includes placing a system of approximately eight shallow ground water extraction wells along the western segment of the SIS (four wells each along both the north and south banks of the stream). The purpose of the recovery well network is to capture impacted shallow ground water associated with releases from the soil residue mound, the central landfill area and the former Seaboard facility in order to protect surface water quality in the western segment of the SIS (upstream of the SIS piped segment and landfill). In addition, one shallow ground water extraction well will be installed east (down gradient) of the landfill and the SIS piped segment. The purpose of the eastern SIS recovery well is to capture impacted shallow ground water to protect surface water quality in the eastern segment of the SIS and the Deep River. Based on extraction rate test results, the estimated average pumping rates are 5 gpm total for the eight well network in the western SIS and 1 gpm for the eastern SIS recovery well.

In the NIS area the conceptual design includes placing a shallow ground water extraction well at a location east (down gradient) of the landfill and the NIS piped segment. The purpose of the eastern NIS recovery well is to capture impacted shallow ground water associated with releases from the northern landfill area in order to protect surface water quality in the eastern segment of the NIS and the Deep River. Based on extraction rate test results, the estimated pumping rate for the eastern NIS recovery well is 10 gpm.

For the southeastern landfill area, the conceptual design includes placing a shallow ground water extraction well at a location east (down gradient) of the landfill near the PW-10I/PW-10D well cluster. The purpose of the southeastern landfill recovery well is to capture impacted shallow ground water associated with releases from the southern landfill area in order to protect surface water quality in Deep River. Based on extraction rate test results, the estimated pumping rate for the southern landfill recovery well is 2 to 5 gpm.

NATURAL TREATMENT SYSTEMS

The need to reduce chlorinated VOCs and 1,4-dioxane concentrations in the Site ground water has prompted a thorough evaluation of the use of natural treatment systems. The natural remediation approach for the Site will consist of two distinct components: a constructed wetland treatment system and an upland phytoremediation system. Currently, it is envisioned that the constructed wetland systems will treat ground water from the extraction points near the Deep River, NIS and SIS and collected landfill leachate, and that treated effluent will ultimately be distributed to the upland phytoremediation system. These treatment systems are described in more detail below.

PHYTOREMEDIATION

One component of the natural treatment system is a phytoremediation system consisting of large stands of trees located on or adjacent to the Landfill that will be subirrigated with the moderately saline pre-treated ground water and leachate (the "recovered groundwater") (ENSR/Phytokinetics, 2003a and 2003b). The tree stands will use all of the recovered ground water

via transpiration and 1,4-dioxane will be effectively removed from the ground water through phytovolatilization. Any VOCs not removable by pretreatment will be biodegraded in the oxidized plant rhizosphere. The full-scale phytoremediation system will consist of two different types of tree stands: *a*) a stand of deciduous trees including poplars that will be subirrigated with recovered ground water from approximately April through October; and *b*) conifer stands that will be subirrigated recovered ground water in the winter months from approximately November through March.

PHYTOREMEDIATION SYSTEM GREENHOUSE STUDY

A Greenhouse Study of the effectiveness of upland phytoremediation for treatment of recovered Site ground water has been conducted. The study was conducted over a six month period (October 2003 to March 2004) to test the hypothesis that phreatophytic poplar trees, and potentially other tree species, can take up dissolved 1,4-dioxane from soil moisture, translocate the compound to the shoots, and then phytovolatilize it. The physiochemical characteristics of 1,4-dioxane limit many biological treatment processes because 1,4-dioxane biodegrades slowly. Also, 1,4-dioxane is difficult to remove in a treatment wetland system, because it is highly soluble in water and does not sorb strongly to organic matter. Thus, it will tend to pass unattenuated through a wetland. It is also very difficult and costly to treat with conventional treatment technologies. In the proposed Site remedy, pre-treated ground water containing 1,4-dioxane will be pumped from an extraction well (PW-DR1) located near the Deep River and used to sub-irrigate a stand of trees on or adjacent to the City of High Point Riverdale Drive Landfill. VOCs will be treated by constructed wetlands or a $HiPO_x$® ozone oxidation system prior to irrigation of the tree stands.

The Greenhouse Study evaluated five different species of trees (hybrid poplar saplings and four species of conifers) to determine the most effective variety for the specific Site conditions. Complete details of the study methodology are found in the *Work Plan for a Greenhouse Study to Test the Feasibility of the*

Conceptual Design for an Upland Phytoremediation System (ENSR/Phytokinetics, 2003b). The results of that study revealed the following major points:

- In the 1,4-dioxane tolerance study, there was no decrease in plant biomass production for any of the species across the four concentrations of 1,4-dioxane tested, therefore it was determined that 1,4-dioxane is not phytotoxic at these concentrations.
- In the phytovolatilization study, the Transpiration Stream Concentration Factor value for the hybrid polar and Ponderosa pine saplings indicated that 1,4-dioxane is readily taken up by these species.
- The hybrid poplar saplings could phytovolatilize 1,4-dioxane at an 11-fold greater rate than the most promising conifer species, the Ponderosa pine.
- The hybrid poplar appeared to be tolerant of the Site's saline ground water and tended to exclude manganese, a potentially phytotoxic metal, which the Ponderosa pine accumulated (but did not show any deleterious effects within the short duration).

The results suggest that fast growing phreatophytic species including poplars and possibly willows (*Salix* spp.) will effectively take up the ground water at the Site without adverse effects from mineral salt accumulation, will not accumulate potentially phytotoxic metals, and will provide an efficient and cost-effective remedial treatment option for removing 1,4-dioxane from the recovered ground water via phytovolatilization.

PHYTOREMEDIATION SMALL-SCALE PILOT STUDY

Based on the results of the Upland Phytoremediation System Greenhouse Study, a small-scale field trial is being conducted at the City of High Point Landfill. The trial is part of the pre-design data acquisition activities needed to confirm that the proposed full-scale system is a viable remediation option either on the Landfill cap or property adjacent to the Landfill. Because the most restrictive location for the tree stand would be the Landfill cap, the trial was designed to assess the acceptability of that location, and the test plots must meet the following performance criteria:

a) the annual volume of Landfill leachate produced with the mature phytoremediation stands in place must be equal to or less than that currently produced; and,

b) the contaminants introduced to the phytoremediation stands via the subirrigation water must be removed by the stands (*i.e*. not contribute to the contaminant mass that currently exists in the landfill leachate).

To assess the feasibility of the upland phytoremediation system, four adjacent plots have been installed on the western portion of the landfill. The four plots vary from unplanted to planted with poplars or with conifers, and vary in substrate composition. Instrumentation at each plot will measure the total volume of input water (subirrigation plus precipitation), the volume of water moving downward through the plots and will estimate the total rate of transpirational water use by the stands of trees in each plot ("V_T"). The trial commenced in November 2004 and will continue through until the end of 2005, with additional data collection through 2006 and early 2007. Sufficient data will be obtained by the late fall of 2005 to prepare and implement a full-scale system in early 2006.

WATER BALANCE

For the upland phytoremediation system, the conceptual design is based on maintaining a water balance in the Landfill cap. A stand of sufficient size and density will be established which will result in the use, via transpiration, of both precipitation and the applied ground water. The design parameters are similar to those for a vegetated landfill cap in which the water losses through transpiration, evaporation, runoff and change in water storage of the soil cap and waste material must equal water inputs.

The rate of transpirational water use for a stand of trees during a given time period can be estimated using the following equation (Ferro et al., 2003):

Equation 1

$$V_T = ET * \theta * LAI * A, \text{ where}$$

V_T = transpirational water use by the stand,

ET_0 = reference evapotranspiration during the given time period,

θ = the water use multiplier for a tree within a stand, which is equivalent to the rate of water use per leaf as a percentage of ET_0,

LAI = leaf area index (the leaf area per unit area of ground surface),

A = the total area of the stand.

Equation 1 can give reasonably accurate estimates of V_T, although another key factor in estimating transpiration is potential plant stresses. The equation assumes that the trees are freely transpiring, and any kind of stress (water, nutritional, toxic substances, etc.) can reduce photosynthesis and stomatal conductance. If the stomates close, the transpiration rate is reduced.

The average ET/precipitation ratio for the City of High Point area is 1.3. In the winter months the ratio is 0.63.

Values for θ and LAI are species-specific and depend on planting density and stand maturity. For a mature 3 to 4 year-old stand of hybrid poplars planted on 7 ft centers (approximately 850 trees/acre), the average rate of water use during the period from April through October is estimated to be 11.5 gpm/acre.

The rate at which a stand of poplars could be subirrigated with recovered ground water without producing excess drainage is approximately equal to V_T minus the rate of soaking precipitation (*i.e*. the precipitation that infiltrates the soil). As the stand of trees matures and V_T increases, the rate that irrigation water could be added also increases. The expected rate at which a mature 1-acre stand of poplar trees could be irrigated is approximately 9.4 gpm per acre.

The values for θ and LAI for the conifer stand are different from those for the poplar stand. Specifically θ is lower and LAI is higher, and the time required for the stand to reach maturity (canopy closure) is approximately 7 years. For a mature stand of conifers, it is estimated that the average rate of water use during the

period from November through March is 4.8 gpm per acre. The rate at which a mature stand of conifers could be subirrigated without producing excess drainage (V_T minus soaking precipitation) is approximately 2.9 gpm per acre.

WATER BALANCE ACCOUNTING

In order to evaluate whether the proposed phytoremediation system will affect water percolation, and thereby increase leachate generation, a small-scale field trial pilot test has been specifically set up to account for water inputs through the system. An accurate water balance accounting will be accomplished as part of the test.

The trees in Plots A through C have been planted in four rows with six trees per row. The rows and the trees within a row have been planted on 6 ft centers. Subsurface drip emitters have been installed at the base of each tree (two 0.5 gph emitters per tree, located 6 in. below ground surface). Note that Plot D will not be irrigated. The trees will be subirrigated as needed with groundwater and leachate recovered from PW-DR1. The trees in Plots A and B will also obtain moisture from infiltrated precipitation. The groundwater and leachate used in the pilot study will not be pre-treated prior to irrigation of the tree stands because the constructed wetland and ozone oxidation systems are not yet in place. The following instruments have been installed in the test plots:

- Two (duplicate) Drain Gauges, set at 3 ft below ground surface ("bgs") to measure the volume of water that is moving downward in Plots A to D (Figure 2);
- Soil-water content meters set at 1 ft, 2 ft, and 3 ft bgs at each of two locations in Plots A to D (Figure 3);
- Water meter, installed in each planted plot to monitor the total volume of recovered groundwater delivered to the trees via the subirrigation system;
- One rain gauge, installed at the site to monitor precipitation in the area of the test plots; and

- Thermal dissipation probes ("TDP") will be installed for 3 trees per plot during the second growing season (total of 9 TDPs). The TDPs measure sap flow and can be used to estimate transpiration rates.

Using this instrumentation, a water balance will be maintained for each of the four plots. For the poplar Plots A and B, the total volume of input water (subirrigation plus precipitation) will be measured by the water meter and the rain gauge. The TDPs will be used to estimate the total rate of transpirational water use by the stands of trees in each plot, and the Drain Gauges will measure the volume of water moving downward. The subirrigation drip emitters will be controlled by soil moisture probes set at 1 ft bgs. Thus, the soil moisture will be maintained at levels that are optimal for the trees (less than 80 centibars of soil suction). For the 864-ft^2 plots, average growing season precipitation is approximately 60 gallons per day.

PHYTOREMEDIATION SUMMARY

Phytoremediation will accomplish the necessary natural treatment of the 1,4-dioxane and the chlorinated organics that may leave the treatment wetlands. Initially, a proposed $HiPO_x$® system is expected to provide 1,4-dioxane pretreatment as the tree stand and canopy matures. Recovered ground water will then be treated in the constructed wetlands, and the phytoremediation system will provide post-wetland 1,4-dioxane treatment. It is estimated, based on the above water balance that a 6-8-acre tract planted with poplar or willow trees will consume all of the extracted ground water necessary to provide effective containment for the Site and all storm water which falls within the treatment system during the growing season from approximately April 1st to September 30th of each year. Then a 25-30-acre tract planted with conifer trees will handle the extracted ground water and storm water from October 1st to March 31st of each year.

TREATMENT WETLANDS

The second component of the natural treatment system is a constructed wetlands system consisting of two cells (likely 1.0 acre, and 2.0 acre in size) of lined, vertical sub-surface flow wetlands constructed in one or more areas on the Site.

Constructed wetlands will be used as a stand-alone treatment technology for chlorinated solvents, and as a treatment technology to be used in conjunction with the proposed $HiPO_x$® treatment system until the upland phytoremediation system reaches maturity.

A treatment wetland can be constructed to passively intercept a VOC ground water plume or ground water can be actively pumped to a distribution system at the base of the wetland. In both scenarios the water slowly percolates to the surface. Treatment occurs as the water is passing through the peat soil and the root bed of the wetland plants. Fate processes in this application include reductive dechlorination of chlorinated ethanes and ethenes, sorption, methanotrophic biodegradation, aerobic biodegradation, and plant uptake. A number of proof-of-concept studies have appeared in the literature (i.e., Kasssenga et al., 2003) that demonstrates the feasibility of this remedy. Additional treatment rationale is presented in the Conceptual Design and Pilot Study Workplan (ENSR and Phytokinetics, 2003a).

Traditional design approaches for treatment wetlands usually define the area of the wetland required for treatment. The approach used at the Site is calculated to find the volume of the wetland bed required for treatment due to the need for introduction of contaminated water deep in the subsurface of the wetland system.

The design approach consists of the following steps:

(1) Estimation of the flow rates and concentrations of the various target constituents.

(2) Utilization of a reactive-transport equation to estimate constituent removal for the target constituents. Estimated removal efficiencies were compared with desired removal efficiencies in order to meet the regulatory requirements for target constituents. The most rate-limiting reaction will control the design of the system.

(3) Calculation of removal efficiencies for different bed depths using the design equation. If the computed values of removal efficiencies are found to be less than the

desired ones, the bed depth is increased until the required removal efficiencies are obtained.

(4) Wetland area is dictated by the need for a particular porewater velocity and by water budget considerations.

GREENHOUSE STUDY

A greenhouse study is being conducted (started late September 2004) as a pre-design activity to test the final feasibility for the constructed treatment wetland system to treat the specific chlorinated solvents in the site groundwater and leachate. The study consists of 2 components:

a) upflow wetland column studies to identify required wetland depths, and

b) serum bottle studies to confirm that biodegradation is taking place.

The existing scientific literature suggests that plant uptake and soil biodegradation should provide efficient removal of the compounds in the rhizosphere of wetland plants. The objectives of the pilot study are to:

a) Determine the depth of wetland substrate required to remove chlorinated solvents at the anticipated flow rates and concentrations indicative of two different extraction points; and,

b) Confirm that the loss of chemicals in the substrate is due to microbial degradation.

This study is conducted in lieu of a field piloting program and will serve as the scientific basis for design of a full-scale wetland treatment system for site VOCs. The pilot study is being conducted over a six month period (through March 2005).

CONSTRUCTED TREATMENT WETLAND SYSTEM DESIGN

While the $HiPO_x$® test results indicate significant reductions in the chlorinated organics (the exception being Chloroethane), the size

of the constructed wetland cells is based on the wetlands receiving the full concentration (without $HiPO_x$® pretreatment) of contaminants. Two wetland cells are proposed to address Northern Intermittent Stream and Southern Intermittent Stream areas. The NIS wetland cell will treat groundwater extracted from beneath the eastern streambed of the NIS at an anticipated flow rate of approximately 6 gpm. The SIS wetland cell will be used to treat commingled ground water, surface water (from the eastern and western SIS extraction wells and Deep River extraction points) and landfill leachate at an anticipated combined flow rate of 40 gpm.

Based on site visits and pre-design efforts, a flow-through constructed wetland has been proposed to treat chlorinated solvents in ground water and surface water prior to irrigation of the phytoremediation system. The objective of the treatment wetland is to passively treat VOCs by a combination of processes including biodegradation, sorption, plant uptake and metabolism. Pretreatment for 1,4-dioxane will be accomplished by use of a $HiPO_x$® system during the maturation period of the phytoremediation tree stand, and by the phytoremediation system as it becomes mature.

The construction of the wetland treatment cells will involve placement of a layer of highly organic soil (compost, etc) and other organic soil materials in the selected areas. The wetland will be planted with plants capable of reaching a high biomass in the North Carolina climate. Treatment will occur as the ground water is passing through the peat soil and through the root bed of the wetland plants. Pumped ground water will be applied in an upflow mode through a manifold at the base of the wetland.

Site inspections have identified candidate constructed wetland cell locations based on acreage available, location outside of reservoir buffer restrictions and with ideal topography. The wetland creation sizing calculations will be completed as a part of the pre-design tasks. The process of gathering further design information is underway at this time, including the greenhouse pilot study to determine biodegradation rates and the identification of wetland substrate construction materials.

SUPPLEMENTAL GROUND WATER TREATMENT SYSTEMS

There will be an initial period during which the poplar stand will be less than 100% effective. There will also be as much as a 7 year period during which the conifer trees will not be 100% effective. This will depend on the final design, the number and type of trees used, the location of the natural treatment system and other factors that are yet to be determined. During this period a $HiPO_x$® system will be used to augment the natural treatment systems.

A physical or chemical treatment process will provide supplemental treatment of extracted ground water and leachate prior to the natural processes becoming mature and fully effective, and to provide an alternative to the natural processes if they do not perform in accordance with the design estimates.

$HIPO_X$® CHEMICAL OXIDATION SYSTEM

Bench scale treatability tests were conducted in June 2004, a $HiPO_x$® field pilot study was conducted during August, 2004 and a laboratory bench scale test using site ground water and leachate was conducted in October, 2004. The tests results establish that that this technology is effective in 1,4-Dioxane treatment. As a result, it is proposed as the alternative method of treatment to reduce the concentration of organic contamination in the extracted ground water and leachate.

In the pilot testing on ground water and leachate from the Site, the $HiPO_x$® system has been shown to be effective in reducing the 1,4-Dioxane and a majority of the chlorinated benzenes and ethenes. It will not destroy more than approximately 20% of the chlorinated ethanes. Therefore, the $HiPO_x$® system cannot be a stand alone treatment process. Testing did reveal that either constructed wetlands or air stripping, either before or after the $HiPO_x$® system, will remove 95% or more of the volatile organics from the ground water. All of the chlorinated organics were removed, including the ethanes. However, the neither the air stripping nor constructed wetlands was effective in removing 1,4-Dioxane. The combination of either constructed wetlands or air stripping and $HiPO_x$® was effective in treating all the VOCs present, including 1,4-Dioxane, to levels below regulatory requirements.

HIOPX CHEMISTRY

The $HiPO_x$® system uses hydroxyl radicals (^{-}OH) to oxidize organic contaminants in ground water and leachate. Hydroxyl radicals are one of the most powerful natural oxidizing agents for the destruction of organic compounds in ground water and leachate treatment applications.

Hydroxyl radicals are formed by the reaction of ozone with hydrogen peroxide. The overall, balanced reaction of ozone with hydrogen peroxide to form hydroxyl radicals is:

$$2O_3 + 3H_2O_2 = 4O_2 + 2OH^{\cdot} + 2H_2O$$

Hydroxyl radicals react very rapidly with organic contaminants to form carbon dioxide and water. They are, however, short-lived and must be continuously generated. In addition to generating hydroxyl radicals, the ozone will also, as demonstrated in the bench scale studies, react directly with the 1,4-dioxane, Chloroethane and chlorobenzene.

The $HiPO_x$® unit consists of a series of in-line reactors. Ozone is injected into each reactor and hydrogen peroxide is injected periodically. The amount of ozone and hydrogen peroxide and the number of reaction zones required for a given water treatment system are determined by the water flow rate, the composition and concentration of organic compounds in the influent and the desired effluent concentrations.

TREATMENT OF THE $HIPO_X$® EFFLUENT

The ground water leaving the $HiPO_x$® system will require additional treatment to be acceptable for any of the options that are available for the ultimate disposition of the treated effluent. Two technologies were identified that are known to be effective in removal of chlorinated organics. Constructed treatment wetlands are effective for this purpose. They are part of the natural process that has been identified as the ultimate goal for the treatment process. The other process is the physical stripping of the chlorinated organics in an air stripper or aerated retention tank. The proposed remedy may include some form of air stripping technology to provide an alternative to the constructed treatment wetlands if necessary.

AIR STRIPPING OR AERATED RETENTION TANK

This system consists of either a tower containing a series of perforated trays or a tank that contains a series of air diffusers. Ground water is pumped into the top of the air stripper and air is blown up from the bottom, passing through the perforations and contacting the water. As the ground water cascades over the trays and contacts the air, volatile organic compounds are stripped out of the water and carried off in the air. The air discharges out of the top of the unit and is dispersed into the ambient air. The aerated retention tank uses the same principle except that the ground water is pumped into a tank where it is retained for a period of time while air is injected through diffusers to strip the volatile organic compounds, which are dispersed into the air. Air stripping or aeration may occur either before or after the $HiPO_x$® treatment, depending on the most effective process configuration. The need to install air stripping will be determined based upon the effectiveness of the constructed wetlands.

TREATED WATER DISPOSAL

GROUND WATER REINJECTION

Ground water reinjection was identified as one of the alternatives to the natural treatment systems for disposition of the process effluent from the $HiPO_x$® system. Ground water extraction tests have shown that approximately 1 to 8 gallons per minute can be extracted from a typical well at the Site. Experience has shown that it is only possible to reinject about half of what can be extracted. DENR requires that for a reinjection system to be approved, the ground water treatment must be 95% effective, and it must be demonstrated that the injected water is recovered by the extraction well system to provide a closed loop flow system. To determine what effect reinjection will have on the shallow aquifer, the computer model was used to evaluate various simulations. The physical and chemical treatment processes as well as the natural treatment systems will produce a 95% overall treatment efficiency. Therefore, reinjection may be used for disposition of the treated effluent.

DISCHARGE TO THE EWWTP

Another alternative to the natural treatment systems for the disposition of the effluent from the $HiPO_x$® treatment system is to discharge the treated water to the EWWTP. This alternative will require that the discharged water meet the pretreatment standards of the EWWTP. In addition, it will require that a pipeline be installed from the $HiPO_x$® treatment area to the inlet of the EWWTP.

SURFACE WATER MANAGEMENT

The remedy will include a surface water management plan. This plan will include a method to address ground water and landfill leachate intrusion into the SIS and NIS piped sections.

The Parties have evaluated methods to eliminate the leakage that is occurring at the joints in the reinforced concrete pipe in the NIS. This evaluation included inserting a new pipe inside the existing one, lining the existing pipe or redirecting the headwaters of the stream

A video survey of the piped section of the NIS revealed that a significant amount of landfill leachate and groundwater enter this section through leakage at the pipe joints. The treatment system will not be capable of effectively treating the volume of contaminated water that would be generated during significant storm events if this leakage continues to be allowed to commingle with the surface water. After considering the alternatives, the Parties propose to re-route the headwaters of the NIS and permanently close the inlet structure, as this is the most effective way to address this problem.

After closure of the inlet, the elevation of the headwaters area will be raised by the addition of clean fill material. Approximately twenty feet of clean fill will be placed in the headwaters area to raise the ground surface elevation to approximately 770 feet msl. This will allow the surface water flowing from the NIS drainage basin to be diverted to the northeast to join an unnamed tributary to the Deep River located on the southern portion of property north of the landfill, which is owned by the Bowman family. An

open ditch, approximately five to ten feet in depth, will connect the NIS headwaters to the new discharge location on the Bowman property. This alternative will require the purchase of additional property or easements for filling and grading operations.

The leachate that leaks into the existing NIS pipe will be drained into a new structure at the pipe outlet, which will allow it to be collected and handled in a manner consistent with the other leachate generated at the landfill. Ground water flowing under the piped section of the NIS will be extracted from a single extraction well located near the outlet end of the outer pipe. That ground water will be processed through the remedial treatment processes

At the SIS, it is proposed to remove the large bolder and tree roots that presently impede flow and allow minor leakage of landfill leachate and impacted ground water into the pipe. Then the leaking joint(s) will be repaired, and the normal stream flow will be allowed to pass through the repaired pipe into the Deep River. Shallow ground water flowing under the piped section of the SIS and the buried SIS valley will be extracted from a single extraction well located near the outlet end of the pipe. That ground water will be processed through the remedial treatment process.

INSTITUTIONAL CONTROLS AND LAND USE RESTRICTIONS

All structures at the Seaboard Facility have been removed. A second security fence has been constructed around the entire perimeter of the Seaboard Facility to prevent unauthorized access. The City also stored excess mulch on the concrete pavement to discourage trespassers, and the Site is inspected periodically. Institutional controls and land use restrictions approved by DENR will be implemented at the Site and necessary adjacent areas. Land use restrictions will be placed on the property to restrict future uses that could present potentially unacceptable exposure risks (e.g., residential development, use of impacted ground water, etc.). The land use restrictions will be in the form of perpetual declarations to be recorded with the property deed and/or through the development of zoning or permit restrictions against the potentially unacceptable activities. A deed declaration will describe the scope of the land use restrictions, and will include a survey and property description to define the areas of concern.

Long-term, periodic site inspections and surface water and ground water quality monitoring will be conducted. The site inspections will be conducted to identify signs of unauthorized access to the Site, or damage to the security fencing. The monitor well pads and covers will also be inspected and repaired as necessary to maintain the integrity of the monitor wells. The frequency and duration of site inspections will be adjusted as necessary, and maintenance of the Site will be conducted on an "as-needed" basis.

GROUND WATER AND SURFACE WATER MONITORING

Ground water sampling of selected wells will be conducted to evaluate potential changes to the contaminant plume over time and to ensure that constituents are contained by the extraction well system and are naturally attenuating to a degree that precludes unacceptable contaminant transport to the on-site streams and the Deep River or Randleman Reservoir. Surface water sampling will address water quality in the Southern and Northern Intermittent Streams and the Deep River or Randleman Reservoir. The actual sampling locations, monitoring parameters and "action levels" for additional evaluation will be established during the remedial design phase. A detailed ground water and surface water monitoring plan including a monitoring schedule will be developed and submitted to DENR for approval during the remedial design phase. The monitoring plan will include a proposed five year schedule and a proposal that it be reviewed annually to determine whether modifications are necessary.

EVALUATION OF EFFECTIVENESS

The effectiveness of the remediation will be evaluated on its ability to achieve compliance with North Carolina surface water quality standards for the compounds of concern in the surface waters of the on-site streams and the Deep River (or future Randleman Reservoir). The elimination or reduction of contaminant concentrations in ground water in the area north of the Deep River will be monitored to assure the effective capture of impacted ground water.

SCHEDULE

The proposed schedule for implementation of remedial action is summarized below.

Table 2- Schedule

Activity	Target Completion Date
Start constructed wetland lab pilot	October 2004
Install small-scale phytoremediation field pilot	November 2004
Parties Present Recommended Remedy to DENR	January 2005
DENR Approval of Proposed Remedy	February 2005
Public Notification Period	March 2005
Submit Remedial Design and GW/SW Monitoring Plan to DENR	April 2005
Receive NCDENR approval of remedial design	July 2005
Contractor selection and equipment procurement	August 2005
Pre-remediation GW & SW monitoring	August 2005
Begin remediation system construction	September 2005
Begin construction of constructed wetland treatment cells	November 2005
Begin construction of full-scale phytoremediation system	November 2005
Remediation system start-up	December 2005
Initial remediation GW & SW monitoring event	March 2006
Submit initial monitoring report to NCDENR	May 2006

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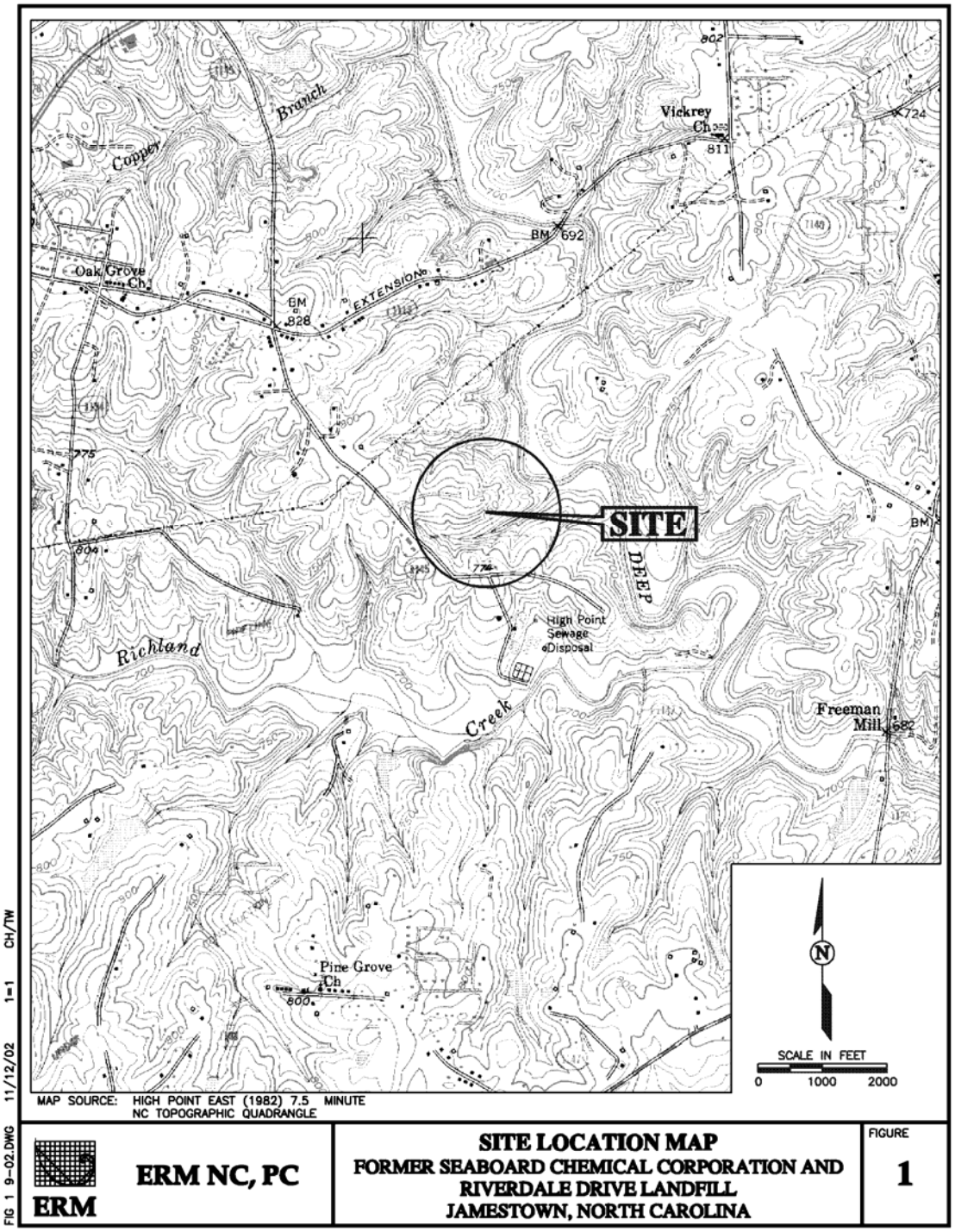

Figure 1-Site Location Map

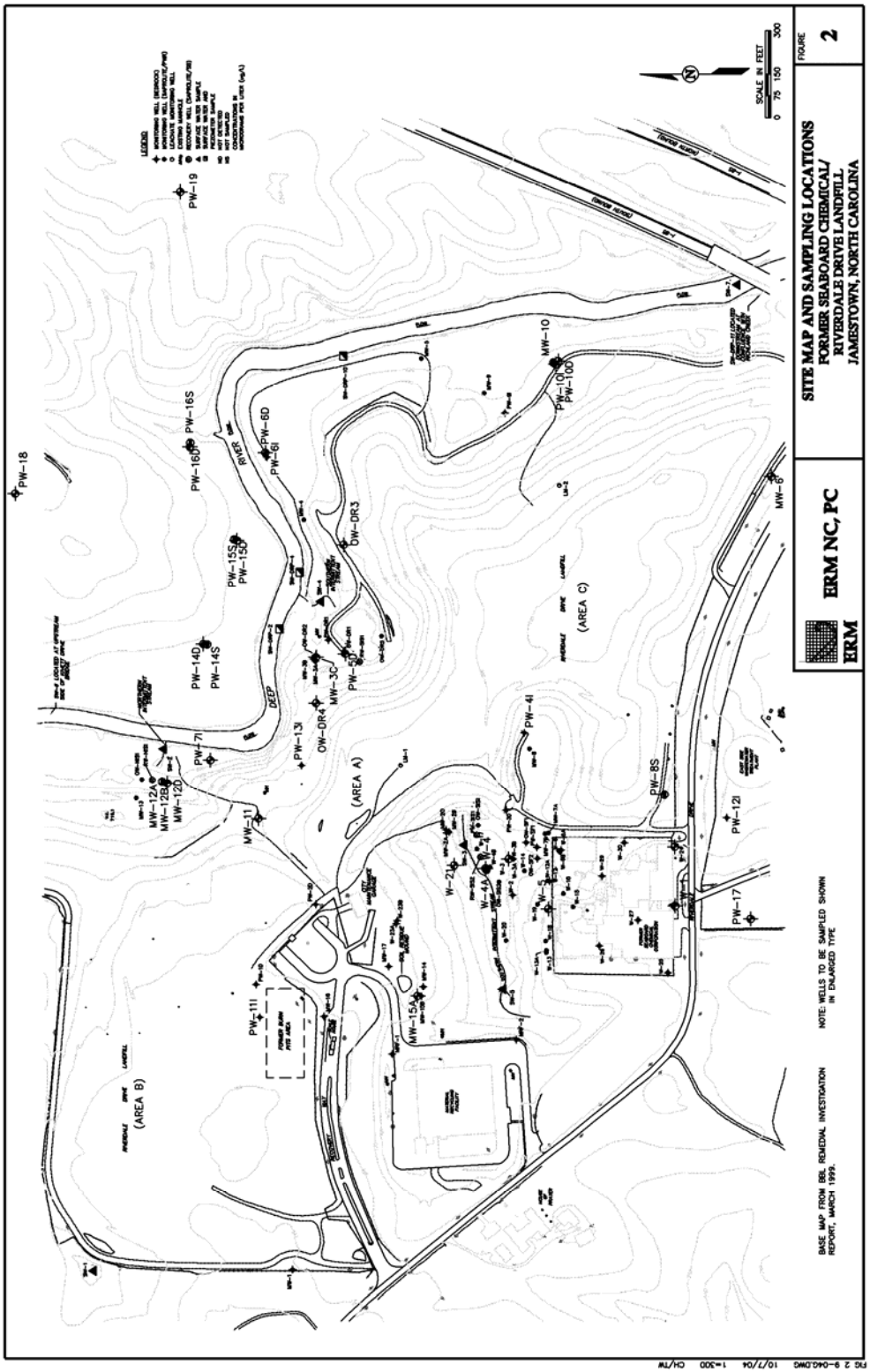

Figure 2-Site Map

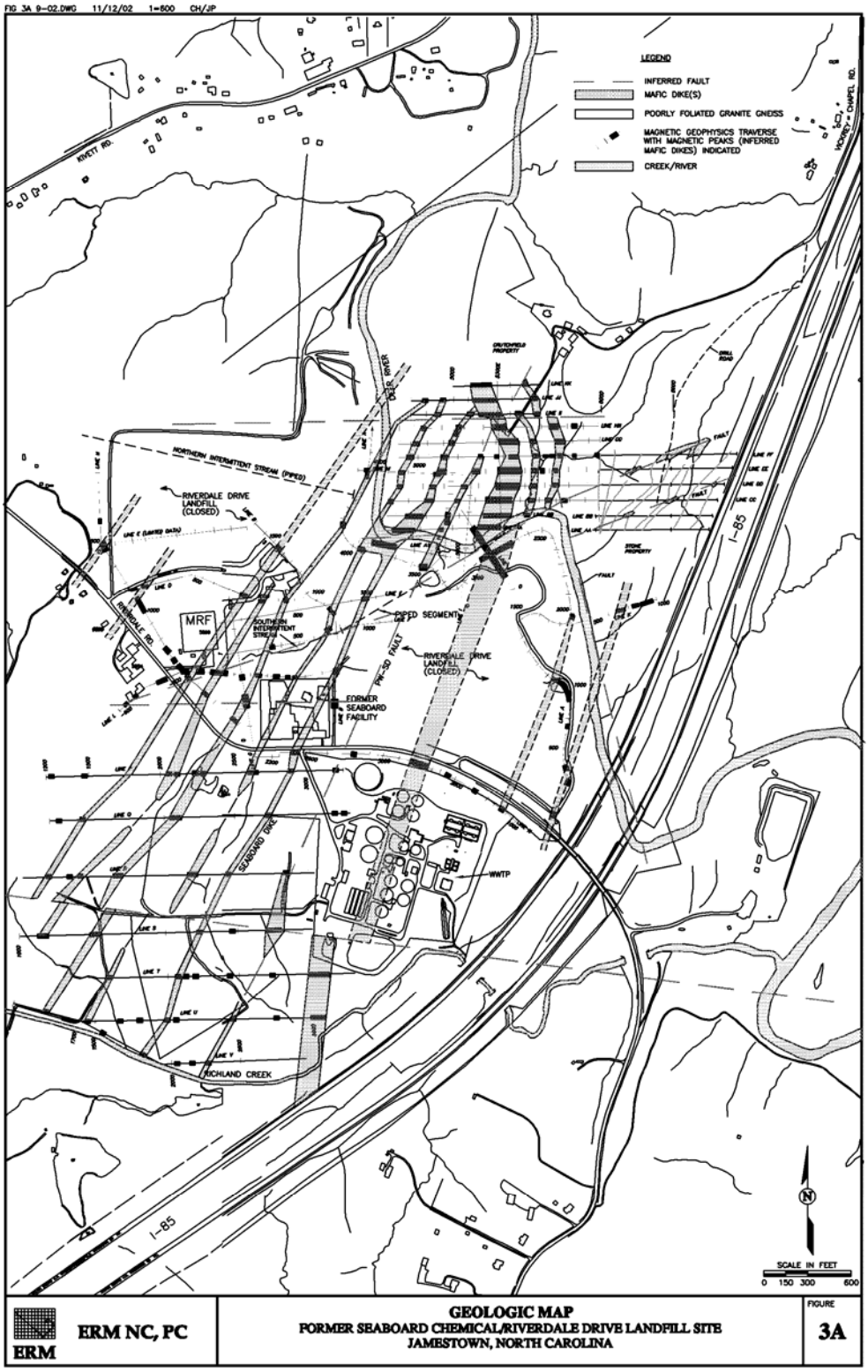

Figure 3-Geologic Map

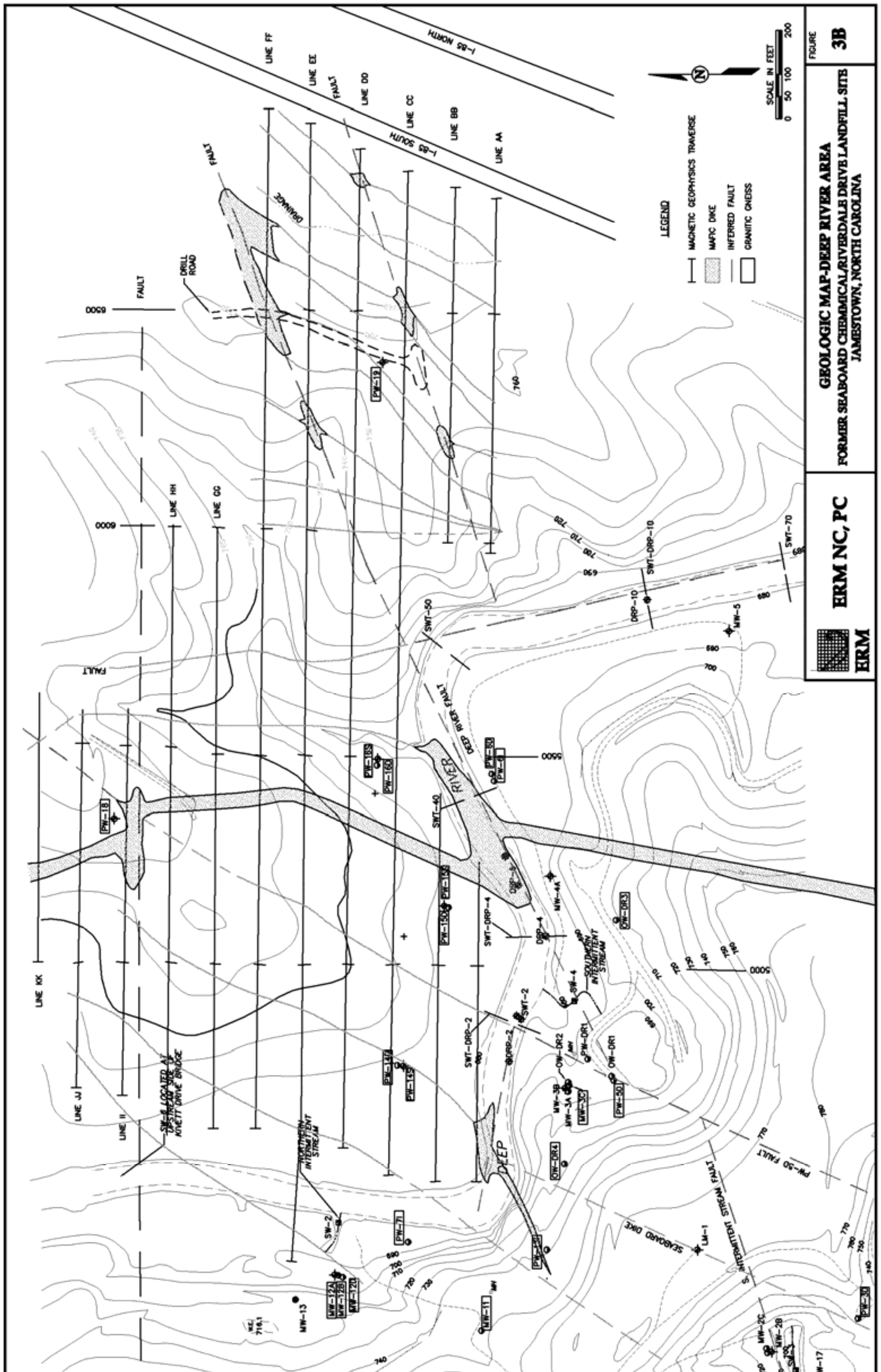

Figure 4-Geologic Map Deep River Area

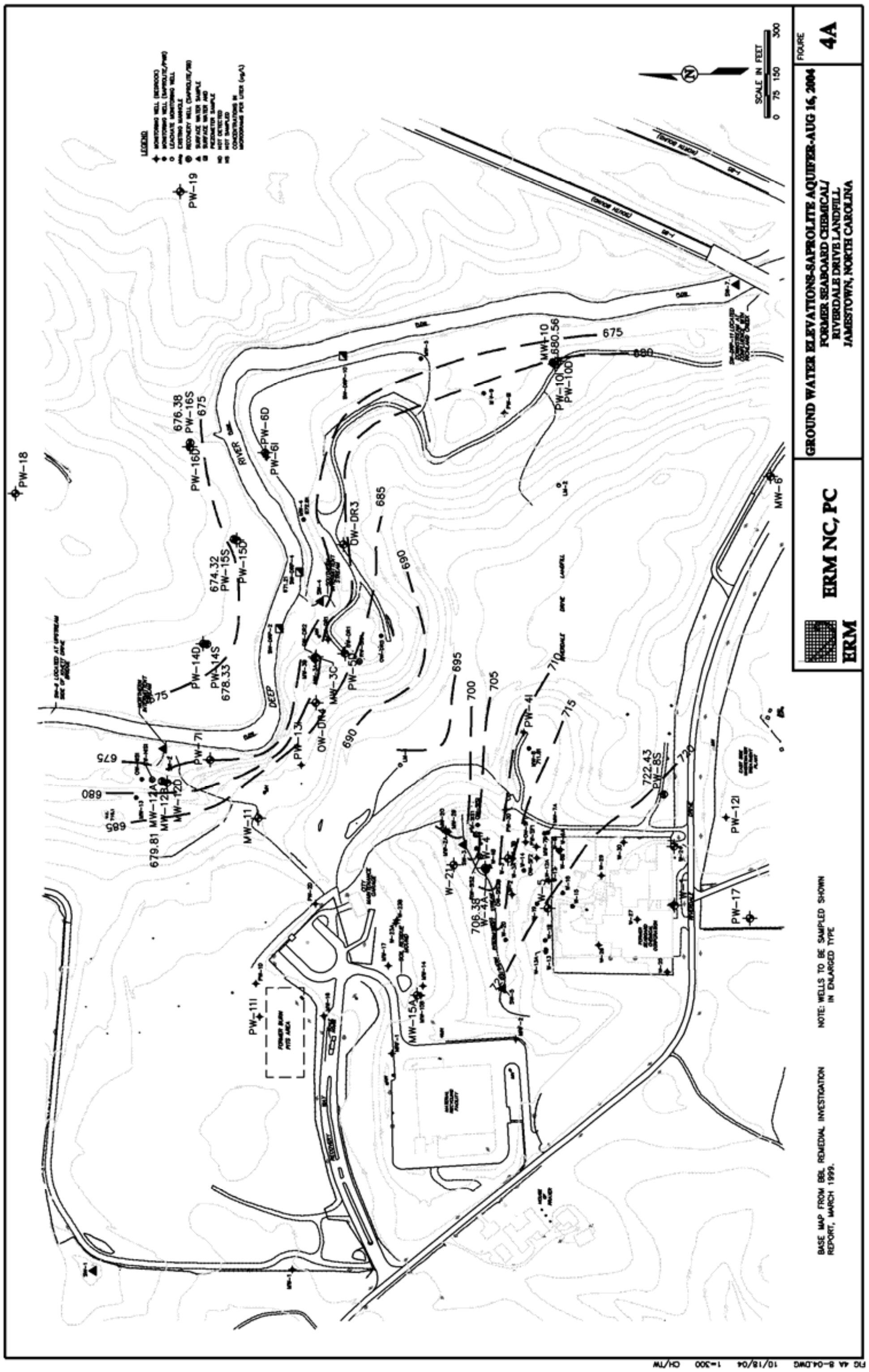

Figure 5-Ground Water Elevations - Saprolite Aquifer

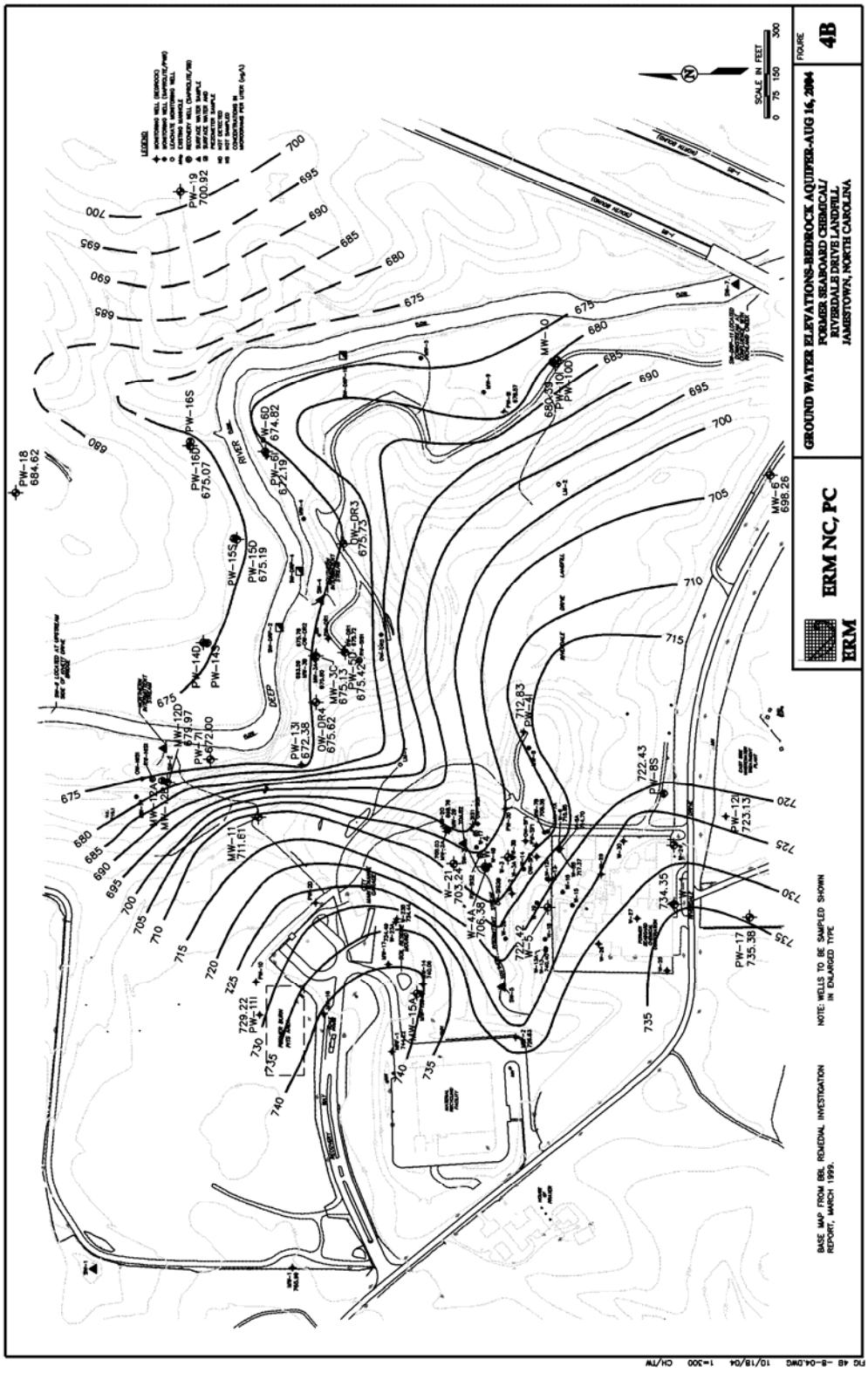

Figure 6-Ground Water Elevations - Bedrock Aquifer

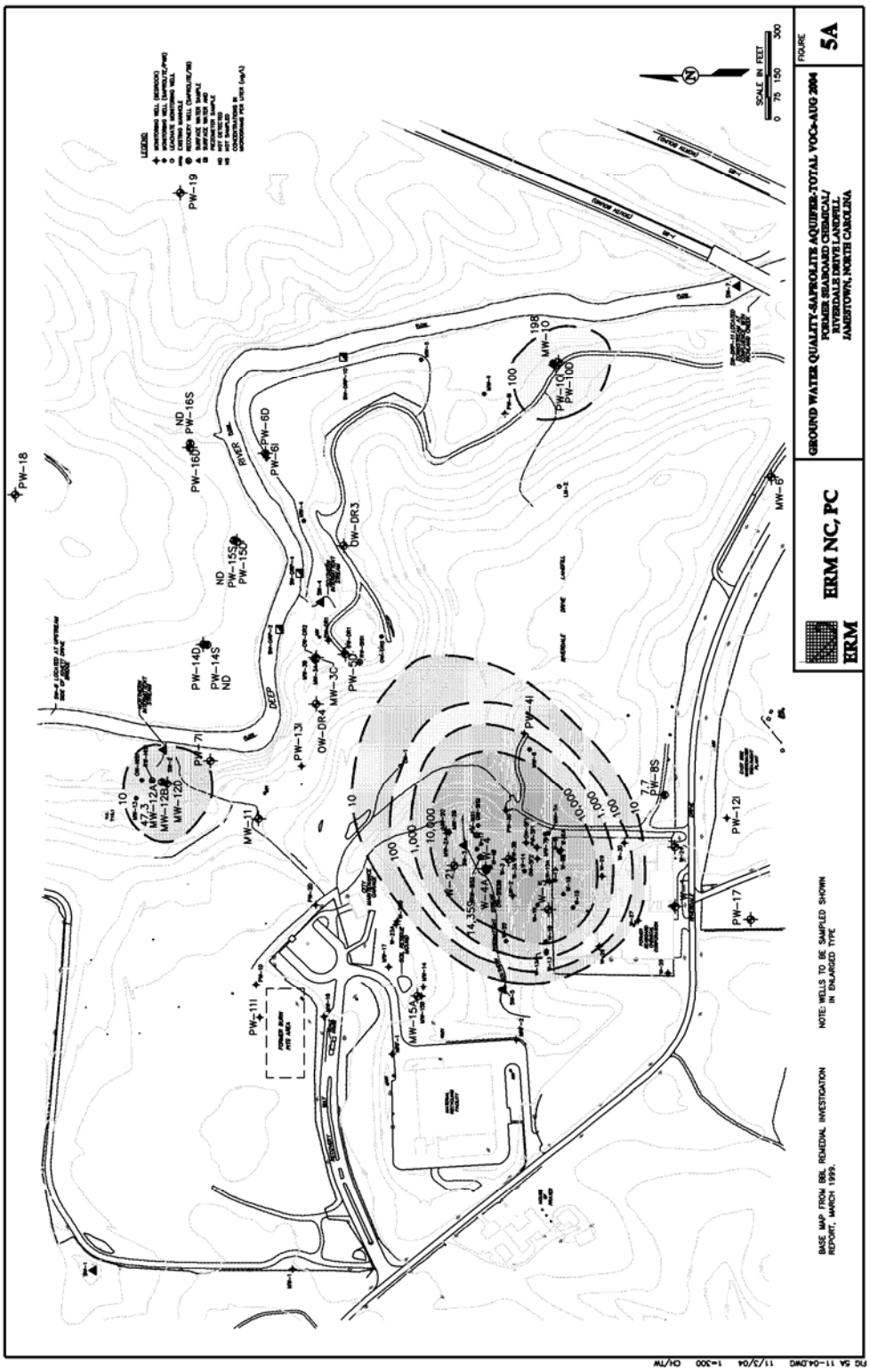

Figure 7-Ground Water Quality – Saprolite Aquifer Total VOCs

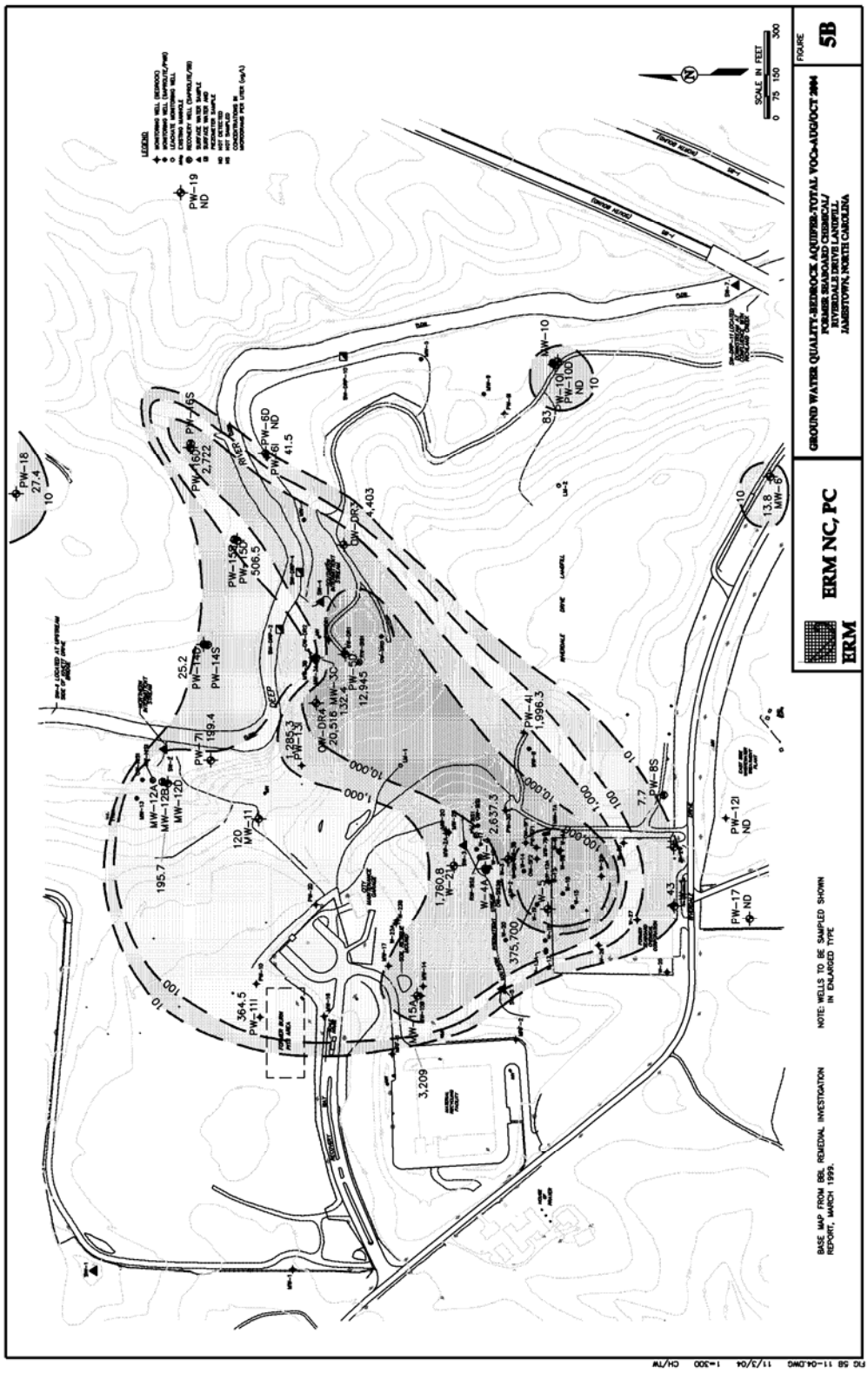

Figure 8-Ground Water Quality - Bedrock Aquifer Total VOCs

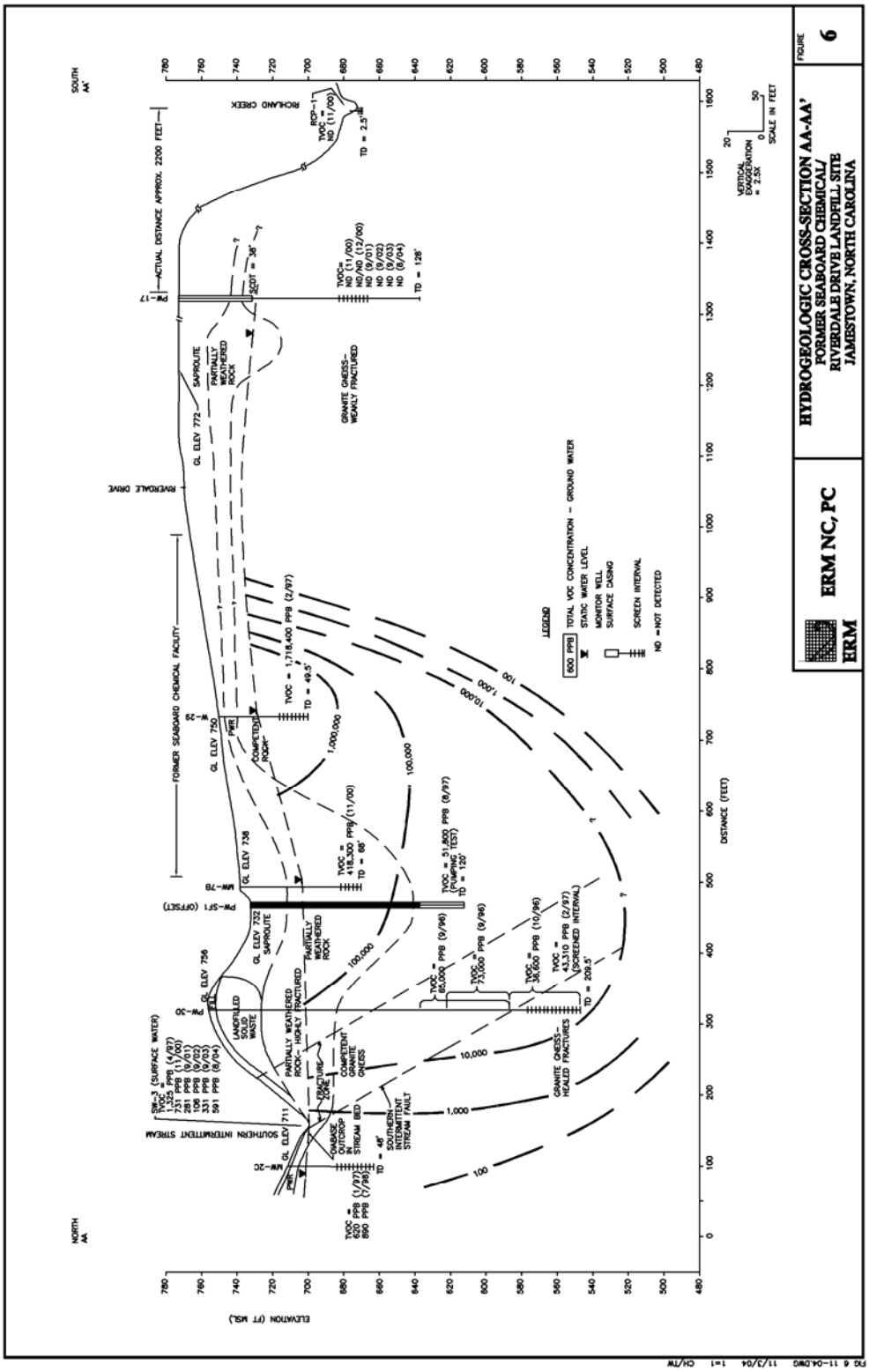

Figure 9-Hydrogeologic Cross Section AA-AA'

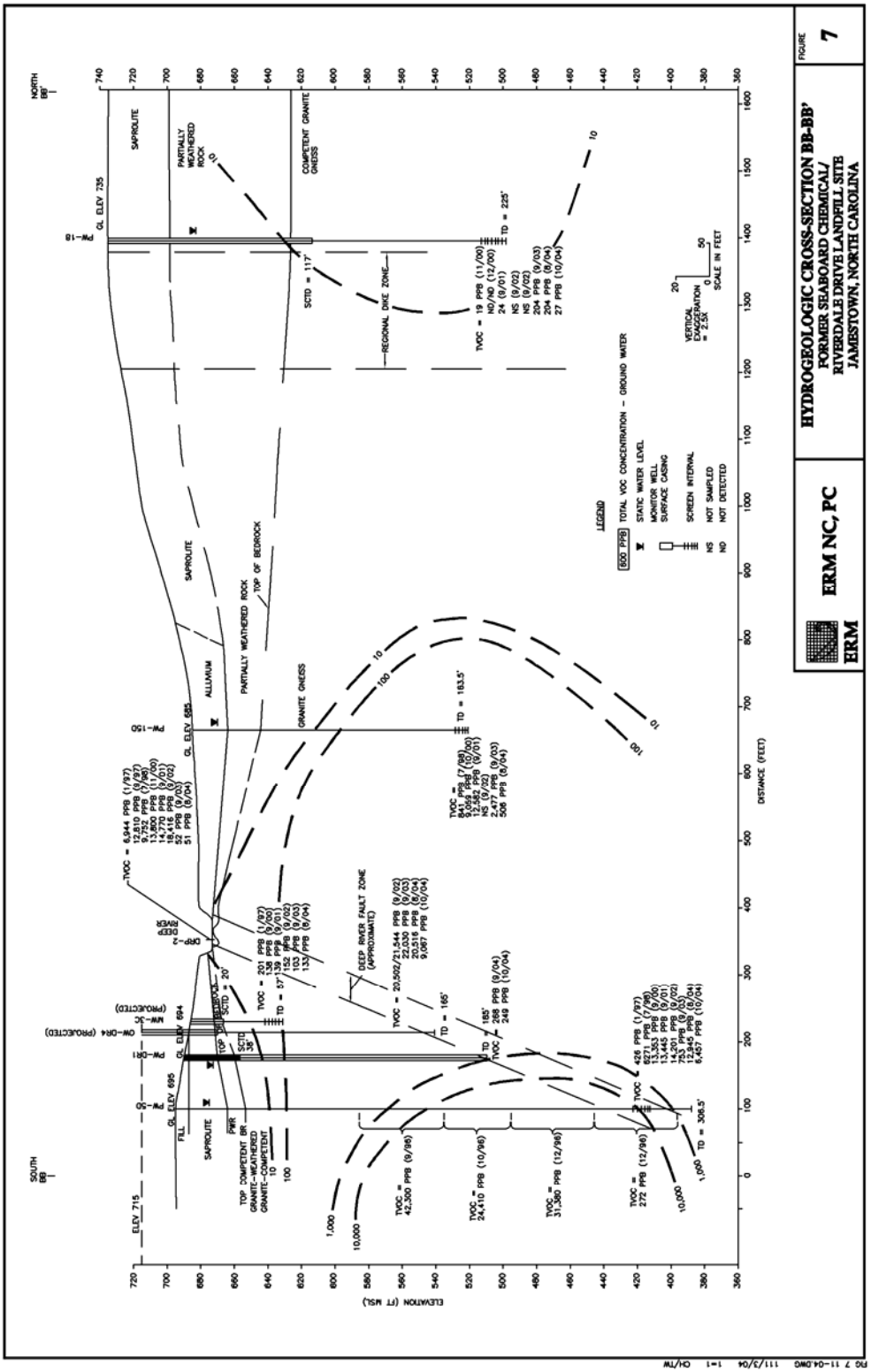

Figure 10-Hydrogeologic Cross Section BB-BB'

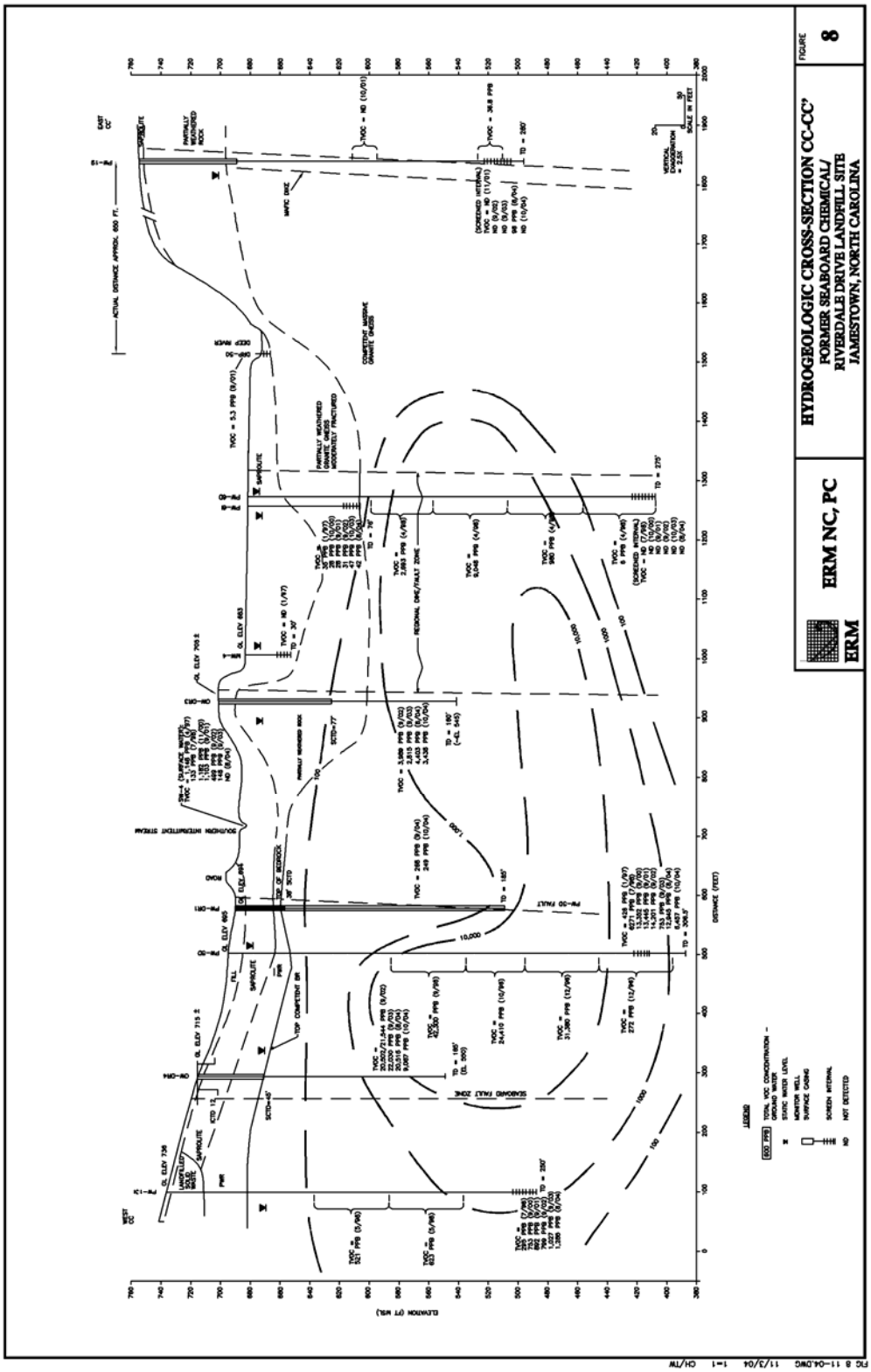

Figure 11-Hydrogeologic Cross Section CC-CC'

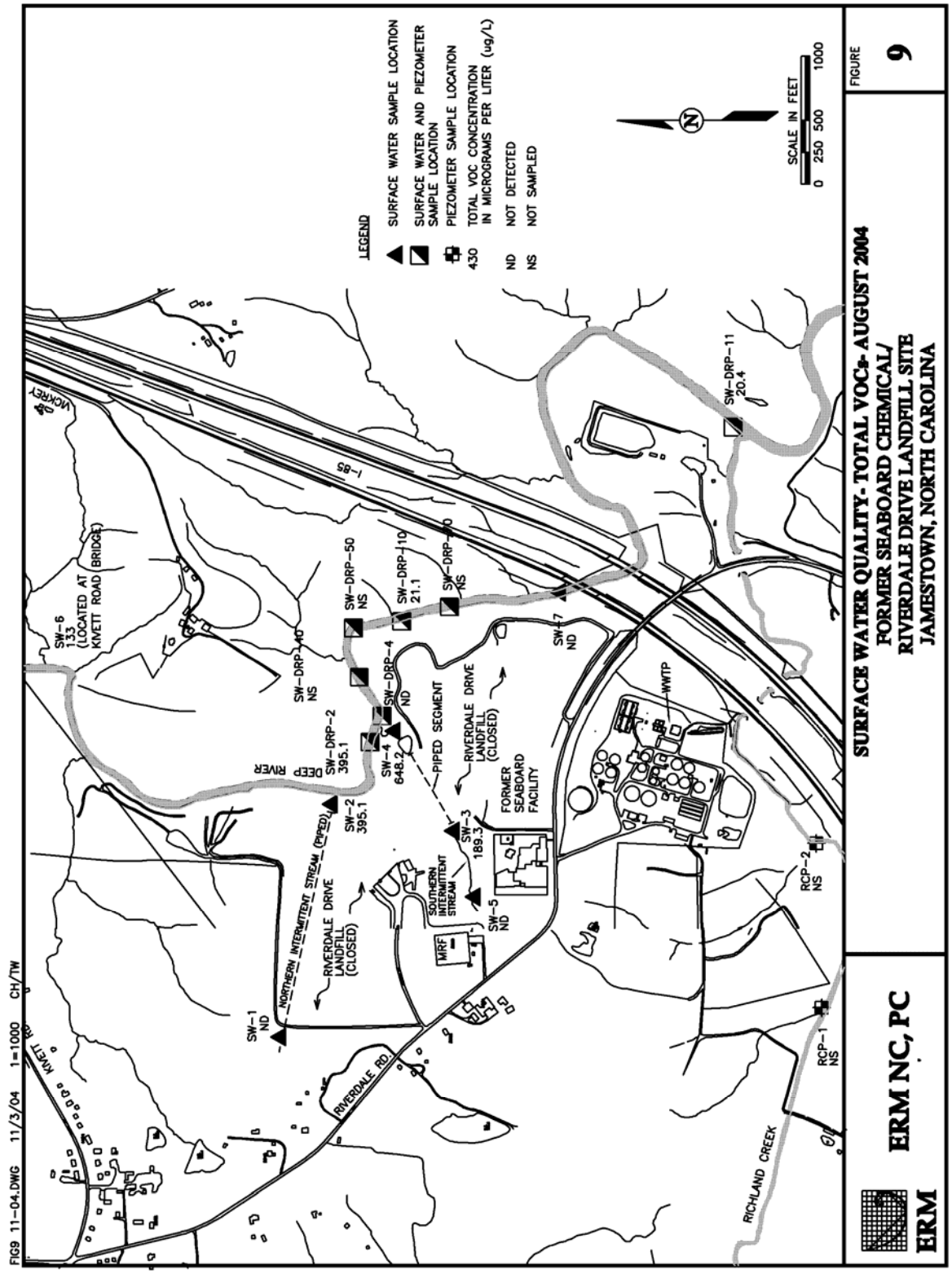

Figure 12-Surface Water Quality - Total VOCs

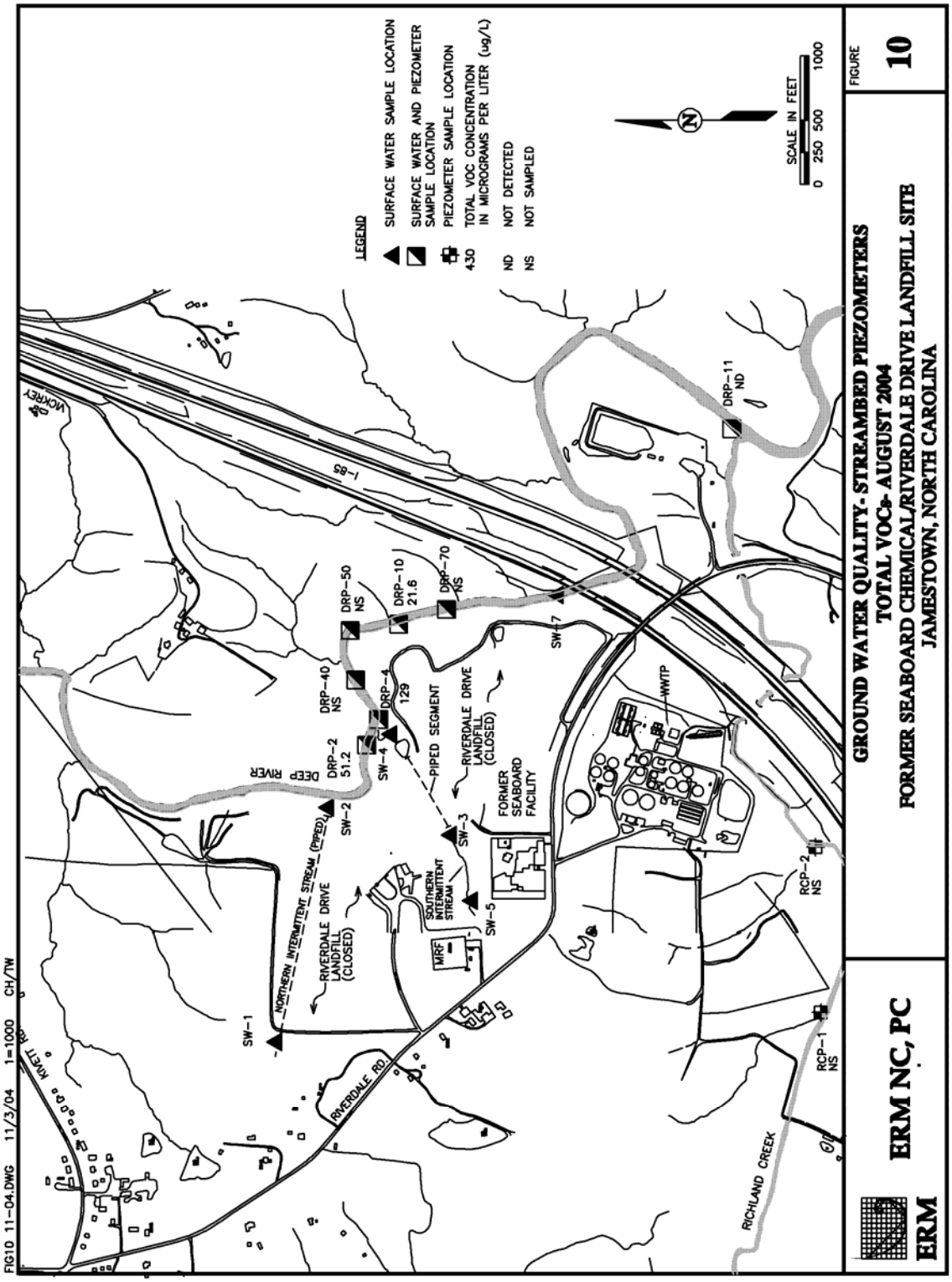

Figure 13-Ground Water Quality - Streambed Piezometers

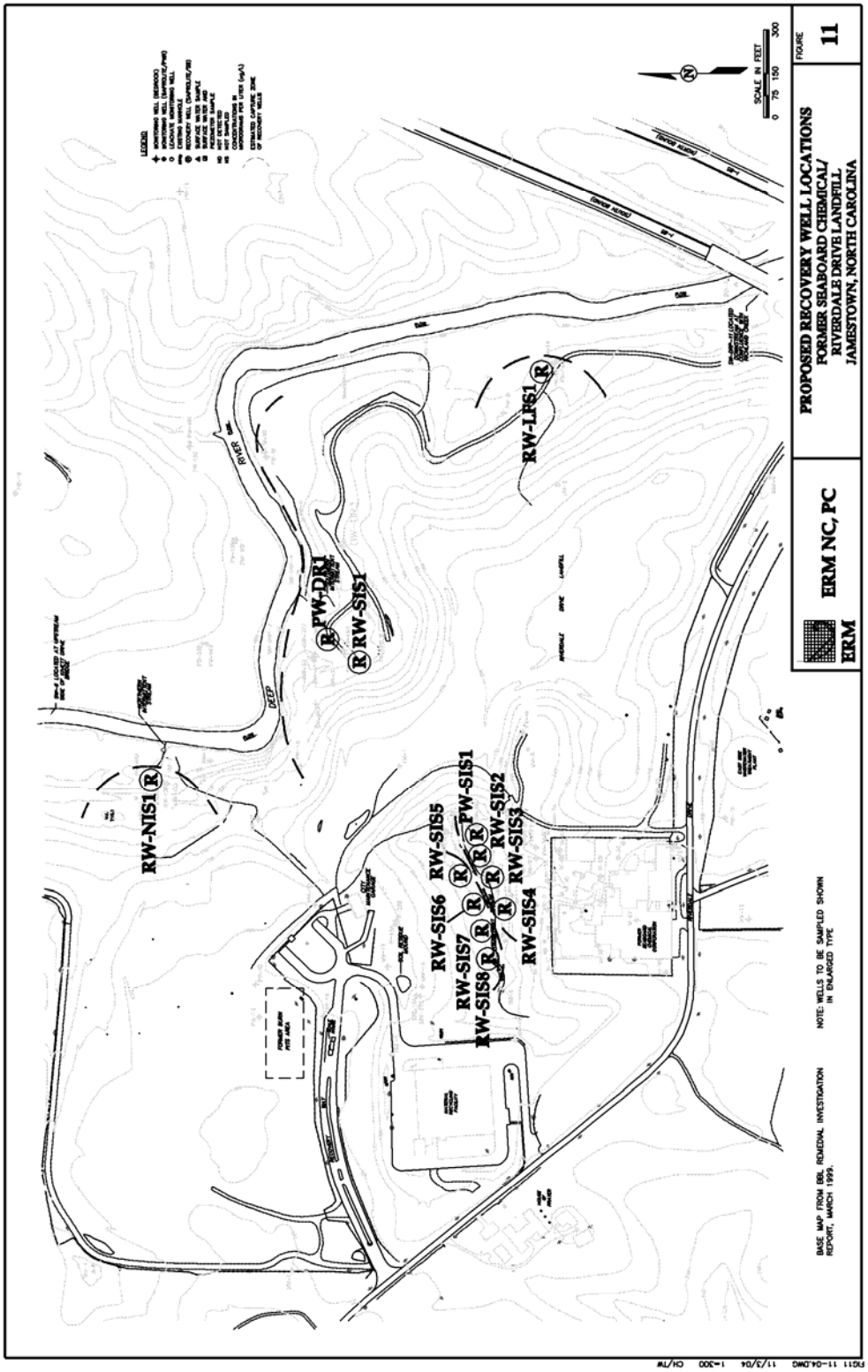

Figure 14-Proposed Recovery Well Locations